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Remarkable botanical records from Corrour in Westerness (v.c.97), including *Baldellia repens* (Alismataceae) and *Illecebrum verticillatum* (Caryophyllaceae), new to Scotland

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Abstract
Biological recording in Britain has increased in accessibility and popularity due to recent technological advances. However, remote locations may still be under-recorded, particularly for aquatic plants and taxonomically challenging groups. We describe a set of notable botanical discoveries made in 2021 at Corrour in the Scottish Highlands (v.c.97 Westerness), including *Baldellia repens*, *Illecebrum verticillatum* (new to Scotland) and six British altitudinal records. At the time of writing, there are now four Nationally Rare vascular plant taxa recorded on the estate and 29 Nationally Scarce taxa. These findings demonstrate the value of collaboration between land managers, ecologists, BSBI staff and the local community. Both *B. repens* and *I. verticillatum* are well established at Corrour in considerable abundance and with clear evidence of regeneration. *B. repens* also occurs in the Tay catchment and may have arrived at Corrour via vegetative dispersal by waterfowl. The origin of *I. verticillatum* is more ambiguous but suggested mechanisms of dispersal include forestry, the railway or hydroelectricity workings. Despite a likely element of accidental human-mediated spread, *I. verticillatum* should be considered an intriguing addition to the flora of Westerness. Climate change could facilitate further establishment of this taxa in northern parts of Britain, and it is likely that other new records of both *B. repens* and *I. verticillatum* await.

Keywords: biological recording; distribution; aquatic plants; establishment; spread; native origin.

Introduction
Biological recording is of fundamental importance to the development and promotion of biodiversity conservation. It improves knowledge of taxonomy, population trends, distributional patterns and community composition (Kelling *et al.*, 2019; White, 2019). This information can be used to generate lists of threatened or scarce taxa,

indicator species and axiophytes, which denote high quality habitat and conservation interest (Preston, 2013; Maes *et al.*, 2015; Walker, 2018). Recording therefore has a central role in monitoring schemes which inform policy development and strategic environmental management objectives (Balmford *et al.*, 2003; Magurran *et al.*, 2010; Barlow *et al.*, 2015).

Britain has a unique and rich history of botanical recording which continues to the present day (Harding & Sheail, 1992; Pescott *et al.*, 2015; Pocock *et al.*, 2015). The ease, accessibility and popularity of this activity has been significantly improved during the last decade by advances in GPS and mobile phone technology including plant identification apps (August *et al.*, 2015; Pocock *et al.*, 2015; Silvertown *et al.*, 2015; Thomas & Fellowes, 2017). The expansion of citizen science, coupled with the increasing power of data analysis tools, has increased the volume of biological records being collected and the ability to investigate them (Roy *et al.*, 2014, 2015; Sutherland *et al.*, 2015). Species range maps and datasets exist with progressively more information and finer-scale resolution (Preston *et al.*, 2002; Botanical Society of Britain & Ireland, 2021a; Stroh *et al.*, in press), which could lead to the assumption that the occurrence of surprising and novel records will eventually diminish over time (Braithwaite, 2021).

However, there are still many opportunities to expand our knowledge of plant distributions in Britain. Isolated and less well-known locations across the country could be under-recorded, particularly for species groups which present taxonomic or identification challenges and tend to be inconspicuous in the landscape. Crucially, plant biogeography is dynamic and constantly evolving in response to anthropogenic drivers such as climate change, land-use modification and built infrastructure. Biological records also underpin the study of establishment and spread of non-native species (Eversham & Arnold, 1992; Roy *et al.*, 2015; Latombe *et al.*, 2017). Yet these taxa can be inconsistently recorded (Powney & Isaac, 2015; Walker *et al.*, 2016; Sutton, 2020a), despite presenting a unique opportunity to advance understanding of population dynamics and community ecology (Shea & Chesson, 2002; Roy *et al.*, 2015).

Unexpected records of unusual or rare plants at novel locations can prompt new questions, such as how have they arrived; are they established; and should they be classified as native or alien? Addressing the matter of a taxon's status may not be straightforward, in part due to the difficultly in distinguishing between completely "natural" spread or unintentional human-mediated dispersal in landscapes that have been modified by people in some way for millennia (Eversham & Arnold, 1992; Preston, 2009; Walker *et al.*, 2019). Instead a more nuanced view of the naiveness concept will better inform biodiversity management (Lemoine & Svenning, 2022). Several taxa that were originally classed as alien when first recorded in novel habitats have been subsequently mapped as native because they were viewed to be spreading without deliberate human introduction. Key examples include *Crassula tillaea* which has colonised a variety of man-made environments such as forestry rides and caravan parks, and halophytes (e.g. *Spergularia marina*, *Atriplex littoralis*, *Cochlearia danica*, *Puccinellia maritima* and *Juncus balticus*) which now occupy salted road verges and tracksides (Preston *et al.*, 2002; Amphlett, 2019; Braithwaite, 2020).

This paper describes a set of surprising botanical discoveries made in the Scottish Highlands at Corrour, Westerness (v.c.97), in 2021. It provides a case study

example of the value of continued biological recording for uncovering unusual and unexpected taxa in remote and understudied areas. The significance of these findings and possible explanations for their occurrence are considered, with particular focus on *Baldellia repens* and *Illecebrum verticillatum*; plants of aquatic habitats or freshwater margins. These interesting records present the opportunity for a discussion on the judgement involved in classifying a new outlying record as "native" or "alien", especially when its spread may have had some human influence, albeit accidental.

Location of the new records - Corrour Estate

Corrour is a privately owned estate in the Scottish Highlands, covering 23,000 ha in Lochaber from the edge of Rannoch Moor to Glen Spean. It is primarily composed of upland habitats with most ground above 300 m and a quarter above 600 m. The highest point is 1102 m at the summit of Beinn Eibhinn. There are *c.*4000 ha of commercial plantation forestry which is being restructured towards native woodland and restored peatland. The other 19,000 ha of open hillside is primarily blanket bog, wet and dry heaths, alpine heath, and montane and acid grassland (Edwards & Headley, 2018). Many of the habitats at Corrour have high nature conservation value. A range of other plant communities corresponding to Habitats Directive Annex I types occur, notably upland eutrophic tall herbs (U17), calcareous grasslands (CG10 & GC11) base-rich fens and alpine flushes (M10 & M11) and snowbeds (U11, U13 and U14).

A key land management ambition at Corrour is to reduce grazing pressure by red deer to a level which improves ecosystem health, facilitates natural tree regeneration and allows expansion of native woodland and montane scrub (Swales, 2014; Edwards & Headley, 2018). The environmental restoration work at Corrour is response driven and underpinned by long-term monitoring (Edwards *et al.*, 2020; Watts, 2020). The estate has employed a Conservation Manager (Sarah Watts) since January 2021 to assist with the delivery of these objectives.

The flora is rich, with 28 Nationally Rare or Scarce vascular plant species recorded at Corrour prior to 2021. These include *Lycopodium lagopus* and *Scheuchzeria palustris* (Nationally Rare), and *Arctostaphylos alpinus*, *Athyrium distentifolium*, *Betula nana*, *Carex capillaris*, *Carex saxatilis*, *Cerastium cerastoides*, *Dryas octopetala, Lycopodium annotinum*, *Melampyrum sylvaticum*, *Nuphar pumila*, *Pyrola media*, *Salix arbuscula*, *Salix lapponum*, *Salix myrsinites*, *Sibbaldia procumbens*, *Vaccinium microcarpum* and *Veronica alpina* (Nationally Scarce). The only statutory protected areas at Corrour are the Rannoch Lochs Special Protected Area (SPA) and the geologically-important Parallel roads of Lochaber Site of Special Scientific Interest (SSSI).

Corrour's freshwater lochs

The estate has a substantial resource of standing freshwater habitats. The largest is Loch Ossian, a 5 km-long oligotrophic freshwater body situated at the centre of Corrour at 400 m asl. Much of the loch is enclosed in a diverse coniferous woodland planted by Sir John Stirling Maxwell in the early 1900s, containing non-native trees of historical and cultural value and managed for continuous forest cover. The remnant native upland birchwood at Leitir Dubh on the south shore is of ancient origin and has considerable biodiversity interest due to the significant population of

the UKBAP species *Melampyrum sylvaticum* (Dalrymple, 2007; Strachan & Servant, 2010; Crichton *et al.*, 2012).

The River Ossian drains from the western end of Loch Ossian and flows north through Strath Ossian into Loch Ghuilbinn. This smaller water body is only 1.2 km long and located at 355 m asl. The surrounding vegetation is composed of open, non-woodland habitats including blanket bog (M17), wet heath (M15), acid grassland (M25) and neutral flushes (M23).

The western boundary of Corrour runs along the eastern edge of Loch Treig, a 9 km-long hydroelectric loch which is dammed at its northern end and is notable for Arctic Charr (Greer *et al.*, 2016). It is situated at *c.*250 m asl although the water level fluctuates considerably depending on rainfall and regulated outflow. The drawdown zone below the high-water mark is within neighbouring land currently owned by Jahama Highland Estates. The West Highland line follows close to the eastern shore of Loch Treig where there are two areas of Plantations on Ancient Woodland Sites (PAWS), scattered veteran trees, pockets of native broadleaves including birch, alder and aspen, and significant natural tree regeneration in recent years. Eastern Treigside therefore qualifies as the BAP priority habitat Wood pasture and Parkland (Strachan & Servant, 2010).

Baldellia repens

The genus *Baldellia* has had a controversial and prolonged taxonomic history, with the identity of *B. ranunculoides* being particularly complex (Kozlowski *et al.*, 2008). There have previously been two distinct subspecies described, *B. ranunculoides* subsp. *ranunculoides* L. and *B. ranunculoides* subsp. *repens* (Lam.) Á. Löve & D. Löve; both of conservation concern in Europe (Jones, 2015). Subsp. *ranunculoides* is much more common across Britain and Ireland than subsp. *repens*, and occurs in Westerness (v.c.97) at two small mesotrophic lochans in west Ardnamurchan (Botanical Society of Britain & Ireland, 2021a). Prior to the discovery detailed below, subsp. *repens* was only known from three lochs in Scotland within the Loch Tay catchment (v.c.88); Loch Tay itself, and Loch Dochart and Loch Lubhair which are situated closely adjacent to each other. It is apparently rare elsewhere in Britain and Ireland, being restricted to isolated sites in Anglesey, Devon and South Kerry (Botanical Society of Britain & Ireland, 2021a).

These two taxa can be separated morphologically, physiologically and ecologically (Jones, 2006; Kozlowski *et al.*, 2008; Botanical Society of Britain & Ireland, undated). The habitat of subsp. *ranunculoides* is temporary gaps within calcareous or mildly brackish pools, dune-slacks, ditches and mesotrophic water-bodies; while subsp. *repens* is a plant of shorelines and long-standing gaps in weakly acidic, heathland pools and oligotrophic lakes with *Littorelletea* vegetation. Although subsp. *ranunculoides* grows in shallow water levels and flowers regularly, subsp. *repens* can occur submerged to depths of at least 3 m but only flowers when the water levels are low enough to expose it. The flowers of subsp. *ranunculoides* are self-fertile, unlike those of subsp. *repens,* which are larger with overlapping petals. Both taxa can have three types of leaf – grass-like in deeper water, floating in shallow water (similar to a small *Potagmogeton* leaf) and spear-shaped when exposed. However, subsp. *repens* is unique in its vegetative spread by runners and because it can form large patches of "floating lanceolate leaves" many metres across (Kozlowski *et al.*, 2008).

In support of these differences, genetic analysis from continental Europe indicates that both taxa should be elevated to full species status, having been linked to independent southern refugia during the last glaciation periods (Arrigo *et al.*, 2011). The recently updated Vascular Plant Red List for Great Britain also lists them as separate species, with 'Vulnerable' status for *Baldellia repens* and 'Near Threatened' status for *Baldellia ranunculoides* (Botanical Society of Britain & Ireland, 2021b). Therefore *B. ranunculoides* subsp. *repens* will hereafter be referred to as *B. repens* (Lam.) Ooststr. throughout this paper.

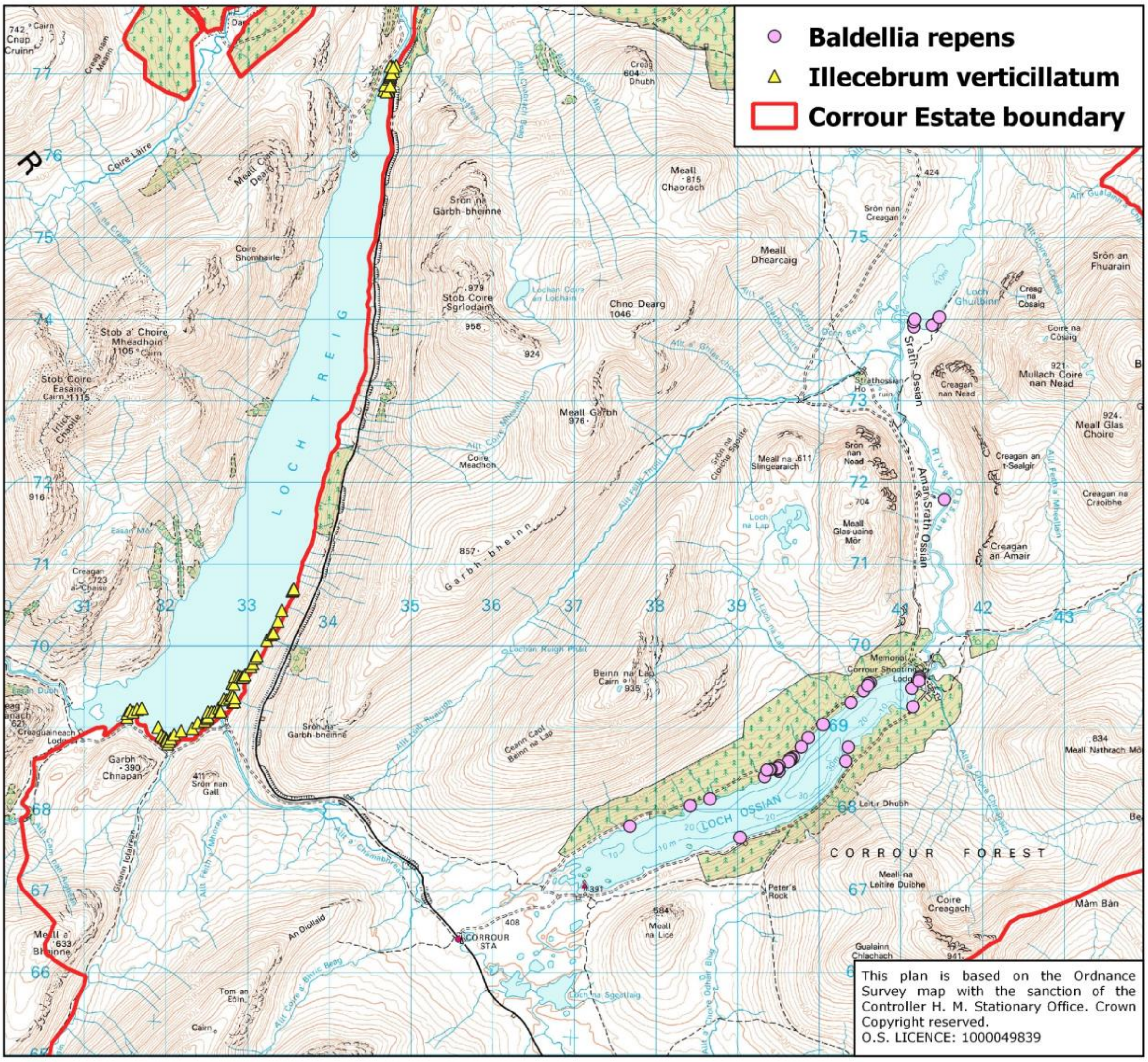

Figure 1. Records of *Baldellia repens* and *Illecebrum verticillatum* from Corrour in 2021

New Baldellia repens *records at Corrour*

On 28/07/2021, Jane Grinstead and Ann McCutcheon (members of the public staying locally) photographed an unusual flower with three large pink petals, seen on the edge of Loch Ossian when water levels were very low. Ann was able to record the precise location using the 'what3words' mobile phone app. Ian Strachan identified it as *B. repens,* the first record for Westerness. Further searching by Sarah Watts from

the shoreline at several locations around the eastern end of the loch found it to be relatively widespread. Additional sites were discovered downstream in the River Ossian and Loch Ghuilbinn (Fig. 1). These represent the fourth and fifth lochs and only the second catchment where *B. repens* occurs in Scotland.

At these sites exposed groups of plants connected by runners were readily observed from the bank growing very close to the water's edge. At Loch Ossian the associated substrate was soft sand overlaid with a mix of stones and shingle, however at the southern end of Loch Ghuilbinn *B. repens* was found amongst a mix of mud and silt. A profusion of flowering allowed for easy identification and the opportunity for familiarisation with the far less obvious vegetative features (Fig. 2). *Ranunculus flammula* was a common associate with similar sized strap-shaped leaves, but those of *B. repens* were noted to have a prominent dark red midrib.

Figure 2. *Baldellia repens* at Loch Ghuilbinn (top) and Loch Ossian (bottom), including submerged vegetative spread visible from the canoe. Images: Sarah Watts

Sarah Watts and Richard Marriott undertook a survey of Loch Ossian in a canoe on 17 August 2021 after flowering had finished. It was quickly determined that *B. repens* was relatively abundant, and so searching focused on checking for presence in individual monads rather than recording every single occurrence. Large dense patches of leaves several metres across were frequently seen close to the shore at the north-east end of Loch Ossian (Fig. 2). A pole was used to sample the aquatic vegetation in deeper water up to 3 m. Submerged leaves of *B. repens* were readily identified from their very strong, distinctive coriander smell when crushed (Jones, 2015; Poland & Clement, 2020). The western end of Loch Ossian near to the Youth Hostel was found to be less suitable for *B. repens*, mostly having a substrate of boulders rather than soft sand.

Illecebrum verticillatum

A small glabrous plant with procumbent to decumbent reddish stems, *Illecebrum verticillatum* L. (Coral Necklace) elongates each summer to form many strands (Pearman, 2008). The pinkish white flowers are densely clustered in whorls in the leaf-axils (Stace, 2019), resembling beads threaded along a necklace. The oval leaves grow in pairs and are slightly cupped in shape.

Although defined as an annual and usually killed by frosts, *I. verticillatum* can frequently survive to the following year and is often easier to see during the autumn and winter months (Pearman, 2010). The species has particularly specific habitat requirements, occurring in very short swards and periodically flooded acidic sandy soils at the edges of freshwater "tide-marks" left where water levels drop (Murphy, 1994). It grows in or by pools in heathland or grassland, or on seasonally wet gravelly tracks, and can spread rapidly over clear ground; thriving in open situations where there is little competition from other plants (Pearman, 2008). Disturbance is therefore essential to maintaining available bare ground and is often created by livestock grazing, trampling or regular vehicle movement, including within forestry plantations (Freshwater Habitats Trust, Undated). Common plant associates are *Hydrocotyle vulgaris*, *Hypericum elodes, Juncus articulatus, Juncus bulbosus*, *Littorella uniflora*, *Lythrum portula*, *Myosotis secunda*, *Potamogeton polygonifolius* and *Ranunculus flammula* (Murphy, 1994; Pearman, 2008).

Illecebrum verticillatum is listed as Endangered on the updated Vascular Plant Red Lists for England and Great Britain (Cheffings *et al.*, 2005; Stroh *et al.*, 2014; Leach, 2019; Botanical Society of Britain & Ireland, 2021b). Its stronghold is in Cornwall (v.c.1 & 2) where it was first recorded in the mid-16th century. However, declines occurred there in the 20th century due to habitat loss attributed to a reduction in hard grazing, mining and other activities causing regular disturbance (French *et al.*, 1999, 2020; Pearman, 2010). The species is not thought to have arrived elsewhere in the country until the 19th century. It has spread into the New Forest, South Hampshire (v.c.11), Bedgebury Forest in West Kent (v.c.16) and Berkshire (v.c.22); all with a connection to conifer forestry operations. There have been more recent appearances in Dorset (v.c.9) and North Hampshire (v.c.12) associated with military training areas (Pearman, 2008). A few casual and transient records further north in England and Wales are mainly associated with railways (Botanical Society of Britain & Ireland, 2021a).

In Scotland, historical records of *I. verticillatum* were made in the early 20th century from Barra and Eriskay by John Heslop-Harrison, although their validity

has since been questioned (Pankhurst & Mullin, 1991). Subfossil pollen from this Hebridean locality suggests that the species did occur there in the distant past, but radiocarbon dating puts this as prior to 4620 BP (Whittington & Edwards, 2000). There is also a casual and presumed introduced record from 1796 for "Dickson's garden", Edinburgh (Botanical Society of Britain & Ireland, 2021a).

Past floras of the British Isles have considered *I. verticillatum* as native to Cornwall and as an alien elsewhere. Nevertheless, the species is generally treated as a benign and valued part of local biodiversity which conservationists wish to preserve (Pearman, 2008; Freshwater Habitats Trust, Undated).

In September 2021 Allan MacLeod, Corrour's Head Stalker, noticed an unusual plant, which he did not recognise, flowering on the shore of Loch Treig. He recorded it on the iNaturalist phone app and sent a photo to Sarah Watts. She identified it as *I. verticillatum*, and a subsequent survey by her at the southern end of Loch Treig discovered the plant to be hugely abundant on sandy substrates in the drawdown zone, around and well below the usual high-water level (Fig.1). After a very dry summer the loch was considerably low, to an extent not seen during recent decades. *Illecebrum verticillatum* was therefore growing on vast areas of exposed ground normally submerged within the loch. It covered immense flowering patches of many hundreds of square metres and was by far the dominant component of the vegetation (Fig. 3), although other associates included *Spergula arvensis*, *Spergularia rubra*, *Gnaphalium uliginosum*, *Equisetum palustre*, *Persicaria hydropiper*, *Juncus bufonius* and *Molinia caerulea*. Such an expansive coverage of *I. verticillatum* in one location has not been seen in Britain during modern times (D. Pearman, pers. comm.)

Ian Strachan also found the species to be plentiful at the northern end of Loch Treig near the hydroelectric dam. A full survey of the locality has not yet been completed but it is feasible that *I. verticillatum* could occur all the way around the perimeter of the loch, given the availability of suitable habitat within the drawdown zone. This discovery represents a first modern record for Scotland of this species, far beyond its known distribution in Britain.

Other notable records from Corrour

A summary of key plant discoveries from Corrour in 2021 are provided in Table 1. At the time of writing, there are now four Nationally Rare vascular plant taxa recorded on the estate and 29 Nationally Scarce taxa. In 2021 there were also six new altitudinal records for Britain achieved at Corrour (Table 1), surpassing those previously listed by Pearman and Corner (2021). These include both the *B. repens* and *I. verticillatum* described above, as well as an exceptionally high *Betula pubescens* growing near the summit of Stob Coire Sgriodain (Fig.4), which is 129 m above the previous altitudinal record from Ben Lawers. However, Table 1 also features two non-native species of dwarf shrub: *Berberis* and *Gaultheria mucronata.* The *Berberis* and *Hammarbya paludosa* were recorded during a site visit by the Mountain Woodland Action Group. In addition, Sarah Watts made a large number of new records for the Nationally Scarce montane willow species *Salix myrsinites*, *S. lapponum* and *S. arbuscula* across Corrour in 2021 (Botanical Society of Britain & Ireland, 2021a), bringing numbers to approximately 150 individuals on the estate.

Figure 3. *Illecebrum verticillatum* flowering at Loch Treig in 2021 and covering large patches of the hydroelectric water drawdown zone. Images: Sarah Watts

Discussion

We have described several remarkable botanical records from summer 2021 made at Corrour, a Scottish Highland estate, including *B. repens* new to v.c.97 (Westerness), *I. verticillatum* new to Scotland and six British altitudinal records. These observations follow a new location and altitudinal record for the Nationally Rare *Scheuchzeria palustris* in Westerness identified during 2018 (Smith *et al.*, 2021). There are now four Nationally Rare vascular plant taxa recorded on Corrour and 29 Nationally

Scarce taxa. Our findings illustrate that, despite the increasing prevalence and technological ease of biological recording (August *et al.*, 2015; Pocock *et al.*, 2015; Silvertown *et al.*, 2015), there are still remote areas in Britain which are rich in undiscovered rare flora. It is therefore useful to include such places in monitoring programmes, in addition to thorough recording of already well-documented and renowned sites of conservation interest (JNCC, 2010; Sutton, 2020b). Known locally scarce species are often preferentially searched for, but there is much to be learned about other taxa including segregates, neophytes and inconspicuous aquatic plants (Braithwaite, 2021). Identifying and recording to subspecies (as was the case for *B. ranunculoides* subsp. *repens/B. repens*), can be key to determining Nationally significant populations of overlooked or under-recorded plants which subsequently become full species in their own right (Jones, 2015).

Figure 4. *Betula pubescens* at 924 m (left; image: Sarah Watts) and *Micranthes nivalis* (right; image: Ian Strachan) on Stob Corie Sgriodain

Two of the new botanical records described above were also of introduced non-native taxa; *Gaultheria mucronata* and *Berberis* sp. Both are neophytes originating in Chile which have naturalised via garden planting for amenity and ornamental purposes (Noble, 2009). *G. mucronata* in particular is an invasive species (Booy *et al.*, 2015), demonstrating the significance of biological recording for identifying new threats to biodiversity, even in isolated locations such as Corrour (Hulme, 2006; Mainka & Howard, 2010). It is important that such non-native invasive aliens continue to be viewed as negative features in the landscape and should be managed accordingly.

Table 1. Notable plant records made at Corrour in 2021, including new records for the estate and new British altitudinal records. Nomenclature follows Stace (2019). All records have been verified by the v.c.97 recorder (Ian Strachan) and David Pearman. NS = Nationally Scarce; NR = Nationally Rare

Species name	Common name	Altitude asl	Grid ref.	Location	Date	Recorder(s)
New records for Corrour in 2021						
Cerastium nigrescens (NS)	Arctic Mouse-ear	942 m	NN 3558 7420	Stob Coire Sgriodain	01/07/2021	Ian Strachan, Jim McIntosh, Sarah Watts
Micranthes nivalis (NS)	Alpine Saxifrage	885 m	NN 3599 7400	Stob Coire Sgriodain	01/07/2021	Ian Strachan, Jim McIntosh, Sarah Watts
Juncus castaneus (NS)	Chestnut Rush	902 m	NN 3783 7373	Glas-choire	09/07/2021	Ian Strachan
Baldellia repens (NR)	Creeping Water-plantain	396 m	NN 4060 6953	Loch Ossian	28/07/2021	Ann McCutcheon, Jane Grinstead
Hammarbya paludosa	Bog Orchid	476 m	NN 4274 7038	Uisge Labhair	18/08/2021	John Holland, David Mardon
Berberis sp. (non-native)	Barberry	519 m	NN 4197 7115	Creagan an Amair	18/08/2021	James Rainey, Sarah Watts
Illecebrum verticillatum (NR)	Coral Necklace	245 m	NN 3267 6919	Loch Treig	13/09/2021	Allan MacLeod
New altitudinal records for Britain						
Gaultheria mucronata (non-native)	Prickly Heath	660 m	NN 4275 7242	Mullach Coire nan Nead	25/03/2021	Allan MacLeod
Corallorhiza trifida (NS)	Coralroot Orchid	403 m	NN 4020 6826	Leitir Dhubh	21/06/2021	Sarah Watts, Jim McIntosh, Ian Strachan
Betula pubescens	Downy Birch	924 m	NN 3555 7420	Stob Coire Sgriodain	01/07/2021	Sarah Watts, Ian Strachan, Jim McIntosh
Baldellia repens (NR)	Creeping water-plantain	399 m	NN 3939 6848	Loch Ossian	10/08/2021	Sarah Watts
Rubus idaeus	Raspberry	766 m	NN 3652 7133	Garbh-bheinn	08/09/2021	Sarah Watts
Illecebrum verticillatum (NR)	Coral necklace	247 m	NN 3283 6931	Loch Treig	15/09/2021	Sarah Watts

Factors contributing to these botanical records in 2021

Our discoveries at Corrour highlight that the employment of in-house ecologists can benefit large landholdings and private estates by rapidly improving data on rare taxa of natural heritage value. The first record of *I. verticillatum* by Head Stalker Allan MacLeod also emphasises the value of experience retained through long-term continuity of environmental management staff. However, this work was supported by good communication and collaboration with a wide range of other individuals, including residents of the local community, BSBI staff and visiting conservation

experts. The guidance and advice provided through regular dialogue with the v.c.97 recorder has been immensely useful to Corrour. It is therefore advantageous to combine local knowledge and volunteer recording with surveying work and project co-ordination by professional ecologists (Roy *et al.*, 2015; Sutherland *et al.*, 2015). Such an approach increases the extent and efficiency of data collection for biological monitoring over multiple spatial and temporal scales (Dickinson *et al.*, 2012; Pocock *et al.*, 2015). Social media also provides an emerging citizen science tool for engaging society with botanical recording and disseminating information on species identification and distributions (Sutherland *et al.*, 2015). For example, the use of Twitter assisted with fast identification of *I. verticillatum* and recognition of its rarity status and conservation interest throughout Britain.

There have been several environmental surveys at Corrour in the past which did not find either *B. repens* or *I. verticillatum*, even when focusing on Loch Ossian specifically (Lassiere, 1993; Strachan, 2009; Strachan & Servant, 2010; Edwards & Headley, 2018). This may be because 2021 was a year of exceptionally prolonged dry weather leading to very low water levels in the lochs and the exposure of large patches of the shoreline and drawdown zone. There was also a profusion of flowering of both taxa allowing for relatively straightforward detection and identification. *B. repens* has a very short flowering period; the extent and density of which can vary significantly between years (Kozlowski *et al.*, 2008). When water levels are higher it would be very easy to miss or overlook vegetative features of *B. repens* unless recorders are actively searching for it from a boat. There is potential to mistake it for *Ranunculus flammula* which is common along the stony margins of oligotrophic water bodies such as Loch Ossian. Loch Treig, where *I. verticillatum* was found, is more remote and has been subject to far less botanical interest than Loch Ossian.

A recent appearance or a significant increase in abundance at Corrour by *B. repens* and *I. verticillatum* could also have led to their discovery in 2021. The arrival of a new taxon at a remote locality requires successful transport and introduction, but subsequent survival and reproduction is necessary for it to persist in the long-term (Blackburn *et al.*, 2011; Roy *et al.*, 2015). Both *B. repens* and *I. verticillatum* are clearly regenerating at Corrour and should be defined as established (Macpherson *et al.*, 1996; Macpherson, 1997), given the extent of their flowering/vegetative reproduction and geographical coverage. Although *I. verticillatum* has the ability to spread rapidly in suitable habitat conditions (Pearman, 2008; Freshwater Habitats Trust, Undated), relatively long timescales would still have been needed for it to propagate over such a large area at Loch Treig.

Potential dispersal vectors and means of establishment of B. repens

Aquatic plants generally have a considerable capacity for long distance dispersal, particularly movement via birds (Vuille, 1988; Figuerola & Green, 2002; Les *et al.*, 2003; Kozlowski *et al.*, 2008; Braithwaite, 2020). It is possible that *B. repens* on Loch Ossian has a connection with the nearby Tay catchment population located *c.*40-50 km away. *Baldellia* taxa have complex life cycles and use a range of asexual and sexual reproductive strategies (Vuille, 1988; Kozlowski *et al.*, 2008). However recent spread by seed between the two sites is unlikely because individuals at Loch Tay do not cross-pollinate and appear to be a single clone. Further observational and experimental work is needed to determine if the Corrour population is also a single

clone or whether it is producing seed and can cross-pollinate with plants from the Tay catchment.

Pseudovivipary is central to the ecology of *B. repens*, which could have originally arrived at Corrour by vegetative dispersal of detached or uprooted corm buds via waterfowl (Kozlowski *et al.*, 2008). Clonal offspring are potentially very long-lived and when established they can spread efficiently via inflorescence stolons (runners). Plants in the River Ossian and Loch Ghuilbinn may have been transferred from Loch Ossian by water movement downstream.

Potential dispersal vectors and means of establishment of I. verticillatum

The origin and mechanism of spread by *I. verticillatum* to Corrour are more ambiguous than *B. repens* because the nearest recent records are from England hundreds of kilometres away. It most commonly propagates by seed but has been known to root from stem fragments (Pearman, 2008; Pearman, 2010). There are several different human-related vectors by which the plant could have arrived accidentally at Loch Treig including forestry, the West Highland Railway or works associated with hydroelectricity. The former may have been possible via the creation of a PAWS forest (Plantation on Ancient Woodland Site) on the eastern shore of Loch Treig in 1930. This occurred during Corrour's period of ownership by Sir John Stirling-Maxwell who undertook considerable ground-breaking forestry planting on the estate including experimental trials with *Pinus sylvestris*, *Pinus contorta*, *Larix decidua*, *Larix kaempferi* and, most influentially, *Picea sitchensis* (Strachan & Servant, 2010; Rausing, 2018). The original 1925 record of *I. verticillatum* at the New Forest in v.c.11 (South Hampshire) occurred in a spruce plantation (Rayner & Townsend, 1929; Brewis *et al.*, 1996) and could have been introduced with the imported conifers. Forestry is also a suggested source of populations in West Kent (v.c.16) and Berkshire (v.c.22) (Pearman, 2008), and may have obscured the native distribution of other taxa of conservation interest such as *Linnaea borealis* and *Goodyera repens* (Adamowski, 2000; Peterken, 2001; Welch, 2003).

Illecebrum verticillatum has occasionally been associated with railways, including moist gravels and clinker of disused lines in Dorset (v.c.9). More recently it has been dispersed by the military to other sites in Dorset and North Hampshire (v.c.12) (Murphy, 1994; Pearman, 2008), and spread by vehicle activity and disturbance through scrub clearance (Plantlife, 2011). However, there is no known link between these activities and Corrour. As with *B. repens*, the feet of migratory waterfowl are another potential source, and considered the most likely reason for the recent arrival of *Juncus filiformis* on isolated waterbodies such as Loch Laggan and Loch Treig (Perring & Farrell, 1977; Blackstock, 1981). Wildfowl are also thought to be vectors for the transient introduction of *Ranunculus reptans* to Britain (Gibbs & Gornall, 1976; Preston & Croft, 2001). Further investigation is needed to explore these suggested dispersal mechanisms, and could involve genetic analysis to identify any probable originating population of *I. verticillatum* from England.

Nevertheless, the hydroelectricity workings which enlarged Loch Treig and have subsequently caused water level fluctuations are certainly responsible for the huge availability of regularly flooded and disturbed ground which is essential for establishment of *I. verticillatum* (Freshwater Habitats Trust, undated). Reservoir drawdown zones should not necessarily be considered barren habitats and can host a distinctive flora that is adapted to rapidly changing conditions and gradients

(Abrahams, 2005; Abrahams, 2006; Callaghan *et al.*, 2020). Annual plants that regenerate quickly from the soil seedbank are particularly suited and may even provide important stabilising effects on the shoreline (Yuan *et al.*, 2013; Cho *et al.*, 2019).

Our botanical discoveries at Loch Treig demonstrate that artificial man-made habitats can be successfully colonised by rare species and provide unique conditions for novel plant communities of conservation interest (Rumsey *et al.*, 2019). Warmer winters in recent years could have also enabled the survival of *I. verticillatum* at Loch Treig when it would previously have been killed off by frosts. Annual plants may be commonly dispersed to distant sites at the very northern margins of their range, but have only recently begun to persist there due to rising temperatures - possible examples include *Poa bulbosa*, *Poa infirma* and *Crassula tillaea*. Climate change could therefore facilitate further establishment of *I. verticillatum* in northern parts of Britain (Pearman, 2008).

Conclusion

Our observations have found that *B. repens* and *I. verticillatum* are both well established and regenerating at Corrour. This work highlights the additional value to collecting information on abundance, habitat type, interactions with associated species and evidence of flowering and/or vegetative spread (Stewart *et al.*, 2015; Sutherland *et al.*, 2015; Walker *et al.*, 2019). Such knowledge obtained while recording can inform discussions on status and likely origin, and improve our understanding of local ecology in the context of conservation management.

There is no reason to suggest that *B. repens* has been very recently introduced or is anything other than native to Corrour, as defined by Preston (2002) and Walker *et al.* (2019). It is likely that this taxon is under-recorded in Britain in comparison to the more widespread and better-known *B. ranunculoides* (Stroh *et al.*, 2014; Stace, 2019). New information on the distribution, morphology and ecology of *B. repens* will aid confirmation of its individual species status, in which case it could be considered Nationally Rare. However taxonomic challenges should not hinder conservation decisions and priorities, because both taxa in the genus *Baldellia* are at risk of decline due to their sensitivity to eutrophication, changes in grazing management and habitat loss (Preston *et al.*, 2002; Kozlowski *et al.*, 2008; Kozlowski & Vallelian, 2009).

Past records of *I. verticillatum* outside of Cornwall were previously classed as alien (Pearman, 2008; Botanical Society of Britain & Ireland, 2021a). However, because it has not been deliberately introduced to Corrour and there is no clear evidence of direct human assistance, then it could be considered "Native, Origin unknown" using the categories described by Walker *et al.* (2019). *I. verticillatum* should therefore be welcomed as an intriguing addition to the flora of Westerness (v.c.97) which has conservation value in its own right and is unlikely to affect local biodiversity, given its need for very specific, disturbed habitats. There is potential for other sites for this species in Scotland to be discovered in the future, particularly under the escalating effects of climate change. Recorders should focus search efforts on the drawdown zones of other hydroelectric lochs in the region.

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