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The Glasgow Naturalist

MACHAIR CONSERVATION:
Successes and Challenges

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Conference Proceedings

Journal of
THE GLASGOW NATURAL HISTORY SOCIETY

Glasgow Natural History Society

(formerly The Andersonian Naturalists of Glasgow)

The Glasgow Natural History Society is a registered charity (SCO 12586) with more than 250 members living in Glasgow, the West of Scotland, throughout the UK and overseas. The Society arranges a full programme of events throughout the year in Glasgow and district and occasionally further afield. These are at both specialist and popular level, designed to bring together the amateur and the professional, the expert and the beginner.

The Society has its own library, and provides grants for the study of natural history. Further details about the Society can be found at www.gnhs.org.uk or by contacting the Secretary, The Glasgow Natural History Society, c/o Division of Ecology and Evolutionary Biology, Graham Kerr Building, University of Glasgow, Glasgow, G12 8QQ, Scotland (E-mail: info@gnhs.org.uk). The Society has microscopes and some field equipment that can be used by members. Please contact the Membership Secretary Mr Richard Weddle at the address above for further details.

The Glasgow Naturalist

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The Society has published a number of books on the flora and fauna of the West of Scotland. Full details can be found at www.gnhs.org.uk/publications.html

Front cover

Greater yellow bumblebee (*Bombus distinguendus*). South Uist. D. Goulson.

Back Cover

Top. Cattle grazing machair. Berneray. R. Webb.
(http://commons.wikimedia.org/wiki/File:Berneray_Machair.jpg)

Bottom. Machair cultivation. Drimsdale, South Uist. M. K. Thorsen.

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Contents

Conference Proceedings R. Downie 1

Oh, dear! What can the Machair be? J. A. Love 3

The RSPB Scotland strategy for machair management with particular reference to birds and achievements of the great yellow bumblebee project D. Beaumont, S. Housden 11

Machair and coastal pasture: managing priority habitats for native plants and the significance of grazing practices D. Long 17

The conservation of Scottish Machair: a new approach addressing multiple threats simultaneously, in partnership with crofters P. Walton, I. MacKenzie 25

Machair invertebrates: the importance of 'mosaiciness' D. I. McCracken 29

Conservation of bumblebees D. Goulson 31

Phenology of *Bombus distinguendus* in the Outer Hebrides T. G. Charman, J. Sears, A Bourke, R. Green 35

Recent research on the northern Colletes mining bee *Colletes floralis* Eversmann J. Bowler, J. Sears, J. Hunter 43

Dé tha cearr air a'mhachaire? S. Angus 53

Machair corn: management and conservation of a historical machair component M. Scholten, B. Spoor, N. Green 63

Habitat management survey for conservation of the great yellow bumblebee *Bombus distinguendus* in the Outer Hebrides L. Hancock 73

Machair and the great yellow bumblebee, *Bombus distinguendus* – a comparison of machair restoration techniques N. Redpath, D. Beaumont, K. Park, D. Goulson 79

Examining the use of corncrake *Crex crex* early cover plots for the conservation of the great yellow bumblebee *Bombus distinguendus* on North Uist J. R. Hanley-Nickolls 80

Factors affecting population density of *Colletes floralis* (Hymenoptera: Apidae) on Islay, Hebrides C. Fiedler 80

Croft management and economics: impacts on bumblebee conservation L. Osgathorpe, K. Park, N. Hanley, D. Goulson 81

Resilience of machair soil to amendment with kelp and synthetic fertiliser M. Thorsen, S. Woodward, D. Hopkins, B. McKenzie 84

Above and below ground responses to the machair agricultural system S. Vink, R. Neilson, D. Robinson, T. Daniell 84

Foraging preferences of the great yellow bumblebee *Bombus distinguendus* on Orkney L. Wilkie 86

The use of exclosures to produce a favourable grazing regime for the orchid, *Spiranthes romanzoffiana*, on the dune/hill intergrade - part of the machair complex, on Colonsay, Inner Hebrides, Scotland R. Gulliver, M. Gulliver, D. Long 86

Crofting & biodiversity on the Machair of the Western Isles A. MacLellan 87

Collecting wild flower seeds on the Uists for propagation R. Weddle, E. Stewart, M. MacKinnon 88

Outreach and education A. Lavery 88

Traditional and modern crofting practices; trends and current issues C. MacPhail 89

Foraging requirements of subadult red-billed choughs in Scotland: the importance of coastal sand grasslands M. Bogdanova, J. Reid, E. M. Bignal, S. Bignal, D. I. McCracken, P. Monaghan 89

Machair Conservation: Successes and Challenges
Conference Proceedings

INTRODUCTION

The papers collected here represent the edited and amplified proceedings of the third conference organised by Glasgow Natural History Society (GNHS) in recent years. The proceedings of the previous conferences, on *Alien Species* and the *Natural History of Loch Lomond and the Trossachs* were published in the *Glasgow Naturalist* as volume 23 supplement (2001) and volume 24 part 3 (2005) respectively. The previous conferences arose from a combination of members' interests and local natural history/conservation issues. The Machair Conference had a somewhat different genesis and might appear somewhat beyond the Society's 'patch'.

The origins of this conference lie in a unique collaboration between GNHS, the Royal Society for the Protection of Birds (Scotland) and the Aculeate Conservation Group. This collaboration arose from recognition of the plight of the great yellow bumblebee (*Bombus distinguendus*), a species with a previously widespread distribution in the UK, but now largely restricted to the Machair grasslands of the Western Isles, Coll, Tiree, Orkney, and a few mainland sites in Caithness and Sutherland. The great yellow bumblebee is now listed as a Nationally scarce species and is on the Priority List of the UK Biodiversity Action Plan.

There is no secret over the causes of the decline in great yellow bumblebee numbers: the bee depends on a wide range of the nectar-rich flowers found in short grasslands, and needs flowers over a long season: modern agricultural practice has severely depleted such grasslands, thereby reducing the ranges of species dependent on them. The RSPB's prime interest in these grasslands has been the corncrake (*Crex crex*) which, like the great yellow bumblebee, is now largely restricted to the last remaining grasslands in the UK where traditional practice has continued to a considerable extent – the Machair. The RSPB's work in Machair areas brought them into contact with the Aculeate Conservation Group, an association of UK bumblebee experts and enthusiasts, and led to the concept of a conservation project targeted at the great yellow bumblebee. GNHS joined the team at an early stage and was actively involved in the submission of a major application to the Esmée Fairbairn Foundation (EFF) in autumn 2004. EFF generously agreed to support the project with a grant of £60,000 over three years (2005-8).

The stated aims of the project were: "To prevent the extinction of the great yellow bumblebee from the UK, and secure its future survival. In line with the UK Biodiversity Action Plan for this species, our main objectives are:

1. To maintain existing populations through appropriate habitat management.
2. To enhance and extend currently available habitat and thereby provide suitable conditions for sustainable population increase.

We also seek to:

3. Raise awareness of and support for the conservation of the great yellow bumblebee and other bees and insects amongst local communities and the wider public".

The project was managed by a group drawn from GNHS and RSPB, with day-to-day management devolved to Richard Weddle (GNHS) and Dave Beaumont (RSPB). The project generated a wide range of work – seed-collection forays, summer projects by University of Glasgow final year students, habitat enhancement and protection, and the creation of educational materials.

During the final year of the project, the Management Group discussed how best to disseminate the results. We quickly concluded that a conference should be organised and that it should not be restricted to the great yellow bumblebee, but consider the Machair as a whole, its biodiversity, the prospects for its future as a wildlife-rich habitat, and the threats it faces.

The Proceedings of that Conference are collected here. The meeting was held in the Graham Kerr Building, University of Glasgow on Monday 8th December 2008. The meeting was very well attended, with over 100 delegates from a wide range of organisations with interests in the Machair and its biodiversity and conservation. Many expressed their view on the timeliness and value of the meeting, and the opportunity it provided for a wide range of people to get together and exchange views.

Our strategy in putting the conference together was to provide a broad overview of the Machair in the morning, covering its locations, history and basic features (John Love), then the key issue of the role of farming practice in Machair maintenance, and the pressures faced by farmers in recent times (Colin MacPhail). We then moved on to biodiversity and conservation issues: Dave Beaumont described RSPB strategy and work on birds, bees and habitat; Deborah Long discussed the plants special to the Machair; Paul Walton discussed the problems relating to invasive species; Dave McCracken surveyed invertebrate diversity, and Maria Bogdanova described recent research on the interaction of choughs and coastal sandy grasslands.

The afternoon focussed on the results of the Esmée Fairbairn funded project, with some additional contributions on related topics: Dave Goulson, Tom Charman and John Bowler covered bumblebees in general and their current declines, the great yellow bumblebee in particular, and the Northern Colletes, a

solitary mining bee of the Machair. Stewart Angus discussed the biodiversity issues facing the Machair. Nicky Redpath and Rose Hanley-Nicholls described their research on wildflower meadow restoration aimed at bumblebee recovery, and corncrake-bumblebee habitat comparisons respectively. The conference concluded with Alastair Lavery's presentation on educational initiatives relating to the Machair and bumblebees.

Between times delegates were able to study an excellent set of posters on the Machair and its biodiversity (fully listed in the Proceedings).

As you can see, a very full and thought-provoking day.

ACKNOWLEDGEMENTS

I would like to thank: the Esmée Fairbairn Foundation for providing the major funding that made this project possible; Scottish Natural Heritage for supporting publication of the Proceedings, including the on-line version available at www.gnhs.org.uk; the University of Glasgow's Division of Ecology and Evolutionary Biology for providing the facilities of the Graham Kerr Building free of charge; the members of RSPB and GNHS who helped manage the project and organise the conference, especially Richard Weddle who acted as overall administrator and Nicola Bell for all the arrangements on the day; the conference speakers who freely provided their expertise and Dominic McCafferty who edited the Proceedings.

Roger Downie
GNHS President

EDITOR'S NOTE

The production of this Supplement would not have been possible without the hard work of a number of dedicated individuals. In particular, I would like to thank June Allardyce for paper formatting and secretarial support, Norman Tait for cover design and image production and Richard Weddle for making articles available online. The assistance of authors and a number of anonymous reviewers is gratefully acknowledged.

Dominic McCafferty

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Oh, dear! What can the Machair be?

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ABSTRACT

Machair is a mosaic of different habitats – beach, sand dunes, dune slacks, pasture, marshes, ditches and lochs. Indeed to explain their relationship to one another and to the wildlife that inhabits them it is more convenient to think of 'machair' as a system, one that conspires to create and maintain the landscape that we celebrate today. Geography, geology, geomorphological processes, climate, plants (in the form of seaweed, marram etc) and animals (molluscs and other calcium-rich marine creatures) all contributed to a habitat mosaic that was to prove so attractive to wildlife. A few thousand years ago humans arrived to populate and work this land . The unique husbandry they came to develop was not only sympathetic to and driven by the local environmental conditions but also, as it happened, served to enrich the biodiversity of the machair. It is only in recent decades that conservationists have come to appreciate this resource and how they must work with the local crofters to retain this biodiversity. But the older generation admit that the wildlife is not as good as it once was. Global climate change, agricultural innovation, and the demands of modern living are now all conspiring to accelarate the erosion of this beautiful, low-intensity land use system, and indeed towards the erosion of the very machair itself.

INTRODUCTION

In recent decades crofters and conservationists alike have come to celebrate the biodiversity of machair but why it all came to be at all goes back millions even billions of years geologically, thousands of years geomorphologically and many generations of human occupation and traditional land use. But there is still debate over what exactly is machair or rather how we should describe it, which is one reason why I have chosen the title for this talk. The other reason, and implied in the title pun, is that all may not be well with machair and its biodiversity. Any crofter will tell you that it is not at all as good for wildlife as it once was.

WHAT IS MACHAIR?

Generations of Gaelic bards have been celebrating the beauty of machair in their poetry. John MacCodrum who lived and worked in North Uist around 1750 composed a poem entitled 'Smeorach Chlann Domhnaill':

`S I `n tir sgiamhach tir a`machair,
Tir nan dithean miogach daithe,
An tir laireach aigeach mhartach,
Tir an aigh gu brath nach gaisear

`Tis a beautiful land, the land of the machair,
the land of the smiling coloured flowers,
the land of mares and stallions and kine,
the land of good fortune which shall never be blighted.

Since 'machair' is a Gaelic word we should of course ask the Gaels themselves. It is a curious irony that the definitive dictionary of the Gaelic language – well over a thousand pages all typeset, illustrated, printed, bound and marketed by the compiler himself – should have been produced by an Englishman, Edward Dwelly (1864-1939). First appearing in 1911 it has remained the classic work of reference to this day - although its author was to die in obscurity in the south of England.

Dwelly had learnt Gaelic so that he could glean as much as possible from native speakers. He gives several meanings of the word 'machair' including 'a low-lying country' - with, curiously enough given his own roots, 'machaireach' being someone who came from the low country in the south! But he adds to this first brief reference 'an extensive, low-lying fertile plain'. He then expands on this with: 'a long range of sandy plains fringing the Atlantic side of the Outer Hebrides. They are closely covered with short green grass, thickly studded with herbs of fragrant odours and plants of lovely hues.' That is very much what the word conjures up in the popular mind, and it is what today we tend to think of as machair.

WHERE IS MACHAIR?

Machair is not restricted to the Outer Hebrides however, as Dwelly implied. It also exists on the Atlantic coasts of mainland Scotland, Orkney, Shetland and Ireland. Gaelic is not indigenous to Orkney and Shetland but 'machair' does appear in placenames elsewhere - such as Machrihanish in Kintyre, Machair Bay in Islay, Magheramore and Maghera Strand in Ireland. In Scotland machair grassland (in its strictest sense) covers some 15,000 hectares, almost half of it in the Outer Hebrides. The best and most extensive is in the Uists and Barra, Coll and Tiree.

On the east coast of Scotland we would refer to such dune systems as 'links' but the sands there have a higher mineral content, rich in silica. There is on the other hand a convincing reference to machair existing in southern New Zealand (Wilson *et al* 1993), one of the areas where Scots and indeed Hebrideans, went to settle after the Highland Clearances. Were they attracted to a landscape which seemed so familiar and which they knew would prove amenable to them? I would also like to add, that I encountered what I thought to be machair on several of the Falkland Islands (another honeypot destination for Hebridean settlers). All that these two exotic locations seem to lack is heavy rain and the human element – cultivation.

DEFINING MACHAIR

Experts differ in where machair begins and where it ends. Frank Fraser Darling (1947) noted how: 'the machair starts with the florally sterile tidal zone of shell sand, then there is the bank of unstable dunes, on the seaward edge of which the marram grass begins to grow thinly.' Professor Bill Ritchie (1979) takes a stricter view that machair is only the non-dune element of a sandy coast, usually only a few metres above sea level yet ultimately dependent for development upon the beach and the dunes. Dr Derek Ranwell (1974) is more expansive considering it: 'a local landscape term applied to dune pasture (often calcareous) subject to local cultivation and developed in humid and windy condition in north and west Scotland.'

Nowadays it is often said that machair is the only natural habitat to bear a Gaelic name. Having lived on a machair in South Uist for sixteen years I have come to see machair as not so much a single habitat but a mosaic of *different* habitats – beach, sand dunes, dune slacks, pasture, marshes, ditches and lochs. Indeed to explain their relationship to one another and to the wildlife that inhabits them it might be more convenient to think of 'machair' as a system, one that conspires to create and maintain the landscape that we celebrate today.

Perhaps G. Dickinson (1977) gives the most useful description: 'Machair... merits the use of the term landscape... acknowledging that its existence depends on the physical environment, the habitats provided by this, the vegetation and animal life of the area, man's activities and all the manifestations of human culture in an interacting 'socio-ecosystem'.' Introducing a botanical element Stewart Angus further developed the idea of a 'machair system' but perhaps the use of good old-fashioned term 'ecosystem' or even 'socio-ecosystem' rather than 'habitat' encompasses all that is necessary. The machair landscape includes beach, dunes, machair plain, rock knolls, marshes, ditches and lochs that are all habitats in their own right, until finally grading into peaty moorland and hills. We shall see how geology, geomorphological processes, climate, geography, plants and animals, even humans, have all contributed to machair - the habitat mosaic or ecosystem that proves so attractive to wildlife.

THE GEOLOGY OF MACHAIR

Machair lies directly upon an unforgiving platform of ancient, acidic rocks, attractively-streaked grey and black and known as gneiss. Samples from Ardivachar in South Uist have been dated at 2,900 million years making them one of the oldest rocks known. Other strata may have formed on top but by 1,500 million years ago it had all been eroded away to expose a bare rock surface of gentle ridges and basins sloping gradually out to the west. Then, as recently as 65 million years ago when dinosaurs still roamed the earth, the rocks began to split apart forming the North Atlantic Ocean. Thus the northwest of Scotland share gneisses with Greenland and parts of eastern Canada.

GEOMORPHOLOGY AND CLIMATE

Two and half million years ago, and not for the only time in its geological history, the earth was gripped in a series of Ice Ages and warm Interglacials between. The last cold episode began 115,000 years ago and ice eventually covered much of northern Britain. Land subsided under its weight, while the ice had locked away so much water that the sea level also dropped. But even at this time the deep trench of the Minch remained flooded. Some 18,000 years ago the ice began to melt, releasing its vast store of water and revealing the Outer Hebrides as one island some 200 km long. Relieved of its weight of ice the land rose, but sea level was rising faster. It is likely that Uist split apart into separate islands about 4000 years ago. It extended much further west however and over the next 8000 years remained lightly wooded with a patchwork of freshwater lochs but, as yet, little sand. The trees would doubtless have been somewhat stunted and bent over by the prevailing oceanic winds.

Under the sea to the west, the ice sheet had dumped glacial debris where, some 6000 years ago, it was mixing with prodigious quantities of crushed shells from animals living in deeper waters. This calcareous sand was gradually swept ashore and blown inland to form beaches, dunes - and the machair plain. Having been brought up at Northton, the superb machair in Harris, Professor William MacGillivray deduced how the system worked as long ago as 1830:

'The generally received theory of the formation of drift sands and hillocks or downs is this: the fragments of the shells of molluscous animals inhabiting the sea near the coasts, are rolled by the waves towards the shore, where they are further broken and comminuted. The wind then blows them beyond the water mark, where, in progress of time, hillocks are formed. These hillocks are occasionally broken up by the winds, and blown inland covering the fields and pasture. . .'

TREES?

Archaeology and soil profiles have revealed how machair developed. It seems that sand and debris deposition offshore progressed apace for another few millenium as sea level continued to rise.

By 6000 BC the climate would have been warmer and drier than today. Pollen analysis and more usefully, beetle remains, indicate that the open birch *Betula* and hazel *Corylus avellana* sp scrub was largely cleared for cultivation, although it would be some time before woodland disappeared altogether. There are remains of trees preserved in peat along the shore, at Stoneybridge in South Uist for instance. But what we would identify as machair nowadays was probably at that time much more stable, with thicker soils able to sustain well-advanced plant communities. Dean Monro could still describe some woodland along the east coast of South Uist as late as 1549.

THE ARRIVAL OF HUMANS.

Although there are no artifacts to suggest that Mesolithic hunter-gatherers were present on Uist, charcoal deposits might suggest that, if not living there, they were at least visiting and setting fire to the woodland. After all, Mesolithic peoples were well established in the Isle of Rum only 50 km to the east, also on Oransay, and on others of the Inner Hebrides further south. Within the next two thousand years prehistoric peoples changed from being hunter-gatherers to farmers. We know of some 200 archaeological sites on the machairs of South Uist alone and who knows how many more remain to be discovered?

While there are numerous burial cairns of Neolithic age (4000-6000 years ago) surviving, in Uist and Benbecula for instance (some even below high water mark), these tend to be further inland. Evidence of houses, on the other hand, are scarce - but erosion has doubtless removed many traces.

It seems that by the Bronze Age, some 1500 or more years ago, sea level had reached a peak and the machair plain had stabilised, with farming now well established. Through the Iron Age machair then went through phases of erosion and deposition. There seems to have been stormy periods eroding the machair between 3800 and 2300 BC for instance, again from 1800 to 1300 BC, AD 200 to 300 and between AD 600 and 700.

Historic sources tell of further major sand blows in recent centuries. In 1756 the houses of Baleshare in North Uist were buried in sand up to their roofs. Indeed the name 'Baile sear' means the eastern town, which implies that there would have been a western town 'Baile siar'. The village of Hussaboste is mentioned in a document dated 1389 and was said to have been washed away in the 15th century. It is remembered locally in a reef offshore called Sgeir Husabost, just west of Baleshare, while local tradition maintains how it was once possible to journey across to Heisgeir (the Monach Isles) by horse and cart.

ECOLOGICAL CHARACTERISTICS OF MACHAIR

Dickinson and Randall (1979) summarised the key features of machair.

1) the highly **calcareous substrate**, with anything from 20% to 80% calcium carbonate on the beaches and declining inland. Thus machair soils, though shallow, have a high pH.
2) the influence of the **oceanic climate**, mild winters with little frost and snow but cool summers. The soil may have dried out by May but there is little plant growth until warmer summer temperatures finally kick in.
3) a **rainfall** of around some 1500mm annually, which encourages, then traps and compacts the sand to facilitate soil formation. Although some machairs may flood to several inches in winter, they dry out quickly in spring.
4) **wind** is of course an essential element, driving sand up the beaches, over the dunes and inland. By such means machair may creep 30 or 40 metres up hill slopes, such as at Eoligarry in Barra. Although south-westerlies prevail, wind and storms can come from any direction, even at the height of summer.
5) Gales off the sea carry **salt spray**, a factor which greatly affects plant growth. Even in June or July the vegetation can burn brown after an unseasonal westerly storm.
6) A final ecological characteristic is **human activity** through stock husbandry and cultivation.

SEAWEED

Having considered physical features such as geology, geomorphology, archaeology and climate, it is now appropriate to assess the botanical contibution to machair development.

William MacGillivray recognised the importance of marram *Ammophila arenaria* but while this is undoubtedly a key plant in the formation and perpetuation of dune habitats and machair, another crucial plant is usually overlooked. This is seaweed, mainly kelp or tangle *Laminaria,* which lies offshore in dense beds that shelter rich communities of marine life, including fish. But these kelp beds also serve to absorb wave energy and thus reduce erosion along the soft, sandy Atlantic shores of Uist, Coll, Tiree etc.

In winter storms kelp is ripped off the seabed, to be carried ashore and dumped on the beach in piles sometimes several metres high. Here crofters have been able to harvest and dry the stipes, later to be processed for valuable alginates etc. – though never again on the scale achieved two hundred years back. These heaps of stranded seaweed continue to reduce the impact of wind and wave and thus protect beaches and dune fronts from erosion. Rotting seaweed abounding in sand flies and other invertebrates provides rich feeding for flocks of starlings *Sturnus vulagaris* and other passerines, wintering waders, gulls and a host of others.

If the cast tangle does not get swept away again on the next spring tides it soon gets covered with sand, to

create beds of damp compost where seeds of coastal annual flowers, and of course marram grass, can germinate and thrive.

THE IMPORTANCE OF LAND PLANTS

Only the hardiest and most salt-tolerant of plants such as sea sandwort *Honkenya peploides*, sea rocket *Cakile maritime* and mayweed *Tripleurospermum maritimum* can withstand rigorous coastal conditions. A salinity in excess of 0.5% is harmful to most plants, salt not only being toxic in itself but it disrupts osmotic processes that make it difficult for roots to take up moisture. To cope with this the plants that can survive near the coast tend to have sap with a higher than normal salt concentration.

One of the most celebrated flowers of Hebridean beaches is the sea bindweed or convolvulus *Calystegia soldanella*. Growing along the dune edge on Eriskay for instance, at the very spot where Bonnie Prince Charlie first set foot on British soil in 1745, it is known as the Prince's flower. Island tradition maintains how the seeds fell out of his pocket as he stepped ashore. Although not wishing to spoil a good story, botanists have to admit that it is also found on Vatersay further south, on some of the Inner Hebrides, at the Giant's Causeway in Antrim, even on South Ronaldsay in Orkney, all places Charlie never ventured! The ability of seeds from such pioneering beach plants to withstand saltwater was first investigated by the celebrated naturalist Charles Darwin, who as a medical student at Edinburgh University had met William MacGillivray, then curator of the natural history museum. Darwin successfully germinated 64 of 87 plant species whose seeds he had immersed in seawater for periods of up to 28 days, enough to travel distances in excess of a thousand miles.

Plants have the facility to react when more sand is dumped on top; the vegetation grows taller and thicker, thus encouraging fore dunes to develop and stabilise. Marram plays a particularly significant role maintaining a protective rampart of dunes between the sea and the machair plain. As MacGillivray astutely observed: 'It is the natural inmate of a sandy soil, to which, in fact, it is peculiar. It is therefore obviously the best that could be selected for the purpose of fixing loose sands.' Its deep roots and thick tussocks trap and bind blowing sand and grow vigorously to keep pace with its accumulation. Furthermore, marram's spiky, in-rolled leaves have a remarkable ability to withstand the dessicating effects of stong winds, which in turn serves to break open and disperse the seed heads.

Behind these dunes of marram, sometimes reaching 10 metres or more in height, the impact of wind and salt spray is reduced sufficiently for a variety of other plants to establish. The first are annuals that perpetuate afresh each year from abundant blown seed Marram finally gives way to red fescue *Festuca rubra* and some other grasses, buttercups *Ranunculus* spp, ragwort *Senecio jacobaea*, storksbill *Erodium cicutarium*, scarlet pimpernel *Anagallis arvensis*, speedwells *Veronica* spp and rue-leaved saxifrage *Saxifraga tridactylites*, all of which can still tolerate a thin covering of wind-blown sand in winter. Perennial plants do not thrive until the sand is less mobile, allowing white clover *Trifolium repens*, bird's foot trefoil *Lotus corniculatus*, silverweed *Potentilla anserina* and ladies bedstraw *Galium verum* to now take hold. Now decaying plant matter can accumulate that helps retain moisture and renders the soil a little more acid. The plants of the stable machair plain are too numerous to list here but it is worth mentioning Ben Eoligarry in Barra, where sand blown 100 metres up the rocky slopes inland supports an unusually profusion of primroses *Primula vulgaris*- alongside other species such as thyme *Thymus praecox*, frog orchids *Coeloglossum viride*, and adder's tongue fern *Ophioglossum vulgatum*.

In June yellow is the dominant colour, from buttercups, vetches *Vicium* spp and bird's foot trefoil; meadow rue *Thalictrum minus* is unusually abundant on machair. On damper ground cottongrass *Eriophorum angustifolium*, silverweed, yellow rattle *Rhinanthus minor*, and marsh marigolds *Caltha palustris* thrive. Red and purple become the prevalent colours later in the summer from red clover *Trifolium pratense*, ragged robin *Lychnis flos-cuculi*, with self heal *Prunella vulgaris* in damp grassland. Baltic rush *Juncus balticus* and curved sedge *Carex maritime* are unusually abundant along the machair from North Uist to Lewis, but some orchids are particular Hebridean highlights.

Botanical interest is reduced where machair meets moorland. It is on this so-called 'blackland' that the croft buildings tend to be located, amidst enriched pasture and hay meadows. In Coll and Barra however small patches of damp, peaty pasture or marsh grazed by cattle are home to one of the rarest orchids in Europe - Irish lady's tresses *Spiranthes Romanzoffiana*. It is principally a North American species, though how it came to colonise the remote western seaboard of Scotland and Ireland is still being debated. One theory is that the tiny seeds were transported on the muddy feet of migrant wildfowl such as white-fronted geese *Branta leucopsis*, something that Charles Darwin demonstrated on woodcock *Scolopax rusticola* and ducks.

ISLAND EFFECTS ON FLORA AND FAUNA

One might expect machair to be rich in species, but in fact can muster no more than 150 species. When the mosaic of associated habitats is included, some islands such as the Monach Isles (Heisgeir) can support some 200 species while Tiree has a list of over 500. But what machair lacks in species is of course compensated for by sheer abundance and spectacle. In contrast, dune pasture on the east coast of Scotland, can support 400-500 species. The paucity of species may well result from the fact that the best machairs are to be found on islands.

To colonise an island, plants and animals have to overcome the barrier presented by the sea. If they

cannot survive the voyage, as seeds or in rafts of vegetation, then there are only two other alternatives available to them – as wind-blown seeds or spores, or by hitching a lift on other animals, be they birds or humans. Many plants have developed sticky seeds, or with hooks that can attach to plumage or fur. Others fruits and seeds may arrive in the crop, gut or droppings of birds or domestic animals yet – as Darwin again demonstrated – can still germinate. Furthermore humans may bring in other plants in fodder crops.

Such principles also apply to invertebrates but the trend for islands to possess fewer species than the mainland still holds. Some 937 beetles are listed for the Inner Hebrides, about 600 for the Outer Hebrides, with only 350 or so for Orkney and for Shetland. Beetles also reflect habitat differences; only 22 species being found on the shore and foredunes, but 155 species on the machair. Similarly 16 earthworm species occur in machair but only 7 on open moorland.

While snails, grasshoppers, flies, spiders and harvestmen might appear numerous enough on machair they are less diverse than on the mainland. There is a group of spiders whose tiny young can disperse over large distances using long threads of gossamer. They are termed balloonists and being able to travel on winds or air currents it is not surprising that they make up a significant proportion of the Uist spider fauna. Bumble bees, on the other hand are strong fliers, and one or two Hebridean specialities are resident on machair grassland. Machair possesses relatively few lepidoptera, meadow brown *Maniola jurtina*, common blues *Polyomattus icarus* and small tortoiseshell *Aglais urticae* being the commonest butterflies with dark arches *Apamea monoglypha* and common rustic *Mesapamea secalis* as the most widespread moths. The belted beauty *Lycia zonaria* is an interesting machair moth, the females being flightless; one theory is that they might have reached offshore islands on rafts of dead wood.

THE IMPACT OF HUMANS

When humans arrived to populate and work this land some six thousand years ago they quickly developed a unique husbandry that was guided by, and ideally suited to, the local environmental conditions. Early farmers were quick to appreciate the bounty from the sea and liberally applied seaweed over their machair cultivations. Seaweed provides a protective cover to the thin sandy soils thus minimising wind erosion, while the alginate content helps bind the soils, facilitates moisture retention and of course, introduces organic material and vital nutrients.

It is significant that at the height of the kelp industry two hundred years ago when crofters were deterred from adding tangle to their fields erosion became a serious problem. In 1811 for example James Macdonald could only observe how 'in winter, and even until the middle of May. . . machair is almost a desolate waste of sand'.

By 1830 however, after the collapse of kelping, William Macgillivray wrote: 'It must not be imagined that this Hebridean sand is on a barren soil, it being destitute of vegetation only when drifting loose. When in some degree fixed by moisture, or the interspersion of pebbles and shells, it affords excellent crops of barley, when manured with sea-weeds, and its natural pastures are by far the best.'

TRADITIONAL LAND USE AND BIODIVERSITY

The real spectacle of machair flowers is greatly enhanced in Uist by another agricultural activity - cultivation. Traditionally the area was cultivated on a two- or three-year rotation so that no more than half the arable machair will come under the plough at any one time. Tiree machair on the other hand, which constitutes nearly half of the island's area, is not normally cropped - perhaps because the interior is less rocky so can be easily ploughed instead. Cultivation has all but ceased in Barra, Harris and Lewis.

In the first year of fallow, wild pansy *Viola tricolor*, poppies *Papaver rhoeas*, creeping buttercup *Ranunculus repens*, forget-me-not, mouse-ear *Cerastium fontanum* and storksbill are added to the flora, with clover and red fescue establishing in the second year as creeping buttercup is gradually replaced by meadow buttercup *R. acris*. Here and there the tiny, scarlet pimpernel adds a further dash of colour.

SOIL DEFICIENCIES

Although lime-rich machair soils would be expected to be relatively productive. However they can be rather low in some essential nutrients and trace elements such as copper, cobalt and manganese. Livestock used to be able to make up some of this dietary deficiency when they were moved from the machair to summer pastures out on the hill grazings. The animals tend to be kept in fenced areas around the croft nowadays so mineral supplements are often necessary.

Sandy soils are open and free-draining so nutrients wash out easily and artificial fertilisers might prove ineffective. Deficiencies in machair soils limit the crops that can be grown. Only the older strains of small oats and rye will thrive, along with the old, six-rowed bere barley. Rye is particularly tolerant of the dry conditions and has strong stalks that resist the wind and allow mechanical binders still to be used. Small oats grow quite well in competition with wild flowers which - if the crop was intended as anything other than cattle fodder - would be condemned as weeds. It is therefore not normally practical to consider expensive herbicide treatment. Early in the season cereal crops are dominated by corn marigold *Chrysanthemum segetum* or charlock *Sinapsis arvensis*, with bugloss *Lycopsis arvensis*, field pansy, cornsalad *Valerianella locusta*, red dead-nettle *Lamium purpureum* and sun spurge *Euphorbia helioscopia*.

BIRDS OF THE MACHAIR

Much has already been published about the rich birdlife of the machairs of Coll, Tiree and Uist. These islands have become the last British stronghold of the corncrake *Crex crex* for example, and are fast becoming so for other farmland birds such as corn bunting *Emberiza calendra*, twite *Acanthis flavirostris* and skylark *Alauda arvensis*. In Uist even the rare little tern *Sterna albirfrons* might forsake the foreshore to nest amongst the cultivations.

It is almost certainly the absence of mammalian predators on these islands that make them safe havens for such ground-nesting birds. None benefit more however, than the waders. During the 1980s over 25,000 pairs bred on machair each year, some 6,000 in Tiree alone, with another 17,000 in Uist and Barra.

The most numerous wader is the peewit or lapwing *Vanellus vanellus*, a bird now increasingly rare on intensive farmland on the mainland. In Uist, lapwing breed in the highest densities amongst the dune slacks and on drier grasslands (up to 85 pairs per km^2) with fewer numbers (40 per km^2) in damp machair and fewest (30 per km^2) on dry cultivated machair and croftland; in Tiree densities are lower. Dunlin *Calidris alpine* are more specific, preferring the tufted vegetation of wet machair to conceal their nests. A record density of some 300 pairs per km^2 has been recorded in one area of South Uist, with some 40% of the British Dunlin population being found on the machairs of the Uists and Tiree alone. Redshank *Tringa tetanus* and snipe *Gallinago gallinago* prefer the taller vegetation of marshes and wetlands.

It is the oystercatcher *Haematopus ostralagus* and ringed plover *Charadrius hiaticula* that are most dependent upon arable practices. Normally they nest on shingle beaches or bare ground, where their cryptically coloured eggs are well concealed; they also like the broken runways on The Reef in Tiree. But both species also nest on dry cultivated machair. Up to 400 pairs of ringed plover have been recorded per km^2 on ploughed land or recent fallow in Uist. This constitutes nearly one third of the total British breeding population of ringed plover.

Storm-cast, rotting seaweed offers important feeding grounds for flocks of wintering waders. Saltspray and wind-blown shell sand add nutrients to machair lochs, resulting in an interesting profusion of freshwater plants associated with prodigious invertebrate populations, all of which provide rich feeding for waterfowl both in winter and summer. Several hundred pairs of mute swans *Cygnus olor* breed. Whooper swans *Cygnus Cygnus* from Iceland overwinter and, although odd birds summered and even laid eggs, for the first time, in 2008, a pair successfully fledged six cygnets in North Uist. Later in October, barnacle and white-fronted geese *Anser albifrons* arrive from Greenland. These wildfowl, along with the resident greylag geese *Anser anser*, like to feed on the stubble.

GREYLAG GEESE

There has always been a relict population of greylag geese resident in Uist, reckoned to be of pure, original native stock.

As long ago as 1764 the Rev. John Walker recognised the damage they could inflict:

'The crops in North Uist and Benbecula, but especially South Uist, are exposed to a very singular misfortune; being sometimes entirely destroyed by the vast flocks of wild geese, which haunt these islands. This bird is never seen in the south of Scotland except in winter but in these islands it hatches and resides all the year round. . .'

Recent counts indicate several hundred greylags in Colonsay, Coll, Lewis and Harris, with several thousand in Tiree and in Uist. Although wildfowlers are permitted to shoot greylags in winter, numbers are increasing each year. These flocks are not of course comparable with the huge numbers wintering on the mainland and in Islay but, in a crofting context, the damage they might do is highly significant. In some parts of Uist geese can compete with sheep for the first spring flush of grass on reseeded pastures in spring, and then flatten or graze ripening corn just prior to harvest in the autumn.

In 1992 Uist pioneered a Goose Management Committee of crofters, estates, the local council, agricultural agencies and conservationists, paving the way for other more formal, funded schemes. Not only do they undertake regular counts but the Schemes also collate complaints, lend out goose scarers and organise shooting parties. On machair their particular remit is to minimise goose pressure on crofting, thus maintaining biodiversity, yet still retaining a viable breeding population of pure-bred Scottish greylags.

KEEPING THE BALANCE

Machair is cultivated to provide winter feed for livestock. Cattle do not graze as closely as sheep, taking the less palatable species as well as the less attractive portions - stems, seed heads, dead plant material, rushes, cotton grass and other less tasty plants. Cattle thus improve the quality of sward for other grazers as well as for wildlife. In addition, trampling creates texture in the sward, tussocks for example providing good invertebrate habitat and thus food for birds. Breaking up coarse vegetation (such as iris *Iris pseudacorus* root systems) further opens up and improves the pasture. Poached ground creates bare patches which are good for invertebrates and as seed beds for annual plants. Dung contains seeds and grain to help the ground regenerate, while adding useful nutrients and humus to the soil.

The mosaic of extra habitats created by low intensity land use enhances biodiversity. But crofting is at the same time implicit in the survival of Gaelic culture in these crofting communities. In turn such a distinctive mix of culture, landscape and wildlife generates

tourism. Thus good crofting, alongside nature conservation, is a highly successful combination that proves vital to the economy of the islands.

Many good examples of machair have been protected first as SSSIs or nature reserves, and more recently under the European Directives. Such designations can attract funding for continuing wise and productive management of the land. Such practises are however labour-intensive so environmental support needs to be both appropriate and generous.

In 1993 Iain MacIver, then President of the Scottish Crofters' Union (now the Scottish Crofting Federation), highlighted the problems.

'As crofters we have always been aware of our responsibility for the unique environment of the crofting areas, and we realise that crofting and conservation can and should go hand in hand. Crofting is integrally linked with the distinctive cultures and languages associated with the Highlands and Islands, and with equally distinctive plant and animal communities. . . We believe that any rural policy should contain social and environmental, as well as agricultural objectives. Crofters should be rewarded for sound management of the countryside, not just for food production.'

ALIEN INTRODUCTIONS

Only otters *Lutra lutra* and seals can be considered truly native to the Hebrides. Subsequently pygmy shrews *Sorex minutus*, field voles *Microtus agrestis*, Orkney vole *Microtus arvalis*, mice *Muss pp* and rats *Rattus* spp, feral cats *Felis domesticus*, rabbits *Oryctolagus cuniculus* and red deer *Cervus elaphus* arrived with man, along with a host of plants. The dangers of introduced species has long been recognised as a worldwide risk for native flora and fauna.

Two or three centuries ago rabbits were brought to the islands as a source of food. Tiree and Berneray (off North Uist) are exceptions, although the latter with its new causeway is now at risk of invasion. Since myxomatosis, people are less inclined to eat rabbits. Numbers fluctuate, and while rabbits will damage crops and pasture their warrens can initiate serious soil erosion, as well as providing bare sand for ragwort and other noxious weeds to set seed and to spread.

Ferrets *Mustela putorius furo* are a recent introduction to Uist, ostensibly to control rabbits but in this they have singularly failed. Together with feral cats ferrets will also prey upon birds. Fortunately though, feral cats are now extinct on the Monach Isles National Nature Reserve.

Mink *Mustela vison* escaped from Lewis fur farms in the 1960s, and have now increased to wipe out many shorebird colonies throughout the Hebrides and the west coast mainland. A strategic trapping campaign has recently removed mink from Uist, and is now concentrating efforts on Lewis and Harris ultimately to remove mink altogether from the Outer Isles. Hedgehogs *Erinaceus europaeus* were introduced to the Uists in the 1970s but instead of munching garden slugs they found wader eggs more appealing. Recent studies by SNH and the RSPB have demonstrated such serious declines in wader numbers in South Uist and Benbecula that strategic control measures were instigated. This has prevented any further spread into North Uist and ultimately seeks to remove them altogether from Benbecula and South Uist.

EROSION

All such problems seem to fade in significance, compared with global climate change. The gradual rise in sea level and an increase in Atlantic storms has intensified erosion. With increasing frequency any natural capacity for sand dunes to recover is hopelessly ineffective. Erosion has long been a threat to machair, and concerns were expressed in Uist in February 1982, only to be repeated in January 1993 (when hurricane force westerlies also drove the oil tanker *Braer* aground in Shetland). Three metres of machair were lost that night along the entire length of Uist and Barra. During an even worse storm on the 11/12th January 2005, southerly winds well in excess of hurricane force 12 blew all night without respite, peaking at about 225 km per hour in Benbecula. Hectares more machair were washed away, huge areas were flooded and one family of five, representing three generations, tragically died.

There are few beaches more lovely and unspoilt than those of the Northern and Western Isles, all a considerable asset for the local tourist trade (though perhaps midges, cool winds and cold seas conspire to prevent over-exploitation!) With care, recreation need not be damaging. Offshore kelp beds, shingle beaches and marram are all vital natural buffers against storms, while it is crucial that cast tangle continues to be applied to machair soils .

CONCLUSION

Machair is both a dynamic and a unique, rare ecosystem. It is one of the best demonstrations of a distinctive and finely-tuned land use and culture successfully supporting an extremely rich wildlife resource. Generations of local folk have understood enough of the system to use it to their advantage, to cherish it for their very survival and to pass on this knowledge to their children. But pressures of modern living threaten to undermine that ancient balance. We now require a better understanding of changes to the machair and its wildlife in order that the continuing needs of local people living and working there can be provided for. After all, machair without people would be a very much poorer place.

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The RSPB Scotland strategy for machair management with particular reference to birds and achievements of the great yellow bumblebee project

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INTRODUCTION

The Royal Society for the Protection of Birds (RSPB) Scotland has a long history of involvement with machair and the rich and varied wildlife it supports. The large numbers and variety of birds found in areas with machair make it of special significance. For example, the machair and associated "blackland" found on the Outer Hebrides support the densest concentrations of breeding waders in Britain and form one of the most important wader breeding grounds in western Europe (Fuller & Jackson 1999). Well managed machair can support huge numbers of breeding birds, surveys in 1983 estimated 17,000 pairs of breeding wading birds on the Uist machair alone including 25% of the total UK populations of ringed plover (*Caradrius hiaticula*) and dunlin (*Calidris alpine*) (Fuller *et.al.* 1986).

Within the machair areas, our nature reserves and management agreements are long standing and intimately reliant on the involvement of local farmers and crofters. For example, our reserve at Balranald on N.Uist was established over 40 years ago and is an excellent example of a partnership between a conservation organisation and a crofting community regularly holding upwards of 30 corncrakes (*Crex crex*) and being one of the top visitor attractions in the Western Isles. On Tiree, our reserve on The Reef is an extensive and diverse machair plain that is maintained and managed in agreement with the local graziers. Here, the practice of seasonal cattle grazing produces exactly the right conditions for wildlife to thrive with clouds of breeding wading birds of many species and an ever changing carpet of wildflowers, including the rare Irish ladies tresses (*Spiranthes Romanzoffiana*Latin name).

Identifying importance and priorities

Since the early 1990's the RSPB have adopted a strategic approach to conservation, largely driven by the need to tackle a multitude of issues with finite resources. This approach led to the production of species and habitat action plans, in line with the Convention on Biological Diversity signed by 150 countries in 1992 and the UK Biodiversity Action Plan. We have been able to do this for bird conservation due to the results of many decades of data gathering and analysis that resulted in the production of red data lists (Batten *et* al 1990), The atlas of breeding bird distribution (Sharrock 1976 and Gibbons *et al* 1993) and Important bird areas in the UK (Pritchard 1992). Using criteria for assessing the conservation status of birds (JNCC 1996), species with recent sharp declines in numbers and contractions in range received a higher conservation priority. High priority species for machair include the many wading birds that can breed at very high densities such as lapwing (*Vanellus vanellus)*, redshank (*Tringa tetanus),* snipe (*Gallinago gallinago)*, ringed plover and dunlin. Also of priority are corn bunting (*Miliaria calandra)* and corncrake, two species that have contracted in number and range due to changes in agricultural practice. Both were much more widespread across the UK but now are quite restricted in range. Once a common and widespread bird, the corncrake had declined to 3250 calling males by the early 1970's with only 478 recorded by 1993 (Green and Gibbons 2000). The concerns over this decline in numbers and range led to corncrake being given the highest level of conservation priority by the IUCN, as being threatened with global extinction.

Finding solutions and developing the role of the RSPB

The RSPB approach to conservation problems, once they are identified, is to research the issue thoroughly and trial a range of solutions, often on our own nature reserves and land holdings. In 1992 the RSPB and NUI Cork jointly funded a PhD study into the ecology of the corncrake and investigated what factors were reducing the UK population (Tyler 1996). The research confirmed that the main problem was the extremely low numbers of young being produced each year (Tyler *et al* 1998). The main factors driving this low productivity were the loss of "traditional" grassland mosaics with tall grass crops or peripheral vegetation persisting into late summer. The move from hay, cut late in the year, to silage cut from as early as May in some areas, had left the only suitable habitat for corncrakes in the crofted landscapes of the Hebrides, parts of Caithness and Sutherland and parts of Orkney.

The approach that the RSPB have taken with the great yellow bumblebee has been very similar. Once widespread across the UK, now restricted to parts of

the Hebrides, the north coast of Scotland and the Orkney Islands, the range contraction and the reasons for it mirror those seen for corncrake (Fig. 1).

In 2003 The RSPB and the Institute of Zoology jointly funded a PhD researching the ecology of the great yellow bumblebee (Charman 2007). The research concentrated on what the bee required during its relatively short season from queens emerging from hibernation in late May to new queens leaving the nest and preparing for hibernation in August. The work identified a sequence of foodplants used through this summer season and together with work being undertaken by the Highland biological recorders helped to piece together some of the reasons why the great yellow bumblebee was no longer widespread across the UK. The main factors appeared to be the loss of foodplants at key times of year, this being linked to increasingly intensive management of grasslands.

Together with the suite of species that have always been restricted to machair such as Slender naiad (*Najas flexilis),* belted beauty moth (*Lycia zonaria atlantica)* and the northern Colletes (*Colletes floralis),* the biota that machair now supported highlighted its importance and the need for sympathetic management. In 1999 the JNCC published the Machair Habitat Action Plan (JNCC 1999) in which the world wide extent was estimated at 25,000ha with 17,500ha in Scotland. The main objectives for this action plan were to maintain the existing extent and reduce by 30% the amount of agriculturally improved machair grassland by 2010. The RSPB has an obvious vested interest in contributing to the achievement of these objectives as in doing so we can achieve our own objectives for corncrake, corn bunting and breeding waders, together with those for great yellow bumblebee and northern colletes, for which the RSPB are action plan joint lead partners.

Testing strategies and actions for recovery of populations and habitats

There are three main grassland management actions that can be adjusted to suite the requirements of corncrake and great yellow bumblebee. Keeping areas of un-grazed vegetation that acts as cover for returning corncrake and/or flower source for emerging bumblebee queens; sowing arable crops that include flowering plants for bumble bees; creating or maintaining species rich grasslands that include red and white clover and other bee food sources, and that are not mown or grazed until late August/September.

Some of the trial management for corncrakes involved developing and testing various arable crops to provide cover in the spring and also winter food for passerines such as twite (*Carduelis flavirostris)* and corn bunting (*Emberiza calandra*). In partnership with the Glasgow Natural History Society (GNHS) and with funding generously provided by Esmée Fairburn Foundation, Heritage Lottery Fund and Forward Scotland, the RSPB were able to modify these arable plots for the great yellow and other bumblebees. This involved simply adding more of the required food plants as identified through research (Charman 2007). By 2008 we were managing 54ha of arable land in this way on 9 sites, providing flowering plants at the start and end of the bumblebee season free from grazing livestock.

Adjustments were also made to the management of hay and silage meadows and field margins and headlands (early cover areas), to make them more suitable for great yellow bumblebees. This involved moving the cutting or grazing dates back to the end of August and into September if possible, leaving uncut and ungrazed flower rich areas and reseeding with suitable flowering plants within the seed mix. Nature reserves with machair on N.Uist, Coll, Tiree, Oronsay and Islay and also reserves and agreements on Skye, Mull, Orkney, in the North of Scotland and at Vane Farm in Kinross (a historic location), have all adapted their management accordingly. This is probably the first time that such targeted action has been directed towards benefiting an invertebrate over such a wide area in Scotland, if not the UK (Table 1).

Where grasslands, including machair, have been agriculturally improved and reseeded with a high proportion of rye grass, a late cutting or grazing date can be problematic. This is because many of the rye grass cultivars are quick and luscious growing and have been developed to be ready for mowing to produce silage early in the summer. Delaying mowing can therefore lead to a collapsed or lodged grass crop. Also, within a relatively intensively managed rye grass sward there are very few flowering plants. This is because they cannot compete with the rye grass, they have no time in which to develop flowers and set seed before the usual cutting dates. They may also have been treated with herbicide prior to reseeding. Agricultural intensification has been shown to have an impact on the variation in crop structure creating a simpler more homogeneous and denser sward. (Wilson *et.al.*2005*).* To change this we have been developing seed mixes that include higher diversity of grass cultivars and species and flowering plants such as red and white clover. Where necessary we have been using such mixes in a programme of reseeding our grass fields as part of the usual rotational management (Table 2).

One of the reasons that machair grassland is so flower rich is the relatively low intensity of management that persists on some of the crofts and farmland. A system of rotational cropping with crops such as bere barley, black oats and rye has been practiced for generations, without herbicide or large amounts of compound fertiliser. The machair grasslands within such systems can have a very high diversity of flowering plants throughout the summer. In partnership with the Bumblebee Conservation Trust (BBCT) and The University of Stirling we are researching methods to restore flower rich machair – (*see Redpath et al* this volume). With this research we hope to be able to provide details of cost-effective management techniques that would enable land managers to recreate

diverse machair where the original sward has been replaced by more intensive, low diversity rye grass leys. By 2008 we were managing just over 1400ha of grass crops that would be cut or grazed at the end of August or early September: 1184ha was within the current range distribution of great yellow bumblebee and 888ha of this was on machair. Our management will ensure that eventually this area will all become species rich grassland.

An integrated approach to conservation

In general, conservation of a habitat or for a widespread population cannot be done via nature reserves alone. Machair, great yellow bumble bees and corncrakes require more than what can be achieved on these relatively small patches of land. To help achieve appropriate management and also to restore good quality habitat in the wider countryside the RSPB work at several levels, from influencing public policy to innovative partnerships, such as the Nadair LIFE project and the Great Yellow Bumblebee Project. Where it makes good conservation sense, we have acquired land and entered into management agreements and these have been used to enhance our advocacy and advisory work. Owning and managing nature reserves allows the development of a series of core sites where high quality management for key species can be guaranteed. These core areas then act as focal points for activity to influence and promote positive management in the surrounding area via advice, demonstration, or simple word of mouth.

An integral part of the great yellow bumble bee project was to publicise and promote good management practice. Working with the BBCT and GNHS we produced an advisory leaflet for farmers, crofters and land managers and also provided specially produced education packs to schools throughout the range of this species. Part of this was the production of a 'Brilliant Bumblebees' poster as part of the Great Yellow Bumblebee education pack. It is currently being translated into Gaelic with two elements - a teachers pack, which includes lesson notes and activities about the great yellow bumblebee, and bumblebee identification materials for children living in the project area to use.

For corncrakes and bumblebees, the research findings and results of trial management were translated into management solutions. RSPB Scotland was involved in the stakeholder process for re-designing Scotland's agri-environment schemes and could therefore input information from this work. As a result there is a range of management options and requirements for these two species within the Government led Scottish Rural Development Programme (SRDP) 2007-2013. This provides a landscape scale £1.6 billion programme of economic, environmental and social measures designed to develop rural Scotland over the six year period.

RSPB Scotland will continue our advocacy through various agri-environment stakeholder and technical working groups, to the benefit of the great yellow bumblebee. One of our key advocacy priorities is highlighting the need for adequate funding for Scotland's agri-environment programme, to the benefit of the great yellow bumblebee and many other species. This will be carried out at all levels of government, from the EU and European Commission, to Westminster, and to Scottish ministers and the rest of the Scottish Parliament. We will also input the results of our management for great yellow bumblebees into the Species Action Framework that Scottish Natural Heritage (SNH) implement for this species. In these ways we aim to influence and promote beneficial management for machair and the species it supports over its whole extent in Scotland.

Has it worked?

In areas that support corncrake and great yellow bumblebee RSPB Scotland now has 20 nature reserves and over 50 land management agreements covering nearly 3,000ha. Over half of this area is managed grassland and this includes some of the very best examples of machair in the world. All RSPB Scotland nature reserves undertake annual monitoring of key breeding and wintering birds and also report on habitat management. We know that in 2008 a total of 1472ha of grass crops were being managed for corncrakes and bees, of which 888ha was machair. With the 92.2ha of early cover and 54ha of arable cover crops this habitat attracted 240 calling male corncrakes, about 20% of the UK total (1178). Thirteen of the 20 reserves have had great yellow bumblebees using them in the past three years. The remaining seven are currently just outside the range distribution of the great yellow bumblebee and now offer the chance of range expansion for this species.

It is safe to say that our programme of work, together with the GNHS and others has helped to raise the profile of this species with the result that it now is recognised in many Local Biodiversity Action Plans, is included in SNH Species Action Framework and features as a priority species in the new SRDP.

Our strategic approach over the next five years will aim to safeguard the extent and quality of the machair habitat and the varied and special wildlife it supports. We will continue to achieve this through a wide variety of means, from the direct management of nature reserves, to partnership projects with others and positive advocacy and policy work. We will also promote the restoration of degraded machair habitat, where possible and practical so that the future of one of Scotland's most unique and enigmatic wildlife havens is secured.

Reserve holdings and agreements *(by island/island group)*	**Early Cover (ha)** *(grazing break from 1st April to September or longer)*	**Cover crop or arable with flowering plants (ha)**	**Late cut or grazed species rich grassland (ha)** *(no grazing or mowing between 1st April and mid to late August or longer)*
Orkney	17	13	64
Durness	12	1.2	58
Broubster	1	2.4	37
N.Uist	13.4	13	94
S.Uist	2.6		9
Skye	1.7	0.4	7.8
Tiree			177
Coll	21		566
Mull	2		
Colonsay			160
Oronsay			42
Islay	21.5	24	175
Vane Farm*			26
Totals	**92.2**	**54**	**1415.8**
Machair	**41**	**13**	**888**
In GYBB range	**68**	**27**	**1184**

* Area being managed by BBCT with the RSPB Scotland nature reserve

Table 1. Locations being managed for the great yellow bumblebee and corncrake between 2004 and 2008 by RSPB Scotland in partnership with GNHS and supported by Esmée Fairburn Foundation, Heritage Lottery Fund, Forward Scotland and SNH.

In-by Grassland seed mix - Orkney		**Kg/ha**
Rye grass	Bastion	2
	Premo	1.5
	Morgana	1.5
	Morenne	4
	Talbot	3
	Fantoom	1
	Lamora	2
	Springfield	3
	Belfort	5
	Condesa	2
Timothy	Scots	7
	Goliath	2
Fescue	Rossa	0.5
	Comtessa	1.5
White clover	Huia	2
	rivendell/kent/donna	2
Red clover	Britta	2
Kidney vetch	*Locally sourced*	0.5
Tufted vetch	*Locally sourced*	1

Table 2. A typical seed mix with sowing rates. This was used in trial plots in Orkney from 2004 and is now the basic seed mix for use on RSPB Scotland nature reserves where reseeding to provide a flower rich grass crop that can be harvested late in the season. Rates and varieties will differ slightly according to location and soil types.

Corncrake distribution 1968 –1972

Corncrake distribution 1988-1991

Fig. 1. Distribution of Corncrake (*Crex crex)* from BTO Atlas data (from NBN Gateway)

Fig 2. Map of past and current distribution of great yellow bumblebee. From Charman (2007).

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Machair and coastal pasture: managing priority habitats for native plants and the significance of grazing practices

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ABSTRACT

In 2007, Plantlife published a list of 42 Important Plant Areas (IPAs) in Scotland, five of which feature machair and coastal pasture. These sites qualify as IPAs, where they are an outstanding example of a habitat of global or European plant conservation and botanical importance with rich plant diversity and the presence of rare and threatened speeies. Plantlife's conservation programme conducts research on priority species within these habitats and devises and tests appropriate management. This paper uses two examples, *Spiranthes romanzoffiana,* Irish lady's tresses, and *Platanthera bifolia,* lesser butterfly orchid, to illustrate how this approach could be used to inform land management practices and the grant programmes that sustain them in order to conserve wild plant populations. These management recommendations focus on grazing that aim to increase populations of these species and wild vascular plant diversity in these habitats.

INTRODUCTION

Although coastal pasture is only one element of the wider machair landscape, it is a key habitat in Plantlife's conservation programme and is home to Irish lady's tresses and also to some populations of lesser butterfly orchid, both of which are priority conservation species for Plantlife Scotland. Other habitats within the machair landscape that are important for plants include traditionally managed flower rich machair and dune slacks within mobile sand dune systems. This paper discusses the management of coastal pasture and machair habitat for two species of flowering plant, with wider ramifications for other rare flowering plants.

Over the last six years, Plantlife has been conducting research and running management trials on two priority species that characterise the coastal pasture element of machair. Results from research at Aberdeen University and ongoing observations of wild plant populations alongside management trials are now set to inform wider land management contract options. Effective land management prescriptions through Scottish Rural Stewardship Scheme (SRDP), enabling land owners to manage for their rare plant populations should aim to result in healthier habitats for these and associated species and should also result, in the longer term, in larger and more robust wild plant populations. This is especially important in view of ongoing environmental change, brought about by climate change and continued decline in traditional land management practices. It is only by enabling current land owners to manage their land sympathetically that these species will be able to expand their populations, thus increasing their resilience in the face of climate change.

Identifying and mapping Imporant Plant Areas

Important Plant Areas (IPAs) are a key target of the Global Strategy for Plant Conservation (2002). The UK governments endorsed this strategy with the publication of Plant Diversity Challenge in 2005, which detailed the UK's response to the 16 targets of the global strategy. Meeting targets 4 and 5 are founded on the identification and protection of Important Plant Areas.

In July 2007, Plantlife, with partners, published a list of 150 IPAs across the UK. Plantlife is now working with partners across the UK to map these IPAs so that they can become a relevant consideration in landscape planning. The UK is following the lead of several Central and Eastern European countries who have already identified and mapped their IPAs. These can be seen at www.plantlife.org.uk.

IPAs are selected where sites meet at least one of three internationally agreed criteria:

Criterion A: the presence of species that are of global or European conservation concern. For vascular plants in the UK, these are species listed as critically endangered, endangered, and vulnerable on the UK Red Data List (Cheffings and Farrell 2007). Machair sites in Scotland qualified if *Najas flexilis* or *Euphrasia* species were present for example.

Criterion B: very high species diversity within a Eunis level 2 habitat (see European Environment Agency http://eunis.eea.europa.eu). For machair habitats these include coastal dune & sand, coastal shingle, rock shores, surface standing waters, littoral zone of inland water bodies, dry grasslands, alpine & sub alpine grasslands, tundra, inland rocky outcrops.

Criterion C: the site is an example of a habitat of global or European plant conservation and botanical importance, as listed in a Special Area of Conservation (www.snh.gov.uk) for plants. These include fixed dunes, alpine and sub alpine calcareous grasslands, alpine and boreal heaths, mesotrophic waters and Atlantic salt meadows for example. Forty two IPAs have been identified in Scotland (see Fig. 1). A list of these sites is available at www.plantlife.org.uk.

One of the first IPAs to be mapped in Scotland is the West coast IPA, which stretches from Kinlochbervie to the Mull of Kintyre, identified for its Atlantic woodland communities and Atlantic heath communities. For each key plant community, core areas are identified. Around these core areas, buffer zones of up to 1 km are drawn. Key predictive environmental variables are used to identify zones of opportunity within these buffer zones. These are areas that could be suitable to support the key plant community if land management was appropriate. For west coast Atlantic woodland for example, this may be an area of open habitat or an area of coniferous plantation that could be managed differently to support, in time, key Atlantic bryophyte and lichen woodland species. The approach is similar to Forest Habitat networks, but is applied to every qualifying plant community identified in the IPA selection procedure.

Mapping of machair IPAs has not yet commenced. As an example, on the island of Coll, it is likely that the Site of Special Scientific Interest (SSSI) would be identified as a Core Area, with a 1 km buffer zone around its boundary. Key predictive environmental variables will be tested statistically to find the most appropriate predictive environmental variables to enable identification of Zones of Opportunity. These environmental variables may include the presence of calcareous, wind blown sand, dune pasture, flat relief and / or wet & windy weather patterns.

IPAs are also assessed in terms of their condition and the threats they face. A *pro forma* IPA information sheet is filled out by a site expert and this is available online at www.plantlife.org.uk. Threats at the coastal pasture and machair IPA sites include year round grazing, the presence of more sheep than cattle, the presence of rabbits, vehicular access, coastal erosion, off shore kelp bed degredation and rubbish dumping. At this point, management advice is needed to mitigate these threats and ensure that management is acting to conserve the IPA qualifying features in the long term.

Managing IPAs for priority species: case study 1: *Spiranthes romanzoffiana*

Irish lady's tresses is a very rare orchid, confined in the UK to the west coast of the Scottish mainland and its islands and to a small number of sites in Northern Ireland. It also grows in Eire and in Canada, the USA and the Aleutian Islands. It is distinguished by a slender spike of white, scented flowers, from July – August or September. It grows in meadows, pastures and heaths.

Historically, its habitats were managed as extensive grazing. Desk research by Wilson (2009) shows that key sites were subject to winter cattle grazing, with cattle removed to summer pastures from May. Parts of in bye land were cultivated on rotation with poorer areas left fallow. In winter, cattle returned to graze in bye land, when poaching would have occurred alongside possible seasonal inundation.

During the early – mid 19th century changes in land use started to occur when kelp was collected and used to fertilise fields. This was accompanied by an increase in the rabbit population to supplement food sources for the local human population. Further increases in the amount of land used for cultivation came with the introduction of lazy beds. There has been some association made in the past between Irish lady's tresses and old lazy beds. This does not appear however to be an exclusive association and lazy beds do not appear to be any more or less suitable than other habitats within coastal pasture.

From the mid 19th century onwards, further changes to land use came as the numbers of cattle declined in favour of sheep, as the value of cattle declined. There is a close association between cattle grazing and wild plant diversity. Cattle are generally non selective feeders and are less likely to target flowering plants specifically. They can also break up swards physically, which can benefit some species. A change from cattle to sheep therefore tends to be less advantageous to rare plants. Sheep can have a tendency to target flowers for consumption. These rare species often require non selective grazing, which acts to limit the vigorous growth of competitive species like rushes. Further deterioration in the condition of habitats of rare flowering plants occurred as land was abandoned as a result of emigration or as human populations became increasingly confined to smaller, marginal crofts on coasts. These negative changes in land management and the concomitant impact on plant communities was less apparent or later on islands where crofters retained a mix of cattle, sheep and arable in township systems.

During the early 20th century, as rural human populations continued to decline, arable cultivation also declined and in bye was used increasingly to produce winter fodder. Cattle numbers continued to fall in favour of sheep. These changes continued to contribute to habitat deterioration for Irish lady's tresses and associated species within the coastal pasture habitat, as competitive grasses and rushes were no longer kept in check by winter grazing or where in bye was converted to fodder production.

From the mid – late 20th century, winter fodder production declined and in bye land was instead increasingly used for summer sheep grazing and was often subject to some improvement. More recently, sheep numbers have declined with the drop in their monetary value and pastures have been abandoned once more. This is leading to even further declines in populations of Irish lady's tresses. Although long lived,

Irish lady's tresses populations at most sites in Scotland appear to be in slow and continuing decline.

Current land management at the best sites for Irish lady's tresses are built around complex but flexible grazing regimes, which can include erratic grazing regimes for cattle and sheep. At one site in Scotland, the timing of grazing does not seem to be as important as the impact of some grazing at some point in the year. The species is long lived so that it can survive grazing, although if flower spikes survive to flower and set seed, its populations are strengthened.

At other sites in Scotland, a wide range of grazing regimes, often with sheep and cattle are employed. Some sites are used for intensive cattle rearing with semi improved swards. On more traditional crofts, cattle graze in bye in winter with a grazing break over the summer. On other sites on partially drained peat bog, light occasional grazing appears to maintain conditions for Irish lady's tresses. On the mainland, sites are part of rough hill grazing. These sites rarely flower however and as such their long term success is under doubt.

Increasing capacity for reproduction of Irish lady's tresses orchid populations

Until recently very little was known about the reproductive capacity of Irish lady's tresses in the UK. The species has probably been lost from its single site in England and has not been seen there for several years. In Scotland, populations on the Outer Hebrides have been tracked for over 12 years by Dr J Robarts and on the Inner Hebrides by Dr R Gulliver (2004), which has shown that plants can persist vegetatively or underground for long periods of time. However, there had been no evidence that the plants were reproducing sexually until Andrew Scobie (2007) found apparently viable seed from a Scottish population. In addition, research by Gulliver (unpub), using *Spiranthes cernua* as an analogue species has demonstrated vegetative reproduction. Gulliver et al (2007) have shown that vegetative reproduction in *S. cernua* occurs through the production of rosettes, the production of new plantlets at root tips and the production of new plantlets at rosette centres. Further research is required to determine which, if any, of these processes occur in *S. romanzoffiana* in the field.

Scobie (2007) notes the existence of seed in Irish lady's tresses and has recorded low but consistent levels of seed production on Colonsay since 2003. Seed production is, however, far more limited than in other orchids. In larger flowering populations, natural pollination levels are high but result in very low levels of capsule production. Within these capsules, the quantity of viable seed is also low and consequently the annual seed output from these populations will be very limited. Forrest et al (2004) found very low genetic diversity in populations on Colonsay and in Ireland but higher diversity in populations from Coll and the Outer Hebrides, Experimental cross pollination studies within and between populations in Scotland suggest that seed production may be constrained by self-incompatibility and / or inbreeding depression (Scobie pers. comm.), which was also noted in North American S. romanzoffiana by Catling (1982).

With consistent, although low levels of seed production, it is essential to maintain flowering populations through the provision of summer grazing breaks to maximise the opportunity for pollination and seed production, however limited that may be. These small populations remain however extremely vulnerable to stochastic events. For example, in the summer of 2007, flowering population sizes were considerably reduced by rabbit grazing, resulting in significantly lower pollination levels and no seed production that year.

Ongoing management trials, supported by evidence from research, have enabled Plantlife to devise some guidelines for management designed to maximise the size of flowering populations of Irish lady's tresses. Gulliver et al (2004, 2007) provides details of exclosures used to manage grazing by cattle and sheep to increase Irish lady's tresses populations. These experiments have shown that a return to a more traditional management regime for machair that removes grazing by sheep and / or cattle in May or June, and reinstates grazing in September, maximises the potential for populations to flower, set seed and expand. Full effectiveness of this regime however can only be attained where rabbit populations are controlled. Sites must also be managed to avoid artificial improvement through the application of artificial fertilisers or drainage for example. Seasonal inundation should be retained, as this also helps to reduce competition from other plant species. Irish lady's tresses populations show some resistance to grazing over time (Gulliver et al 2005), although for long term population growth, contiguous summer flowering within large populations is required.

Monitoring of Irish lady's tresses populations has been crucial in assessing population change over time. To this end, volunteer Flora Guardians are recruited to count flower spikes every year to track the potential of populations to expand. Plantlife is looking for more Flora Guardians to complete this type of work on the Inner and Outer Hebrides. Please contact Plantlife Scotland if you can help.

Managing IPAs for priority species: case study 2
Lesser butterfly orchid

Lesser butterfly orchid *Platanthera bifolia* produces white / greenish white flowers from May to July. It is distinguished from greater butterfly orchid *Platanthera chlorantha* by the shape of the flower, the angle of its pollinia and by its height.

Lesser butterfly orchid is pollinated by night flying moths and achieves a generally high rate of seed set. Vegetative propagation, if it occurs at all is very rare. It grows throughout Europe to the Himalayas and in North Africa. In the UK, it grows on heathland,

grassland, scrub margins and open woodland; it has suffered a 33% decline between 1964 and 2002 across the UK (Preston et al 2002). This decline is why the species is now listed as a priority species on the Scottish Biodiversity List and in SNH's Species Action Framework. Its key threat is the continuing loss of its habitat.

Land management at lesser butterfly orchid sites
In 2008, Plantlife Scotland and the Farming Wildlife Advisory Group (FWAG) and Scottish Natural Heritage conducted a field assessment of management at 22 sites for lesser butterfly orchid across Scotland. Interviews with land managers illustrated that in general, higher numbers of cattle had been kept on site in the past and sometimes also higher numbers of sheep. Overwintering cattle seemed to support larger populations and light summer grazing seemed to benefit lesser butterfly orchid populations by reducing competitive grasses. In contrast, silage making in the past had limited orchid numbers. One site on Skye was regularly burnt, which was believed to help maintain orchid numbers, presumably by reducing competition from other species.

At sites where lesser butterfly orchid numbers remained high, all sites had been lightly grazed by cattle at some time during the year. Where cattle grazing had been more intense in autumn / winter, orchid population numbers appeared to increase.

Management recommendations for flowering plants in coastal pastures

1. Grazing patterns and timings for cattle; sheep; deer:
Optimal grazing regimes to maximise orchid numbers focus on maintaining grazing by cattle and / or sheep in winter with short exclusions during flowering periods in the summer. Grazing breaks are ideally as short as the flowering season only, roughly three months for these species, resulting in fairly short swards. Currently, sites with large populations are all managed as part of a farm grazing regime that removes rank vegetation in autumn and winter. During flowering periods in June, July and August, many good sites have moderate levels of grazing. Other nearby species may be more palatable, which means that orchids are not necessarily targeted by grazers.

2. Choice of livestock
Both sheep and cattle are grazed on good orchid sites: as long as animals are used to remove large quantities of coarse grasses, then any grazing animals could be used. Heavy grazing pressure must however be released in summer to allow flowering. Some good mainland sites are winter grazed by deer, which has a similar effect.

3. Rabbit control
Grazing control during flowering periods must include rabbit control in order to be effective. The potential for seed production in Irish lady's tresses is being severely curtailed by rabbits removing flowering spikes and is having a significant impact on seed production.

4. Conservation management agreements
Of five sites visited with conservation management agreements in place that specified grazing levels and exclusion periods, only one site was being managed successfully for lesser butterfly orchid. This success was linked to three factors:

- Grazing exclusion period was short enough to cover flowering of this species only
- Grazing levels were high enough to maintain a short sward
- Management regime was specifically targeted at this species

Problems occur where conservation agreements are targeted at other species that require lower levels of grazing. This is resulting in problems when summer growth is not removed and then becomes unpalatable in autumn. Equally, the desire to meet cross compliance measures (the requirement to meet certain environmental standards under agri environment schemes) means that winter cattle grazing is restricted to limit poaching of the soil. This means that suitable habitat conditions for these orchid species are not maintained. Winter sheep grazing tends to trample vegetation but not remove it.

These observations suggest that summer stock levels should be maintained to manage competitive grasses or sites should be stocked heavily in late summer before grasses become unpalatable. Grazing exclusions should be kept short and restricted to small sites to manage and concentrate grazing on key sites.

A one size fits all approach to species rich grassland management clearly does not suit lesser butterfly orchids or Irish lady's tresses orchids. This causes a conflict at some sites between corncrake (*crex crex*) management and *Spiranthes* management for example. Several of the sites on Coll and the area around Loch Fada on Colonsay are under corncrake management, which requires an extended grazing break during summer months resulting in a much taller sward. This is less than ideal for Irish lady's tresses, and population numbers are falling under this regime.

5. Land management supported by SRDP
There has been a tendency for SRDP prescriptions to over compartmentalise for environmental management, leading to rigid management regimes that cannot manage a mosaic of habitats and deliver a range of rare species habitat needs. Well managed sites benefit from being part of more extensive grazing regimes, which are more flexible for owners, tenants and neighbours and enable them to move animals from site to site, ensuring that site specific management is appropriate. Increasing flexibility of schemes in terms of grazing will make them more economically viable and attractive for farmers to adopt and effectively deliver more environmental benefits.

6. Winter poaching
Winter poaching may be useful in preparing the ground for good spring growing conditions. Observations at sites indicate that both plants can withstand years of very heavy grazing and plants will come back once grazing is reduced to moderate levels. Winter poaching could therefore be used as a management tool to maintain existing populations and encourage expansion.

7. Supplementary feeding to maintain appropriate grazing levels on designated sites
Many sites are relatively poor pastures and farmers do not leave animals out long enough because of loss of condition. Restrictions on supplementary feeding are standard clauses in many prescriptions at designated sites to avoid nutrient increase and introduction of foreign seeds from hay / silage. However, where the lack of winter grazing is limited specifically by this factor, relaxing rules on supplementary feeding would enable farmers to graze for longer which would benefit habitats. Supplementary feeding could be through 'concentrates only' systems for example. The use of native breed cattle should also be encouraged as some breeds struggle to maintain body eondition on these pastures.

8. Haymaking and cropping times
Only one site visited was being managed successfully for lesser butterfly orchid through hay making. The quality of the hay was poor and does not produce a viable crop. Several sites could have been used to produce hay / silage and if this had been done, the lack of grazing during the hay making period could allow vegetation to become too rank for this species. Haymaking is not therefore recommended as a management tool. There is not enough information on the impact of cultivation on these species, although it would be prudent to presume against cultivation.

9. Protecting sites from new woodland plantings
One site visited has lost orchid populations to woodland regeneration schemes. The presence of lesser butterfly orchid and Irish lady's tresses (where appropriate) should be a material consideration in planning woodland regeneration schemes.

10. Monitoring
There is an urgent need to continue monitoring how plants react to changing management practices. Plantlife currently has three volunteer Flora guardians for Irish lady's tresses and 12 for lesser butterfly orchid. Monitoring needs to include sward height measurements in early June and early September and the number of flower spikes produced. Plantlife is always looking for more volunteer Flora Guardians so please get in touch if you can help.

Required changes to land management scheme prescriptions

If the conservation of rare species is to be effective through SRDP prescriptions, flexibility needs to be increased. Managing for single species does not automatically result in increased levels of biodiversity and managing for bird species, for example, does not necessarily benefit rare and threatened plants. There is instead a need for flexible schemes that can be adapted to each site, so that land managers can manage smaller parcels of land and move livestock between them as required. This provides land mangers with increased flexibility when managing for conservation while at the same time maintaining herd condition. The introduction of supplementary feeding, through concentrates for example, would also enable land managers to use animals more effectively to maintain the mosaic of habitats that these species require and that in the long term provides an ecosystem approach to land use, enabling production and conservation to work side by side. There is an urgent need to devise modern land management prescriptions that are sufficiently flexible to build on the best practices of the past and ensure that crofters and small land managers can afford to continue to manage their land in environmentally and economically sustainable ways. Much is still to be learned from traditional land management, when these species did in fact thrive as a by-product of dynamic and diverse rural land management.

To find out about becoming a Flora Guardian for rare plants and threatened habitats in Scotland, please contact Plantlife Scotland at the address above or go to our web site www.plantlife.org.uk/scotland/get_involved.

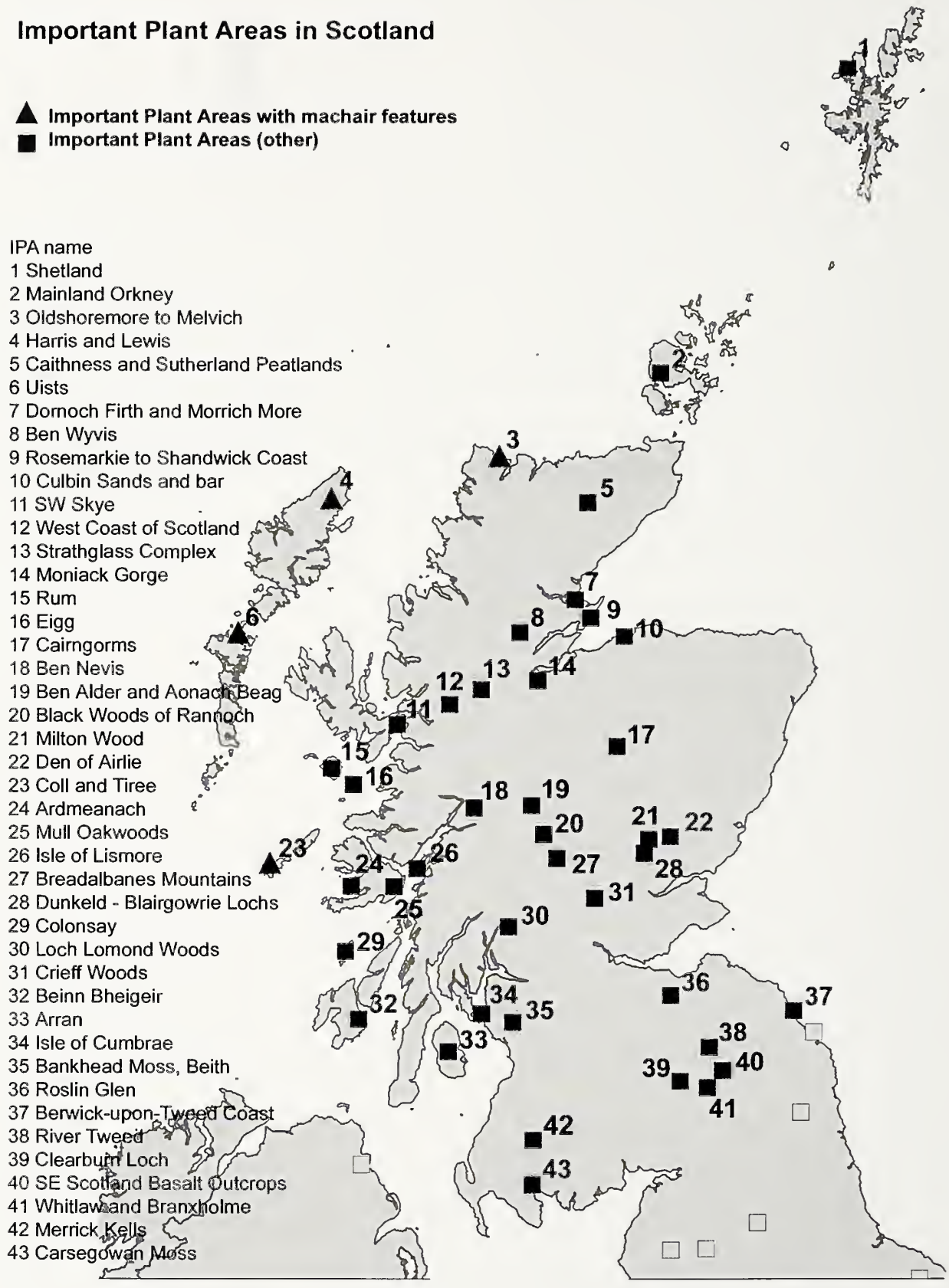

Fig. 1: Map of the location of Important Plant Areas in Scotland.

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The conservation of Scottish Machair: a new approach addressing multiple threats simultaneously, in partnership with crofters

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ABSTRACT
Scottish machair is a unique cultural, agricultural and conservation resource that is dependent on active management by crofters and farmers operating low intensity livestock systems. Socioeconomic changes threaten its future, and so that of the associated ecological community including species of high conservation priority. The Scottish Rural Development Programme (SRDP) includes measures for machair but extensive consultations identified significant gaps and shortfalls in this mechanism for securing machair conservation. Direct input of new finance is needed to: assist and facilitate positive crofting management; promote best practice; and develop future agri-environment programmes that secure beneficial machair agricultural management in the longer term.

Over the past two years, The Royal Society for the Protection of Birds Scotland (RSPB Scotland) developed a successful bid for LIFE+ funding from the EU for a machair conservation project in the years leading to the next SRDP (2010 – 2014). The proposal has been awarded over £1 million in LIFE+ funding. As this paper is submitted for publication, negotiations are underway between RSPB Scotland, Scottish Natural Heritage and Comhairle nan Eilean Siar to secure the remaining 50% funding required to undertake the project.

INTRODUCTION

Presentations at this conference, and wider recent discussions, have highlighted several key issues relating to Scottish machair, including:

- Its high biodiversity value, particularly with respect to species and assemblages disappearing or lost from comparable areas in Europe.
- The rarity and singular nature of the habitat, particularly the globally unique Uist arable machairs.
- The insular, isolated nature of many of the important wildlife populations dependent on machair, and consequent elevated extinction risks.
- The emergence of multiple threats to this biodiversity.
- The central role that crofting agricultural systems play in generating and maintaining this biodiversity and the intimate, longstanding connections between island culture, crofting and machair. Effective conservation of machair will only succeed if it supports local agricultural systems, with crofters and farmers in a central role in developing actions and delivering management.
- The socio-economic changes that are underway will increasingly affect crofting practices and patterns of machair management.
- A high proportion of designated machair sites are in unfavourable conservation status: around 70% of the machair Special Area for Conservation (SAC) area (14% of the global resource) is in unfavourable condition, nearly all of this 'declining'.
- Increasing impacts of resident greylag geese (*Anser anser*) are a cause of considerable concern among crofters and farmers.
- There is a widespread perception that agri-environment schemes in Scotland currently operate under a funding shortfall.

With these issues in mind, RSPB Scotland has for the past two years, in consultation and partnership with numerous individuals and organisations, been leading the development of a project proposal in the shape of a bid for funding under the EU LIFE+ Nature scheme.

The final proposal was submitted in December 2008, in partnership with the statutory conservation agency Scottish Natural Heritage (SNH) and Comhairle nan Eilean Siar (CnES), the Western Isles local authority, and with support of the Scottish Crofting Foundation a range of crofters and stakeholders. The bid was for a 4-year, multi-disciplinary project for the conservation of Scottish machair, costing just over £2 million in total.

The partnership learned in August 2009 that the bid for EU funding has been successful, with 50% (the maximum available, over £1 million) of project funding being awarded by the European Commission via LIFE+. Following negotiations, a co-financing agreement between SNH, CnES and RSPB Scotland has recently been secured. The required funding package is now in place and work on the Conserving Scottish Machair LIFE+ Project will begin in January 2010.

THE PROJECT

Scottish Machair is listed on Annex 1 of the EU "Habitats Directive", being a high biodiversity value habitat occurring over a total global area of approximately 19,000 ha, with 70% of this in western Scotland, mostly on the offshore islands (the remainder in western Ireland). This listing makes it a primary consideration for EU environmental policy and qualifies machair conservation for funding under the EU LIFE+ Nature scheme.

Projects bidding for LIFE+ Nature funding must meet several specific conditions before being considered eligible, including the following:

- Projects should contribute to the implementation of the Birds and Habitats Directives and support the further development and implementation of the Natura 2000 network of sites designated under EU law (Special Protection Areas, SPAs, and Special Areas for Conservation, SACs);
- Projects should focus on long-term, sustainable investments in Natura 2000 sites and the conservation of species and habitats targeted by the Directives;
- Projects must have strong 'best practice' or 'demonstration' elements;
- They must include a large element of 'concrete conservation actions';
- LIFE+ does not fund research projects;
- Actions must be complementary to actions that can be financed from other EC funds, notably mainstream land management funding, in Scotland under the SRDP.
- Projects should deliver 'added European value'.

During two six-month full-time secondment periods during 2007 and 2008, a RSPB Scotland Project Development Officer (IM), funded by SNH, conducted formal and informal consultations with crofters, farmers, relevant organisations, academics, civil servants and agency staff. The aim was: to identify the principal threats to machair habitats, to construct objectives in relation to these, and use these to develop a project proposal that simultaneously fulfils the conservation needs of Scottish machair; the practical agricultural requirements of the people who manage it; and the strict conditions of the LIFE+ Nature scheme outlined above.

The result was identification of the following project objectives, actions and outputs summarised below.

OVERALL PROJECT PURPOSE

To secure and improve the conservation status of 70% of the world's machair habitat and its associated species by implementing and demonstrating sustainable management methods that optimise the conservation interest and are compatible with local agricultural practices.

Specifically, the project will target machair habitat on three SACs and will secure the conservation of associated bird species in 10 machair SPAs - this covers a total area of 23,766 ha (Fig.1). The project will bring 3,200 ha of machair habitat into favourable condition and improve the conservation status of the Annex 1 species corncrake (*Crex crex*) and chough (*Pyrrhocorax pyrrhocorax*), and the regularly occurring migratory species dunlin (*Calidris alpine*) and ringed plover (*Charadrius hiaticula*).

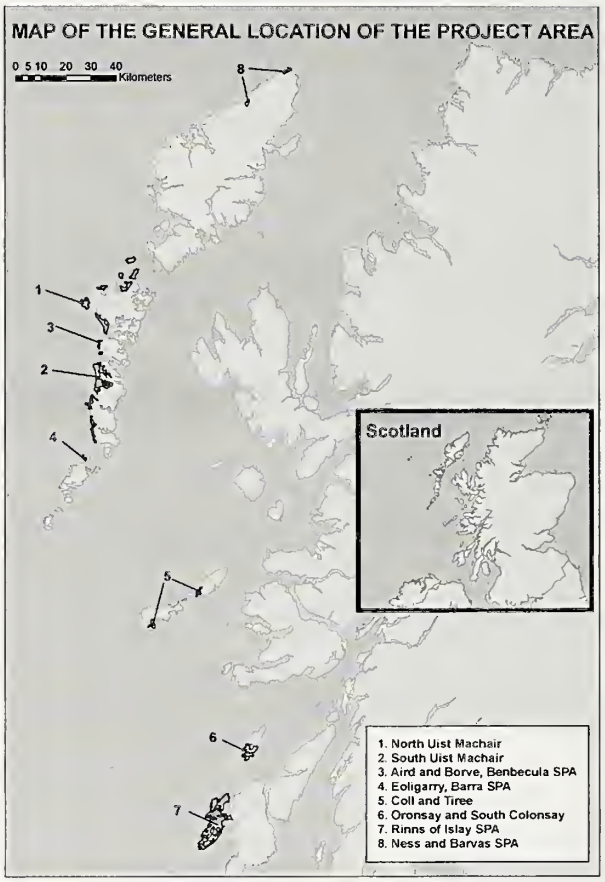

Fig. 1. Map of the project area.

The principal mechanisms that will be employed are:

- **Direct undertaking of agricultural management** beneficial to wildlife and economically sustainable, either by providing additional financial support to crofters; employing contractors as appropriate; deploying project staff and machinery directly.
- **Coordination, facilitation and demonstration** of sustainable agricultural methods to the crofting community, advisors and policy makers.
- **Provision of skills training, machinery, labour and advice** to assist with conservation management.
- **Boosting and extending the two local greylag goose management schemes** to assist the implementation of beneficial management practices.
- **Enhanced and extended monitoring and information gathering** within the project area to evaluate the effects of the management practices implemented on target biodiversity, and to identify any blockages that hinder the achievement of conservation objectives.

- **Development of bespoke agri-environment measures** for inclusion in next SRDP to bolster the longer-term sustainability of extensive agricultural systems on Scotland's machair.
- **Development of community-led machinery ring** to provide additional capacity and flexibility to crofters and farmers.

SPECIFIC PROJECT OBJECTIVES

Objective 1 – Expand the area of late harvested crop on arable machairs.

Earlier harvesting of arable crops is a threat to arable and fallow weed communities on machair habitats. The project will aim to alleviate some of the pressures that lead to early harvest and mitigate any negative effects of later harvesting.

- Actions and means involved: The project will build capacity among the crofting community to provide the additional resources needed during the busy harvest period to encourage an expansion in late harvested crop. The project will increase funding for the local greylag goose management schemes to reduce the threat posed by geese to late standing crops. The project will fully monitor and evaluate the effects of these actions.
- Expected results: An increase in the area of late harvested arable crop on cultivated machairs in Uist and Benbecula. Harvesting dates will ensure that arable weed communities have set seed. Demonstration of these techniques to crofting communities and the costs, technical and biodiversity implications fully evaluated.

Objective 2 – Effect a reduction in the area of under-sown arable crop.

Under-sowing areas of arable crop with grass seed reduces the biodiversity of arable weed communities in crop and fallow years. This may also have a negative effect on nesting habitat of wader species. The project aims to promote a better understanding of the fundamental connections between thriving machair communities and good environmental condition of machair habitats with a view to promoting a more holistic approach to management.

- Actions and means involved: The project will seek an increase in arable winter fodder production on machair to compensate for lower quality grazing on natural fallows. Additional areas of machair will be cropped and where appropriate, in-bye fields will be used for grass fodder production. Through a process of collaboration, this fodder will be made available to crofters who do not under-sow crops on arable machair SACs. Skills training, machinery and labour will be made available where these are the limiting factors for either traditional arable cultivation or additional fodder production.
- Expected results: A reduction in the area of under-sown crop on key arable machair sites on SACs. Raised awareness of the biodiversity benefits of arable fallows in the machair system. An expansion by 15 ha in the area of cropped machair in the Uists and Benbecula. Collaboration between managers of arable machair and grassland machair sites.

Objective 3 – Undertake best practice arable crop production including cultivation techniques and demonstrate these to the crofting community.

Machair crofting is increasingly carried out using large, modern machinery and the most cost effective techniques, with contractors carrying out an ever-increasing amount of land management. However, certain practices may not deliver the same conservation benefits as traditional methods. Without clear demonstration of the benefits of more sensitive techniques, these technical advances and modern practices may severely affect the conservation interest on machair SACs and SPAs.

- Actions and means involved: The project will identify a range of arable crop production techniques that are more suited to conservation management yet still deliver local agricultural requirements. The project will provide suitable agricultural machinery to allow beneficial management practices to be undertaken on key machair sites. The project will demonstrate and promote these practices to the wider crofting community, to key stakeholders in the agricultural and conservation sectors and to relevant government agencies.
- Expected results: Demonstration of techniques to at least 50% of active crofters and to all major crofting contractors on the Uists and Benbecula. Implementation and monitoring of appropriate techniques on 60 ha of machair habitat on machair SACs. The availability of fully evaluated and costed agri-environment scheme measures for consideration during development of future Rural Development Programmes.

Objective 4 – Establish best practice in-bye management as part of a whole crofting unit machair biodiversity package

The Annex 1 species corncrake uses in-bye grassland fields for breeding. With sensitive management planning, these in-bye areas could continue to provide corncrake benefits while providing additional locally grown fodder for crofting communities.

- Actions and means involved: The project will work with crofters to ensure the availability of sustainably produced grass silage as over-winter fodder. This will be used to offset the winter livestock feed requirements of those crofters who do not under-sow their arable crops. A collaborative approach to machair management will be facilitated between crofters and farmers with different types of holding. On Tiree, the project will seek to re-introduce arable crops into in-bye field rotations to give late cover for corncrakes when adjacent grass fields are cut. The project will run a greylag goose management scheme on Coll & Tiree to give crofters greater flexibility in in-bye management.

- Expected results: More sustainable in-bye management with grass silage output linked to the wider machair crofting system. Secure corncrake management on corncrake SPAs in the project area. Demonstration of beneficial collaborative management to the crofting community.

Objective 5 – Identify constraints to active management and increase the capacity to undertake beneficial management in crofting and farming communities on designated sites.

Socio-economic factors are largely responsible for limitations in the availability of labour and appropriate machinery to undertake the beneficial management practices required on designated sites. This has lead to more reliance on contractors and less flexibility in management practices and the timing of management.

- Actions and means involved: The project will develop, demonstrate and promote conservation management techniques that best suit the circumstances in today's crofting communities. The project will work with these communities to establish the critical blockages that prevent management that is appropriate for biodiversity outcomes. The project will provide machinery and training to give additional flexibility and expand opportunities for individual crofters to undertake management.
- Expected results: better understanding of the drivers of change in crofting communities and full evaluation of the practices and incentives necessary to maintain High Nature Value farming on these Natura sites.

Objective 6 – Expand the skills and knowledge base and support the RDP to deliver better management of designated sites by crofting and farming communities.

There is a very real risk that current economic pressures, combined with changes in market demand as a result of the Common Agricultural Policy (CAP) reform, will further increase the speed at which agricultural practises will change on machair habitats. A lack of new entrants to agriculture combined with an increased average age among land users adds to current pressures on available labour. However, unless communities continue to use their natural environment as a means of levering additional agricultural support there is a very real danger that the environmental benefits from previous agri environment schemes will be lost.

- Actions and means involved: This project will work with crofting and farming communities to build a skills capacity through workshops, the provision of guidance material on best-practice management and by demonstrating key skills. The project will work with Scottish Government to identify and develop measures and seek their inclusion in revised and subsequent Rural Development Programmes.
- Expected results: Expanded skills base, opportunities for new entrants and better understanding of best practice management methods. Raised awareness in communities of the economic and environmental benefits of the High Nature Value farming practices undertaken throughout the project area.

Objective 7 – Secure the supply of local arable seed

Local crop seed varieties that are able to flourish with minimal inputs ensure the continuation of a low input cereal system, which is crucial for the maintenance of the biodiversity interest of Scotland's machairs. However, recent events such as accidental damage to seed stores and extensive damage to standing seed crops by greylag geese, have highlighted the vulnerability of the seed supply.

- Actions and means involved: The project will assist with the protection of designated seed crops and will build secure storage facilities for the native seed Uist crop.
- Expected results: Weather, predator and flood proof storage facility established on Uist. Reduced risk of having to use imported seed and additional inputs. Raised awareness of the importance of local seed to the machair system.

CONCLUSION

The successful construction of a funding package for the Conserving Scottish Machair LIFE+ Project presents an opportunity to develop a sustainable future for Scottish machair systems that maintain a biodiversity resource of international significance. That this was achieved at a key political juncture for crofting and at a time of intense financial pressure on agencies and local authorities demonstrates a high level of commitment to the future of machair among the key organisations. Discussion and consultation with crofters and farmers indicated similar enthusiasm for progress among the communities and individuals who actually deliver machair management. Project implementation will be complex and doubtless issues will arise as the programme develops. If the positive and cooperative approach that people brought to the preliminary negotiations can be maintained, however, there is good prospect for achieving sustained, positive outcomes.

ACKNOWLEDGEMENTS

The authors thank SNH and CnES partners for their support and commitment during project construction, all the stakeholders who attended the initial project meetings and helped with subsequent negotiations, and the crofters and farmers who guided the project development work. Progress would not have been possible without the constant support of the RSPB International Funding Unit.

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Machair invertebrates: the importance of 'mosaiciness'

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ABSTRACT

Machair systems are not particularly rich in invertebrate species but do contain a much more diverse range of invertebrates than would normally be expected from what is generally thought of as a dry grassland habitat. This invertebrate diversity is driven by the fine-scale, field-scale and landscape-scale mosaic-iness produced by variations in underlying soil conditions, the impact of wind and sea-spray on the soil, the range of markedly different habitat types occurring in close proximity to each other and the strong over-arching influence that cropping and grazing management has on those habitats. The occurrence of these varied invertebrate assemblages is one of the more important reasons why the machair system holds such large and important populations of breeding birds such as dunlin, *Calidris alpina*, lapwing, *Vanellus vanellus*, oystercatcher, *Haematopus ostralegus*, redshank, *Tringa tetanus*, and snipe, *Gallinago gallinago*. Without the invertebrates the birds would not be there in such high numbers and without the continued combination of environmental and management factors, the diversity of invertebrates occurring on the machair would be much less.

MACHAIR INVERTEBRATES: WHAT'S KNOWN ABOUT THEM?

The machair grassland systems of the west of Scotland are well known for their botanical and ornithological richness but very little is actually known about their associated invertebrate assemblages. Other than the work on great yellow bumblebee, *Bombus distinguendus*, and northern colletes, *Colletes floralis*, reported elsewhere in this issue (this version), most of what is known about machair invertebrates is based on a single survey (using ultraviolet light traps for Lepidoptera and pitfall trapping of surface-active invertebrates) conducted by the Institute of Terrestrial Ecology (ITE) at 24 sand grassland locations in the Outer Hebrides during June and July 1976 (Welch, 1979, 1989).

The pitfall trapping indicated that although the invertebrate assemblages that can be surveyed by this method (such as beetles, centipedes, millipedes, slugs and snails and spiders) were not particularly rich in species, the assemblages themselves did contain a much more diverse range of invertebrates (with differing ecological requirements) than would normally be expected from such dry grassland habitats. However, the ITE survey was relatively limited in terms of the focus on only one element (the sand grassland component) of the wider machair system, the small number of those sites sampled, the duration of the trapping period and the relatively small range of invertebrates that can be surveyed accurately by these trapping methods. As a result, this article will not attempt to describe the invertebrate assemblages occurring on machair in any great detail but rather will try to highlight the underlying environmental and management factors influencing machair invertebrate assemblages in general.

PATCH MOSAICINESS: THE INFLUENCE OF THE ENVIRONMENT

Many terrestrial invertebrates spend all or some part of their life-cycle either on or under the ground, and so soil type and condition is a good place to start. Calcareous sand underlies many of the elements of the machair system and this can influence invertebrates in a variety of ways:

- Despite relatively high rainfall levels, the sand allows large areas of the machair to be reasonably free-draining for a large part of the year. These relatively dry soil conditions not only provide a good medium through which the predatory larvae of ground beetles (Carabidae) and rove beetles (Staphylinidae) can move but also serve to enhance the survival of the larval and pupal stages of other beetles which live underground. For example, the brown chafer, *Serica brunnea*, is one of the most characteristic beetle species of sand grassland systems and its larvae can spend many months in the soil feeding on the roots of grasses and other plants.
- The calcareous nature of the sand also means that snails can obtain the basic building blocks for their shells. The presence of the snails also provide a greater range of potential prey for predatory beetles, such as the ground beetles and rove beetles already mentioned and also for snail-feeding specialists such as *Silpha* species of carrion beetles.
- The relatively dry and calcareous nature of the soil also helps drive the botanical richness of the machair, with the nutrient poor conditions allowing a wider range of broad-leaved plants to compete effectively with the grasses. The occurrence of such a wide range of broad-leaved plants provides ideal conditions for a wider range of invertebrates, not only those, such as bees, attracted to the flowers of these plants but also just as importantly others, such as

weevils (Curculionidae), which feed on the roots, stems and leaves of these plants. The sand or marram weevil, *Philopedon plagiatus*, is another characteristic species of herb-rich machair systems.

- The inherently fragile nature of the soil combined with exposure to wind and sea-spray creates a range of sizes of open, sandy patches which not only warm up quickly in the spring and summer (and hence provide good basking opportunities for invertebrates) but also provide good hunting areas for ground beetle species such as *Notiophilus aquaticus* which need open, unobstructed areas in which to spot (using their very large eyes) and then run down their prey.

FIELD MOSAICINESS: THE INFLUENCE OF CROPPING AND GRAZING

The management superimposed on the machair system by crofters also adds to the variety of conditions available for invertebrates to exploit:

- The planting of small patches of crops within the machair also serves to help create open, sandy areas with their associated fauna (as described above). In addition, the use of seaweed or livestock dung to fertilise these patches of crops helps increase the organic matter and moisture content of the soil. These patches of moister, more nutrient-rich soil provide suitable conditions for the development of more moisture-loving invertebrates such as the larvae of root-feeding Bibionidae flies and the predatory larvae of soldier flies (Stratiomyidae) which also prefer higher organic matter soils.
- Grazing and trampling by sheep, and especially cattle, also helps to open up the swards at ground level, providing a greater range of micro-climates for a wider range of invertebrates to make use of. Providing the grazing is not too intense, this also creates a wide variety of vegetation heights and structures. These tall and short patches of vegetation can support a greater range of different assemblages of invertebrates than would be possible if the vegetation was all of a similar height and structure. Livestock dung is also an important component of the machair system in its own right and contains its own characteristic fauna of dung beetles (such as the wide variety of *Aphodius* spp.) and dung flies (such as *Scatophaga stercoraria*).

THE IMPORTANCE OF LANDSCAPE MOSAICINESS All of the above factors are important in their own right in driving the fine and field-scale invertebrate assemblage structures seen on the machair system. The additional important feature of the machair is that by its very nature its differing soil conditions mean that a wide range of different habitats occur in close proximity to each other. So for example, within a 200 m radius of any one point there is likely to occur a close-knit combination of blown sand, patches of crops, grassland with varying heights and structures and lower-lying areas of wetter vegetation. This additional mosaiciness at the landscape scale helps to ensure that the conditions needed to sustain the different invertebrate assemblages occurring on the machair may change locations but nevertheless are still likely to occur somewhere close by throughout the year.

THE WIDER IMPORTANCE OF MACHAIR INVERTEBRATES

Finally, since many of these component parts of the machair system are managed at low intensity, they are, from an invertebrate point of view, relatively undisturbed. Consequently, many of the characteristic machair species of invertebrates take a relatively long time to complete their life-cycles and grow to a relatively large size (e.g. the brown chafer, ground beetles such as *Calathus fuscipes*, or *Geotrupes* spp. dung beetles). Other characteristic species (such as the sand weevil or *Aphodius* spp. beetles) may not be large species but the varied conditions across the machair are such that these species can be particularly abundant. All these species are good food for insectivorous birds and the occurrence of these invertebrates on the machair is one of the more important reasons why the machair system holds such large and important populations of breeding unlin, *Calidris alpina*, lapwing, *Vanellus vanellus*, oystercatcher, *Haematopus ostralegus*, redshank, *Tringa tetanus*, and snipe, *Gallinago gallinago* (Fuller *et al.*, 1986). Without the invertebrates the birds would not be there in such numbers and without the continued combination of environmental and management factors acting on the machair, the diversity of invertebrates occurring on the machair would be much less.

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Conservation of bumblebees

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ABSTRACT

Declines in bumblebee species in the last 60 years are well documented in Europe, where they are primarily driven by habitat loss and declines in floral abundance and diversity, in turn driven by changing agricultural practices. Amongst the most significant of these for bumblebees has been the loss of species-rich unimproved grasslands (haymeadows, chalk downland, machair etc.). Evidence suggests that the species which have declined most are specialists in collecting pollen from Fabaceae, especially red clovers, and loss of unimproved grasslands and abandonment of red clover leys have greatly reduced the abundance of red clover across western Europe. High densities of commercial honeybee hives may also impact upon bumblebees in some areas. Effects of habitat degradation and fragmentation on bumblebees are likely to be compounded by the social nature of bumblebees and their largely monogamous breeding system (queens mate only once) which renders their effective population size low. Recent studies suggest that surviving populations of some rare species consist of <30 breeding females, and such populations are susceptible to chance extinction events and inbreeding. Conservation measures must be implemented at the landscape-scale if they are to be effective, for small patches of habitat on nature reserves do not support viable bumblebee populations in the long term. Given the importance of bumblebees as pollinators of crops and wildflowers, it is vital that adequate steps be taken to prevent further declines. Suggested measures include careful management of surviving species-rich grasslands such as machair.

Many bumblebee species have declined in recent decades, particularly in developed regions such as Western Europe and North America (Goulson 2003a, Thorp & Shepherd 2005, Kosior et al. 2007, Goulson et al. 2008a). In the UK, three of the 25 native species have gone extinct and a further eight species having undergone major range declines (Goulson 2003a). The most severely affected species tend to be those with long tongues associated with deep perennial flowers (Goulson et al. 2005). Similar patterns are evident in Europe. In a review of declines in bumblebees of 11 central and western European countries, Kosior et al. (2007) describe extinctions of 13 species in at least one country between 1950 and 2000. Four species (*B. armeniacus*, *B. cullumanus*, *B. serrisquama*, *B. sidemii*) went extinct throughout the entire region.

Most researchers agree that the main cause of bumblebee declines in Western Europe and North America is the intensification of farming practices, particularly during the latter half of the 20th century (Goulson 2003a,c). Permanent unimproved grassland was once highly valued for grazing and hay production but the development of cheap artificial fertilizers and new fast-growing grass varieties has meant that farmers could improve productivity by ploughing up ancient grasslands. Thus hay meadows gave way to monocultures of grasses which are grazed or cut for silage. Between 1932 and 1984 over 90% of unimproved lowland grassland was lost in the UK (Howard et al. 2003).

There is evidence to suggest that bumblebee forage plants have suffered disproportionate declines. A recent study in the UK found that of 97 preferred bumblebee forage species, 71% have suffered range restrictions, and 76% have declined in abundance over the past eighty years, exceeding declines of non-forage species (Carvell et al. 2006). Leguminous crops (notably clovers, *Trifolium* spp.) used to be an important part of crop rotations in much of Europe, and these are highly preferred food sources, particularly for long-tongued bumblebee species (Goulson et al. 2005). Since the introduction of cheap artificial fertilizers, rotations involving legumes have been almost entirely abandoned, and it has been argued that this is one of the primary factors driving the decline of many bumblebees (Goulson & Darvill 2004, Rasmont & Mersch 1988).

In addition to floral resources, bumblebees need suitable nesting sites, the precise requirements for which vary between species (Kells & Goulson 2003). The carder bees (*Thoracobombus*) such as *B. muscorum* tend to nest in dense grassy tussocks while other species such as *B. distinguendus* nest underground in cavities. Both groups often use abandoned rodent nests. The loss of hedgerows and of unimproved pastures is likely to have reduced availability of nest sites for both above and below-ground nesting bumblebee species (Banaszak 1992). Those species that nest above ground frequently have their nests destroyed by farm machinery, particularly

by cutting for hay or silage. The scarcity of weeds and field-margin flowers on modern intensive farms means that there are less seeds, and therefore less food for voles and mice. Lower populations of these mammals will lead to fewer nest sites for both above and below-ground nesting bumblebee species.

One further potential threat to bumblebees is that they have to contend with commercial honeybees (*Apis mellifera*). Their potential impacts are reviewed by Goulson (2003b). Although honeybees are thought to be native to the UK (although probably not to the Western Isles), commercial beekeeping maintains much higher honeybee densities than could occur naturally. Recent studies suggest that honeybees have negative effects on native bumblebees. Walther-Hellwig *et al.* (2006) found that short-tongued bumblebees avoided areas of forage close to honeybee hives, while carder bumblebees switched to foraging later in the day and were displaced from their preferred foodplant. Thomson (2004) experimentally introduced honeybees and found that proximity to hives significantly reduced the foraging rates and reproductive success of *B. occidentalis* colonies. Thomson (2006) found a strong overlap between the foraging preferences of the two species, which peaked at the end of the season when floral resources were scarce, corresponding with a negative relationship between honeybee and bumblebee abundance. In Scotland, Goulson and Sparrow (in press) found that workers of four common bumblebee species were all significantly smaller in areas where honeybees were present. There is also evidence that honeybees can act as vectors for the bumblebee specific disease *Crithidia bombi* via flowers (Ruiz-Gonzalez & Brown 2006). Deformed wing virus, a viral honeybee pathogen, has been found in wild bumblebee nests (Genersch et al. 2006), and appears to have higher virulence to bumblebees than to honeybees.

As a consequence of the various factors discussed above, populations of a number of bumblebee species have become increasingly small, fragmented and separated from one another by large distances. In the UK, where distributions are best known, declines appear to have followed a characteristic pattern. The last bumblebee species to disappear from the UK (*B. subterraneus*, the sister species of *B. distinguendus*), was once widespread across southern England, but declined rapidly in the years after World War II. By the 1980's the few remaining populations were small and isolated, surviving on habitat islands (nature reserves) that had escaped agricultural intensification. However, these populations subsequently disappeared despite the apparent suitability and protected status of the remaining habitat (Goulson 2003a). The species was last recorded at Dungeness National Nature Reserve in 1988. Several other UK species such as *B. distinguendus* and *B. sylvarum* are in the late stages of a similar process, and are likely to go extinct in the near future. Why do isolated populations go extinct? Understanding the consequences of the fragmentation of remnant populations of bumblebees is of great importance to conservationists, given the current distributions of many rare species.

Small populations of all taxa are inherently more vulnerable to local extinctions due to environmental and demographic stochasticity (Frankham et al. 2002). If these populations form part of a broader metapopulation then regional extinctions can be balanced by subsequent recolonisation, but if fragmentation is severe then extinct patches may never be repopulated. In addition, a functioning metapopulation ensures that dispersal maintains genetic cohesion. However, if habitat fragmentation results in the isolation of populations, then they may face an additional extinction threat through inbreeding (Frankham et al. 2002). There are a number of reasons why bumblebees may be particularly badly affected by habitat fragmentation. It is the effective population size (N_e) which determines the rate of genetic drift in a population. In bumblebees, as in many other social insects, N_e depends on the number of successful colonies, not the number of bees in the population. Each bumblebee colony contains just one breeding female, and in most bumblebees she will have mated with a single male (Estoup et al. 1995, Schmid-Hempel & Schmid-Hempel 2000). Therefore, it seems that population sizes of bumblebees may be low, making them particularly susceptible to the loss of genetic diversity.

Given the potentially serious consequences of inbreeding in bumblebees, it is essential that we understand its prevalence within wild bumblebee populations. Until recently, studying the population genetics of rare bee species was extremely difficult, as lethal sampling was necessary. Work in this area was greatly aided by the development of a non-lethal DNA sampling technique (Holehouse et al. 2003), and this has recently been applied to studies of fragmented populations of rare species: *B. muscorum* (Darvill et al. 2006), *B. sylvarum* (Ellis et al. 2006) and *B. distinguendus* (Bourke & Hammond 2002). All three studies found significant population structuring. For example in *B. muscorum,* all populations >10 km apart were significantly differentiated, as were some populations just 3km apart, suggesting that this species has very limited dispersal abilities. Ellis *et al.* (2006) used microsatellite markers to group workers into sisterhoods and so estimated the number of colonies (and hence N_e) in populations of *B. sylvarum*, a species which is highly endangered in the UK. Estimates of N_e were very low (range 21-72) suggesting that these populations are very vulnerable to loss of genetic diversity through drift. In all rare species studied to date, genetic diversity (allelic richness and heterozygosity) is low compared to common species (Darvill 2007). If fragmented populations of rare bumblebee species are suffering from reduced fitness through inbreeding then we must take steps to conserve what genetic diversity remains. Management strategies in vertebrates routinely consider genetic factors, and

we may need to adopt similar measures in the management of rare bumblebee populations.

An interesting aspect of bumblebee declines is that a small number of species have remained relatively abundant. What is the difference between the species that have declined (and in some cases gone extinct) and those that have not? It seems that the rare and declining species tend to be long tongued and have narrower diets, with a very large proportion of the pollen they collect being from Fabaceae (many of which have deep flowers) (Goulson and Darvill 2004; Goulson et al. 2005, 2006, 2008b). This is supported by a substantial data set of bumblebee foraging records gathered from throughout the UK, and separated according to whether they were collecting pollen, nectar, or both. Some species tend to get 90-100% of their pollen from Fabaceae (for example *B. hortorum, B. ruderatus, B. subterraneus* and *B. humilis*), and these tend to be long-tongued and, with the exception of *B. hortorum*, they are all declining species. It should be noted that *B. distinguendus* almost certainly falls within this group. Parallel studies of more diverse bumblebee communities in Poland confirm similar patterns (Goulson et al. 2008b). Studies of the nutritional quality of pollen reveal that Fabaceae pollen is unusually high in protein and essential amino acids (Hanley et al. 2008). Fabaceae tend to dominate species-rich grasslands such as machair, because their ability to fix nitrogen gives them a competitive edge in nutrient-poor soils. Hence the massive loss of species-rich grasslands throughout the UK has had a disproportionate effect on those bumblebee species that favour Fabaceae as their pollen source.

CONCLUSIONS

It is clear from studies of population structure that most bumblebee species cannot be conserved by managing small protected 'islands' of habitat within a 'sea' of unsuitable, intensively farmed land. Large areas of suitable habitat are needed to support viable populations in the long term. Unimproved flower-rich grassland is one of the most important habitats for bumblebees, but has been largely lost to agriculture in Western Europe and North America. Many of the bumblebee species that have declined most are specialized on collecting pollen from Fabaceae, especially *Trifolium pratense*, and Fabaceae tend to dominate species-rich grasslands. This explains why machair supports substantial populations of rare bumblebees; large areas survive (although much has been lost), and it can be exceptionally rich in Fabaceae. Restoration of areas of this habitat will boost bumblebee populations. Substantial benefits for bumblebee conservation could also be obtained by reintroducing clover (e.g. *Trifolium pratense*) ley crops into rotations, reducing dependency on artificial fertilizers.

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Phenology of Bombus distinguendus in the Outer Hebrides

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INTRODUCTION

In recent years British bumblebees have suffered massive declines in range and abundance (Alford 1975, Edwards & Williams 2004, Goulson 2003, Goulson *et al.* 2008, Williams 1985). One species has gone extinct and six others are listed as priorities for conservation action under the UK Biodiversity Action Plan (http://www.ukbap.org.uk/NewPriorityList.aspx). Of the remaining extant British species, *Bombus distinguendus*, the Great Yellow Bumblebee, has suffered the largest reduction in range (Gray 2003). *B. distinguendus* was formerly widely distributed throughout the British Isles, but is now restricted to a number of islands in the Inner and Outer Hebrides and Orkney and a handful of sites on the north coast of Scotland (Edwards 1997, 2002, http://data.nbn.org.uk/).

The patterns of distribution and decline shown by British bumblebees suggest that the loss, fragmentation and degradation of habitats are the major drivers of decline (Alford 1975, Carvell *et al.* 2006, Osborne & Corbet 1994, Williams 1982, 1985, 1986). Bumblebees have three main requirements during their colony cycle: (1) a suitable nest site, (2) a supply of pollen and nectar throughout the season and (3) a suitable place to hibernate (Sladen 1912, Free & Butler 1959). Recent landscape change has impacted on all of these requirements, however, the loss of forage is perhaps the biggest single cause of bumblebee decline (Carvell *et al.* 2006, Fussel & Corbet 1992, Goulson *et al.* 2008).

There is considerable scope to improve the availability of forage for bumblebees through direct planting and improved management of existing resources. This is already being achieved by agri-environment schemes for a small number of common and widespread species (Carvell *et al.* 2004, Pywell *et al.* 2006). However, there is insufficient understanding of the ecology of scarcer bumblebees to be able to develop effective conservation management.

The aim of this work was to fully describe the phenology of *B. distinguendus* in order to inform future management. Specifically it was aimed to establish when important forage plants are used and the timing of the colony cycle. *B. distinguendus* has previously received some study, but these studies have been relatively short and can only provide snapshots of its colony cycle (Edwards 1997, 1998, 1999, 2000, Hughes 1998).

METHODS

During summer 2005 T.G.C. collected a continuous time series of data on the flower use and colony cycle of *B. distinguendus*, on South Uist in the Outer Hebrides (23 May to 22 August 2005). The study area comprised the strip of machair stretching from Garrynamonie (Geàrraidh ma Mònadh, NF739160) in the south to Grogarry (Groigearraidh, NF755398) in the north (c. 25 km long and c. 2 km wide). High density patches of forage were visited at regular intervals throughout the season to record foraging bumblebees and flower abundance.

Patch selection

1 – 5 patches of each of ten focal flower species were selected (Table 1). These focal species are regularly used by *B. distinguendus* (Charman 2007) as well as being widespread and abundant in the Hebrides, i.e. they are plant species that provide a significant proportion of the forage requirements of *B. distinguendus*.

Where possible, each patch of a flower species was located in a different township in order to sample a different landscape context (e.g. different townships had different cropping patterns). Patches were selected to be the largest size and have the highest plant density within a township (to attract sufficient *B. distinguendus*) and to be accessible (e.g. not in hay crops). When two patches from the same township had to be used, these were at least 200 m apart. Some patches contained more than one forage species (Table

1). A linear 'bee walk' transect was established within each forage patch (see Table 1 for lengths).

Bee walk method

The field season was divided into nine periods of approximately 10-days: late-May, early-, mid-, and late-June and July and early- and mid-August (Table 1). Bee walks were conducted when patches were actively flowering by walking along the transect and systematically searching all forage within 2 m either side of it for foraging bumblebees. All bumblebees were identified to species and caste and the plant species they were foraging on was recorded. Each bee walk was repeated 2 – 8 times in a given period (Table 1). Usually these walks were conducted in succession on the same day. Given the high turnover of bees (*pers. obs.* from marking bees, also Heinrich 1979, Williams 1997) and that it usually took at least 30 mins to complete a walk, repeat counting of bees during the same foraging trip is likely to have been infrequent.

Quantifying abundance of floral resources

The number of flowers of bird's-foot trefoil, white clover, yellow rattle, kidney vetch, red clover and knapweed were counted in twenty 0.5 m^2 quadrats per patch (distributed regularly throughout the patch) once during each time period. Patches of tufted vetch tended to be smaller and have a more uniform flower density so flowers were counted in ten 0.5 m^2 quadrats per patch. Lesser burdock, spear thistle and ragwort are tall, widely dispersed plants that are not well suited to being monitored using quadrats and so instead they were monitored by counting the number of active flowers per plant on twenty randomly selected plants.

Flower use phenology

Phenologies were calculated separately for queen, worker and male *B. distinguendus* at each focal plant species. Each patch received more than one bee walk in each period when it was in bloom. For each patch , the average count of *B. distinguendus*, of each caste, seen per bee walk in each time period was calculated. These average bee counts were expressed as a proportion of the maximum average bee count at the patch, producing an index of bumblebee abundance ranging from 0 (no *B. distinguendus* of a given caste seen per bee walk at a patch) to 1 (maximum number of *B. distinguendus* of a given caste seen per bee walk at the patch). The bumblebee abundance indices in each time period were averaged across different patches of the same focal plant species (except for kidney vetch, which was only sampled with one patch). When doing this for a given caste, only the focal patches where at least one bee of that caste had been recorded were used. Finally these average *B. distinguendus* abundance indices were plotted against time period for each focal plant species.

Flowering phenology

The same method was used to calculate flowering phenologies as had been used for flower use phenologies, except that the first averaging step was not required because only one count of flowers was made per time period.

RESULTS

Caste composition

The first queen *B. distinguendus* of the year was seen on 21 May 2005. During May and June only queens were on the wing (Fig. 1). Workers emerged during July, and came to dominate by the end of July. They remained dominant through August but were joined by males, which became relatively more abundant as August progressed. A very small number of newly emerged queens were seen in August, but not all queens seen in August were newly emerged queens. Some were very worn and tattered and it is likely that thy had successfully founded a nest earlier in the season, but had subsequently lost dominance and had been forced to forage outside.

Flower use and flowering phenologies

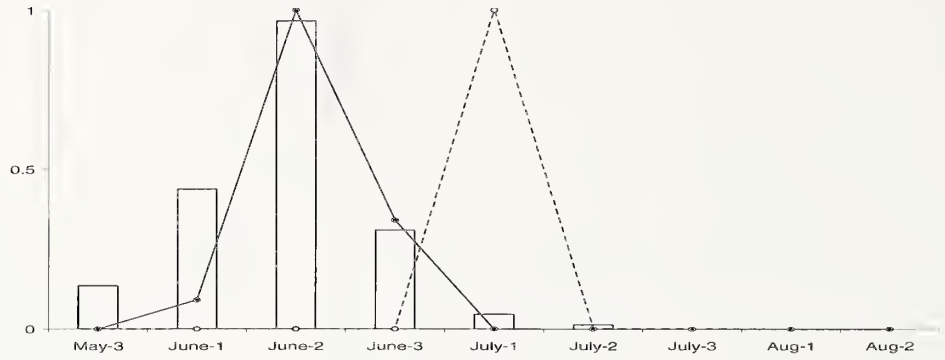
3,438 visits to focal plant species by bumblebees of known species and caste were recorded. 407 of these were by *B. distinguendus* (111 queens, 266 workers and 30 males). Surprisingly, *B. distinguendus* was not recorded foraging at yellow rattle during the bee walks in 2005. However, the yellow rattle phenology has been included for completeness because it often is a regularly used forage source (Charman 2007). Fig. 2 shows the flower use phenologies of queen, worker and male *B. distinguendus* at each of the ten focal plant species alongside the flowering phenologies of each focal plant species. *B. distinguendus* use of the focal species closely matched the flowering pattern of the focal species for all ten flowers, except yellow rattle as described above. Bird's-foot trefoil, white clover, kidney vetch, yellow rattle, tufted vetch and red clover were all heavily used by queens, and, to a greater or lesser extent, by workers. Due to its early flowering period, bird's-foot trefoil was mostly visited by queens. Despite a similarly early start, white clover had a very protracted flowering period, which went through to July, when it was used by workers. The bulk of kidney vetch, yellow rattle, tufted vetch and red clover flowering occurred slightly later, in late June and July, during which time they received a mixture of visits from queens and workers. Lesser burdock, spear thistle, ragwort and knapweed provided forage for workers and males from late July through August and also received a handful of visits from queens, some of them newly emerged that year.

Fig. 1. The caste composition of *B. distinguendus* seen foraging on bee walks on South Uist during each time period in 2005.

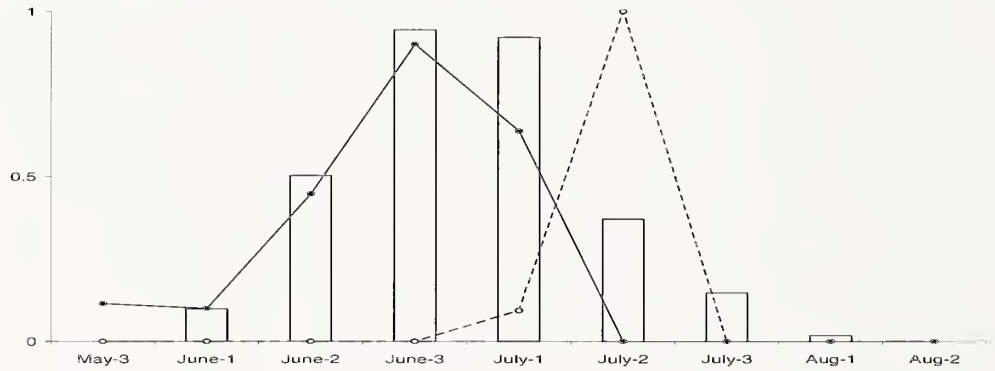
ID	Location	Description	Focal plant species										Length of transect or no. of plants	Number of visits								
			BT	WC	YR	KV	TV	RC	LB	ST	RG	KN		May	June			July			August	
														L	E	M	L	E	M	L	E	M
1	NF 7390 1583	Defunct fallow strip										1	200	-	-	-	-	-	-	-	2	2
2	NF 7389 1595	Fallow strip	1	1	1	1							280	-	8	8	4	4	3	3	2	-
3	NF 7365 1688	Dunes	1										320	-	8	8	4	2	-	-	-	-
4	NF 7367 1745	Fallow strip		1									300	-	-	16	8	4	3	3	2	-
5	NF 7336 1758	Fallow strip					1						85	-	-	-	2	2	2	2	-	-
6	NF 7342 1768	Fallow strip						1					300	-	-	-	-	4	2	2	2	2
7	NF 7308 1981	Fallow strip		1				1					300	-	-	12	8	4	3	2	2	2
8	NF 7309 1982	Fallow strip			1								275	-	-	-	1	4	3	-	-	-
9	NF 7331 1999	Fallow strip			1								200	-	-	-	1	4	3	-	-	-
10	NF 7315 2029	Dunes							1	1			310LB, 120ST	-	-	-	-	-	2	2	2	2
11	NF 7279 2627	Margins of track										1	80	-	-	-	-	-	-	-	2	2
12	NF 7284 2641	Fallow strip		1									280	-	-	4	8	4	3	2	2	-
13	NF 7279 2656	Dunes	1				1						400	-	8	8	4	4	2	2	2	-
14	NF 7286 2658	Fallow strip									1		400	-	-	-	-	-	1	2	2	-
15	NF 7283 2658	Fenced strip margin										1	180	-	-	-	-	-	-	-	2	2
16	NF 7549 3639	Fallow strip						1					300	-	-	-	-	1	3	2	2	2
17	NF 7520 3644	Dunes					1						120	-	-	-	2	2	2	2	2	-
18	NF 7515 3680	Dunes	1	1									375	7	8	8	4	4	3	-	-	-
19	NF 7539 3881	Dunes									1		330	-	-	-	-	-	1	2	2	2
20	NF 7542 3899	Dunes	1										300	8	8	8	4	4	-	-	-	-
21	NF 7545 3899	Margin of fallow strip							1	1			368LB, 82ST	-	-	-	-	-	2	2	2	2
			5	5	3	1	3	3	2	2	2	3										

Table 1. Characteristics of focal patches used on South Uist in 2005, including the plant species that they cover and the number of bee walks they received in each time period. BT = bird's-foot trefoil, WC = white clover, YR = yellow rattle, KV = kidney vetch, TV = tufted vetch, RC = red clover, LB = lesser burdock, ST = spear thistle, RG = ragwort, KN = knapweed. The length of transects used to survey each patch are also given (in m) except for lesser burdock and spear thistle (where much of the transects were simply gaps between individual plants) and instead sampling effort for these patches is given in terms of the number of plants surveyed.

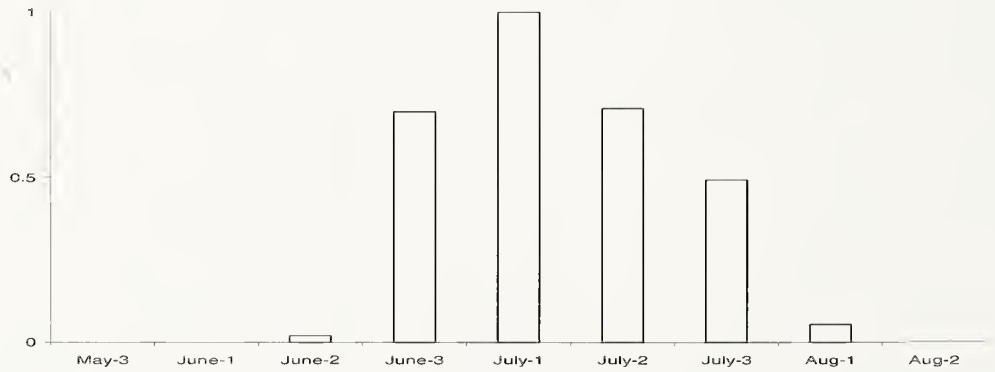
(a) Bird's-foot trefoil



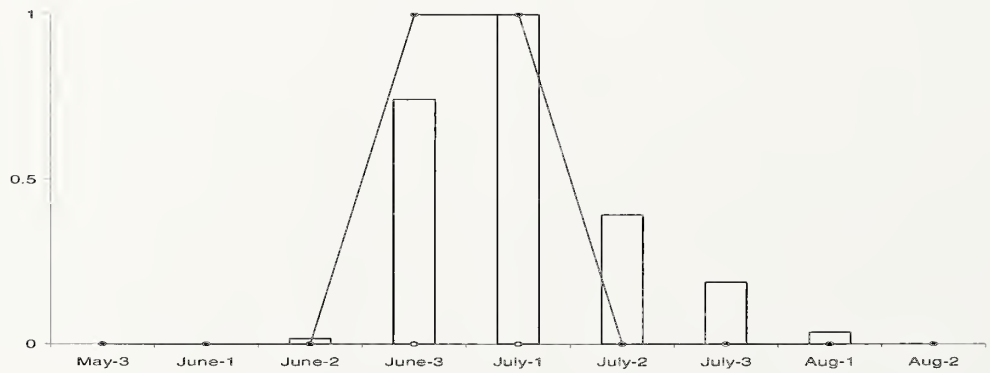
(b) White clover



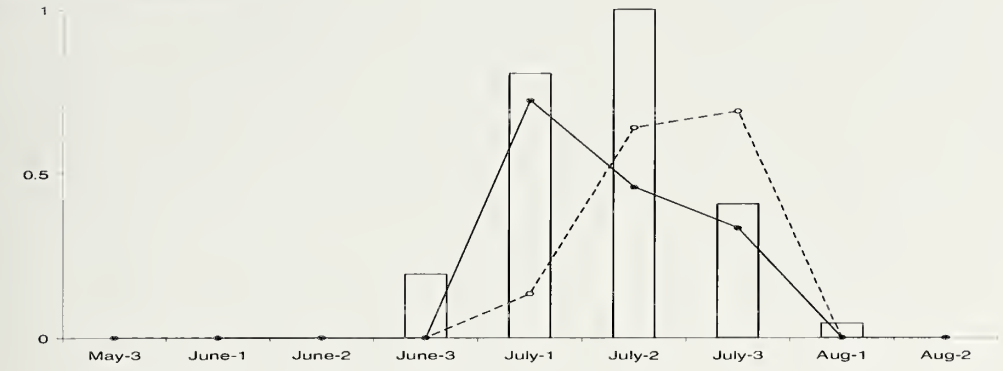
(c) Yellow rattle



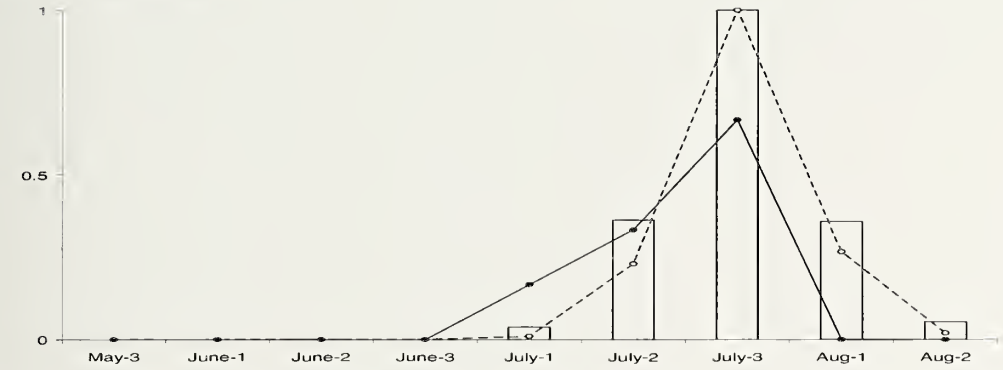
(d) Kidney vetch



(e) Tufted vetch

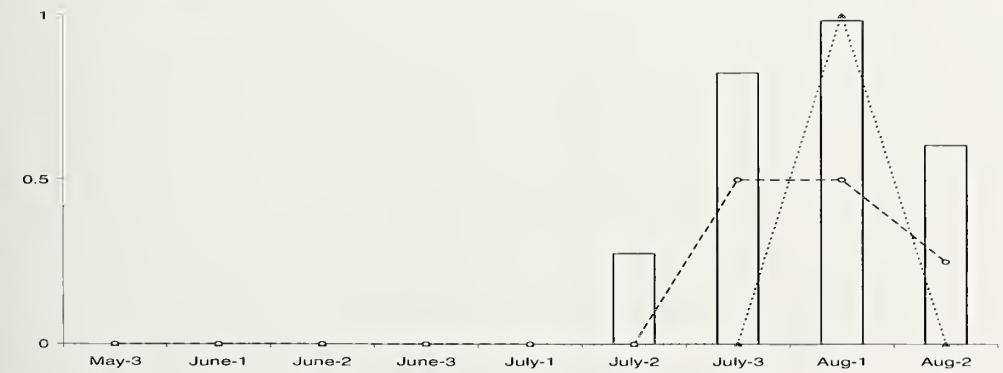


(f) Red clover



(g) Lesser burdock

(h) Spear thistle



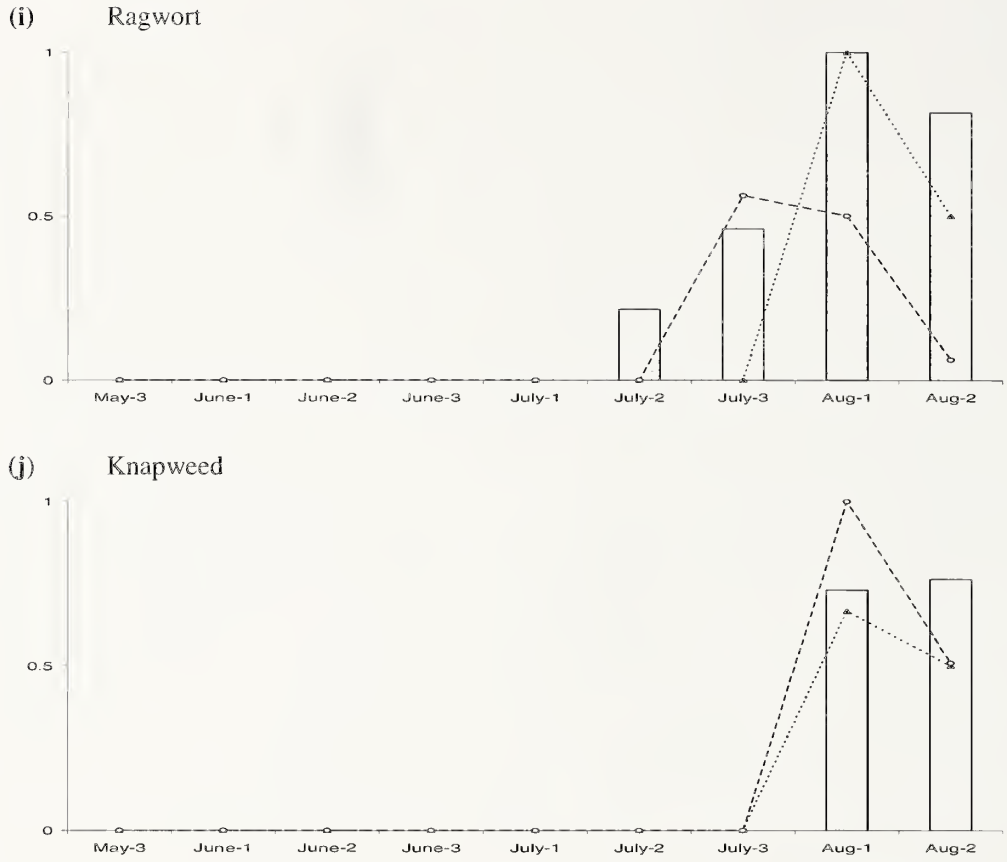


Fig. 2. Abundance of *B. distinguendus* and abundance of flowers of the focal plant species in each time period during summer 2005, for each focal plant species (a – j). The abundance of flowers is illustrated with bars and the abundance of *B. distinguendus* is illustrated with points joined with lines. Queens are shown with solid circles joined by solid lines, workers by hollow circles joined by dashed lines and males by solid triangles joined with dotted lines. June-1 = early-June, June-2 = mid-June, June-3 = late-June, *etc.*

DISCUSSION

This study used regularly repeated, standardised counts of bumblebees and flowers at high-density patches of forage to quantify the phenology of the flower use of *B. distinguendus* and its colony cycle in the Outer Hebrides. This has showed that *B. distinguendus* is a "late"-emerging and nesting bumblebee (Edwards & Williams 2004) with a "medium" length (Benton 2006) colony cycle. No single plant species provided resources throughout this period, which implies that *B. distinguendus* therefore requires a succession of suitable forage species in order to successfully complete its cycle and reproduce. The flowering periods of ten of these regularly visited plant species have been described.

Synthesising data gathered in this study with that in previous work (Edwards 1997, 1998, 1999, 2000, Hughes 1998), an "average" *B. distinguendus* colony cycle in the Outer Hebrides can be described as follows: The first queens to emerge usually appear during mid to late May. Nest-searching follows in mid June through to early July with a peak of activity in late June. Workers start to emerge from the beginning of July onwards and foragers gradually switch from a community dominated by queens, to, by the end of July, one dominated by workers. Males are seen foraging from the start of August. The timing of new queen emergence is least well known, as new queens are rarely observed. Like males, they can be seen from the beginning of August, although it appears that their main emergence period is a week or two later (Benton 2006). It should also be noted that there is considerable variation between seasons in the timing of the *B. distinguendus* colony cycle. For example, in 2004 the switch from foraging *B. distinguendus* largely comprising queens to foraging *B. distinguendus* mostly being workers occurred about 10 days later than in 2005 (Charman 2007).

Edwards and Williams (2004) divide bumblebee species into two main groups, "early" and "late", whose colony cycles, they propose, are timed to take advantage of specific periods of floral abundance. They suggest early species are associated with garden/woodland edge habitats, which provide forage from early in the season, while in contrast, "late" species are open-ground species associated with flower-rich, but late-flowering grasslands. Assigning a bumblebee phenology to one of these groups is complicated by a north – south gradient in the timing of colony cycles. Within the same species, bumblebees in more northern regions emerge considerably later than their southern counterparts (e.g. Benton 2000, MacDonald & Nisbet 2005). However, a comparison with phenologies within the Highland region (MacDonald & Nisbet 2005) reveals that *B. distinguendus* is indeed a "late" species. For example, in Highland, *B. terrestris* queens emerge in late March, and are on the wing until May.

Many late-emerging species have suffered large declines, while most early-emerging species remain widespread and abundant (Edwards & Williams 2004). This study has shown that *B. distinguendus* is a relatively late emerging and nesting bumblebee, and having suffered a large-scale decline, also fits this pattern. Colony cycle phenology could be associated with magnitude of decline by a number of different mechanisms. For instance, the amount of late forage available in Britain may have declined more than the amount of early forage (Edwards & Williams 2004) – in the 20th century there has been a large-scale shift from late-cut herb-rich hay meadows to early-cut or intensively grazed monocultures of grass, and between 1932 and 1984 over 90% of unimproved lowland grassland has been lost (Fuller 1987). In addition, if nest sites are limiting, then by the time "late" species emerge most nest sites may have already been occupied by "early" bumblebee species.

The approximate three month colony cycle (late May to late August) places *B. distinguendus* in the "medium" length group (Benton 2006, Goodwin 1995). No single plant species provided resources throughout this three month period and *B. distinguendus* therefore requires a succession of suitable forage in order to successfully complete its cycle and reproduce. Furthermore, these different plant species are present in different vegetation communities, at different stages of succession. For example, knapweed is found in areas that have not been disturbed except by light winter grazing. In order to maintain populations of *B. distinguendus* it is therefore important to retain a variety of different land uses on the machair.

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Recent research on the northern Colletes mining bee Colletes floralis Eversmann

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ABSTRACT

The northern Colletes mining bee is a UK Biodiversity Action Plan (UKBAP) priority species listed as Rare. Since 2001, nesting aggregations of this species have been monitored annually on the RSPB Reef reserve on the Isle of Tiree in the Inner Hebrides. Eight nesting aggregations were found on the reserve in 2001-2002, one was lost to natural causes in 2004 whilst three new aggregations were discovered in 2005-6 bringing the total of active aggregations to ten in 2007 and 2008. Seven of the nesting aggregations were associated with man-made features. This highlights the ability of the species to nest at new locations as they become suitable and suggests a possible management tool for enticing bees to nest in areas currently lacking suitable nest-sites. Management in the form of winter cattle grazing has maintained a stable population on the reserve. Since 2000, surveys for northern Colletes have been undertaken by staff and researchers from RSPB and Hymettus Ltd (formerly the Aculeate Conservation Group) in areas with historical records and of other potentially suitable herb-rich coastal habitat. These have revealed the continued presence of the bee at two sites in N. Ireland: Ballymaclary/ Portstewart Strand/Umbra and White Park Bay/ Bushfoot Strand, one in England: Duddon Estuary, and six in Scotland: Berneray to Vatersay in the Outer Hebrides, Tiree/ Coll, Islay, Colonsay / Oronsay, Irvine in Ayrshire and Machrihanish in Kintyre. Optimal habitat management for the bee is being encouraged in all these areas.

INTRODUCTION

The northern Colletes *Colletes floralis* Eversmann is a small mining bee with a large but highly fragmented range encompassing herb-rich grasslands along the coasts of the United Kingdom, Ireland and the Baltic countries as well as in the mountain ranges of the Alps, Pyrenees and other mountain ranges extending into western Asia. The species has undoubtedly become much scarcer throughout its range as a result of changes to its herb-rich habitat, through under-grazing, agricultural intensification and development. It is now rare throughout its range, with key populations remaining along the coasts of Ireland and northwest Britain with a particular stronghold on the machairs of the Scottish Hebridean Islands. It is the subject of a UK Biodiversity Action Plan (UKBAP) and is listed as Rare.

Northern Colletes nests in localised aggregations, digging burrows in light sandy substrates. Adults normally emerge from mid-June onwards and remain active until mid- to late-August with mating from mid-June through July. They are polylectic, gathering pollen from a wide variety of plants within areas of flower-rich grassland adjacent to their nesting sites (Westrich 2001). Aggregations of northern Colletes burrows are typically found in bare patches of sandy soil in flower-rich grassland and dunes, on slopes with a southerly aspect, and where vegetation is short and sparse. Activity seems to be temperature dependent and the bees are usually only active in sunshine.

Some 30% of the low-lying Isle of Tiree in the Inner Hebrides is dominated by wind-blown shell-sand and its extensive machairs are known to be occupied by large numbers of northern Colletes bees. The RSPB manages 380 ha of machair at The Reef reserve through traditional winter cattle grazing. The Reef represents one of the most intact machair plains in the Hebrides and is a stronghold for the bee. Since 2001, all nesting aggregations of the bee on the RSPB's reserve have been monitored annually in July to assess the bee's status there. Since 2000, RSPB has jointly led the UKBAP for northern colletes together with Hymettus Ltd (formerly the 'Aculeate Conservation Group'), with the aim of maintaining the bee's current range. Initial work concentrated on determining the current distribution and status of the bee within the UK. Populations are being maintained through appropriate management on nature reserves within this range and through provision of management advice in areas outwith nature reserves.

METHODS

The Reef RSPB reserve

Attempts have been made to locate all nesting aggregations of northern Colletes bees on The Reef RSPB reserve since 2001. On 9 July 2001, the first nesting aggregation (site 1) was found on a south-

facing slope at the eastern end of the sand dunes by visiting RSPB ecologist, Jane Sears. This was the first record of breeding northern colletes on Tiree since 1937, despite a brief search in August 1999. A search was then made the following day of all other apparently suitable nesting areas, focussing on the south-facing slopes of sand dunes that line the southern edge of The Reef. All active nesting aggregations were recorded and mapped. On 10 July 2002, these sites were revisited but the search was extended to include flat areas in the north and west of the reserve, as it was discovered that bees could also nest on man-made slopes at the edge of old pits and ditches. All known nest-sites and other apparently suitable areas were then visited annually for a further six years. All visits were made between 10 am and 4 pm on a date in the second week of July when bees are know to be most active and on days of full sunshine with wind speeds of less than Force 3. Care was taken to avoid days that were preceded by particularly wet and cold days, as it was felt this might reduce bee activity. In the years 2001-2003, only the presence of bees was recorded together with a subjective measure of whether it was felt that bee activity was obviously higher or lower than the previous year at each aggregation. From 2004, an attempt was made to make the assessment more objective by recording the maximum number of bees recorded at each nest aggregation during the visit.

UK-wide survey

A key part of the UKBAP for northern Colletes was to obtain up to date information on the current range and status of the bee in the United Kingdom. From 2000 onwards, RSPB and Hymettus Ltd surveyors with knowledge of this species made searches of known locations where bees had been recorded previously throughout its known historical range, whilst additional searches were made of other adjacent areas that appeared to hold suitable habitat. Searches were made during the northern Colletes' flight period from late June to early August, often concentrating on the middle of this period, when there was the greatest amount of burrowing activity. Areas of suitable habitat were searched for signs of activity on sunny days between 1000 and 1700 hrs. When active-looking Colletes-type burrows were discovered, they were watched for 10 to 20 minutes to check for *C. floralis* activity. Recently used (active) burrows were identified from their size, shape, habitat and presence of freshly discarded soil in front of the burrow entrances (Hunter 2002).

RESULTS

The Reef RSPB reserve

A total of 11 nesting aggregations was recorded on the Reef between 2001 and 2008 (see Fig. 1 and Table 1). Of these, four were associated with the coastal dunes south of the B8065 road, whilst the remainder occurred in areas of flatter machair and were associated with the vegetated edges of old pits (3), rubble piles (3) and ditch edges (1). Thus, 64% of the nesting aggregations were associated with man-made artefacts and just 36% appeared to be at wholly natural sites. Five nesting aggregations were located in July 2001, although no bees were observed at one of these (site 3). The following year, these five nesting aggregations were all found to be active, one (site 1) with a decreased level of activity. Three new nest aggregations were found in areas in the west and north of the reserve, that had not been searched in 2001. All eight nest aggregations were active in July 2003, with decreased levels of activity at one and increased levels at three others (Table 1). However, in 2004, one of the nest aggregations (site 111) was found to have become covered with dense vegetation and was not used again, although bee activity at an adjacent location (site 112) was thought to have increased as a result. New nesting aggregations within the key search areas were located in 2005 (1) and 2006 (2), whilst an extension was noted to one aggregation (site 3) in 2008. Numbers of bees recorded at all 10 active nest aggregations between 2004 and 2008 are given in Table 1.

UK-wide survey

The range of the northern Colletes was poorly known prior to the 1970s (Fig. 2) with occupied 10km grid squares recorded only in South Uist (1), Tiree (2), Ayrshire (1) and Northern Ireland (1). This map is more of a reflection of the distribution of recording effort by knowledgeable entomologists than an accurate reflection of the distribution of the species at the time. Anecdotal reports suggest that the bee was still relatively common and widespread in this period with additional possible records from Lewis, Harris, Skye, Rum and the NW coast of the Scottish Mainland.

In the period 1970 to 1999, Hymettus Ltd members undertook some targeted searches for the bee and its range became better known in the Outer Hebrides, with some seven occupied 10km grid squares running from Vatersay in the south through Barra and South Uist to Benbecula in the north (Fig. 3). In addition, there were confirmed records from Colonsay in the Inner Hebrides, Torrs Warren in Dumfries & Galloway and the Duddon Estuary in Cumbria. However this map is unlikely to reflect the full distribution of the bee at the time. For example, there were no records from sites such as Tiree, Ayrshire and Northern Ireland, that had been active since before the 1970s and which were still active in 2008.

In response to the UKBAP, more comprehensive survey work was undertaken in 2000-2008 mainly by Hymettus Ltd and RSPB. The results reveal a more complete picture of the bee's range (Fig. 4). In the Outer Hebrides, ten 10km grid squares were occupied from Berneray in the north, through North Uist, Benbecula, South Uist and Barra to Vatersay in the south. In the Inner Hebrides, three squares were occupied on Tiree, two on Coll, two on Colonsay/Oronsay and four on Islay. Northern Colletes had never previously been recorded on Islay, yet in 2006 an RSPB survey discovered five nesting aggregations including a very large one at Killinallan dunes near Loch Gruinart. In mainland Britain, two

squares were occupied near Irvine in Ayrshire, one at Machrihanish on the Kintyre Peninsula and two at the Duddon Estuary in Cumbria. In Northern Ireland, an RSPB survey in 2003 re-discovered the bee after an absence of records for over 70 years. Five 10km squares were occupied encompassing a large area of extensive habitat near Lough Foyle including large nesting aggregations at Ballymaclary, Umbra and Portstewart Strand, as well as two smaller isolated nesting aggregations further east at Bushfoot Strand and White Park Bay. However, searches of apparently suitable habitat in Lewis, Harris, Skye, Rum, Mull and Iona and the mainland coasts of Sutherland and Wester Ross have failed to find the bee.

DISCUSSION

The Reef RSPB reserve

Results of eight years of monitoring on The Reef RSPB reserve indicate a relatively stable population of northern Colletes there, with the majority of nest aggregations being occupied from one year to the next and with no obvious trend in numbers observed at individual sites or overall. These findings suggest that the current management regime of heavy winter cattle grazing between November and March, followed by reduced grazing levels in April-May and a complete grazing break between June and October suits the requirements of this species. The winter cattle grazing produces short-cropped banks and poached areas suitable for use by nesting bees, but at the same time allows a full set of machair flowers to bloom and set seed, providing a diverse nectar and pollen source for the bees throughout their flight period (mid June to early August).

One nest aggregation was lost to vegetation and soil build up, whilst three new nest aggregations were formed during the study period and another aggregation was extended. This indicates the dynamic nature of the species, which appears capable of developing new nesting aggregations as conditions dictate, assuming these lie close to both necessary food resources and existing nest aggregations to provide a source of bees. The fact that over 60% of nest aggregations on the reserve were at sites involving man-made artefacts such as pit banks, rock-piles and ditch edges is encouraging as it again shows that the species is capable of making use of new sites as they become available. This finding is also suggestive of possible management techniques for encouraging bees to nest in areas with suitable food resources but which lack natural nesting habitat.

UK-wide survey

The survey work conducted since 2000 as a result of the UKBAP has revealed the most complete picture to date of the known range of the northern Colletes in the UK. Comparison of this work with previous distribution maps is confounded by the less complete coverage of earlier years. At face value, it appears that the bee is now more widespread than it was in the past, whereas it is likely that the distribution maps mask a considerable reduction in range, which has resulted from changes in agricultural practices since the middle of the twentieth century. The species appears now to be absent from several locations where it is believed to have occurred previously, such as Lewis, Harris, Skye, Rum and the mainland coasts of Sutherland and Wester Ross (Hunter 2004, MacDonald 2002). Survey work in 2008 of apparently suitable habitat on Mull and Iona also failed to locate the species there (Hunter 2008). Numbers on Colonsay and Oronsay appear small and erratic (Wynde 2002), whilst the species has recently been lost from Torrs Warren, its final known site in Dumfries and Galloway, as a result of cessation of grazing there (Hunter 2004) and possibly also afforestation.

On the plus side however, the continued presence of the bee in both Northern Ireland (Hunter 2003a, Sears and Hunter 2005) and England (Robinson 2004, 2006, 2007) has been confirmed and management recommendations are in place to help maintain and increase these populations (e.g. Hunter 2003b). The discovery of very large new nesting aggregations on Islay (Hunter 2006, 2008), an island not previously known to hold the bee, is very encouraging, as is the continued presence of the bee in mainland Scotland near Irvine in Ayrshire (Little 2007) and at Machrihanish, Kintyre (Hunter 2008). The currently large and thriving populations on Tiree/Coll (Hunter 2001, 2002 and this study; Wellock 2004) and the Outer Hebrides (e.g. Neill 2001, Edwards 1998, 2001, RSPB data) are also cause for optimism. The key now is to ensure optimal management of the existing populations. In Scotland, this has been helped by the presence of bees at RSPB reserves on Islay, Oronsay, Tiree, Coll and North Uist, where management has been tailored to suit the species and by the inclusion of the bee and its machair habitat as priorities within the new Scottish Rural Development Plan in both the Argyll Islands and the Outer Hebrides. The latter plan is critical in helping to maintain low intensity cattle-based agricultural systems in the Hebrides, which enable sound conservation management of the machair and the valuable biodiversity it supports, including the northern Colletes mining bee.

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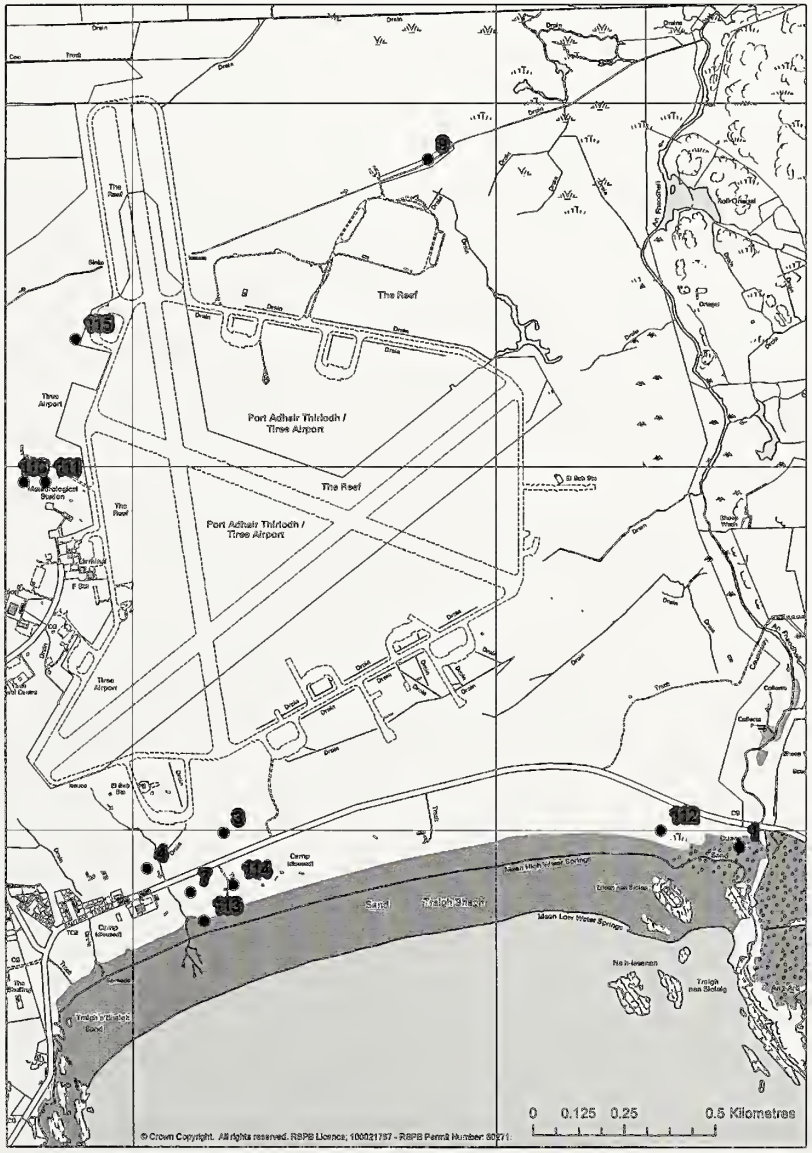

Fig. 1. The Reef RSPB reserve, Tiree showing the location of 11 nesting aggregations used by northern Colletes bees 2001-2008 (from Bowler 2007).

Fig. 2. Records of northern Colletes before 1970 by 10km grid-square (data from SNH 2000).

Fig. 3. Records of northern Colletes 1970-1999 by 10km grid-square (data from SNH 2000)

Fig. 4. Records of northern Colletes 2000-2008 by 10km grid-square (data from various sources – see reference list and acknowledgements).

Site	Habitat	2001	2002	2003	2004	2005	2006	2007	2008
1	Natural bank	Active	Active (-)	Active (+)	Active (20)	Active (15)	Active (25)	Active (20)	Active (15)
3	Edge of pit	Inactive	Active	Active (+)	Active (50)	Active (30)	Active (10)	Active (20)	Active (35)
4	Edge of pit	Active	Active	Active	Active (180)	Active (50)	Active (30)	Active (20)	Active (50)
7	Edge of pit	Active	Active	Active	Active (40)	Active (20)	Active (80)	Active (60)	Active (35)
9	Edge of ditch	Active	Active	Active (+)	Active (30)	Active (20)	Active (20)	Active (20)	Active (70)
110	Old rubble pile	Not found	Active	Active	Active (+) (60)	Active (40)	Active (160)	Active (120)	Active (70)
111	Old rubble pile	Not found	Active	Active	No signs (-)	No signs	No signs	No signs	No signs
112	Natural bank	Absent	Active	Active (-)	Active (40)	Active (40)	Active (20)	Active (30)	Active (45)
113	Natural bank	Absent	Absent	Absent	Absent	Active (30)	Active (30)	Active (10)	Active (8)
114	Natural slope	Absent	Absent	Absent	Absent	Absent	Active (10)	Active (10)	Active (5)
115	Old rubble pile	Absent	Absent	Absent	Absent	Absent	Active (6)	Active (5)	Active (35)

Table 1. Presence of northern Colletes at eleven numbered sites on The Reef RSPB reserve on Tiree during survey visits in the second week of July 2001-2008 (from Bowler 2001-08). NB: (+) indicates increased activity on the previous year, (-) indicates decreased activity, 2001-2004. Figures in brackets represent maximum counts of bees on each visit in 2004-2008.

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Plate 1

1. Machair in bloom. North Uist. T. N. Tait.
2. Early marsh orchid (*Dactylorhiza incarnate ssp coccinea*). Udal Point, North Uist, T. N. Tait.
3. Six Spot burnet moth (*Zygaena filipendulae*). Prestwick dunes. T. N. Tait.
4. Choughs (*Pyrrhocorax pyrrhocorax*). Islay. D. Palmer.
5. Greater yellow bumblebee (*Bombus distinguendus*). North Uist. N. Redpath.
6. Corncrake (*Crex crex*). Oronsay. D. Palmar.

Plate 2

1. White pyramidal orchid. Killinallan, Islay. C. Fiedler.
2. Male *Colletes floralis* foraging on Asteraceae. Saligo Bay, Islay. C. Fiedler.
3. Field pansies (*Viola arvensis*). Corran, Isle of Jura. T. N. Tair.
4. Corn bunting (*Emberiza calandra*). Balranald, North Uist. T. N. Tait.
5. Red clover (*Trifolium pratense*) on machair. South Uist. D. Goulson.
6. Skylark (*Alauda arvensis*). Corran, Isle of Jura. T. N. Tait.

Machair Habitats and Species

Plate 1

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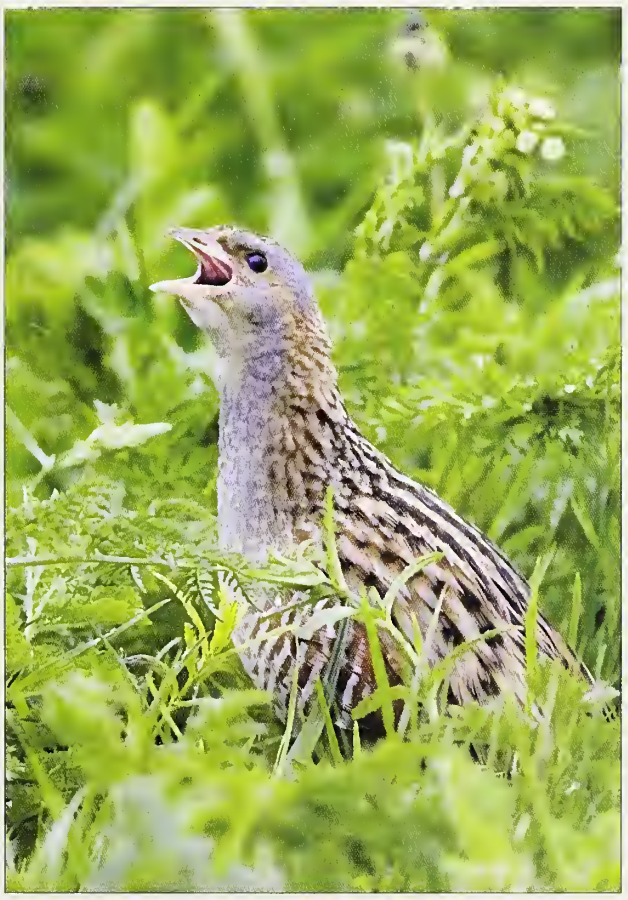

Machair Habitats and Species

Plate 2

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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.

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Machair corn: management and conservation of a historical machair component

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ABSTRACT

The contribution of local cereal cultivation to machair wildlife is widely acknowledged. All three traditional machair corn species, small oat (*Avena strigosa)*, bere *(Hordeum vulgare)* and rye (*Secale cereale*) are locally produced. Local varieties that are maintained by farmers over generations are known as landraces and are rare, rapidly disappearing forms of agricultural diversity. Collecting seed for *ex situ* conservation and associated documentation of 27 samples provided by 24 seed growers gave insight into local seed production. There was found to be a dynamic pattern of seed movement between crofters, a trend towards specialisation in seed production and an overall robust seed quality albeit with high disease levels. The three corn varieties are mostly maintained as mixtures; the 'pure' component stocks are maintained by a smaller number of growers; and the number of keepers of the local rye was low. Although the last years have seen good seed harvests, there are no seed reserves.

Introduction

Cereal cultivation on the machair predates the first millennium (Parker Pearson, 2004). *Coirce béag* or small oat (*Avena strigosa* Schreb., rye (*Secale cereale* L. and bere (*Hordeum vulgare* L. have been grown here over centuries (Caird, 1979, Findlay, 1956) and have developed a tolerance to the nutrient deficiencies of the machair soils so that they can yield without extra input of nutrients. Such cultivation forms part of the extensive low-input system of cattle rearing, in semi-natural habitats and meets the 'High Nature Value' farming criteria as formulated by the European Environment Agency (2004). Its importance for machair wildlife has long been recognised (Angus 2001) and is acknowledged in the Habitat Action Plan for machair (http://www.ukbap.org.uk/UKPlans.aspx?ID=30). The Western Isles have a specific Cereal Fields Habitat Action Plan (http://www.cne-siar.gov.uk/biodiversity/planningprocess.asp#localactionplans).

The three corn landraces have survived into the twenty-first century on a scale likely unparalleled in North-west Europe (Scholten *et al.*, 2008). Landraces are comparable to rare animal breeds: local varieties developed under local conditions and maintained by local farmers over generations. Bere and small oat are not commercially available and the islands have to be self-reliant for seed. Small oat (*Avena strigosa* Schreb.), is a different botanical species from mainland oat (*A. sativa* L.) and a rare crop; the Uists form the largest remaining area of this crop in North-Western Europe (Scholten *et.al.* 2008). Often mixed together with local rye (*Secale cereale* L.) and bere (*Hordeum vulgare* L.), these mixtures form another speciality of the Uists. Mixed grain cultivation goes back to medieval times (Slicher van Bath, 1963), known under names as dredge corn or maslin. Species mixtures form a buffer against very risky, unpredictable environments and farmers' strategy of using mixtures to aim at yield stability rather than a maximised yield, has been seen as a defining element of landraces (Zeven, 1998). The combination of small oat and rye is known from former other traditional growing areas, such as Galicia in Spain (Vavilov, 1926) and West-Jutland in Denmark (www.ngb.no).

Worldwide, landraces have been largely replaced by modern cultivars that are bred and marketed by breeding companies and seed merchants. The survival of landraces has been associated with patterns of fragmentation, marginal agricultural conditions, economic isolation and cultural (linguistic) autonomy (Brush 1995). The Scottish landraces, surviving on the most remote islands, the Southern Outer Hebrides and Northern Isles, fit this pattern where crofters have retained historical landraces and the associated Gaelic and Norse words. Although the scale of Uist cultivation and seed production has remained substantial, seed shortages were observed in 2004-5 and future declines seem likely in the face of a decreasing and ageing crofting population and crofting agriculture facing abandonment and intensification. These trends elsewhere in Europe are seen as major problems for the long-term survival of landraces (Negri *et al.*, 2000). Fragmentation and isolation may affect the genetic diversity of the landraces and the resilience of local seed production. How much diversity is present has been studied so far only for bere and results showed high diversity within and between island populations (Southworth, 2007).

As landraces became increasingly rare, international conservation legislation has been developed, such as

the Convention on Biological Diversity (CBD, 1992) and more explicitly the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, 2001), ratified by the UK in 2006. These treaties commit national governments to conserve agricultural diversity *ex situ* as well as *in situ*; Article 5.1. promotes or supports farmers and local communities' efforts to manage and conserve on farm their plant genetic resources for food and agriculture and Article 6.2 promotes, as appropriate, the expanded use of local and locally adapted crops, varieties and under-utilised species. In Scotland, the need to conserve landraces has been highlighted more in local conservation plans, such as the LBAP Western Isles, than at national level. Local action proposals in support of landraces have not been followed-up. However, a new Working Group on Scottish Landraces and Traditional Varieties was created in 2008 to report to the Scottish Biodiversity Committee on conservation and use in Scotland. Conservation of the genetic diversity of Scottish landraces is facilitated through the Scottish Landrace Protection Scheme which provides *ex situ* backup for local growers (www.scottishlandraces.uk).

Machair agriculture, has been coined "stern adversity" (Kerr, 1955), with land of the lowest agricultural capability (Hudson, 1982), highly exposed to winds, prone to soil erosion, with the high alkalinity causing nutrient deficiencies; low in organic matter, with periodic droughts, a heavy weed burden and harsh weather conditions. Harvest failures due to diseases or bad weather have been reported throughout the history of cereal cultivation and seed stocks had to be reintroduced from time to time, for example in the seventeenth century from Ireland (for the Hebrides), while Shetland imported from Orkney and Germany (Shaw, 1980). At least since early twentieth century the seeds were purchased and improved varieties were brought in. A Welsh bred small oat cross was grown on the Uists in the 1950s and yielded better than the local indigenous strains (Darling, 1955, Gray 1955, Grant 1979). In the 1970's Scottish bred lines were tested and locally released on Tiree at the end of the trial (Wright *et.al.,* 2002). The end of formal breeding of oat varieties for marginal environments explains the survival of the local strains of small oat (ibid.). The cessation of commercial seed supply meant that crofters were left with the task of producing local seed in sufficient quantity and quality and at the right time.

The term local or informal seed sector is used mainly in developing countries for farmers' seed production in situations where the formal seed sector (commercial seed companies, plant breeding institutes) fails to supply seeds or varieties; it is used as a diagnostic tool to analyse strengths and weaknesses of local seed systems in order to assess adequate support actions (Almekinders, Louwaars and de Bruijn, 1994, Sperling, 2008). The two sides of seed, the genetic value, such as for example the tolerance of Manganese deficient soils , as well as physical, planting value for farmers should be addressed in any study of the management of landraces. In order for farmers to be 'seed secure', key elements of seed availability, access and quality have to be ascertained (Sperling, 2008). Key questions are: how do farmers obtain seed, what technology is used to produce and select seed, what is the frequency of seed replacement and the nature of seed flow; and what mechanisms are in place to ensure seed quality? (Thiele, 1999).

This paper aims to describe and analyse how small oat, Uist rye and bere are maintained; how seed production and supply is organised and what constraints and weaknesses are present. It will focus on the physical value of the seed while the genetic diversity of the local strains will be the subject of further study.

MATERIALS AND METHODS

Data about local management and seed production were collected in 2008 simultaneously with seed collecting for *ex situ* conservation. Collecting for genebank conservation usually aims at acquiring maximum diversity within a region; combatting genetic erosion; acquiring gene/genotypes for breeding programs and analysis of agro-ecogeographical patterns of distribution of diversity (Hayward and Sackville Hamilton, 1997). Targeting isolated farmers is also recommended. As many farmers as possible were sought outside the core area of the Uists.

Collecting mixtures requires a special approach: individual components should be collected separately (Guarino *et al.,* 1995) and farmers consulted on how they maintain mixtures, species composition and mixture ratio (Guarino & Friis-Hansen, 1995). Seed production and selection methods, seed flow, variety and mixture maintenance, seed quality and genetic diversity, and farmers' evaluation of their own variety were based on methodologies summarised in Almekinders and Louwaars (1999).

The collecting strategy aimed at:

- representing all areas where cereal landraces are still grown
- targeting rarity: isolated growers and 'pure' or single stand crop stocks
- stratifying by island and machair townships in core areas
- documenting management practices with interviews with crofters and additional information.

Semi-structured interviews were held, the duration attuned to available time and interest of the crofter. These were supplemented with observations from previous fieldwork in 2006 and historical and 'grey report' documentation.

Seed quality data were provided by the Official Seed Testing Station (OSTS) at SASA where seed samples were cleaned and seed purity, mixture composition, germination and disease levels analysed.

RESULTS

Fieldwork was conducted in May and October 2008 and focused on the Uists starting with a list of 19 'bigger producers' provided by SAC Balivanich. In addition, other Uist crofters were approached by snowball effect, previous contacts or serendipity, i.e. chance encounters on the machair. On Tiree, Lewis, and Orkney contacts were via SAC or RSPB. Islay, Colonsay and Oronsay had corn imported from Orkney whereas Harris was provided through the RSPB reserve on North Uist. An overview of geographical varieties and their names is given in Table 1.

Twenty seven seed samples were collected from 24 different growers, selected according to seed availability, the originality of the seed stock and geographical representation. Twenty-two of the seed donors were on the Uists and three of them donated two stocks: one rye and small oat separately; two others bere and small oat, with rye. From Table 2 it can be seen that three people did not grow their own seed stock and two shared seed. Reasons given for not growing own seed by these three and others were lack of machinery and lack of help on time, destruction of seed crops by geese, weed contamination of own seed, and old age.

Most seed was collected as mixtures. From previous fieldwork single stand oats and bere were known but a chance discovery of a pure stand of rye, was a novelty and led to a further emphasis on collecting single stand stocks. An overview of seed samples, species composition, seed source, seed supplied to others, and seed swap information is presented in Table 2 and will be discussed in the following section.

Varieties, Names, Perceived Diversity And Evaluation

A first indication of diversity of landraces is the variety of local names. An overview of landrace names in contemporary use is given in Table 1. Small oat or *coirce béag* is likely one of the older Scottish names for *A. strigosa*. In his historical overview of oat cultivation in Great Britain, Findlay (1956) lists 'small oat' as the name in 17th century oat classifications, distinguishing it from 'gryt' (big) oats and mixed oats. The Gaelic name for small oat was *coirce béag* on Uists and Tiree, in contrast with big oat or *coirce mor*. In contrast, the interviewed Lewis crofter and his wife named their seeds black oat or *coirce dubh*[1]. On Orkney two traditional types of black oats were mentioned, Murkle oat, an *A. sativa* type and the traditional (hairy) black oat, an *A. strigosa* strain, which were grown together on Orkney in the past (Findlay, 1956). Only two growers were found with either of the two types. Shetland *aet* was mentioned by two Uist crofters as being darker than the small oat. In contrast to the small oat, there were no specific local names for the Uist rye nor for the Uist barley which was sometimes named bere, sometimes barley or Uist barley. Given the prevalence of mixtures, the absence of a specific Gaelic word for the cereal mixtures is striking. Gaelic dictionaries, i.e. Clyne (1989), Dwelly (1902) do not list any. The word corn is however used as a general term for either bere, oats or rye or all three (Anon, 2003).

Asked about variation within the Uist small oat, Uist crofters were unanimous in their opinion that there was only 'one island variety', which was 'the same all over the islands because it has been mixed many times'. Using alternatives, i.e. spraying mainland oat with manganese was often mentioned as not being an option, as it was too risky and too expensive. The most frequently mentioned reasons for growing small oat were its ability to stand the soil nutrient deficiencies and its volume. Rye and bere were mixed in for volume; the rye was seen as good in dry years and good standing support for the small oat. Some crofters were experimenting with different mixture components: Triticale, peas and mainland oat. Three occurrences of Shetland oats introduction to the Uists and Tiree were mentioned. Asked about the most desirable improvement to the small oat, increasing crop volume was most frequently mentioned.

Mixtures, species composition, single component stocks and maintenance

Most Uist corn nowadays is grown in oat-rye mixtures and the seed is also harvested from these mixtures. There were broadly two types of mixtures: oat-rye and oat "with a bit of rye". For the first type some crofters would give as guideline a mixture ratio oat to rye of 70:30 or 60:40 for dry machair. The second type of mixtures was closer to single stands that had been contaminated in harvesting equipment with other corn. Both forms show the problems associated with mixture maintenance: very few growers had access to individual component species of the mixture to adjust component ratios while unintentional mixing during harvest is impossible to reverse as there is no seed cleaning equipment. This led to a wide range in mixture ratios, apparent during field visits in 2006 (Scholten, unpublished data) and clearly visible in the mixture ratios found in seed analysis at the Official Seed Testing Station (OSTS) at SASA with for example rye ratios ranging between 4% and 54%. The lower level represents contamination through harvesting equipment, while the latter may be a mixture in which rye is taking over, assuming no sampling bias in the seed sample.

Depending on the growing season, harvested seed mixtures will often be different from the sown original. Some crofters felt that rye had a tendency to take over and one person had seen this actually happen in his mixture and had had to add oat to balance. Two crofters felt that combine harvesting of the seed was causing changes in the mixture composition, leading to an increase in the rye component. Some crofters grew

[1] In contrast, Dwelly (1902) gives *coirce-dubh* as applied to all kinds of oats when black with blight (probably smut, M.S.) especially *Avena strigosa.*

the mixtures as they were, while others would check the mixture composition before sowing and adjusted the ratio with either single stocks or a mixture with a higher oat ratio; or adjusted the ratio before harvesting by choosing a proper mixture ratio for seed harvesting. Mixtures with a lot of rye were called 'strong mixtures' by one crofter. Approximately one third of crofters used a three-cereal mixture, with bere mixed in before at sowing time. Bere ripens earlier than small oat and rye, hence the need and practice to grow pure bere for seed. Seed surpluses were bruised for feed or fed to hens. The number of bere seed growers on Uist is estimated at a dozen. Of the other 'pure' stands, nine 'clean' oat samples were collected, i.e. samples with other components less than 5%. One crofter with single oat observed that 'clean' seed was in big demand. The number of pure oat growers is probably higher than this.

Pure rye was the rarest stock. Only three sources were found, of which two could be collected. One crofter used a clean rye, stock inherited from his father, on the driest part of the machair and 'for rabbit holes'. The third source, 'very good rye seed' source on South Uist was not available anymore due to a tragic farm accident a few years ago.

From historical accounts and mentioned by one crofter, it appears that single stand crops were grown on inbye or *dubhthalamh* while mixtures were used on *talamh gainmheach*, machair land. Single stands had specific uses, for example traditionally oat was used for cows having calved (Anon, 2003). *Carmina gadelica* mentions different months for winnowing each of the bere, small oat and rye (Carmichael, 1992), an indication that separate seed crops were kept for each of the mixture species. On Tiree, seed was traditionally produced on the inbye (Anon, 2003). The practice of growing single stands seems to have declined in parallel with the decrease in cereal cultivation on the inbye land.

From historical sources it is not clear how old the practice of mixed cultivation is on the Hebrides. For Lewis only pure oats, *Coirce béag* on the machair, and barley were mentioned by McDonald in 1919. The absence of rye on Lewis was confirmed in 2008 by two crofters. The Lewis stock collected had been sourced from Ness 22 years ago and was originally grown as a single stand small oat to which Uist rye, oat and bere had been gradually added. The same McDonald describes for the Uists machair in 1919 a rotation of barley or potatoes, followed by oats followed by rye, but did not mention mixtures. These appear in mid-twentiest century observations such as Darling (1955) reporting small oat mixed with bere as typical for Uists and Tiree. Robberts, Kerr and Seaton (1959) in their description of machair grasslands of the Hebrides, mention 'pure rye' being used on the dryer areas and bere on the heavier soil while small oat with or without rye was the main cereal. Tiree mixtures of small oat with rye were described by Grant (1979).

Seed production and seed movement

Historically, corn seed would have been produced as part of the crop itself, on stooks, with a thresher to separate seed from straw and chaff, which also removed the smaller seeds. Nowadays, traditionally binder-harvested seed, slowly dried in three stages on stooks is confined to Benbecula and South Uist. Most seed was combine-harvested. When harvesting the crop as silage, seed has to be harvested separately, left to ripen in the field after the black bales are harvested. Many erofters with combine-harvested seed mentioned problems with drying the seed. This was done in the shed on the shed floor, on trailers or in containers by turning the seed regularly. Only one crofter used an electric fan.

There was general agreement amongst crofters and farmers that there had been sufficient seed in the last couple of years thanks to good weather and more combines available. None of the seed growers kept a seed reserve as a rule. Most of the seed of the Uist seed growers was for own use but 16 of the 22 seed growers supplied neighbours or some regular customers with up to one third of their own seed harvest.

Findlay (1956) describes oat seed replacement, the swapping of seed between farmers, as historically done with the aim to refresh degenerated (weed infected) seed; to replace grain damaged by weather during harvest and in general that it was considered good practice to change seed between 'warm' and 'cold' soils and vice versa. Some of these practices were still remembered or even present. Seed exchange between heavier and lighter soils had been common practice on Tiree according to a Tiree crofter. One Uist crofter mentioned the (past) practice to swap seed between machair and *dubhthalamh* as the latter produced seed with less weeds than the machair with its heavy weed burden, especially of charlock. A variety of reasons for seed swapping was given in 2008. Most crofters had swapped or replaced seed for quality reasons (cleaner seed) or for seed health reasons; one farmer had exchanged his complete stock with Tiree oat because of its superior volume; one stock had to be replenished after the 2005 January gale; another after geese had eaten an entire seed crop. Crofters with pure bere, small oat or rye stocks tended not to swap their seed stocks.

The regional pattern of seed movement showed a geographical limit to the Hebrides: between Uists and Tiree and to Lewis and Harris, but not beyond. Orkney bere is coming to Islay from the Agronomy College. Of the two remaining growers on Lewis, only one had his own seed stock, his neighbour's original stock had been eaten by rats and both were supplemented with additional seed sourced from North Uist by the local RSPB. A small group of crofters in Northton, South Harris, were supplied with the same stock.

Seed quality

The quality of the seed (dryness, good filling, free of weeds and diseases) was an apparent source of pride for many; 'good seed' and 'good seed producers' were often mentioned and one crofter refused to donate seed because he thought the seed of insufficient quality. Most seed was taken from the main silage crop by leaving weed-free patches or the area with the best ratio oat to rye for seed harvesting. Producing a good seed head requires a different agronomy than produeing straw for volume. The practice of using the best land - inbye if available - mentioned earlier, was confirmed by some growers who used the best fields for seed production, for example a field used as night meadow by cows in the previous year; or fields on wetter machair or a field in the first year after ploughing. Lower seeding density rates, fertilizer in formulas 16-16-16 or 17-17-17, for good grain heads and to lessen the risk of lodging, were applied. Herbicide was used by a couple of growers to prevent charlock choking the seed crop.

Seed quality data presented here are preliminary, based on OSTS analysis of one third of the samples. Germination rates ranged from 94% to 65% and 47% at the lower end, the latter likely due to moisture problems mentioned by the donors as seed having gone fusty. Moisture problems showed up as *Penicillium* infection rates as high as 98%. Snow mold (*Fusarium nivale* and *Microdochium nivale*) and smut (*Ustilago* spp) were the most prevalent with infection rates ranging from 1 – 76%, respectively and from 0 to over 600000 smut spores per sample. Loose smut is the most prevalent disease on oat and some growers had used seed treatment against smut prior to seeding in the past; few had used it this year. Not all samples had smut and of the smut-free samples twohad had seed treatment but one none. On rye seed, ergot, *Claviceps purpurea,* was prevalent in all analysed samples in quantities far above accepted tolerance levels (SAC Disease Notes www.sac.ac.uk/mainrep/pdfs/tn601ergotcereals.pdf.)

DISCUSSION AND CONCLUSION

Fieldwork in 2008 set out to collect a representative collection of local corn seed for *ex situ* conservation while documenting the management and seed production of local varieties. The focus was qualitative, i.e. on different management styles of a group of active seed growers and suppliers on Uist, rather than surveying overall seed production. Of the two aspects of seed, the physical or planting value was studied (quantity and quality of seed) while the genetic diversity of the different stocks, to be studied in detail in a later phase of the project, was approached by questions about how (many) local stocks were maintained and how their agronomic performance was valued.

Seed supply was seen as sufficient. However, as one crofter remarked, it is unclear what will happen in a wet summer when drying seed after combine harvesting in a favourable season becomes an issue. None of the growers kept a seed reserve.

Most seed was produced as mixtures of small oat and rye, with or without bere. Pure stock seed growers formed a minority of seed producers, and of these, only very few maintained pure stocks of bere and rye. These pure stocks form a mechanism to control mixture ratios. Accessibility to rare stocks may be a problem as some crofters were trying to source mainland barley or rye for mixing in (see also Colin MacPhail, this volume). The variability of mixture composition observed in 2006 and 2008 could become a problem with changing, more variable summer weather.

Given the hazardous nature of cropping and harvesting on the islands, the dynamic nature of local seed production with fair amounts of seed sharing and swapping, is not surprising. The risk of damage to seed crops by geese was a dominant coneern, making crofters bale up their seed stock instead of risking loss, and even the choice of a seed patch in the field was determined not by good seed heads but where the threat of geese was least. Seed drying problems after harvesting and during storage, and seed treatment against smut can be added to the list of challenges facing seed growers.

Five out of 22 Uists growers in this study did not produce their own seed. This is likely an underestimation because the trend in seed production seems to be more seed produced by fewer crofters. The number of seed stocks is likely to decrease further: eaten by geese; baled in order to safeguard a crop; and seed production given up by older crofters. Sixteen of the 22 Uist crofters provided up to a third of their seed crop to other crofters and at least two crofters were mainly growing corn for seed. Espinosa and Fauré (2004) who interviewed 34 crofters on South Uist about developments in crofting styles found a similar pattern of specialisation. Amongst their six types of machair crofting, only three involved seed production and only one type involved seed supply to others.

Local and scientific names	Area	Number of growers
Bere (*Hordeum vulgare* L.)	Orkney, Shetland	5-20
Bere or barley or Uist barley *Eorna* (pure)	Uists and Barra	A dozen
Bere *Eorna*	Tiree	1
Small oat / *Coirce béag* (*A. strigosa* Schreb.), rye (*Secale cereale* L.) and bere *Eorna*	Uists and Barra	100 – 250
Black oat / *coirce dubh* (*A. strigosa* Schreb.)	Lewis	2
Tiree oat / *coirce béag* (*A. strigosa* Schreb.)	Tiree	1
Shetland oat/ Shetland ait (*A. strigosa* Schreb.)	Shetland	Less than 10
Orkney traditional black oat (Murkle) (*Avena sativa* L.)	Orkney	2
Orkney traditional black oat (*A. strigosa* Schreb.)	Orkney	1

Table 1. Overview of Scottish cereal landraces names and estimated number of growers 2008.

Island	Species	Own seed	Seed supplier	Seed swap	Most recent swap and extent
Benbecula	small oat + some rye	0	0		
Benbecula	small oat + some rye	0	0	1	2-3 years ago 100%
Benbecula	small oat + some rye	1	1	1	3 yrs
Benbecula	rye	1			
Benbecula	small oat + rye	1	1	1	few years ago 75% from 2 sources
Benbecula	bere + bit oats	1	1	0	
Berneray	small oat + bit rye	1	0	1	some years ago - some
Lewis	small oat + rye + bit bere	1	shared	1	some years ago
North Uist	bere	1	1	0	
North Uist	small oat + some rye	1	1	0	
North Uist	rye	1	0	0	
North Uist	small oat	shared	shared		
North Uist	small oat	1	1	0	
North Uist	smal oat + rye + barley	shared	shared		not on a regular basis
North Uist	small oat + some rye	1	1	0	
North Uist	small oat + rye	1	1	1	a little every 4-5 years
North Uist	bere	1	1	1	a little every 4-5 years
North Uist	small oat + some rye	1	1	1	few years ago
South Uist	small oat + rye + barley	1	0	0	
South Uist	small oat + rye	1		1	2 yrs ago, a couple of bags
South Uist	small oat + rye	1	1	1	2 years ago 100%
South Uist	small oat + some rye	1	1	1	3 years ago 100%
South Uist	small oat + rye + Triticale + bere	1	1	1	4 years ago, partially
South Uist	small oat + rye + Uist barley	1	1	1	3-4 years ago
South Uist	small oat + rye + bit bere	1		0	
South Uist	small oat + rye	0		n/a	
Tiree	small oat + rye + bit bere	1	0	1	some years ago, few bushels
	27				

Table 2. Overview seed samples from 22 growers, species ratio, source, supply and seed exchange (1 = yes)

If the (few) younger crofters in this study represent the future of Uist seed production, there will be corn mixtures of three landraces, with extra bere mixed in from own stock or sourced elsewhere; left-over seed will be used on barren dune pits to prevent erosion; alternative (mainland) varieties will be sourced to improve silage yields; a patch in the field with 'good seed heads' will be harvested by a combine (which is owned); seed will be shared, supplied to or sourced from others; and all of this done as an extra shift to full-time jobs.

Almekinders, Louwaars, and de Bruijn (1994) summarised the limitations of local seed systems with: sub-optimal performance of local varieties, seed storage problems and accessibility problems impeding seed exchange. They recommended improving storage as well as the physical and genetic quality of seed of the local genepool. Darling - more than fifty years ago and glaringly topical – noted for the Hebrides a lack of storage facilities, the need for community-level seed sourcing and the need for better yielding varieties (Darling, 1955). Of the three elements of seed security listed by Sperling (2008), lack of availability of better yielding stocks, lack of access to individual components of corn mixtures as well as high disease loads of seeds can be seen as the weak sides of Uist local seed production.

In the short term, the action point in the Western Isles' LBAP to include seed production of local varieties into agro-environmental schemes should be followed up. This would acknowledge the practical work and expertise of local seed growers who by supplying seed to others, provide a community service, and by maintaining a variety of local seed stocks and guaranteeing the survival of local varieties, a public service of *in situ* conservation.

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Habitat management survey for conservation of the great yellow bumblebee Bombus distinguendus in the Outer Hebrides

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INTRODUCTION

The great yellow bumblebee *Bombus distinguendus* is one of a range of species that has declined as a result of agricultural intensification (Western Isles LBAP, 2004). Prior to 1970 the bee was more widespread on mainland Britain; it is now restricted to the Outer Hebrides, Orkney Isles, Coll and Tiree and scattered locations on northern mainland Scotland (NBN Gateway website, 2008) (Fig. 1). The sites where the bee remains are priority habitats for conservation: machair and neutral grassland. The great yellow bumblebee has been designated a Nationally Scarce species and included in the UK Biodiversity Action Plan (UK Biodiversity Group, 1999). As the Outer Hebrides are the stronghold for this species investigations into what can be done to ensure its survival have been concentrated in this area. This study investigated farming operations and corncrake conservation sites in relation to the requirements of the great yellow bumblebee. Fieldwork was carried out in the Outer Hebrides in September 2005; whilst I was working as a volunteer for the Royal Society for the Protection for Birds. The work was supported by a grant from the Esmée Fairbairn Foundation, administered by the Glasgow Natural History Society.

Machair management survey

The aim of this study was to establish the machair management protocol that best suits the great yellow bumblebee. In South Uist, crofters or their agents were consulted to determine the management practices they employ in areas of machair where the great yellow bumblebee occurs. A list of 42 sites where the bee is known to occur was provided by the RSPB: data was gathered for 24 of these sites.

From Fig. 2 it can be seen that all sites used both the 'rotation system' and 'the regeneration method'. All sites have a rotation system based on one year of mixed cereals followed by one of fallow. During the fallow year no seed is added to sites allowing wild plants to regenerate naturally.

Fertiliser application differed between sites; some used seaweed alone, whereas others used seaweed in combination with manure. Seaweed alone was favoured on 63% of the 24 sites, probably because it is freely available. Manure is only used as an additional fertiliser on crofts where cattle are kept inside for part of the year (37% of sites). All sites are grazed throughout the winter and 42% are also cut for silage or hay at the end of the summer. This difference in site management seems to be traditional, having been used by generations of crofters.

The type of fertiliser used may have little effect on bee populations although less fertiliser input would tend to create greater wildflower diversity (Royal Horticultural Society, 2009). Similarly, whether the machair is cut or grazed at the end of the growing season may have little effect on subsequent bee use (a comparative study of bee use of these differently managed areas would ascertain this). However, cutting the machair for hay or silage and leaving the cuttings for a few days would allow the seeds to fall to the ground (Royal Horticultural Society, 2009); this would maintain a seed bank in situ.

The most important factors for the great yellow bumblebee are the availability of nesting sites in rank grassland, and a provision of forage plants throughout the flying season (SNH, 2008). As one of the few places in the UK where the bee is surviving, it is suggested that traditional practices (the level of fertiliser application, rotation and grazing) create the habitat requirements of the bee (Western Isles LBAP, 2004). Anecdotal evidence from one landowner suggested that it would be better to leave machair areas fallow for longer than one year, allowing the soil to "fix better". Further study would be required to assess any potential benefit to a longer fallow period.

The results of this survey can be used to advise site development elsewhere to create more favourable areas for bees. Further comparison of bee usage of sites with different management regimes will confirm the efficacy of traditional practices. More robust models for site management could then be established.

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Fig. 1. 10km squares with records for great yellow bumblebee in Great Britain and Ireland for the ten years preceding this study (1998-2008). As can be seen the species is found in a few locations including the Orkney Isles, Outer Hebrides, Coll, Tiree and a few locations on the northern mainland of Scotland.

Habitat attribute	Target condition	Score by visual assessment of characteristic*				Max score
Floral diversity	>=3 species used by *B.distinguendus*	0 sp.	1 sp.	2 sp.	>=3 sp.	
		0	**1**	**2**	**3**	**3**
Cover and abundance of suitable flowering plants	>25% of area covered by 1 or more species of suitable flowering plant	0	1-10%	11-25%	>25%	
		0	**1**	**2**	**3**	**3**
Cover and abundance of suitable nest/hibernation habitat (rank grass/vegetation	Between 10 and 20% of area covered by lodged grass/vegetation	0	1-9%	10-20%	>20%	
		0	**1**	**2**	**1**	**2**
Cover and abundance of rye grass	Less than 25% of area covered by rye-grass	0	1-25%	>25%		
		2	**1**	**0**		**2**
Size of cover areas	>= 0.1ha each	<=0.1ha	0.2 – 0.5ha	0.6-1ha	>1ha	
		0	**1**	**2**	**3**	**3**
					total	**13**

* Score for each attribute shown in bold

Table 1. Scores given to attributes used to assess corncrake corners for bee suitability. Corncrake corners were visually assessed for factors shown in this table. The highest score given relates to the target condition: score decreases with habitat suitability. The maximum score of 13 denotes a very suitable habitat for bees.

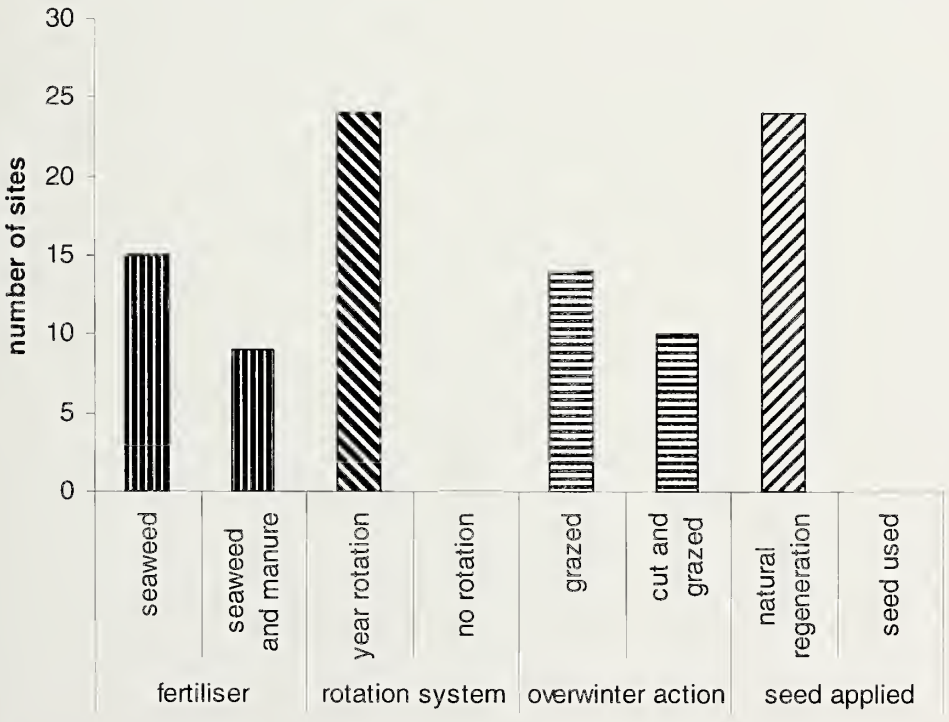

Fig. 2. Management prescriptions of 24 machair sites used by the great yellow bumblebee. Crofters were asked about the type of fertiliser used, the crop rotation system, what happens to plant material at the end of the growing season, and whether seed is applied to the land in fallow years. As can be seen, there is variation only in type of fertiliser and whether silage is gathered.

Fig. 3. Habitat score given to 44 corncrake corners in various parts of the Outer Hebrides. Sites were visually assessed and given a score based on the attributes shown in Table 1. The results show that the majority of sites are in the mid-range of scores with no site reaching the maximum possible.

Fig. 4. Results of 44 corncrake corners assessed only for floral density, floral variety and bee nesting habitat. Table 1 shows the target condition for these factors and the score given for each. One site reached the maximum score with the majority of sites scoring relatively high.

Corncrake corners for bee conservation?

There is potential for directing a unified conservation effort to benefit both the great yellow bumblebee and the corncrake (*Crex crex*) as it is thought that loss of machair habitat is responsible for the decline of both species in the Western Isles (RSPB, 2007). Corncrake "corners" have been created in the Outer Hebrides to provide cover in the form of tall vegetation. These areas are located close to fields where hay or silage are grown and are used by the birds when the fields are cut, and when they arrive from Africa in the spring (Western Isles LBAP, 2005).

Forty four corncrake corners in North and South Uist were surveyed for their potential suitability for bees. Ideally, set-aside areas would provide everything bees need i.e. a constant supply of suitable flowering plants from April to September when the bees are active (RSPB, 2007) and suitable areas for nesting. The bees tend to nest underground in old rodent holes which are more abundant in uncut vegetation (RSPB, 2007). Table 1 shows the habitat attributes used for visually assessing corncrake corners and the target or 'best' condition for each of these in terms of suitability for bees. These criteria were provided by the RSPB based on bee habitat requirements. A score of 13 (the maximum possible) would indicate that the site was most suitable: as the score declines, so does potential suitability for bees. Fig. 3 shows that of the sites surveyed, none reach the maximum score. Two score 11 and six score 10. The majority of sites are in the mid-range of scores; none were completely unsuitable.

As bees forage relatively close (1-2km) to nesting sites (Macdonald, 2003) these attributes in close proximity would provide good habitat. Therefore the results from the corncrake corner survey were examined more closely for floral density, floral variety and nesting habitat suitable for bees. Of all corncrake corners assessed, only one site has the maximum score for this set of attributes; this suggests that this site is already suitable for bee use. As Fig. 4 shows, eight sites are missing one 'point' from the scoring system to reach the highest level – the majority of these sites (7) need improvements in nesting/hibernation habitat to boost their suitability. The provision of additional tall vegetation (herbs and grasses) would also be beneficial to corncrakes for cover (Western Isles LBAP, 2005); this may be a habitat feature that improves with time as the set aside areas become more established.

This study gives various options for the management of corncrake corners. As mentioned in the previous paragraph, enhancing nesting opportunities at the seven sites which are already relatively suitable for bees would be the easiest option and would quite quickly provide good sites. Conversely, improving sites that are currently inadequate for bees would increase opportunities for colonisation. This would primarily involve improving cover of suitable flowering plants, for example by adding plug plants or seeds of those flowers used by the bees.

Another option for the management of set-aside areas is to consider corners not used by corncrakes. Data provided by the RSPB shows the use of corners (bird present or within 100m) by corncrakes in 2004 and 2005. Of the 44 corners surveyed, six were not used by corncrakes in the two consecutive years. These sites are not wholly suitable for bee use, and all vary in the factors which are lacking. Further study would confirm the lack of corncrake use: following this the sites could be dedicated to bee conservation.

Improving corncrake corners alone will not ensure the continued survival of the great yellow bumblebee. The key factor is that land management continues to be sympathetic; machair maintained and, if possible, such practices expanded to create more sites for the bee and other species with similar requirements.

SUMMARY

Conservation of the great yellow bumblebee is dependent upon the provision of sites for both forage and nesting. Healthy populations are associated with machair habitat for foraging and nearby rank vegetation in sand dunes and banks for hibernation as well as nesting. The key aspects of machair management, which can be replicated on other sites to provide suitable habitat for the bees are:

- Seaweed and occasionally manure as fertiliser
- A crop rotation system including at least one year of fallow
- Natural regeneration in fallow year rather than seed application
- Machair cut in late summer and/or grazed over winter.

No corncrake corners are totally suitable for bee use. This does not mean that the bees do not use these sites, but it does give a number of options:

- Improve the 'best' sites to encourage more bee use.
- Concentrate on low scoring sites which are unsuitable for bees to increase the number of potential sites
- Focus on corners which are not used by corncrakes to create additional sites principally for bees.

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Map of great yellow bumblebee distribution: the information used here was sourced through the NBN Gateway website and included the following resources: BWARS, HBRG, SNH. data.nbn.org.uk Accessed 23/11/08. The data providers and NBN Trust bear no responsibility for the further analysis or interpretation of this material, data and/or information.

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Machair and the great yellow bumblebee, Bombus distinguendus – a comparison of machair restoration techniques

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The great yellow bumblebee, *Bombus distinguendus*, is one of the rarest bumblebee species native to the UK. Despite an extensive historic distribution with populations once scattered across much of the UK, the great yellow bumblebee is at present found only in the Outer and Inner Hebrides, the Orkney islands and sporadically along Scotland's north coast (Goulson, 2003; Benton, 2006). The main reason for this decline is largely accepted to be the intensification of agriculture and the subsequent loss of flower-rich habitats (Benton, 2006).

The machair grasslands of the Hebrides are now considered to be a key habitat for the remaining populations of the great yellow bumblebee. Small scale agricultural crofts operate traditional systems on the machair which comprise rotational cultivation and controlled grazing (Love, 2003). The low-intensity nature of these systems promotes a diverse abundance of flowers which in turn support a number of rare species including the great yellow bumblebee. However, the increasingly economically unviable nature of crofting has necessitated the modernisation of some crofting techniques. The replacement of seaweed and manure with artificial fertilisers and heavy sheep grazing throughout the year changes sward composition and reduces the floral diversity of the machair (Love, 2003). This in turn reduces the availability of potential great yellow bumblebee foraging resources.

The aim of this research was to determine the most practical and effective method for restoring bumblebee forage plants to areas of machair which have become degraded as a result of changes in agricultural practice. In order to do this a field trial has been created on the Southern Hebridean island of Oronsay, situated twenty five miles west of the Scottish mainland.

Fig. 1. The great yellow bumblebee

Fig. 2. Bumblebee wildflower mixture, Isle of Oronsay

The trial involves a comparison of five treatments which differ in their floral composition, including wildflower seed mixtures which contain plants identified as being important for the great yellow bumblebee (Charman, 2007). Other treatments include a seed mixture already implemented for bird and bumblebee conservation and a commercially available grass seed mixture enhanced with white clover (*Trifolium repens*) and red clover (*Trifolium pratense*), two species on which the great yellow bumblebee is known to forage throughout the summer (Charman, 2007).

After establishment in April 2007 the field trial was left to mature for one year in order to allow plant growth. In June, July and August 2008 each of the treatments were surveyed for the abundance and diversity of foraging bumblebees and the numbers of available inflorescences were recorded. This monitoring process will be replicated in the summer of 2009 and 2010 so that the longevity of each treatment can be tested. The differing success of each treatment will be quantified in order to assess which is the most practical and financially viable method for returning bumblebee forage material to machair which has lost floral integrity due to changes in croft management.

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Examining the use of corncrake Crex crex early cover plots for the conservation of the great yellow bumblebee Bombus distinguendus on North Uist

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This study looked at the land management currently in place for the conservation of the great yellow bumblebee (*Bombus distinguendus*) on the island of North Uist in the Outer Hebrides. The RSPB, a lead partner on the *B. distinguendus* Biodiversity Action Plan (BAP), manage this land by means of an agri-environment scheme in which crofters are paid to fence off areas of inbye agricultural land from grazing. This is primarily to create early cover for corncrake (*Crex crex*) breeding and has been co-opted to enhance the habitat currently available to *B. distinguendus* and to increase this habitat with a view towards range expansion. This was reasoned as follows: firstly, both species have suffered from the loss of herb rich grasslands, and secondly they share historical and current ranges in Britain. These 'corncrake corners' were hypothesised to provide areas of extended forage for *B. distinguendus* both at the start and the end of the flying season, and also to provide areas of forage in agricultural inbye land where flowering plants are noticeably absent.
Surveys of floral diversity and foraging bumblebee abundance were carried out on plots at four different sites on North Uist on land managed for corncrakes and *B. distinguendus*, control plots agricultural inbye land not included in the scheme and machair plots to answer the following questions:

1) Do the corners provide suitable forage for *B. distinguendus*, and therefore is there the potential for *B. distinguendus* to make use of these areas?
2) Is there any evidence that *B. distinguendus* currently forage within the corncrake corners?

Variation in densities of *B. distinguendus* between plots was related to the forage availability within the plot. Corncrake corners were dominated by plants such as *Iris, Phragmites*, nettles and umbellifers, which do not provide forage for *B. distinguendus*. Only machair plots had a significantly higher density of *B. distinguendus* than agricultural inbye land. Therefore itt was concluded that the most suitable form of land management for the conservation of *B. distinguendus* on agricultural land in the Outer Hebrides is the promotion of 'traditional' methods of machair management.

Factors affecting population density of Colletes floralis (Hymenoptera: Apidae) on Islay, Hebrides

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Colletes floralis (Fig. 1) is a northerly distributed solitary mining bee associated with coastal habitats (Michener, 2000). It is a BAP species, classified as Rare and RDB3 listed (UK BAP Plan, 2004). It is polylectic, visiting a variety of plant species (Westrich, 2001) to collect pollen and nectar as provisions for its offspring, and to feed. As well as being a species of conservation interest in its own right, it is also an important food source for chough, *Pyrrhocorax pyrrhocorax* (amber list bird of conservation concern) on Islay. Machair grassland is a highly specialised and complex sand dune system, confined worldwide to the northwest coasts of Ireland and Scotland (Gaynor, 2006). It is an important habitat for *C. floralis* on Islay, providing a rich diversity of floral resources and semi-fixed dune substrate for nesting.

Fig. 1. *Colletes floralis* female (above) and male (below).

The population density of *C. floralis* at two sites on Islay, Ardnave (NR 2973) and Killinallan (NR 3072) was determined, focusing on five nest sites at each - all in grey dunes and southerly-facing. The amount of bare sand and floral resources were investigated as factors that could affect female nesting density. At each nesting site, a 50 x 50cm quadrat was thrown randomly between 5 and 10 times (depending upon the size of the site) and all *C. floralis* burrows within it counted. The average number of burrows was multiplied by the size of the nesting area (estimated in m^2) to calculate burrow density. At the same time, the percentage area of bare sand at the nest site was estimated. Nine 100 metre transects were conducted at both Ardnave and Killinallan; the floral abundance, species richness and number of inflorescences were recorded. Pollen samples were taken from 30 females at Killinallan for analysis.

A greater number of nesting females were found at Killinallan than at Ardnave ($F_{6, 75}$ =17.364, p<0.001), at an average of 27 per m^2 and 13 per m^2 respectively. Burrow density increased significantly with increasing size of the nest site ($F_{6, 75}$ = 7.361, p<0.001). Burrow density was not significantly influenced by the amount of bare sand (t = 0.297, df = 72, p = 0.767). *C. floralis* was found nesting in the mobile fore-dune and in grey dunes, and were nesting in various aspects. Both sites were floristically rich with 27 and 25 species of flowering plant at Ardnave and Killinallan respectively. The number of inflorescences did not differ significantly between sites (ANOVA, $F_{1,180}$ = 0.922, p = 0.339), but the species composition was significantly different (ANOVA, $F_{46, 180}$= 45.362, p<0.001). Pollen analysis results will be published in an article for the Bees Wasps and Ants Recording Society newsletter in the near future.

Population density is greater at Killinallan than Ardnave. There is less nesting habitat available at Ardnave so this may be a limiting factor. Forage may not be a limiting factor since the number of flowers, their abundance and the species richness is similar between sites. Floral composition may be important however. *C. floralis* may provide important pollination services to the machair habitat, since *Bombus* species were the only other bees observed. Population density increases with increasing size of the nest site, supporting findings that *C. floralis* nests in aggregations, attracted by the strongly scented pheromone, linalool (Albans *et al.*, 1980). *C. floralis* was found nesting in mobile fore-dune and grey dune areas, which suggests that sand that has been stabilised by vegetation is favoured. Within this habitat, aspect and the amount of bare sand are not primary factors in nest site choice, suggesting *C. floralis* can exhibit plasticity in its site choice.

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Croft management and economics: impacts on bumblebee conservation

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The crofting agricultural system is unique to the Scottish Highlands and Islands. The low intensity of

traditional crofting practices results in a farming system that is sympathetic to the landscape and enables a diverse array of organisms to survive alongside it (Love, 2003). Crofting on the machair habitats of the Western Isles is particularly valuable to biodiversity, with several rare and endangered species persisting in these habitats. Winter cattle grazing and cultivation of the machair plain is a prime example of how crofting practices benefit wildlife: the combination of grazing and occasional cultivation promotes the growth of a wide variety of wildflowers throughout the summer months that are an important foraging resource for invertebrate fauna (Love, 2003), particularly for the island's bumblebee species (MacDonald, 2003). Butterflies and moths also benefit from the abundance and variety of wildflowers (Love, 2003), whilst other organisms such as the corn bunting (*Emberiza calandra*) historically found suitable habitat within traditionally cultivated areas (Wilson *et al.*, 2007).

Britain is home to approximately 10% of the world's bumblebee fauna. However, of the 25 native British species three are extinct, a further six are rare or endangered and are UK Biodiversity Action Plan (BAP) species. Only six species remain common and ubiquitous throughout Britain (Goulson, 2003). The primary driver of this decline has been attributed to post war agricultural intensification and the subsequent loss of suitable foraging habitats (Benton, 2006; Goulson, 2003; Goulson, Lye and Darvill, 2008). Flower rich habitats such as permanent unimproved pasture are important foraging resources for bumblebees (Carvell *et al.*, 2006). However, the development of rapid growing varieties of grass (Goulson, Lye and Darvill, 2008) combined with the decreased cost of nitrogenous fertilisers (Strijker, 2005) has substantially increased agricultural productivity leading to a significant reduction in these habitats (Goulson, 2003). As a result of this and other intensification measures the UK lost over 90% of its lowland unimproved grassland between 1932 and 1984 (Fuller,1987).

The Western Isles have not escaped the impacts of agricultural change. Owing to the increasing average age of active crofters, increasing input prices and declining sheep prices, traditional crofting methods that have maintained important machair habitats are now becoming economically unviable. The expense of contracting labourers to carry out croft operations in a traditional manner often outweighs the financial benefits received by crofters and exacerbates the problem. As a result there is increasing reliance on more efficient and intensive agricultural methods, such as the replacement of seaweed with nitrogenous fertilisers to improve fertility. The complete abandonment of croft land is also an issue and both intensification and land abandonment have serious implications for bumblebees in the Western Isles that depend on low intensity crofting operations to persist.

Of the five bumblebee species found on the Western Isles the great yellow bumblebee (*Bombus distinguendus*) is the species most frequently associated with crofting and machair. It is currently only found in the Outer Hebrides, Coll and Tiree, in pockets along the north coast of the Scottish mainland and in Orkney (Fig. 1a). The present distribution closely reflects the distribution of machair in the UK (Fig. 2) and has resulted in the great yellow bumblebee becoming synonymous with this habitat. However, this species was previously widespread throughout Britain (Fig. 1b) until experiencing a decline in its range and distribution of over 95% in the past 60 years (Fig. 1b). This has led to it becoming the UK's rarest bumblebee (Benton, 2006) and its listing as 'nationally scarce' on the UK Biodiversity Action Plan (BAP) (Benton, 2006; UK BAP). In line with the decline of other bumblebee species, agricultural intensification and subsequent habitat loss have driven the decline of the great yellow bumblebee (Benton, 2006). The great yellow bumblebee is classified as a long tongued bumblebee and specialises in collecting pollen from flowers with deep corollas belonging to the Fabaceae family (Goulson *et al.*, 2005). The loss of Fabaceae rich grasslands from farming systems throughout Britain is thought to have made an important contribution to the decline of the great yellow bumblebee. Red clover (*Trifolium pratense*) belongs to the Fabaceae and has been identified as an important species for long tongued bumblebees (Goulson and Darvill, 2004), and it remains abundant on the machair of the Western Isles.

Fig.1a. Current distribution of the great yellow bumblebee in the UK (2000-2008). Map from NBN Gateway.

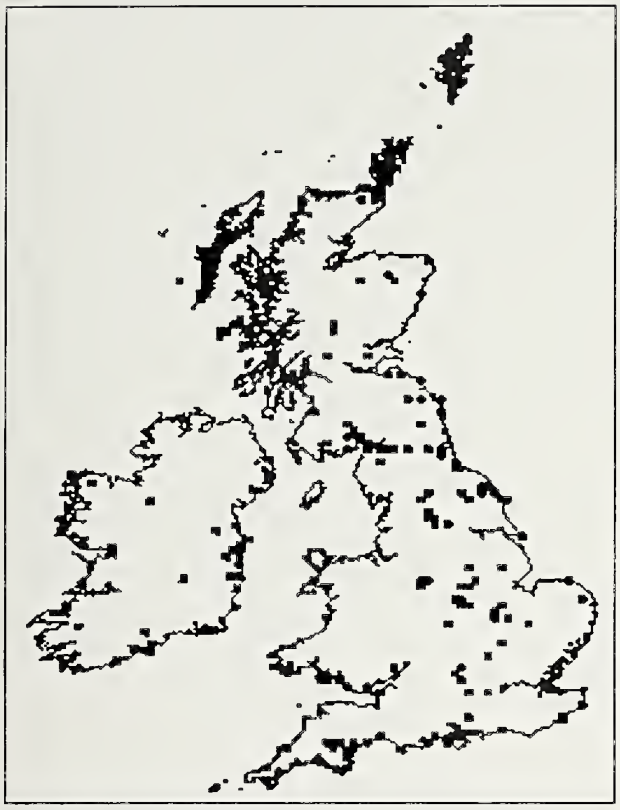

Fig.1b. Historical distribution of the great yellow bumblebee in the UK between 1900-1999. Map from NBN Gateway.

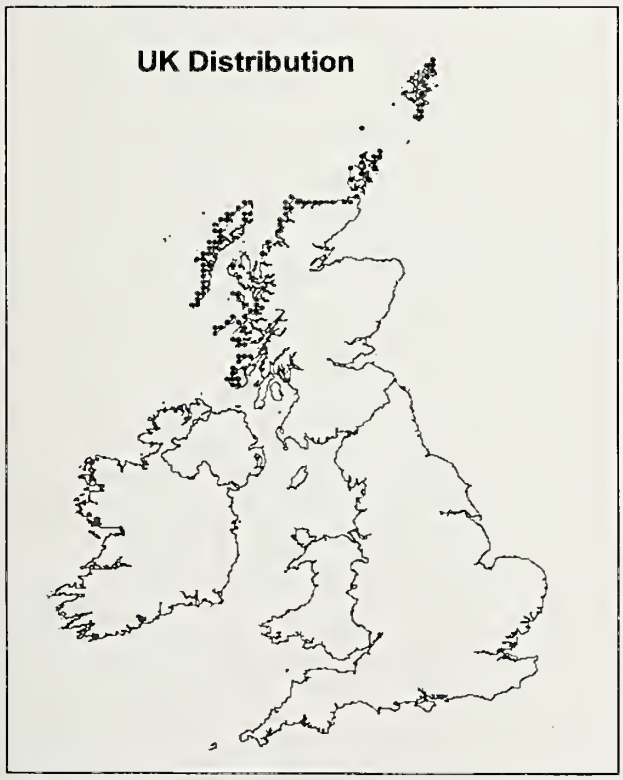

Fig 2. Current UK distribution of machair habitats. Map from JNCC.

The intrinsic benefits of crofting to the great yellow bumblebee and other biodiversity are of great interest to conservationists. A three year study to investigate the interaction between croft management, economics and great yellow bumblebee conservation is currently underway at Stirling University. Through this work the relationship between bumblebee abundance and current croft management practices are being investigated, alongside an analysis of the current economics of the crofting system. The development of farm production models which combine ecological and economic data collected in summer 2008 will allow the potential impacts of different croft management decisions on rare bumblebee populations to be investigated. From the outputs of the models we hope to be able to promote croft management practices that are both economically viable for crofters to undertake and that are beneficial to bumblebees in the Western Isles.

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Resilience of machair soil to amendment with kelp and synthetic fertiliser

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Crofting on the machair, traditionally a low-intensity agricultural system, is practised on calcareous sandy soils with low organic carbon. Cultivation includes shallow ploughing, using kelp (seaweed) as a fertiliser and soil conditioner (Angus, 2001). During the previous decade, deeper ploughing and partial substitution of kelp by inorganic nitrogen, phosphorous and potassium (NPK) fertiliser has occurred in response to socio-economic pressures on machair crofts. The effects of these agronomic changes on the machair are not known. A field experiment was conducted on a cropped field with bere barley (*Hordeum vulgare*) at Drimsdale, South Uist in the summer 2006, to study how these changes may affect soil stability, microbial biomass and activity on the machair. Experimental treatments were ploughing and no ploughing, and amendments with NPK fertiliser, kelp or in combination. Soil samples were taken four times through the growing season from May to September.

The field experiment revealed a decoupling between organic soil amendments and response in microbial and soil physical measures. Some significant differences between fertiliser treatments occurred for most of the properties studied, but these were small compared with the differences between sampling times. Furthermore, the observed fertiliser treatment effects were not consistent between sampling times, but generally fertilisers decreased aggregation, soil water retention, microbial biomass and activity relative to the unamended control. Of the properties measured, only soil water retention and abundance of saprotrophic fungi were in a few cases significantly affected by ploughing.

That fertiliser amendments did not shift the values of the measured properties outside the ranges found during the season for the control indicates resilience of the machair soil. The lack of response to organic fertiliser is surprising, and in contradiction to findings by Haslam and Hopkins (1996), who found an increase in pore volume, aggregate stability, microbial activity and biomass following addition of kelp to a sandy soil in amounts similar to those used in the present study. We propose that the machair soil does not respond to fertiliser in a growing season because the soil is at an equilibrium characterised by low aggregate stability and an average level of microbial activity and biomass.

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Above and below ground responses to the machair agricultural system

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Much of the conservational value of the machair is dependent on the maintenance of its crofting tradition (UK Biodiversity Group 1999) which is characterised by small scale, rotational mixed cropping and extensive grazing (UK Biodiversity Group 1999; Angus 2001). This combination of agricultural practices creates a complex and diverse mosaic of habitats and plant communities (Crawford 1990, 1997; Owen et al. 2001) which sustain a large diversity of invertebrates and birds (UK Biodiversity Group 1999).

Organic and low input agricultural systems, such as the machair, are reported to have a higher diversity of micro-organisms than intensely managed farms (Mäder et al. 2002; Hijri et al. 2006). Intensification has contributed to the loss of this below ground diversity in low input agricultural systems (Helgason et al. 1998; Bardgett 2005). The diverse microbial communities in soils are important for the maintenance of a wide range of ecosystem services (Wall 2004) and changes in below ground community composition (van der Heijden et al. 1998a; Allison et al. 2008) and diversity (van der Heijden et al. 1998b) could potentially make such systems less sustainable, reduce resilience to disturbance and result in changes in plant community structure. Due to the challenging nature of research on microbial communities, relatively little is known about soil systems in general and low input systems in

particular, despite the obvious importance of these systems.

In order to gain a better understanding into the effects of land use practices and spatial and temporal variation on soil communities, an extensive study examining the bacteria and arbuscular mycorrhiza (AM) fungi community structure of machair soil was conducted in 2007 and 2008 along a latitudinal gradient on five islands in the Outer Hebrides. AM fungi and bacteria are two key components of soils and are considered to be important determinants of the ecosystem processes which drive above ground community composition (van der Heijden et al. 1998b; Wardle et al. 2004).

Individual cores of approximately 6 cm diameter containing soil and roots of each of two common machair plant species (*Bellis perennis* and *Festuca rubra*) were taken at three seasonal sampling times and a number of different locations, each including the three main land uses occurring on the machair; cropped, fallow and grassland. DNA was extracted from the roots and bulk and rhizosphere soil compartments from each core and, using general molecular methods, the structure of the bacteria and AM fungi community was assessed (Blackwood 2006). In addition, a survey of the plant communities at all sampling sites was carried out at the summer sampling point and various abiotic soil factors were measured.

Our initial results on a subset of samples suggest that the microbial community reflects the variation in land use on the machair. There are significant temporal ($P<0.001$), land use ($P<0.001$) and soil compartment ($P<0.001$) effects with a number of significant interactive factors, reflecting the complexity of these relationships. Results also suggest a relationship between the above ground vegetation, below ground bacterial community and moisture content of the soil within the different land uses and soil compartments. Further studies are being conducted to corroborate these correlations by assessing the impact of different plant communities and soil moisture levels on below-ground communities in glasshouse-based microcosm experiments.

To our knowledge this is the first study into the biotic communities in machair soils, despite the potential importance of these below ground components. Our aim is that the results from these investigations will not only contribute to a greater understanding of the machair soil system and its interaction with its vegetation but also to further gain an understanding into the effects of agronomic practices on soil communities and their function in general.

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Foraging preferences of the great yellow bumblebee Bombus distinguendus on Orkney

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The great yellow bumblebee *Bombus distinguendus* has become scarcer and more limited in its distribution in the last century, and in the UK is found only in the Western Isles, Coll, Tiree, Orkney and on the north coast of mainland Scotland (International Bee Research Association, 1980). In summer 2006 a study was undertaken on RSPB reserves in Orkney to explore the foraging preferences of this species.

Two great yellow bumblebee nests were found at Marwick Head RSPB reserve. To identify where the bees were foraging a full list of flowering plants within 250m radius of the first nest was compiled, and bees were marked with a water-based paint. Pollen samples were taken from bees returning to the nest, and further samples were taken from bees at Brodgar RSPB reserve. Analysis of the pollen showed that bees from the two sites foraged on *Trifolium* sp. and *Phacelia tanacetifolia*. Samples from the Marwick Head bees comprised mainly of clover pollen, however no clover patches were found within 250m of the nest, and no marked bees were observed in adjacent patches. This suggests that great yellow bumblebees may not establish their nests in areas where food is immediately available, and that they travel more than 250m from the nest to forage.

Between 12th July and 9th August 2006 vegetation and bee surveys were carried out at ten RSPB nature reserves. Stepwise regression of the data suggested that the presence of clover or *Phacelia* plants at a site did not increase the likelihood of great yellow bumblebee presence. Historical records from throughout Orkney suggest great yellow bumblebees use a wide range of plant species, with preference depending on geographic location.

The survey data were compared to historical bee records and to studies carried out in the Western Isles. There were differences between the suite of forage plants used in the Western Isles and on Orkney. On Orkney great yellow bumblebees form colonies relatively late, in June or July, and forage species used in the Western Isles, such as *Lotus corniculatus*, may flower too early on Orkney for great yellow bumblebees to use. Plants such as *Stachys* sp. and *Centaurea nigra* are needed so bees can forage until late-September.

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The use of exclosures to produce a favourable grazing regime for the orchid, Spiranthes romanzoffiana, on the dune/hill intergrade - part of the machair complex, on Colonsay, Inner Hebrides, Scotland

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Nine plants of the Biodiversity Action Plan orchid, Irish Lady's-tresses - *Spiranthes romanzoffiana* were discovered in bloom in 1997 on a single visit at one site - KA - at the back of dunes on Colonsay; and 24 at a second nearby site - KB - in 1999. At each site the number of plants in bloom have been monitored in each subsequent year (2000 - 2008). This includes the number found at positions where flowering plants have never previously been recorded.

The substrate at KA and KB is wind blown sand. KA is on sloping ground with some water movement down from the surrounding hill in wet weather, possibly supplemented by a weak underground spring(s). KB is in a shallow hollow between large craggy outcrops. It is very gently sloping with a small amount of water movement through the soil. Exclosures were erected in 2001 to provide a Summer Grazing Break (SGB). A grazing break had previously occurred between 1996 and 2000 under the terms of an Environmentally Sensitive Area grazing regime.

The capsules of *Spiranthes romanzoffiana* do not develop as they do in Autumn Lady's-tresses orchid - *Spiranthes spiralis*; nevertheless the withered structures are now known to contain small numbers of seed. The grazing break allows seed development and hence the possibility of population maintenance via sexual reproduction.

The number of plants in bloom has varied greatly from year to year. In 2008 numbers were the lowest ever recorded since 1998 in KA and there were no plants flowering in KB.

There are a number of factors which could be responsible for this decline. These may be acting in combination. They include a) drought in May and June; b) increases in rabbit grazing; c) the presence of a decline phase in the population (known from other *Spiranthes romanzoffiana* populations); and d) changes in above-ground sward structure, with changes in root and rhizome density. Sward structure changes could in turn be due to more than one cause, e.g. cumulative effect of SGBs 2002 - 2007 or presence of a dune-wide grazing break between early May and late July in 2008.

Stock (sheep and cattle) movement through and into the exclosures is facilitated by two gates. *Spiranthes romanzoffiana* often occurs in disturbed habitats. One challenge at KA and KB is to ensure adequate levels of sward disturbance and heavy winter grazing within the exclosures when the basic grazing regime is set at the whole-dune level.

At other sites in Scotland it may be possible to negotiate SGBs by management agreements rather than exclosures. Some new sites are found in the west of Scotland in most years, these quite often contain one or two plants. Conversely the species has become locally extinct at many of its former sites. Several aspects of the biology of the species and its interactions with a) competitors and b) habitat structure, are still unknown. A full understanding of the behaviour of the species above and below ground requires detailed research. Attempts to secure relevant funding for studies on both conservation biology and conservation management are ongoing.

Crofting & biodiversity on the Machair of the Western Isles

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The three machair posters were part of a bilingual (English & Gaelic) Crofting & Biodiversity Exhibition produced by the Western Isles Local Biodiversity Action Plan Partnership in May 2008. The posters highlight the key role of crofters in maintaining machair biodiversity through traditional practices.

Machair is unique to the north and west of Scotland and Western Ireland and is at its most extensive in the Western Isles. Crofters play a key role in maintaining the machair flowers and other wildlife through traditional practices. These include seasonal or rotational grazing by livestock, rotational cropping that allow some years of fallow and the growing of both cereals and hay using natural fertilizers, seaweed and farmyard manure. The use of these natural fertilisers adds bulk, improves fragile soils and increases productivity.

Rotational or seasonal grazing – the removal of livestock for the summer or rotation of one half of the machair to another for a number of years – is advantageous to stock and to wildlife. Keeping cattle and sheep at appropriate stocking levels gives a variety of plants the opportunity to flower and form seed, which is beneficial to both insects and birds. It also gives grazing stock the opportunity to seek out a wider variety of forage.

The cereal crop in the western Isles is grown in various mixtures of small oat, rye and bere barley. These mixtures are useful in the rigorous conditions of the Hebridean summer where experience tells that they will give the best crop possible in any given year. The total cereal crop in the western Isles is a small percentage of the Scottish crop, but it is hugely important, as winter-feed for cattle, in the way it supports biodiversity and in its survival as a genetic resource. These grains have been grown for centuries possibly millennia, and are therefore comparable to rare breeds like Highland cattle, Hebridean sheep and Eriskay ponies. Crofters are to be congratulated for their hard work in preserving them.

Large areas of single crops do not provide the variety of habitat that can be found on small rotational plots of hay, corn and potatoes. This diversity in turn supports a greater range of plants, birds, insects including bumblebees. Reserving a portion of the crop for stooking also maintains numbers of small birds such as corn buntings that benefit from the associated spillage of seed. Many of these same birds have a beneficial impact in summer when feeding their young on insects and other invertebrates gathered from crops.

Crop rotation and the use of locally sourced and appropriate seed reduce the need for expensive pesticides. This provides an opportunity for the biological control of pests, for example the various species of hoverfly larvae that feed on greenfly.

Increasing populations of some bids and animals, particularly graylag geese and rabbits, have had a detrimental impact on cereal crop returns, on hay and on grazings. Recently there has been some success in reducing their impact.

Collecting wild flower seeds on the Uists for propagation

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Three volunteers from Glasgow Natural History Society visited the Uists for a week in September 2005 to collect seeds from plants known to be used by the great yellow bumblebee (*Bombus distinguendus*) over the months when it is active. Six sites were visited and a useful amount of seed (just under 1kg) was collected for many of the species; some of this stock has since been used for reseeding in the Balranald area.

The species collected were: bird's-foot trefoil (*Lotus corniculatus* L.), tufted vetch (*Vicia cracca* L.), red clover (*Trifolium pratense* L.), yellow rattle (*Rhinanthus minor* L.), kidney vetch (*Anthyllis vulneraria* L.), lesser burdock (*Arctium minus* (Hill) Bernh.), and knapweed (Centaurea nigra L.). We failed to find any mature seedheads of yellow iris (*Iris pseudacorus* L.), and were too late in the year to collect seeds of cow parsley (*Anthriscus sylvestris* (L.)).

The conclusions of this feasibility study were that seed collecting is labour-intensive and would need to be done over a longer period during the year in order to cover the full range of species adequately. The yield of seed was low relative to amount of seed-heads collected, because some of the seed had already been lost through natural dispersion or consumption by invertebrates etc.

Propagating seed for inclusion in seed mixes, though a useful aim, was not achievable in the timescale of this project, though it remains a medium-term objective. The most effective procedure would be to harvest seeds mechanically from successful 'cover areas' on each island, and to use the cleaned seed for reseeding those, and other, areas in the same locality.

In the meantime, bumblebee habitat areas could be created or improved using existing wildflower seed-mixes and allowing natural reseeding from nearby areas.

We are grateful to Scotia Seeds, Mavisbank, Brechin for advice on collecting the seed and for cleaning it, and to Lyn Dunachie for producing a splendid poster for the conference. And we are very grateful to the Blodwen Lloyd Binns trustees for a grant towards the costs of travelling to the islands.

Outreach and education

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As part of the Glasgow Natural History Society/RSPB Scotland programme for the great yellow bumblebee (*Bombus distinguendus*), RSPB Scotland prepared a set of teaching materials for primary schools on bumblebees in general and the Great Yellow in particular. The material demonstrated the importance of bumblebees, provided schools with identification materials and activities for learning about the species likely to be encountered in their area. There was a special emphasis on practical steps that can be taken to provide food plants and habitat for bumblebees.

Two important characteristics of the project were that it was geographically restricted to schools within the current range of *B. distinguendus* or those areas where it is like to expand, covering the Western Isles, the Argyll Islands, north Sutherland and Orkney. This in turn led to the decision to produce all pupil materials in English and Gaelic versions.

The materials were designed to link to the existing curriculum and to the new curriculum being developed at the time of writing and to other initiatives, such as EcoSchools. An over-riding priority was to provide materials that were sufficiently local, so that they would work in the areas targeted. Much school biodiversity material does not work in highland or island Scotland.

The project was supported by The Heritage Lottery Fund, SNH, The Esmée Fairbairn Foundation and the Scottish Government. It was greatly helped by advice from the Bumblebee Conservation Trust and Murdo MacDonald.

Traditional and modern crofting practices; trends and current issues

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The machair landscapes of the Uists both offer opportunities to and place constraints on agriculture. These have interacted with the legal framework of crofting and the social constraints of working on open common grazings to produce a characteristic and valued landscape and biologically-rich and rare habitats. The presentation looks at likely future developments in the still largely prevalent 'traditional' agricultural systems in the light of changing agricultural techniques and current financial and administrative pressures and outlines the importance of comprehensive support measures which take a holistic view of the crofting economy and crofter aspirations.

Foraging requirements of subadult red-billed choughs in Scotland: the importance of coastal sand grasslands

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The red-billed chough (*Pyrrhocorax pyrrhocorax*) is a speeies of conservation concern across Europe and in the UK. The Scottish population of the species is restricted to two of the Inner Hebridean islands, Islay and Colonsay, and is the subject of a long-term study by the Scottish Chough Study Group. Previous analyses of long-term data from this population showed that population growth rate is strongly affected by survival of subadult birds. However, despite its relevance to conservation management, detailed knowledge of the habitat requirements of subadult choughs (and the potential link between habitat use and survival) has been lacking.

To address these questions, a study was recently conducted on the Isle of Islay which holds 70-80% of the Scottish population of the species. Variation in habitat use was examined over two years, at several spatial scales ranging from island-wide to precise foraging location scale. Subadult choughs relied almost entirely on coastal sand grasslands year round but different sites were used to a different extent. Two main sites supported a large number of birds year round, other sites were used part or most of the year by fewer birds. This did not simply reflect differences in size among the sites but appeared to be partly due to relatively subtle habitat differences among them. Furthermore, within each site subadult choughs foraged repeatedly at particular locations and were never observed foraging at others. The used locations covered a range of habitat features and differed from unused ones in a number of characteristics. Overall, the locations where choughs foraged had sparser, slightly shorter and more variable vegetation and larger amounts of relatively old cow dung compared to unused locations. Flexible management strategies should be devised that take into account habitat variation among sand grassland sites and maintain a mosaic of habitat features within sites, thus ensuring that choughs have access to a variety of resources at all times.

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Advice to Contributors

1. The Glasgow Naturalist publishes articles, short notes and book reviews. All articles are peer reviewed by a minimum of two referees. The subject matter of artieles and short notes should concern the natural history of Scotland in all its aspects, including historical treatments of natural historians. Details of the journal can be found at: www.gnhs.org.uk/publications.html

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4. References should be given in full according to the following style:

   Pennie, I.D. (1951). Distribution of Capercaillie in Scotland. *Scottish Naturalist* 63, 4-17.

   Wheeler, A. (1975). *Fishes of the World*. Ferndale Editions, London.

   Grist, N.R. & Bell, E.J (1996). Enteroviruses. Pp. 381-90 In: Weatherall, D.J. (editor). *Oxford Textbook of Medicine*. Oxford University Press, Oxford.

5. An organism's genus and species should be given in italics when first mentioned. Thereafter the common name is only required. Please use lower case initial letters for all common names e.g. wood avens, blackbird; unless the common name includes a normally capitalised proper name e.g. Kemp's ridley turtle. The nomenclature of vascular plants should follow Stace, C.A. (1997). *The new Flora of the British Isles*, (Second Edition). Cambridge University Press, Cambridge. Normal rules of zoological nomenclature apply. When stating distribution, it may be appropriate to give information by vice-county.

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