NOBANIS –Invasive Alien Species Fact Sheet

Campylopus introflexus

Author of this fact sheet: Jonas Klinck[1,2], [1]Danish Forest and Nature Agency, Ministry of the Environment, Haraldsgade 53, 2100 Copenhagen Ø and [2]Copenhagen University, Section for Macroecology, Evolution and Climate, Department of Biology, Universitetsparken 15, 2100 Copenhagen Ø. Mail: jonas@klinck.dk

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Species description

Scientific names: *Campylopus introflexus* (Hedw.) Brid., Dicranaceae
Synonyms: *Dicranum introflexum* Hedwig
Common names: Heath Star-moss (GB), Kaktusmoos (DE), stjerne bredribbe/vestlig bredribbe (DK), võõr-kõverharjak (EE), Jautrioji raštuotė (LT), Parastā līklape (LV), Hæruburst (IS), Grijs kronkelsteeltje (NE), ribbesåtemose (NO), Krzywoszczeć przywłoka (PL), hårkvastmossa (SE).

Figure 1. Grey dunes on Fanø, Denmark. All the yellow-green low vegetation is *Campylopus introflexus.* Photo by Jonas Klinck September 2008.

Figure 2. *Campylopus introflexus*. Photo by Maike Iserman.

Figure 3. Moss carpet at Reykjanes, a high-temperature geothermal area in south-western Iceland. The dark green moss is *Campylopus introflexus.* Photo by A. Elmarsdóttir, July 2001.

Species identification
Campylopus introflexus is an acrocarpous, perennial moss forming dense cushions or mats. Plants are 0.5 – 10 cm often found in dense mats or cushions of yellowish to olive green colour. Leaves are 4-6 mm, lanceolate ending in a characteristic hyaline hair tip, often reflexed 90° (Frahm 2002). When plants are dry these hair tips form a white star, when seen from above (see fig 2).
Seta 7-12 mm, yellowish brown to brownish in age, often with several sporophytes from the same plant, curved or sinuose. Capsules are brown, 1.5 mm, slightly asymmetric and curved when empty. Spores are small, 12-14 µm (Frahm 2002).

Native range
Campylopus introflexus is widespread in the Southern hemisphere, in the Southern part of South America and Africa and parts of Australia as well as islands in the Pacific, Atlantic and Indian Ocean (see figure 4) (Gradstein & Sipman 1978; Klinck 2009; Söderström 1992).

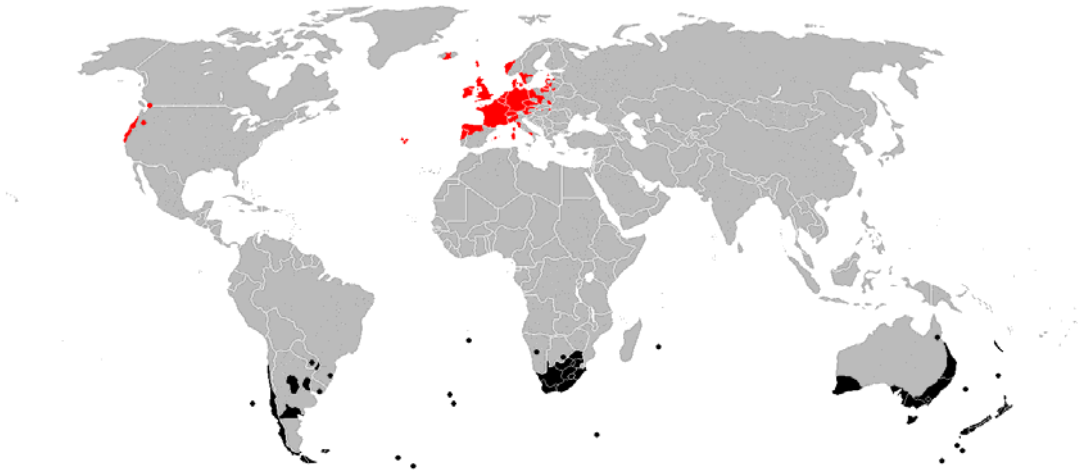

Figure 4. Native regional distribution shown in black. Alien regional distribution shown in red. From Klinck 2009.

Alien distribution

History of introduction and geographical spread.
Campylopus introflexus was first discovered outside its native range in 1941 in the Southern part of Great Britain (Richards 1963). From 1941 and onwards it spread through Great Britain and Ireland where was recorded for the first time in 1942 (National Biodiversity Data Centre 2010). It spread to mainland Europe where it was first discovered in 1954 in Brittany (France) (Størmer 1958).

It continued its spread through Europe and was discovered in Italy in 1956 (Reimers 1956), the Netherlands in 1963 (Barkman & Mabelis 1968), Belgium in 1966 (Jacques & Lambinon 1968), Germany in 1967 (Neu 1968), Denmark in 1968 (Frahm 1971), Faroe Islands in 1973 (Boesen *et al*. 1975), Sweden in 1976 (Johansson 1977), Norway in 1978 (Øvstedal 1978), Luxembourg in 1979 (Werner 1979), Spain in 1980 (Casas *et al*. 1988), Austria in 1980 (Grims 1980), Switzerland in 1980 (Urmi *et al*. 2007), Iceland in 1983 (Icelandic Institute of Natural History 2010), Poland in 1986 (Lisowski & Urbañski 1989), Czech Republic in 1988 (Novotný 1990), Slovakia in 1995 (Holotova & Soltes 1997), Portugal in 1996 (Sérgio 1997), Lithuania in 1996 (Jukonienė 2003), Russia - in Kaliningrad Province in 2000 (Razgulyaeva *et al*. 2001), Latvia in 2000 (Abolina &

Reriha 2004), Hungary in 2006 (Szücs & Erzberger 2007), Estonia in 2007 (Vellak *et al*. Submitted 2009), southern Corsica (Cogoni *et al*. 2009) (see figure 5).

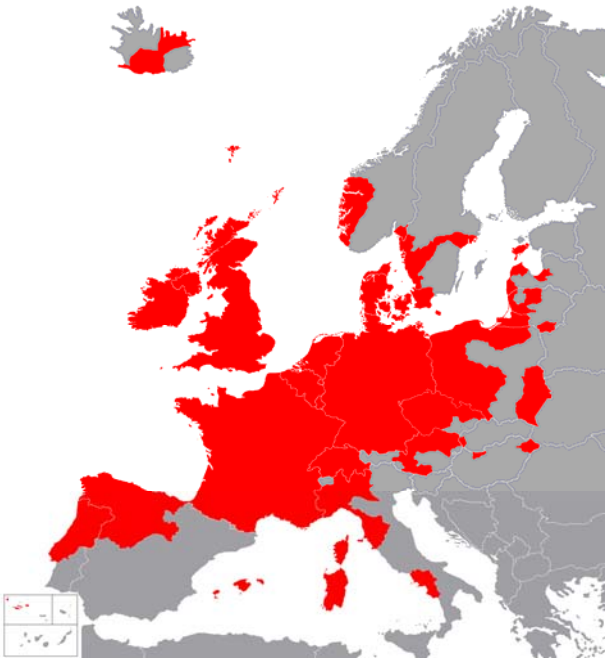

Figure 5. Alien regional distribution in Europe shown en red (Klinck 2009 with the addition of two new polish regions).

Campylopus introflexus was reported from the Campania region in Italy in 1956 (Reimers 1956) but since this collection was probably made without knowledge of Giacominis distinction between the two species *C. introflexus* and *C. pilifer* in 1955 (Giacomini 1955) it is very likely that, at this southern location it is in fact the species *C. pilifer*. The other and probably only observation from this southern region is from 1965, so the presence today at this southern location needs to be confirmed. It is nevertheless included on the map.
According to Adam Stebel the lack of registrations of *Campylopus introflexus* in the central part of Poland is due to lack of studies in the area rather than lack of its presence (pers. comm. Adam Stebel).

Campylopus introflexus shows a rapid spread. In the Netherlands there are no records before 1950 and more than 200 around 1990 (Greven 1993) In Great Britain the number of records were doubled between 1990 and 2008 (Hill *et al*. 2009) with 1025 records during 1960-1990 up to 2180 in the period from 1990 to 2008.

Outside Europe it was first registered as a neophyte in California, USA in 1975 (Frahm 1980), where it is now invasive (pers. comm. Brent Mishler), and in Oregon, USA in 1981 (Christy *et al.* 1982). Generally, it is seen as naturalised in the Northeastern United States (Miller 2009). It was first observed in Canada in 1994, where it was found on a bog in British Colombia (Taylor 1997). All previous specimens of supposed *Campylopus introflexus* from North America, mainly collected in the Southeastern part of USA, have proven to be *Campylopus pilifer* (Frahm 1980).

Pathways of introduction
Campylopus introflexus is a case of secondary introduction, since it is believed to have spread by itself from the first introduction to England (Hassel & Söderström 2005). The circumstances regarding the initial human mediated introduction to England are not known.

Alien status in region
Campylopus introflexus has been found in all countries in the region except Finland and Greenland (Hassel & Söderström 2005; Klinck 2009). See table 1.

Country	Not found	Not established	Rare	Local	Common	Very common	Not known
Austria				X			
Belgium						X	
Czech republic				X			
Denmark						X	
Estonia			X				
European part of Russia			X				
Finland	X						
Faroe Islands			X				
Germany						X	
Greenland	X						
Iceland				X			
Ireland					X		
Latvia			X				
Lithuania				X			
Netherlands						X	
Norway				X			
Poland				X			
Slovakia			X				
Sweden				X			

Table 1. The frequency and establishment of *Campylopus introflexus*, please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** –The species is not found in the country; **Not established** – The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** – Few sites where it is found in the country; **Local** – Locally abundant, many individuals in some areas of the country; **Common** – Many sites in the country; **Very common** – Many sites and many individuals; **Not known** – No information was available.

Ecology

Habitat description
Campylopus introflexus has a high ecological tolerance and its preferred growing sites differ from region to region. It is most often found on sandy soils, peat, sphagnum bogs and moist heaths which have been disturbed e.g. by peat cuttings or fire (Richards 1963; Richards & Smith 1975). In the coastal regions of Northwestern Europe, it is often found on dry, undisturbed sites with leached, relatively acid (pH 4-6) slightly humose top soils, primarily on grey dunes. Due to the large pH range it is able to establish on the primarily calcareous grey dunes (Van der Meulen *et al.* 1987). In

colder climate, such as the Icelandic, it is found on geothermal ground within the volcanic active zone (Icelandic Institute of Natural History 2010). Similarly, it occurs on geothermal fields of the Southern Tuscany, Italy, with a soil pH around 3 to 4, and soil temperatures about 45 °C (Chiarucci *et al*. 2008). It grows on cliff shelves, in the edges of swampy areas, along paths and forest edges as well (Hallingebäck *et al*. 1985). In dry heathlands dominance increased at the edge of adjacent forests, especially in combination with grazing and thus disturbance effects (Piessens *et al*. 2008).

Reproduction and lifecycle
Campylopus introflexus reproduces easily, both from small spores (10-14 μm) and from fragments (Söderström 1992). Dispersal by spores is the most likely cause for the establishment of the species in the Nordic countries (Tomas Hallingbäck, pers. comm.). *C. introflexus* is easily fragmented; stem tips and other parts break off and are blown away by the wind and establish if the habitat is suitable (Van der Meulen *et al*. 1987). Fragments are, however, rather large and do not disperse over greater distances as easily as the spores, but can be transported by wild animals and by cattle, as well as by human activities and vehicles over large distances. The finding of *C. introflexus* on two of the Faroe Islands even before the species was found in Norway and Sweden illustrates the enormous dispersal capability of the spores (Lewinsky 1982).

Dispersal and spread
The local dispersal and persistence of *Campylopus introflexus* is achieved by dispersal of vegetative propagules and the production of spores enable long distance dispersal (Söderström 1992). The individual carpet grows to a thickness of 2-10 cm and endures for several years in a perennial fashion. The dry moss carpet is often seen to fragment and break loose from the ground (Equihua and Usher 1993). Dispersal of these tufts can give rise to new individuals when moisture is available. Furthermore, shoot tips, covered by a protective layer, can break and after dispersal by wind, or by animals like rabbits, may give rise to new individuals (Hallingbäck *et al*. 1985). The growth dynamics of the moss carpet as well as the diversity of dispersal mechanisms available explains the apparent success of *C. introflexus*.

Impact

Affected habitats and indigenous organisms
Campylopus introflexus has been recorded from a wide range of European habitats, most of them having some features in common: ample light and nutrient-poor decalcified soils. The habitats where *C. introflexus* seems to have the largest impact is in the grey lichen rich dunes on the western coast of Northern Europe, inland dunes as well as in disturbed peat bogs.

Flora
When spreading, *Campylopus introflexus* has been observed to change lichen dominated dry sand grassland to a monotonous dense carpet of *C. introflexus* within 15 years (Biermann & Daniëls 1997). A follow up on the study area in 2004 (Daniëls *et al*. 2008) showed that the *C. introflexus* dominated areas are being succeeded again by lichen. It is stated that the impact of *C. introflexus* is only local and temporal. It is estimated that this succession to original conditions might take 15-20 years, under stable environmental condition (Daniëls *et al*. 2008).

Since the 1970s *Campylopus introflexus* has expanded considerably both in distribution and in cover on coastal and inland dunes for example in the Netherlands. This encroachment has led to the reduction of lichen-rich plant communities. *C. introflexus* not only outcompetes rare lichens from pioneer stages of the Violo-Corynephoretum canescentis, but also more common species lichen

species of older succession stages with decalcified sand (Ketner-Oostra & Sýkora 2004). The encroachment by *C. introflexus* influence species composition, but the succession of plant communities remain the same and in some communities lichen diversity remain high (Ketner-Oostra & Sýkora 2008). Encroachment by *C. introflexus* has been found to have little if any influence on lichen establishment. If *C. introflexus* has lower vitally due to a cover of sand blown-over, common humicolous lichens may act as secondary pioneers (Ketner-Oostra & Sýkora 2004). Ketner-Oostra & Sýkora (2008) concludes that lichen species of the both pioneer, humicole and aero-hygrophytes groups can establish themselves on and between the moss (live, dead in parts, or humified) in a mixed carpet of *C. introflexus* and *Polytrichum piliferum*, and also when *C. introflexus* is the dominant moss species.

No difference was found in the vegetation development between undisturbed stands dominated by native *Polytrichum piliferum* or by *Campylopus introflexus*, or a carpet of both species. They were gradually and at the same speed colonized by lichens, most lichens managed to colonize dead as well as living parts of the moss carpets (Hasse 2007). The author suggests this may indicate that the moss carpets in the long term are replaced by lichen. The data provide no evidence that a moss carpet of *C.introflexus* causes permanent damage to the long term development of *Corynephorus canescens* vegetation (Hasse 2007). This is supported by Minarski & Daniëls (2006) who observed that after approximately 10 years of *Campylopus*-dominance in *Corynephorus canescens* grassland, the lichen vegetation recovered during progressive succession. Hasse (2007) suggests that it is conceivable that *C. introflexus* can be a potential major threat to the native vegetation if it covers the whole dune complex and diaspores from lichen therefore aren't available for re-colonization.

Polytrichum piliferum has been seen to decline in *Campylopus introflexus*-dominated plots, whereas *C. introflexus* did not decline in the *P. piliferum* dominated plots (Hasse 2007). The relative decline of *P. piliferum* in comparison to *C. introflexus* indicates, according to the author, a higher competitive capacity of *C. introflexus*.

A glasshouse experiment showed that germination of seeds from *Calluna vulgaris* was significantly negatively affected by the carpet of *Campylopus introflexus*. A 60% reduction in germination was found. This depressive impact on germination is mainly due to a result of a proportion of seeds being lost because they sink into the moss carpet and are then deprived of light. Some seeds are trapped near the apices of the moss shoots where they may germinate if enough water is present; but they face a risk of drying, fragmentation, overturning and uprooting (Equihua & Usher 1993). A by Bernth (1998) showed that *C. introflexus* has a significant negative effect on the germination of seeds of *Calluna vulgaris* in the field as well.
The carpet of *C. introflexus* on the other hand, has a positive effect on the post-germination performance of the seedlings of *Calluna vulgaris.* Under glasshouse conditions the seedlings grow quicker and also mature and reproduce earlier. After eight months the production of reproductive biomass of the plants that grew on the moss carpet was 10 times larger than those grown on bare ground (Equihua & Usher 1993). They also examined *C. introflexus* for an allelopathic effect on the germination of *Calluna vulgaris*, but found no effect.

Fauna
A study in the Netherlands (Vogels *et al*. 2005) showed that moss-encroachment by *Campylopus introflexus* in lichen rich grey-dunes has a large impact on soil-entomofauna both above and below the ground. Moss encroachment leads to the formation of a humus layer in the dry dune grassland or grey dunes. The Sciaridae and the Empidoidea showed a preference for moss-encroached vegetations, due to formation of a thicker humus layer. The thicker humus layer facilitates the

settlement of soil-inhabiting larvae due to changes in the microclimatic conditions in the soil, which leads to e.g. smaller risk of desiccation.

An increasing homogeneous surface of a moss-encroached area, leads to a shift in species composition, from diurnal (day-active) to nocturnal (night active) species, which Vogels *et al*. (2005) suggests could be due to a more extreme warm and dry microclimate, with less opportunity for shelter during the day. The activity of the carabid beetles and spiders was much lower in the moss-encroached vegetation types, which is suggested to reflect lower densities in the moss-encroached vegetation types. The authors suggest this is due to a lower amount of food in the moss-encroached dry dune grassland since spiders and carabid beetles are primarily limited by food abundance (Vogels *et al*. 2005).

In the Netherlands the encroachment by *Campylopus introflexus* has been mentioned as one of the reasons why the Tawny Pipit (*Anthus campestris*) has disappeared from the Dutch dunes, due to a change in microclimate that may have lead to a decrease in arthropods availability and thus food abundance for the bird (Turnhout 2005).

Genetic effects
There is a variant of *Campylopus pilifer*, which resembles a mixture of the *C. pilifer* and *C. introflexus* with erect hyaline hairpoints in dry condition, but with a height of the lamellae of only 2 cells. This variant, *C. pilifer* var. *brevirameus* (Dix.) has already been found in several places in the western part of Europe, South Africa, Seychelles, Réunion and Argentina, in some of the places coexisting with *Campylopus introflexus*. It cannot be confirmed nor excluded that *C. pilifer* var. *brevirameus* is of hybridogenous origin (Frahm & Stech 2006).

Human health effects
No human health effects have been reported.

Economic and societal effects (positive/negative)
Campylopus introflexus threatens habitats that are often species rich and extremely rare in the region, but the species has no immediate economic effects, since these habitats are not of concern for human land use (agricultural or forestry). The cost of the loss of biodiversity for future generations is difficult, if not impossible, to assess but equally important.

Management approaches

Prevention methods
No prevention methods have been described for this species. *Campylopus introflexus'* ability for long-distance dispersal of spores and secondary dispersal without human interaction prohibits such measures.

Eradication, control and monitoring efforts
Eradication of *Campylopus introflexus* is not possible due to its ability for long-distance dispersal of spores and secondary dispersal.

Control of *Campylopus introflexus* on local scale is possible. The species does not tolerate burying by sand repeatedly over a period of years. A study on the effects of blowouts in coastal dunes showed that *C. introflexus* disappears if the accumulation of sand on the moss carpet exceeds a few mm. per year (Boxel *et al*. 1997). Ketner-Oostra & Sýkora (2000) observed that *C. introflexus*

appeared to be dead, due to sand blown in as an effect of a dry summer. However, a deposit of 2 mm. of sand three times during 4 months was not enough to kill the moss (Hasse & Daniëls 2006), this could indicate that repeated coverage over several years is needed before the *C. introflexus* dies. Burning of the moss with a weed burner for 15 seconds killed 80%, 30 seconds killed 90% and 60 seconds killed 100% of the moss carpet in a small scale experiment in the grey dunes of Fanø, Denmark (Klinck 2009).

In the same experiment salt strewn on the moss carpet in the amount of 250 g/m^2 killed more than 90 % of the carpet. Due to the dense carpet, no other species were present and the effect on other species could therefore not be investigated (Klinck 2009).

Disturbance by cutting up and turning cuts randomly did not inhibit the dominance of *Campylopus introflexus*, since the moss fragments mostly stayed alive and were able to form new shoots that colonized newly created gaps (Hasse 2007).

Sod cutting – the removal of vegetation down to bare sand, did only have a short term effect on the presence of *Campylopus introflexus*. Four years on *Campylopus introflexus* returned almost to the same cover percentage as before the sod cutting but coexisting with more species of moss and higher plants than before the cutting (Ketner-Oostra & Sýkora 2000).

When exposed to the herbicide Asulox [methyl (4-aminophenyl sulfonyl) carbamate] which is used to control the spread of bracken (*Pteridium aquilinum*) *Campylopus introflexus* showed a little reduction in growth but was not killed by the herbicide (Rowntree *et al*. 2003).

The known moss killer Ferrous sulfate ($FeSO_4$) did not have an effect on the moss carpet when applied after the normal recommendation (Klinck 2009).

In Dutch mainland dunes, long-term permanent plot has been studied and different management measures (burning, soil damage, left litter, cutting and removal of Scots pines) have been applied in order to control *Campylopus introflexus* and prevent the loss of lichen-rich dune vegetation (Daniëls & Krüger 1996).

Information and awareness

No information and awareness raising campaigns have been reported for this species. It is recognised in the DAISIE-project (DAISIE 2009) as one of the 100 worst alien species in Europe (Kettunen *et al*. 2008).

Knowledge and research

Long term studies in areas with *Campylopus introflexus* have been carried out in the Netherlands (Biermann & Daniels 1997; Daniëls *et al.* 2008) and in Denmark (Vestergaard *et al.* 2008).

Recommendations or comments from experts and local communities

Experts like Isermann (2005) and Ketner-Oostra & Sýkora (2000, 2004, 2008) show clearly the strong negative effects of *Campylopus introflexus* on biodiversity in coastal dune areas. Other studies show that these effects on biodiversity is only local and temporary, where after a return to the pre-invasion vegetation can be observed (Klinck 2009, Daniëls *et al*. 2008, Hasse 2007, Minarski & Daniëls 2006). It can be defined only as a mild or temporary invasive species since the IUCN's definition of an invasive species states, that an invasive species threatens biodiversity. I do therefore not think that resources should be used in controlling or eradication of *C. introflexus* in the coastal dunes. Funds for conservation of the delicate lichen rich dune systems should instead be

used to reduce nitrogen deposition, which leads to encroachments by graminoids, and is probably a greater threat to this delicate natural habitat (Ketner-Oostra & Loo 1998). Continuous and efficient monitoring of the coastal dune system is recommended in order to continuously document the effects of *C. introflexus*.

References and other resources

Contact persons

Maike Isermann (DE), University of Bremen, Vegetation Ecology and Conservation Biology, Leobener Straße, 28359 Bremen, Germany. Phone: +49 (0) 421/218-62925. E-mail: iserm@uni-bremen.de

Ib Johnsen (DK) Biological Institute, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen Ø, Phone: 35320137, Email: Ibj@bio.ku.dk

Kristian Hassel (NO) Department of Natural History, Norwegian University of Science and Technology, N- 7491 Trondheim, Norway, E-mail: kristian.hassel@vm.ntnu.no

Lars Söderström (NO) Biologisk Institutt, Norwegian University of Science and Technology, N-7491 Trondheim**,** Phone**:** + 47 735 96061, E-mail: Lars.Soderstrom@bio.ntnu.no

Laurens B. Sparrius (NL), Dutch Bryological and Lichenological Society (BLWG), Vrijheidslaan 27, NL-2806 KE Gouda, The Netherlands, sparrius@blwg.nl, tel. +31182538761.

Austra Abolina (LV) Latvian Forestry Research Institute "Silava", Rigas str. 111, LV-2169 Salaspils, Latvia, E-mail: austra@silava.lv

Tomas Hallingbäck (SE) Swedish Threatened Species Information Centre, Swedish University of Agricultural Sciences, Box 7007, SE-750 07 Uppsala, Phone: + 46 18-67 24 67, Email: Tomas.Hallingbäck@ArtData.slu.se

Anna Maria Fosaa (FO) Faroese Museum of Natural History, V. U. Hammershaimbsgøta 13, FO-100 Tórshavn, Faroe Islands, Email: anmarfos@ngs.fo

Kimmo Syrjänen (FI) Finnish Environment Institute, Nature and Land Use Division, Species Protection Unit, P.O.Box 140, SF-00251 Helsinki, Finland, E-mail: kimmo.syrjanen@ymparisto.fi

Gróa Valgerður Ingimundardóttir (IS) Icelandic Institute of Natural History, Hlemmur 3, P.O. Box 5320, IS-125 Reykjavik, Iceland, Phone: + 354 5 900 514, E-mail: gogo@ni.is

Adam Stebel (PL), Department of Pharmaceutical Botany, Medical University of Silesia in Katowice, ul. Ostrogórska 30, PL-41-200 Sosnowiec; E-mail: astebel@sum.edu.pl

Zigmatas Gudžinkas (LT), Institute of Botany, Vilnius University, Žaliųjų ežerų 49, LT-2021 Vilnius, Lietuva, Phone: (5) 2711618, E-mail: zigmantas.g@botanika.lt

Kai Vellak (EE), University of Tartu, Institute of Botany and Ecology, Lai 40, EE-Tartu 51005, Estonia, Email: kai.vellak@ut.ee

Etienne Branquart (BE), Belgian Biodiversity Platform, http://ias.biodiversity.be/ias/.

Colette O'Flynn (IR), National Diversity Data Centre, Research Officer, Beechfield House, WIT West Campus Carriganore, Waterford, Ireland, Tel: +353 51 306248. Email: info@biodiversityireland.ie

Eva Mikulášková (SK and CZ), Ústav botaniky a zoologie MU, Email: loskotova@centrum.cz

Links

NeoFlora – Invasive non-native plants in Germany – *Campylopus introflexus*

Missouri Botanical Garden – Key to *Campylopus*

DAISIE- Delivering Alien Invasive Species Inventories for Europe - http://www.europe-aliens.org/

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