NPWS

Leannan River SAC

(site code 002176)

Conservation objectives supporting document- *Najas flexilis* (Willd.) Rostk. & W.L.E. Schmidt

Version 1

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Contents

Please note that this document should be read in conjunction with the following report: NPWS (2019) Conservation Objectives: Leannan River SAC 002176. Version 1.0. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht.

1. Introduction

1.1 *Najas flexilis*

Najas flexilis (Willd.) Rostk. & W.L.E. Schmidt (EU Habitats Directive species code 1833) is a small, annual, submerged macrophyte of freshwater lakes that is listed on Annex II and Annex IV of the EU Habitats Directive. In Ireland, the species is also protected under the Wildlife Acts (1976 and 2000), being listed on the Flora (Protection) Order, 2015 (Statutory Instrument No. 356 of 2015). It has been assessed as *Near Threatened* in Ireland and *Vulnerable* in Europe (Wyse Jackson *et al*., 2016; Bilz *et al*., 2011).

Globally, *Najas flexilis* (slender naiad) has a somewhat disjunct distribution that can be described as circumboreal (Preston and Croft, 2001). It is much more frequent in North America than in Eurasia (Godwin, 1975; Haynes, 1979; Preston and Croft, 2001). It has a northerly distribution in Europe, extending south to the Alps, but fossil evidence shows it was formerly much more widespread (Godwin, 1975; Preston and Croft, 2001; Wingfield *et al*., 2004). It is recognised as a rare and declining species in many countries (Preston and Croft, 2001). The core of the species' European range is in Scotland and Ireland (Wingfield *et al*., 2004, 2005; Roden, 2007).

The species was first recorded in Ireland by Daniel Oliver in Cregduff Lough, Co. Galway in 1850 (*Botanical Gazette*, No. 22, October, 1850). *Najas flexilis* is now considered to occur in 52 lakes, be extinct from six lakes[1], while records for eight lakes[2] have been rejected (Roden and Murphy, 2014; Roden *et al*., 2016, 2017, 2018, in prep.; NPWS, in prep.). Extant populations are found in counties Clare, Donegal, Galway, Kerry and Mayo. Connemara appears to be the species' Irish stronghold, having records from approximately 36 lakes (see Figure 1).

A fragile, relatively short (rarely >30 cm) and permanently submerged species of the lower euphotic depths, the plant is often overlooked (Preston and Croft, 2001; Roden, 2004; Wingfield *et al*., 2004). *Najas flexilis* is typically found on flat to gently sloping areas of the lake bed with soft substrata of mud, silt or fine sand (Preston and Croft, 2001; Roden, 2002, 2004). It can occur at all depths between 0.5 m and 10 m, but is frequently associated with the lower depths of macrophyte growth, with scattered plants gradually giving way to bare mud or silt (Preston and Croft, 2001; Roden, 2002). The well-documented patchy distribution of the species within lakes is considered to be primarily determined by wave action, sediment type and competition; the first two being closely interlinked (Roden, 2004, 2007; Wingfield *et al*., 2004). Unsurprisingly for an annual species, *Najas flexilis* is an early coloniser and a relatively poor competitor and, therefore, may be associated with naturally disturbed conditions (Wingfield *et al*., 2004).

Najas flexilis is usually found in clear-water, lowland lakes (Preston and Croft, 2001). It shows a clear association with mixed geology, typically having peatland dominated catchments with some base-rich bedrock (basalt, limestone, marble or sedimentary deposits) or calcareous sand (Preston and Croft, 2001; Roden, 2004; Wingfield *et al*., 2004). Catchment geology may influence the distribution

[1] Loughs Nafeakle, Ibby, Namanawaun, Keel, Glenade and Cloonee Middle

[2] Lough Derg (Donegal); Lough Adoolig and Muckross Lake (Kerry); Truska Lough, Lough Illauntrasna, Lough Anillaunlughy and Lough Sruffauncam (Galway) and Fin Lough (Mayo)

of the species through substratum type, as well as through nutrient and mineral chemistry. Roden (2004) noted that the species does not prosper in Old Red Sandstone catchments, possibly owing to the coarser sands that form the lake substratum in these areas.

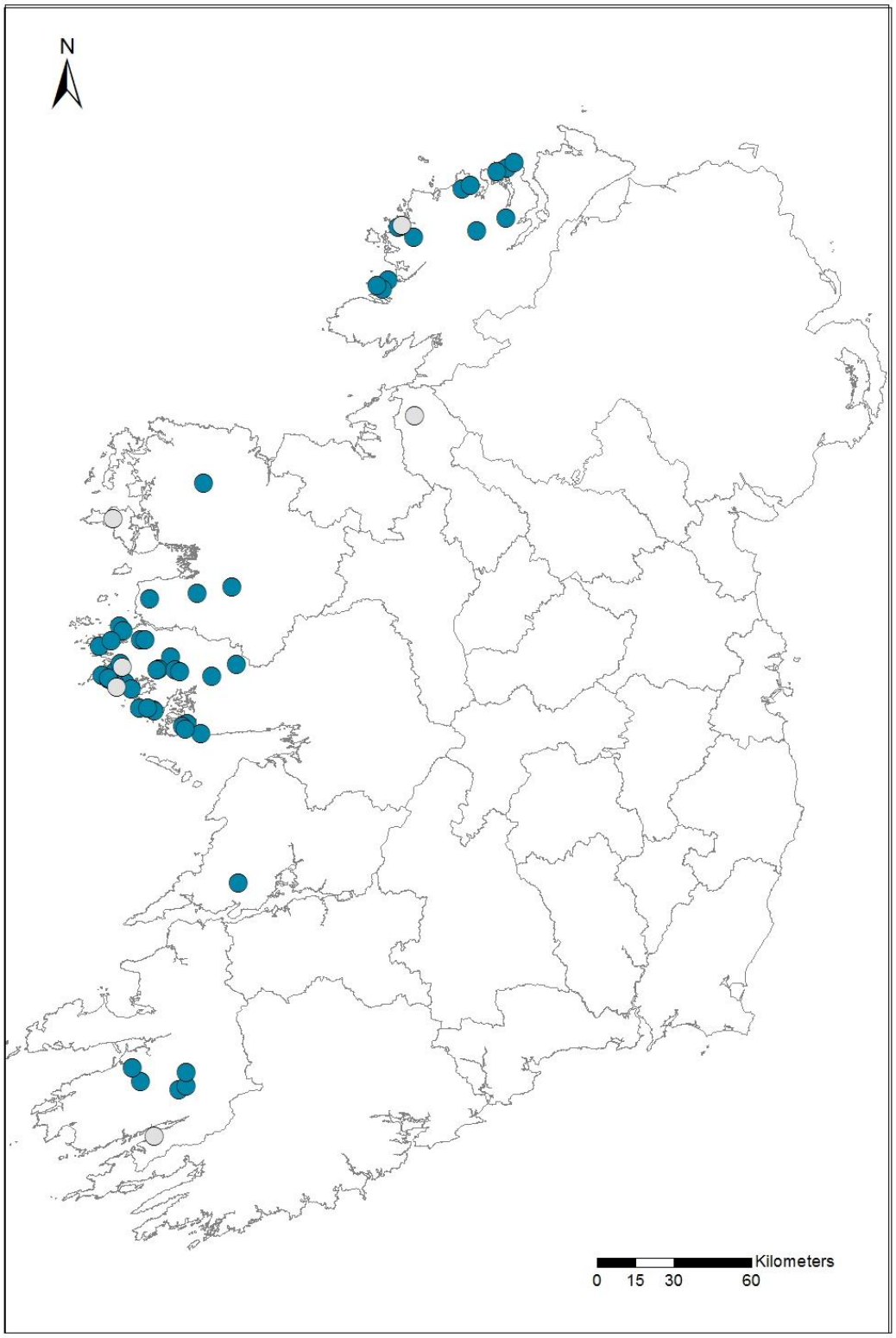

Figure 1. **The distribution of *Najas flexilis* in Ireland.** Based on lake centroids for 52 lakes considered to hold extant populations of the species (solid blue discs) and six lakes where it is considered extinct (light grey discs).

Najas flexilis is not found in marl or other hard water lakes (EU Habitats Directive Annex I habitat code 3140) (Roden, 2007). Neither does *Najas flexilis* occur in dystrophic, peaty lakes (Roden, 2002). In Ireland, *Najas flexilis* appears to be associated with the EU Habitats Directive Annex I habitat 3130 (Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or Isoëto-Nanojuncetea) (O Connor, 2015).

Roden (2004) noted the frequent co-occurrence of *Potamogeton perfoliatus* and *Isoetes lacustris* in *Najas flexilis* lakes, which is indicative of the mixed geological conditions favoured by the last species (the pondweed being common in hard water lakes; the quillwort characteristic of soft-water, oligotrophic lakes). N.F. Stewart (pers. comm.) has noted its common association with *Nitella confervacea*. Roden (2004) described two distinct groups of associated species in Irish *Najas flexilis* lakes; the first group included *Callitriche hermaphroditica*, several *Chara* species and broad-leaved pondweeds (*Potamogeton* spp.). A similar list of associated species was noted by Preston and Croft (2001) and in lake Groups 2, 3 and 4 of Wingfield *et al*. (2004). The second group of associated species identified by Dr Cilian Roden included *Elatine hexandra* and *Nitella translucens* (Roden, 2004). Wingfield *et al*. (2004) Group 1 lakes appear to have similar associated species. In some Irish lakes, both groups of associated species occurred and these accounted for the most species-rich *Najas flexilis* lakes, having a number of species that are rare or scarce along the west coast of Ireland (e.g. Ballynakill Lough, which is also home to *Hydrilla verticillata*) (Roden, 2004). *Hydrilla verticillata* is known only from two Irish lakes, both of which also contain *Najas flexilis* (Roden, 2007). Roden and Murphy (2014) re-examined relevé data for Ireland and identified four groups: group 1 was shallow water with *Chara virgata*; groups 2 and 3 were more species-rich and differentiated, in part, by *Elatine hexandra*, *Nitella translucens* and *Hydrilla verticillata* and group 4 had low species richness, low *Najas flexilis* abundance and was found in deeper water. An on-going project on *Najas flexilis* and its associated habitat (3130) is reviewing their characteristics and requirements (Roden *et al*., in prep.). Initial findings indicate a significant association between both good *Najas flexilis* populations and high lake species richness, and clear water with a deep euphotic zone (Roden *et al*., 2016, 2017, 2018, in prep.).

Eutrophication is considered a significant pressure on the species, which grows at the lower levels of the euphotic zone and can easily be out-competed by perennials, such as pondweeds (*Potamogeton* spp.), and 'shaded' by abundant phytoplankton (Preston and Croft, 2001; Roden, 2004, 2007; Wingfield *et al*., 2004; Roden and Murphy, 2014). Acidification is also considered a threat to the species (Roden, 2004; Wingfield *et al*., 2004).

In Ireland, *Najas flexilis* is considered to be in Poor/Unfavourable - Inadequate conservation status as a result of hydromorphological change, eutrophication and impacts linked to peatland damage (Roden, 2007; NPWS, 2008; O Connor, 2013; NPWS, in prep.). Hydromorphological change mainly results from drainage for agriculture, forestry and turf-cutting, but the potential impacts of abstractions warrant further investigation (NPWS, in prep.). As well as contributing to hydrological changes, damage to peatland contributes to increased water colour and turbidity, and greater loads of dissolved and particulate organic matter. Diffuse losses from agriculture, domestic wastewater systems (septic tanks), forestry and golf courses, and point sources from urban wastewater treatment plants are considered to be the principal sources of nutrients in *Najas flexilis* catchments (O Connor, 2013; NPWS, in prep.). Competition from *Elodea canadensis* has been noted as impacting on *Najas flexilis* at a number of Irish lakes (O Connor, 2013; NPWS, in prep.). The invasive behaviour

of this non-native species may be a temporary response following introduction. Alternatively, it may be a response to eutrophication and have a longer-term impact (NPWS, in prep.). The overall trend in conservation status of *Najas flexilis* was assessed as Deteriorating for the 2013–2018 cycle, owing to two population extinctions, population decreases at a further nine lakes and decreasing habitat quality at eight lakes (Roden *et al*., in prep.; NPWS, in prep.).

1.2 Leannan River SAC

Leannan River SAC is an SAC in North Donegal, extending from Lough Gartan to Rathmelton, connecting Cloghernagore Bog and Glenveagh National Park SAC (002047) with Lough Swilly SAC (002287). The SAC comprises the River Leannan and its main tributaries and lakes, including Loughs Fern, Gartan and Akibbon. The SAC is selected for two habitats listed on Annex I of the EU Habitats Directive, and four species on Annex II, including *Najas flexilis*. All six habitats/species are aquatic, with the two habitats (3110 and 3130) found in lakes.

Najas flexilis occurs in Loughs Akibbon and Fern in Leannan River SAC. The species was first recorded in Lough Akibbon on the 22nd of September 1977 by J. Ryan, in an area to the south-east dominated by *Sparganium emersum* and near the centre of the lake with *Chara globularis* (Heuff, 1984). Since then, *Najas flexilis* has been recorded at the lake on at least seven occasions, the most recent (based on NPWS records) being the 22nd of August 2018 by C. Roden, P. Murphy and J. Ryan (Roden *et al*., in prep.). Appendix 2 presents Dr Cilian Roden's notes of his 2002 survey of Lough Akibbon, as well as sketch maps of the location of the species in the lake during that survey (Roden, 2004). Based on the 2018 survey of the lake, however, Dr Roden has revised his assessment of its conservation value owing to the relatively large population of *Najas flexilis* which is widespread across the lake bottom (C. Roden, pers. comm.). The 2018 conservation condition of *Najas flexilis* at Lough Akibbon was provisionally assessed as Poor (Unfavourable – Inadequate) owing to evidence of habitat enrichment, including increased charophyte and reedbed biomass (Roden *et al*., in prep.; NPWS, in prep.).

Najas flexilis was first recorded in Lough Fern on the 23rd July 2009 by Environmental Protection Agency (EPA) biologists. It was found again by EPA biologists in 2010, whilst the most recent record (based on NPWS data) was on the 29th August 2017 by C. Roden, P. Murphy and J. Ryan (Roden *et al*., in prep.). The 2017 conservation condition of *Najas flexilis* at Lough Fern was provisionally assessed as Poor (Unfavourable – Inadequate) owing to evidence of habitat deterioration, including large quantities of decaying organic matter and depth and coloured/turbid water (Roden *et al*., in prep.; NPWS, in prep.).

1.3 Conservation objectives

A site-specific conservation objective aims to define the favourable conservation condition of a habitat or species at site level. The maintenance of habitats and species within sites at favourable condition will contribute to the maintenance of favourable conservation status of those habitats and species at a national level.

Conservation objectives are defined using attributes and targets that are based on parameters as set out in the EU Habitats Directive for defining favourable status, namely population, range, and habitat for the species.

Note that the attributes and targets may change/become more refined as further information becomes available.

As both Lough Akibbon and Lough Fern were provisionally assessed as Poor (Unfavourable – Inadequate) conservation condition, the overall conservation objective is restore.

2. Range

The known distribution of *Najas flexilis* in Leannan River SAC is shown in Appendix 1. The species is known from Lough Akibbon and Lough Fern in the SAC.

The target for the attribute species distribution is: Maintain current range, subject to natural processes.

3. Population

Surveying and measuring populations of *Najas flexilis* is challenging (Roden, 2004, 2007; Wingfield *et al*., 2004; NPWS, 2013, in prep.; O Connor, 2013). While Roden (2007) used a five point population size scale from 'Very Large' to 'Extinct', he acknowledged that these were subjective categories and that it is very difficult to estimate population size or propose any robust or repeatable abundance estimate for the species. Wingfield *et al*. (2004) also stated that accurately measuring plant abundance to assess the condition of the population in deep water communities is extremely difficult.

The problems with *Najas flexilis* populations at lake and national scales are discussed in O Connor (2013), and include:

1. *Najas flexilis* is difficult to survey as it grows under water at depths of up to 10 m. It is often commonest and most abundant in the lower depths of the euphotic zones, where it is most difficult to survey (Roden, 2002)
2. Counting the number of individuals can only be done by snorkelling or scuba diving
3. It is generally only possible to sub-sample a population using snorkelling or scuba diving
4. The potential habitat in a lake is difficult to quantify, particularly in the absence of bathymetric data and substratum characterisation
5. The density of the plant is likely to vary within a lake[3], depending on factors from substratum particle size and geochemistry, to light penetration, to wave exposure and competition from other macrophytes, epiphyton or phytoplankton
6. There is a limited season for the survey of this annual species. Seedlings have been noted to begin to germinate in Scotland in June (Wingfield *et al*., 2004) and the plant can survive until October; however, August is generally cited as the time to survey (of the 277 records on the

[3] Roden (2002) noted that the plant can occur both as scattered individuals and as dense stands.

NPWS *Najas flexilis* database for which a month is provided, 98 were made in August and 129 in July (see O Connor, 2013)

7. The plant is fragile and easily uprooted by storm events, so the density can vary within a single growing season

8. Added to that is the evidence that inter-annual fluctuations in population size occur naturally, as well as driven by anthropogenic pressures, and are linked to factors such as seed-germination (Roden, 2007; in prep.)

As a result, assessing changes in the condition of *Najas flexilis* populations is likely to require consideration of a number of species' attributes.

Snorkelling is considered the best method for estimating the cover abundance of the species (Roden, 2007; Wingfield *et al*., 2004), and is the method recommended by the NPWS. The issues associated with, and lower reliability of, shoreline and boat surveys are documented by O Connor (2013).

Further research is required to develop detailed methods, attributes and targets for *Najas flexilis* populations. The objectives below may, therefore, be subject to change in the future.

3.1 Population extent

While the spatial extent of *Najas flexilis* within a lake may be subject to some temporal/inter-annual variations, in viable populations it should not change significantly over time. Replacement of *Najas flexilis* with other rooted macrophytes (e.g. *Potamogeton* spp. or *Elodea canadensis*) would indicate a decline in the *Najas flexilis* population. Both the area and the spatial distribution of the population should be considered.

Najas flexilis is widespread in both Lough Akibbon and Lough Fern (Roden *et al*., in prep.). At Lough Akibbon in 2018, it occurred throughout the lake, covering an area of 20–25 ha. Roden *et al*. (in prep.) observed that Lough Akibbon's shallow depth provides a very extensive area for colonisation. Surveys by EPA biologists also demonstrate the widespread extent of *Najas flexilis* at Lough Akibbon. N.F. Stewart and others found it at the 'NE end' on the 14th/16th July 1991 and at the 'SE side near E end' on the 7th September 1991. D.T. Holyoak also recorded it at the north-east corner of Lough Akibbon in August 2002. As noted above, the first records for the species from the lake (September 1977 by J. Ryan) were from the south-east and near the centre of the lake (Heuff, 1984).

In 2017, *Najas flexilis* was absent only from the north-west of Lough Fern, but it was noted that the lake was under stress, with extensive blackened, decaying vegetation and highly coloured water, and that the species may occur at greater depth and, therefore, over a larger area in more favourable periods (Roden *et al*., in prep.). They estimated that the area of *Najas flexilis* habitat could vary from a maximum of over 150 ha to a minimum of about 10 ha owing to very poor transparency (Roden *et al*., in prep.).

The target for population extent is: Maintain/restore the spatial extent of *Najas flexilis* within the lakes, subject to natural processes.

3.2 Population depth

Najas flexilis can occur at all depths between 0.5 m and 10 m, but is frequently associated with the lower depths of macrophyte growth, with scattered plants gradually giving way to bare mud or silt (Preston and Croft, 2001; Roden, 2002). Roden (2007) highlighted that depths between 1 m and 5 m are particularly important for the species. A number of anthropogenic impacts can affect light penetration and lead to decreases in the depths to which *Najas flexilis* can grow. These impacts include increasing phytoplankton biomass, water colour or turbidity. Changes to water level fluctuations as a result of abstractions or drainage can also affect *Najas flexilis* growth in more shallow water, owing to exposure and increased wave action. Consequently, the full depth range (i.e. minimum/most shallow to maximum/deepest) of the *Najas flexilis* population should be considered.

Roden *et al*. (in prep.) recorded *Najas flexilis* in relevés between 1.4 m and 2.6 m depth in Lough Akibbon in 2018 and observed that there is a very extensive area of substratum between 1.5–3.0 m available for colonisation by the species. In 1977, it was recorded in relevés at 2.3 m (#155) and at 1.7 m (#73) (Heuff, 1984), and the EPA found it between 1.4 m and 1.9 m in 2010. At Lough Fern in 2017, *Najas flexilis* was recorded in relevés between 1.3 m and 2.0 m depth (Roden *et al*., in prep.) and the EPA found it at 2.1 m in 2010. Roden *et al*. (in prep.) considered that in periods of better transparency, *Najas flexilis* would occur at greater depths in Lough Fern.

The target for population depth is: Maintain/restore the depth range of *Najas flexilis* within the lakes, subject to natural processes.

3.3 Population viability

Wingfield *et al*. (2004) used certain traits (leaf area/shoot length x reproductive number/shoot length) to assess plant fitness and indicated a score of less than one would give rise to concern. The use of plant traits to assess population fitness is recommended for *Najas flexilis* monitoring programmes. Measurement of traits can be done in the field, e.g. presence of flowers/seeds on plants, or by removing specimens, e.g. leaf area, shoot length and number of reproductive structures (Wingfield *et al*., 2004; Benthic Solutions, 2007). Plant fitness is an indicator of the viability of the population. Seed production in *Najas flexilis* appears to be reduced by both eutrophication and acidification (Wingfield *et al*., 2004).

Roden *et al*. (in prep.) noted that vegetation in deeper water at Lough Fern was blackened and decaying in 2017.

The target for population viability is: Maintain/restore the fitness of *Najas flexilis*, subject to natural processes.

3.4 Population abundance

As noted above, it is extremely challenging to get reliable, repeatable estimates of *Najas flexilis* population size. It is, however, desirable to record an estimate of the species cover abundance at all sites. Use of the DAFOR or similar categorical scale for recording the cover per square metre is advisable. Cover abundance is likely to vary within a lake, with depth, substratum and exposure. It may also vary inter-annually. Sustained, significant declines in the cover abundance of *Najas flexilis*,

however, would indicate a population decline. Changes in cover abundance over time should be monitored at a number of stations, covering a range of natural abundances, within each lake.

The widespread distribution of *Najas flexilis* at Lough Akibbon and Lough Fern indicate large populations occur in the lakes. Roden *et al*. (in prep.) recorded *Najas flexilis* cover values of up to 20% in relevés at Lough Akibbon in 2018, and concluded that the species is very abundant largely owing to the lake's shallow depth which provides a very extensive area for colonisation between 1.5m and 3.0m. While earlier estimates suggested that Lough Akibbon had a 'Large' population, on the five point scale from 'Very Large' to 'Extinct' (Roden, 2004, 2007), the more recent data indicate an estimate of 'Very Large' would have been more appropriate. Roden *et al*. (in prep.) recorded *Najas flexilis* in seven relevés in Lough Fern in August 2017, but cover values did not exceed 10% and it was absent from the north-west (Roden *et al*., in prep.). Given that Lough Fern was under stress in 2017, the population size may be larger in more favourable periods (Roden *et al*., in prep.).

The target for population abundance is: Maintain/restore the cover abundance of *Najas flexilis*, subject to natural processes.

4. Habitat for the species

Habitat for the species relates to the area and quality of the available habitat for the species. For freshwater species in Ireland, however, the area of the habitat is generally an insensitive measure of its conservation condition. In general, *Najas flexilis* habitat is more likely to be damaged rather than destroyed/lost. While lakes can be reduced in area by drainage or, for small and shallow lakes, by processes of natural succession, the most common impacts in Irish *Najas flexilis* lakes are nutrient enrichment and peat staining/deposition. As a result, most of the objectives detailed below relate to the quality of the species' habitat and include attributes such as hydrology and water quality.

The condition of the habitat of *Najas flexilis* was provisionally assessed as Poor (Unfavourable – Inadequate) in Lough Akibbon (2018) and Lough Fern (2017) (Roden *et al*., in prep.; NPWS, in prep.). J. Ryan observed that the charophytes were growing more vigorously in Lough Akibbon in 2018 than during his 1977 survey, and that density and extent of the reedbed at the southern end was indicative of enrichment. At Lough Fern, the vegetation (largely *Nitella* sp.) at depth was blackened, dead and decaying, and the water was very cloudy and coloured. As the survey took place after a storm, it is possible that the poor condition was temporary; however, EPA water quality data (see below) suggest it is more sustained.

4.1 Habitat extent

It is acknowledged that it is likely to be difficult to map and measure the area of *Najas flexilis* habitat in a lake. Both the lake area and the area of available habitat for the species within that lake should be considered. As noted above, *Najas flexilis* is widespread in both Lough Akibbon and Lough Fern, but the species habitat may extend to greater depths in Lough Fern during more favourable periods. Roden *et al*. (in prep.) estimated that the area of *Najas flexilis* habitat in Lough Akibbon is 20–25 ha, and in Lough Fern may vary from 10 ha to over 150 ha, depending on water transparency and habitat condition.

The target for the attribute habitat extent is: Maintain/restore the habitat for *Najas flexilis*, subject to natural processes.

4.2 Hydrological regime

Fluctuations in lake water level are almost ubiquitous in Ireland owing to the highly seasonal rainfall patterns. Water level fluctuations can, however, be amplified by a variety of anthropogenic activities including water abstractions, drainage of the lake outflow and drainage of the upstream catchment. Upstream drainage leads to more rapid run-off and is associated with other significant pressures, notably the degradation of peatlands, which causes the release of organic acids, ammonia and other organic matter, and the direct transport of nutrients and other pollutants to lakes.

Increased water level fluctuations can impact on *Najas flexilis,* particularly at the upper depths of growth (see also 2.2 above). The area of lake bed influenced by wave action typically increases and, hence, the substratum can be significantly altered. The results include loss of macrophyte habitat, up-rooting of plants through wave action and contraction of submerged vegetation zones. Increased fluctuations can also lead to nutrient releases from the littoral sediments as a result of exposure and re-wetting, and consequent changes in species composition. Nutrient release leading to increased phytoplankton biomass, as well as increased wave action leading to re-suspension of fine sediment, could decrease light penetration and impact on *Najas flexilis* at the lower depths of growth.

Water is abstracted from Lough Fern (McGarrigle *et al*., 2010), which may alter the natural hydrological regime.

The hydrological regime of the lake must be maintained so that the area, distribution and depth of the *Najas flexilis* habitats are not reduced.

The target for the attribute hydrological regime, water level fluctuations is: Maintain appropriate natural hydrological regime necessary to support the habitat for *Najas flexilis.*

4.3 Lake substratum quality

Najas flexilis is typically found on soft substrata of mud, silt or fine sand (Preston and Croft, 2001; Roden, 2002, 2004). An association with relatively organic, flocculent sediment is noted in the UK (Wingfield *et al*., 2004). The sediment chemistry of *Najas flexilis* lakes is described by Wingfield *et al*. (2004). *Najas flexilis* almost exclusively utilises phosphorus from the sediment; however, enrichment of the sediment appears to lead to declines/losses of the species (Wingfield *et al*., 2004). Calcium and iron concentrations in the lake sediment are also likely to influence the species distribution. Research is required to further characterise the substratum type (particle size and origin) and substratum quality (notably pH, calcium, iron and nutrient concentrations) favoured by the species in Ireland.

Roden *et al*. (in prep.) recorded substrates of fine mud, sand cobbles and rock in Lough Akibbon, but *Najas flexilis* was generally associated with mud and silt. *Najas flexilis* was also mainly found on silt in Lough Fern, but also associated with some sand and rock (Roden *et al*., in prep.). The blackened vegetation at lower depths and the cloudy water in Lough Fern in 2017 are indicative of disturbance of the substratum in the lake (Roden *et al*., in prep.).

The target for the attribute lake substratum quality is: Maintain/restore appropriate substratum type, extent and chemistry to support the population of *Najas flexilis.*

4.4 Water quality

Najas flexilis is typically associated with high water quality, i.e. the absence of eutrophication impacts. This is demonstrated by naturally low dissolved nutrients, clear water and low algal growth. Lake water quality ('Ecological Status') is measured by the EPA for Water Framework Directive (WFD) purposes using the following attributes: nutrient concentrations, phytoplankton biomass, phytoplankton composition, phytobenthos status and macrophyte status. Phytoplankton biomass and composition, phytobenthos status and macrophyte status all demonstrate biological responses to nutrient enrichment.

Significant quantities of data are available on lake water quality (eutrophication) in Ireland from the EPA and Local Authorities; however, these data are classified in accordance with general environmental (water quality) objectives and do not take into consideration the specific requirements of protected species. In particular, water clarity and colour (see section 4.6 below) may be key 'supporting conditions' for *Najas flexilis*. As a consequence, the attributes (variables/quality elements) or the targets (thresholds/standards) used may be inappropriate to assessing the quality of the habitat for *Najas flexilis*. In particular, it is thought likely that *Najas flexilis* may tolerate or even reach optimal densities in lakes that are above the oligotrophic boundary in terms of dissolved nutrients (see further discussion below). In the absence of species-specific variables and thresholds, however, the targets adopted here are 'High Status' or oligotrophic. Hence, the targets may be overly stringent. A schema is presented in Figure 2 below indicating the likely target for *Najas flexilis* within the water quality classification system required by the WFD. The more stringent targets are preferable to adopting the alternative target of the good-moderate (or eutrophic) boundary, as it is clear that *Najas flexilis* can be impacted by eutrophication well below the latter threshold. Also, when one considers that lakes regarded as in reference condition had summer chlorophyll *a* concentrations of c. 4 µg/l (Free *et al*., 2006) and given that *Najas flexilis* was formerly much more widespread in Ireland and Europe (Godwin, 1975), it is reasonable to assume that favourable and viable populations of the species existed in oligotrophic lakes before large-scale anthropogenic land-use change.

Najas flexilis is usually found in clear-water, lowland lakes (Preston and Croft, 2001). The species has been described by a number of authors as characteristic of 'mesotrophic' lakes (Preston and Croft, 2001; Wingfield *et al*., 2004, 2005; Roden, 2007). This demonstrates a disparity in the use of the term 'trophic' amongst the fields of ecological science, with botanical and phytosociological scientists using 'mesotrophic' to indicate the species' requirement for plant nutrients generally, whereas freshwater ecologists have a more restrictive definition of trophy, first established by the OECD and based primarily on concentrations of the macronutrient phosphorus in the water column (Total Phosphorus or TP) and the response as biomass of single-celled, planktonic algae (cholorophyll *a*) (OECD, 1982). The mesotrophy noted by botanists and phytosociologists reflects a requirement for certain cations, perhaps calcium and magnesium, as evidenced by the species' association with circum-neutral waters, rather than a need for significant concentrations of phosphorus or nitrogen in the lake water. As noted above, the species' association with mixed geology, including some base-enrichment, is well-documented (Preston and Croft, 2001; Roden, 2004; Wingfield *et al*., 2004). The species, in Ireland at least, appears to be strongly associated with lakes that are naturally oligotrophic, as defined by freshwater ecologists, that is, naturally low in dissolved and particulate forms of phosphorus and nitrogen.

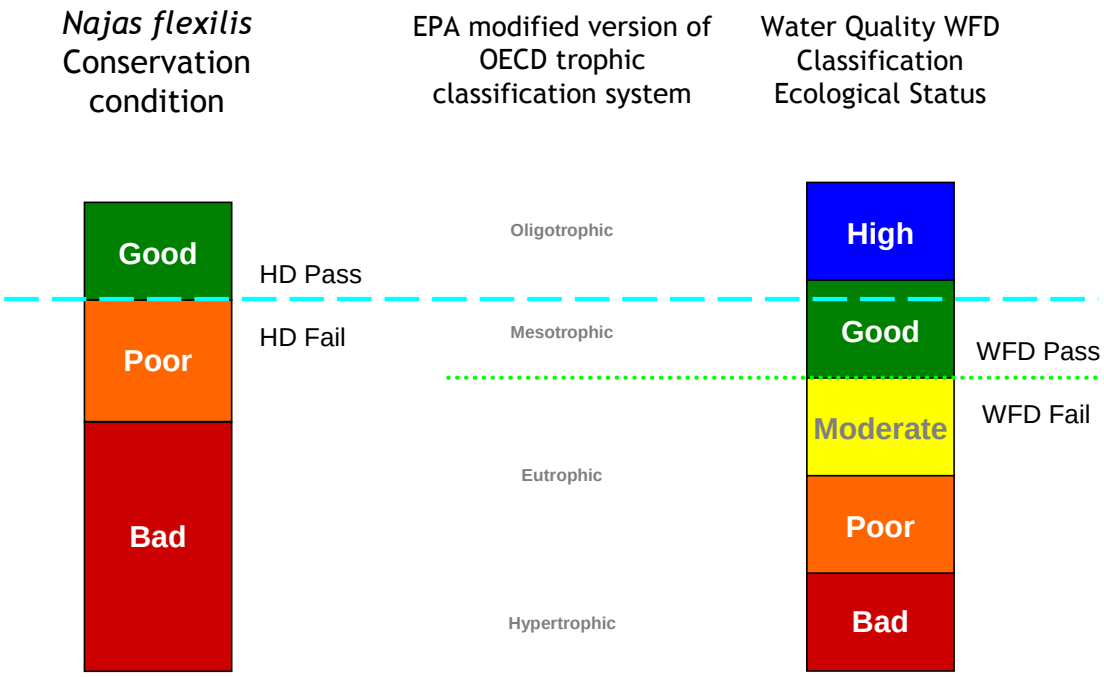

Figure 2. **The use of Water Framework Directive (WFD) water quality targets for the habitat of *Najas flexilis.*** It is likely that the most appropriate target for *Najas flexilis* water quality lies somewhere below the high-good boundary, within the slightly-mesotrophic band (based on chlorophyll *a* and/or total phosphorus measurements) (indicated by dashed blue line). This target is still significantly higher than the basic WFD pass of the good-moderate boundary (dotted green line); hence, the targets used here are equivalent to high status.

Enrichment of lake water and sediments with phosphorus and nitrogen (eutrophication) is considered a significant pressure on the species (Preston and Croft, 2001; Roden, 2004, 2007; Wingfield *et al*., 2004). Nutrient enrichment increases primary production in phytoplankton, epiphytic and epipelic algae and in vascular plants (macrophytes). All of these can compete with *Najas flexilis* for the available resources, notably light, carbon dioxide, nutrients and space/substratum. *Najas flexilis* is generally recognised as a poor competitor (Roden, 2007; Wingfield *et al*., 2004). As *Najas flexilis* is frequently found at the lower levels of the euphotic zone, "shading" by phytoplankton, taller rooted species or attached algae is a particular problem. Alkalinity, pH, calcium, magnesium and total phosphorus were all significantly higher in seven Scottish lakes from which *Najas flexilis* had been lost, where eutrophication was the suspected cause of the extinction (Wingfield *et al*., 2004).

The most common nutrient sources documented in the Irish *Najas flexilis* catchments are:

1. Agriculture
2. Domestic wastewaters from on-site systems
3. Discharges from urban wastewater treatment plants
4. Forestry
5. Golf courses

(O Connor, 2013; NPWS, in prep.).

4.4.1 Water quality: nutrients

Eutrophication is considered to have a significant negative impact on *Najas flexilis* (Preston and Croft, 2001; Roden, 2004, 2007; Wingfield *et al*., 2004). As discussed above, in the absence of specific nutrient targets for *Najas flexilis*, the default target used here is oligotrophic or high status for general nutrient conditions.

No standards have yet been set for total phosphorus in Irish lakes; however, the Irish EPA used an interim high status value of annual mean total phosphorus (TP) of less than 10 µg/l for 2007–2009 and 2010–2012 status classification (Tierney *et al*., 2010; Bradley *et al*., 2015). This same threshold was used as the oligotrophic lake standard in the Phosphorus Regulations (McGarrigle *et al*., 2002) and is the boundary used by the OECD system (OECD, 1982). Free *et al*. (2016) found that the TP concentrations for the high/good boundary ranged from 8 µg/l to 11 µg/l. As a result, an annual mean TP of <10 µg/l is considered necessary for *Najas flexilis* lakes. Where the mean TP concentrations are lower than this standard, there should be no significant increase in annual mean, i.e. no upward trend.

Total ammonia in *Najas flexilis* lakes should also be in high status as defined by Schedule Five of the European Communities Environmental Objectives (Surface Waters) Regulations (S.I. 272 of 2009), that is mean annual total ammonia of ≤ 0.040 mg N/l or annual 95th percentile of ≤ 0.090 mg N/l.

WFD nutrient condition status failed the high status target for *Najas flexilis* in Lough Akibbon, having good Total Phosphorus status in the monitoring cycles 2013–2015 (mean TP 13 µg/l), the 2010–2012 (12 µg/l) and 2007–2009 (14 µg/l) (Fanning *et al*., 2017; Bradley *et al*., 2015; McGarrigle *et al*., 2010). Ammonia status was high in all cycles.

WFD nutrient condition status was moderate in Lough Fern owing to Total Phosphorus in the monitoring cycles 2013–2015 (mean TP 34µg/l) and the 2010–2012 (27 µg/l) (Fanning *et al*., 2017; Bradley *et al*., 2015) and good (19 µg/l) in the 2007–2009 cycle (McGarrigle *et al*., 2010), thus it has consistently failed the high status target for *Najas flexilis*. Ammonia status was high in all cycles.

The target for the attribute water quality, nutrients is: Restore average annual TP concentration of ≤ 10 µg/l TP, average annual total ammonia concentration of ≤ 0.040 mg N/l and annual 95th percentile for total ammonia concentration of ≤ 0.090 mg N/l.

4.4.2 Water quality: phytoplankton biomass/chlorophyll **a**

Nutrient enrichment (with phosphorus and/or nitrogen) can promote phytoplankton growth leading to shading of *Najas flexilis* and reduced light penetration. Phytoplankton biomass is commonly measured as chlorophyll *a*. Schedule Five of the European Communities Environmental Objectives (Surface Waters) Regulations (S.I. 272 of 2009) establishes the criteria for calculating lake status using chlorophyll *a*. Two sets of thresholds are given, linked to lake types. The thresholds established for the moderate and higher alkalinity types (7, 8, 11 and 12) are considered more appropriate for *Najas flexilis* lakes. The target for *Najas flexilis* lakes is considered to be high status or oligotrophic conditions and, therefore, the mean chlorophyll *a* concentration should be less than 5.8 µg/l during the growing season (March-October). Where the cholorophyll *a* concentrations are lower than this threshold in a *Najas flexilis* lake, however, there should be no significant increase in growing season means, i.e. no upward trends.

WFD phytoplankton biomass/chlorophyll *a* status was high in Lough Akibbon in all cycles since 2007 (Fanning *et al*., 2017; Bradley *et al*., 2015; McGarrigle *et al*., 2010).

WFD phytoplankton biomass/chlorophyll *a* status was high in Lough Fern in the 2007–2009 cycle (mean 4.58 µg/l), but only good in the 2010–2012 and 2013–2015 cycles (means of 6.51 µg/l and 8.61 µg/l, respectively) (Fanning *et al*., 2017; Bradley *et al*., 2015; McGarrigle *et al*., 2010).

The target for the attribute water quality, phytoplankton biomass is: Restore average growing season (March-October) chlorophyll *a* concentration of < 5.8 µg/l.

4.4.3 Water quality: phytoplankton composition

The EPA has developed a phytoplankton composition metric for nutrient enrichment of Irish lakes. As for the other water quality attributes, the target for phytoplankton composition status is high.

Phytoplankton composition is not routinely measured in Lough Akibbon. Phytoplankton composition status at Lough Fern was good in the 2007–2009, 2010–2012 and 2013–2015 cycles (Fanning *et al*., 2017; Bradley *et al*., 2015; McGarrigle *et al*., 2010).

The target for the attribute water quality, phytoplankton composition is: Restore high phytoplankton composition status.

4.4.4 Water quality: attached algal biomass

Nutrient enrichment can favour epiphytic (attached to plants) and epipelic (attached to substratum) algal communities that can out-compete *Najas flexilis*. The cover abundance of attached algae should, therefore, be low.

In 2017, the vegetation at depth in Lough Fern was very blackened and partly decayed. It appeared to largely have been made up of *Nitella* sp., but may have included filamentous algae (Roden *et al*., in prep.).

The target for the attribute water quality, attached algal biomass is: Maintain/restore trace/absent attached algal biomass (< 5% cover).

4.4.5 Water quality: macrophyte status

Nutrient enrichment can also favour more competitive submerged macrophyte species that can out-compete *Najas flexilis*. The EPA monitors macrophyte status for Water Framework Directive purposes using the 'Free Index'. As discussed above, the default target for *Najas flexilis* adopted here is high status, defined in Schedule Five of the European Communities Environmental Objectives (Surface Waters) Regulations (S.I. 272 of 2009) as having an Ecological Quality Ratio (EQR) of ≤ 0.90.

Both lakes have consistently failed the high status target for macrophytes since 2007. Macrophyte status was moderate in Lough Akibbon in the 2007–2009 and 2010–2012, and good in 2013–2015 (McGarrigle *et al*., 2010; Bradley *et al*., 2015; Fanning *et al*., 2017). WFD macrophyte status was poor in Lough Fern in the three cycles: 2007–2009, 2010–2012 and 2013–2015 (McGarrigle *et al*., 2010; Bradley *et al*., 2015; Fanning *et al*., 2017).

As noted above, the 2018 conservation condition of *Najas flexilis* at Lough Akibbon was provisionally assessed as Poor (Unfavourable – Inadequate) owing to evidence of habitat enrichment, including

increased biomass of charophyte (more vigorous growth near outflow) and reedbed (large area to the south of the lake, with high density) (Roden *et al*., in prep.; NPWS, in prep.).

The blackened and decaying vegetation at depth in Lough Fern in 2017 indicates at least temporary impacts, possibly as a result of anoxia following enrichment.

The target for the attribute water quality, macrophyte status is: Restore high macrophyte status.

O Connor (2013) used five WFD 'quality elements' (nutrient condition, phytoplankton biomass/chlorophyll *a*, phytoplankton composition, macrophytes status and phytobenthos status) to assess the national conservation status of the habitat for *Najas flexilis* for the 2007–2012 cycle. The target was for all five elements to reach high status (lowest common denominator approach). For the 2013–2018 cycle, habitat condition data from the species-specific survey of Roden *et al*. (in prep.) were used to assess the conservation status of the habitat for the species, but the five EPA quality elements were also examined to test the applicability of WFD metrics (NPWS, in prep.). EPA WFD status data (Fanning *et al*., 2017) were available for 17 of the lakes surveyed 2014–2018 (Roden and Murphy, 2014; Roden *et al*., in prep.) and indicated better condition at three lakes, the same condition at eight and worse at six lakes, indicating that further work may be required to fully elucidate the relationship between WFD status and the conservation condition of *Najas flexilis*.

4.5 Acidification status

Acidification is considered to be a significant threat to *Najas flexilis* (Preston and Croft, 2001; Roden, 2004; Wingfield *et al*., 2004). Wingfield *et al*. (2004) noted that at pH of less than 7 the abundance of *Najas flexilis* is low. They also documented reduced reproductive capacity in more acidic conditions (pH 6.46–6.98), with seeds low in number or absent (Wingfield *et al*., 2004). The annual nature of *Najas flexilis* makes it particularly sensitive to environmental change, and year to year fluctuations in pH, alkalinity and calcium could affect seed production, promoting genetic drift and loss of genetic diversity (Wingfield *et al*., 2004). However, little is known about the seed longevity and if the seedbank is persistent, the species may be able to survive some perturbations. Wingfield *et al*. (2004) observed that pH, conductivity, alkalinity, calcium and potassium were significantly lower in two lakes from which the species appeared to have been lost owing to acidification, while sediment iron was significantly higher (Wingfield *et al*., 2004). The likely causes of acidification in Irish *Najas flexilis* catchments may include a complex mix of natural, as well as anthropogenic, factors and are discussed in detail in O Connor (2013).

Wingfield *et al*. (2004) considered that *Najas flexilis* has rather specific environmental requirements and occupies a relatively narrow realised niche in Britain and Ireland. The pH of the water ranged from 6.62–8.3 (median of 7.46) and conductivity ranged from 55–447 µS/cm (median of 235 µS/cm) at 42 lakes studied (Wingfield *et al*., 2004). Alkalinity ranged from 6.71–69.71 mg/l (median of 23.45 mg/l) at 29 lakes, and calcium concentration in the water had a range of 2.06–33.4 mg/l (median of 9.59 mg/l) at 30 lakes (Wingfield *et al*., 2004). Alkalinity data were available for some *Najas flexilis* lakes from the Irish EPA 2007–2009 water quality report (Tierney *et al*., 2010). Summary data have been re-calculated since O Connor (2013), removing lakes for which records have been rejected and populations considered extinct (NPWS, in prep.). The remaining alkalinity data for 13 lakes from Tierney *et al*. (2010) have a range of 3.3–106 mg/l, with a median of 15.2 mg/l

and average of 26.1 mg/l for. Summary data are provided in Table 1 for four Donegal lakes (Loughs Akibbon, Anure, Port and Shannagh), having overall averages of pH 7.39, conductivity 174.6 µS/cm and total alkalinity 35.3 mg/l. These are based on data provided by Donegal County Council covering the period 2006–2012. Note, these summary data have also changed since previous conservation objectives supporting documents and O Connor (2013) owing to the rejection of *Najas flexilis* records for Lough Derg.

Table 1 **Physico-chemical data for four *Najas flexilis* Donegal lakes.** Data courtesy of Donegal County Council.

Lake	**Summary**	**pH**	**Conductivity** µS/cm	**Total Alkalinity** mg/l	**Total Hardness** mg/l	**Calcium** mg/l
Akibbon	Range	6.39-8.15	90-203	19-60		7.4-23.6
	Median	7.21	138	36		12.3
	Average	7.24	136.0	38.2		12.8
	n	31	31	31		30
Anure	Range	6.89-7.26	86.4-137.2	14-14	16.2-18.1	
	Median	7.17	91.8	14	18.1	
	Average	7.12	101.8	14.0	17.4	
	n	4	4	3	3	
Port	Range	7.73-7.85	181-359	40-94	50-120.1	
	Median	7.79	184.3	40	52.5	
	Average	7.79	241.4	58.0	74.2	
	n	3	3	3	3	
Shannagh	Range	5.16*-8.44	166-265	16-52	50-52.5	
	Median	7.6	205.5	31.5		
	Average	7.5	202.5	31.8	51.3	
	n	44	46	26	2	
Overall	Range	5.16*-8.44	86.4-359	14-94	16.2-120.1	7.4-23.6
	Median	7.45	176.5	34	50	12.3
	Average	7.39	174.6	35.3	47.2	12.8
	n	82	84	63	8	30

*two measurements of pH 5.16 are given for Shannagh; however, these appear to be outliers, as all other values are above 6.6. Removing these would marginally increase the overall median and average values to 7.47 and 7.45, respectively

Wingfield *et al*. (2004) found that the calcium concentration of the sediment was a good predictor for the number of reproductive structures, an indicator of plant fitness and population viability.

Median pH values should be greater than 7 pH units. Water and sediment alkalinity and concentrations of cations (notably calcium) should be appropriate to *Najas flexilis* habitat. Further

research is required to establish more specific targets for the species, including study of intra-annual variations. The EPA also classifies Acidification/Alkalisation status in lakes and uses it in overall Water Framework Directive (WFD) status. In line with the other WFD attributes used, the target for WFD Acidification/Alkalisation status is high.

The WFD Acidification/Alkalisation statuses of Lough Akibbon and Lough Fern were high in the 2007–2009, 2010–2012 and 2013–2015 cycles (Fanning *et al*., 2017; Bradley *et al*., 2015; McGarrigle *et al*., 2010).

The target for the attribute acidification status is: Maintain appropriate water and sediment pH, alkalinity and cation concentrations to support the populations of *Najas flexilis*, subject to natural processes.

4.6 Water quality: colour

Increased water colour and turbidity decrease light penetration and can reduce the area of available *Najas flexilis* habitat, particularly at the lower euphotic depths. The primary source of increased water colour in Ireland is disturbance to peatland. Drainage of peatland for peat-cutting, agriculture and forestry, as well as overgrazing by sheep, are the primary causes of such disturbance in Ireland.

No species-specific or national standards for water colour currently exist. It is likely that the water colour in *Najas flexilis* lakes would naturally be significantly < 50 mg/l PtCo. Of the 197 lakes nationally for which data on colour were available in Free *et al*. (2006), the average and median concentrations were 41 mg/l PtCo and 33 mg/l PtCo, respectively.

Roden (2002, 2004) noted that the water in Lough Akibbon was highly coloured. Free *et al*. (2006) reported a colour of 46 mg/l PtCo for Lough Fern. Roden *et al*. (in prep.) noted that the water in Lough Fern was highly coloured and cloudy in August 2017, with a euphotic depth of around 2 m.

The target for the attribute water quality, colour is: Maintain/restore appropriate water colour to support the populations of *Najas flexilis*.

The use of the attribute water transparency and a species-specific target (in metres) would also be a useful measure of changes in light penetration. Secchi disk measurements could be used, with a target of no decrease in Secchi disk transparency. Dissolved and total organic carbon (DOC, TOC) concentrations may also prove useful measures.

4.7 Associated species

As detailed in section 1.1, *Najas flexilis* is associated with a more diverse range of macrophyte species than found in the more base-poor lakes in peatland catchments.

Heuff (1984) reports on the species associated with *Najas flexilis* in Lough Akibbon in 1977. N.F. Stewart and others surveyed the north-east end of Lough Akibbon on the 24th July 1991 and, along with *Najas flexilis,* recorded *Equisetum fluviatile, Isoetes lacustris*, *Alisma plantago-aquatica, Apium inundatum, Baldellia ranunculoides, Callitriche hamulata, C. hermaphroditica, Caltha palustris, Cardamine pratensis, Carex rostrata, Eleocharis palustris, Glyceria fluitans, Hydrocotyle vulgaris, Iris pseudacorus, Juncus acutiflorus*, *J. bulbosus, Lemna minor*, *Littorella uniflora, Lobelia dortmanna, Menyanthes trifoliata, Myosotis scorpioides, Myriophyllum alterniflorum, Nuphar lutea, Nymphaea alba, Potamogeton alpinus, P. crispus, P. gramineus, P. natans, P. obtusifolius, P. perfoliatus, P.*

polygonifolius, P. pusillus, P. x *angustifolius,* possibly *P.* x *nitens, Potentilla palustris, Ranunculus flammula, Schoenoplectus lacustris, Sparganium angustifolium, S. erectum, Utricularia vulgaris*, *Fontinalis antipyretica, Chara virgata* and *Nitella flexilis*. N.F. Stewart, with M. Hughes, again visited the lake on the 7th September 1991 and recorded the following species at the south-east side near the eastern end: *Equisetum fluviatile, Isoetes lacustris*, *Pilularia globulifera*, *Apium inundatum, Baldellia ranunculoides, Callitriche hamulata, C. hermaphroditica, Carex rostrata, Elatine hexandra, Juncus bulbosus, Littorella uniflora, Najas flexilis, Potamogeton crispus, P. perfoliatus, Schoenoplectus lacustris, Sparganium erectum, Utricularia vulgaris*, *Fontinalis antipyretica, Chara virgata* and *Nitella flexilis*. Appendix 2 lists the associated species recorded by Roden (2002, 2004), which included: *Callitriche hermaphroditica, Elatine hexandra, Littorella uniflora, Potamogeton berchtoldii, Potamogeton lucens, Potamogeton perfoliatus*, *Fontinalis antipyretica, Chara virgata, Nitella confervacea, Nitella flexilis*. Roden *et al*. (in prep.) recorded the following species in Lough Akibbon in 2018: *Equisetum fluviatile, Isoetes lacustris, Alisma plantago-aquatica, Callitriche hermaphrodita, Elatine hexandra, Eleocharis palustris, Littorella uniflora, Myriophyllum alterniflorum, Najas flexilis, Nymphaea alba, Nuphar lutea, Phragmites australis, Potamogeton alpinus, Potamogeton crispus, Potamogeton gramineus, Potamogeton lucens, Potamogeton obtusifolius, Potamogeton perfoliatus, Potamogeton pusillus, Potamogeton* x *zizii, Sparganium angustifolium, Utricularia* sp., *Fontinalis antipyretica, Chara virgata, Nitella confervacea, Nitella flexilis*. Roden *et al*. (in prep.) stated that Lough Akibbon has a maximum depth of 3 m and, consequently, vegetation nearly covers the entire lake bed. Sheltered shores support dense beds of *Schoenoplectus lacustris* and *Equisetum fluviatile* (and nearby small patches of *Nymphaea* and *Nuphar*), while more exposed shores support *Littorella uniflora*, with *Isoetes lacustris* occurring below 1 m (Roden *et al*., in prep.). Large beds of *Chara virgata* occur at depths of greater than 1 m in the south-west, which give way to extensive areas of a community of *Najas*, *Nitella* and *Callitriche* (Roden *et al*., in prep.). They noted that the vegetation found with *Najas flexilis* is species-rich and includes *Nitella confervacea*, *Nitella flexilis*, *Callitriche hermaphroditica* and *Potamogeton* spp. (Roden *et al*., in prep.).

Roden *et al*. (in prep.) recorded the following species in Lough Fern in 2017: *Equisetum fluviatile, Alisma plantago-aquatica, Callitriche brutia* subsp. *hamulata, Callitriche hermaphrodita, Elodea canadensis, Lemna minor, Littorella uniflora, Myriophyllum spicatum, Najas flexilis, Nuphar lutea, Phragmites australis, Potamogeton alpinus, Potamogeton berchtoldii, Potamogeton crispus, Potamogeton natans, Potamogeton obtusifolius, Potamogeton perfoliatus, Potamogeton pusillus, Schoenoplectus lacustris, Sparganium emersum, Fontinalis antipyretica, Chara aspera, Chara virgata* and *Nitella* ?*spanioclema*. Roden *et al*. (in prep.) stated that *Phragmites* and *Schoenoplectus* beds occur mainly at the south end of the lake and most of the shore is rocky with abundant *Littorella*, and *Chara aspera* common in slightly deeper water (> 1.0 m). Below 1 m, *Nitella* dominates, with *Elodea canadensis*, *Potamogeton* spp. and occasional *Najas flexilis*. As noted above, the vegetation at depth in Lough Fern was blackened and decaying in 2017 (Roden *et al*., in prep.).

Competition from both native and non-native species is a potential threat to *Najas flexilis*. Roden *et al*. (in prep.) have particularly noted competition from *Elodea canadensis* (see also NPWS, in prep.). Wingfield *et al*. (2004) noted competition by the native species *Myriophyllum alterniflorum* and *Chara* spp. as possibly impacting on *Najas flexilis* in a Scottish Loch. Competition from native species could be part of a natural lake-succession or, more likely, promoted by environmental disturbances such as eutrophication. Eutrophication will inevitably convey an advantage on invasive non-native

and native perennial species. Wingfield *et al*. (2004) observed that competition is not always a problem, but is more likely to be where nutrients and light promote excessive growth. The issue of competition from both native and non-native species is discussed further in O Connor (2013).

The target for the attribute associated species is: Maintain/restore appropriate associated species and vegetation communities to support the population of *Najas flexilis.*

4.8 Fringing habitat

Fringing habitats are an integral part of the structure and functioning of lake systems. Most lake shorelines have fringing habitats of reedswamp, other swamp, fen, marsh or wet woodland that intergrade with and support the lake habitat. Fringing habitats can contribute to the aquatic food web (e.g. allochthonous matter such as leaf fall), provide habitat (refuge and resources) for certain life-stages of fish, birds and aquatic invertebrates, assist in the settlement of fine suspended material, protect lake shores from erosion and contribute to nutrient cycling. Equally, fringing habitats are dependent on the lake, particularly its water levels, and support wetland communities and species of conservation concern. It must also be cautioned that expansion in the area and/or density of reedbeds (*Schoenoplectus lacustris* and *Phragmites australis*) may indicate eutrophication impacts.

The target for the attribute fringing habitat is: Maintain the area and condition of fringing habitats necessary to support the population of *Najas flexilis*.

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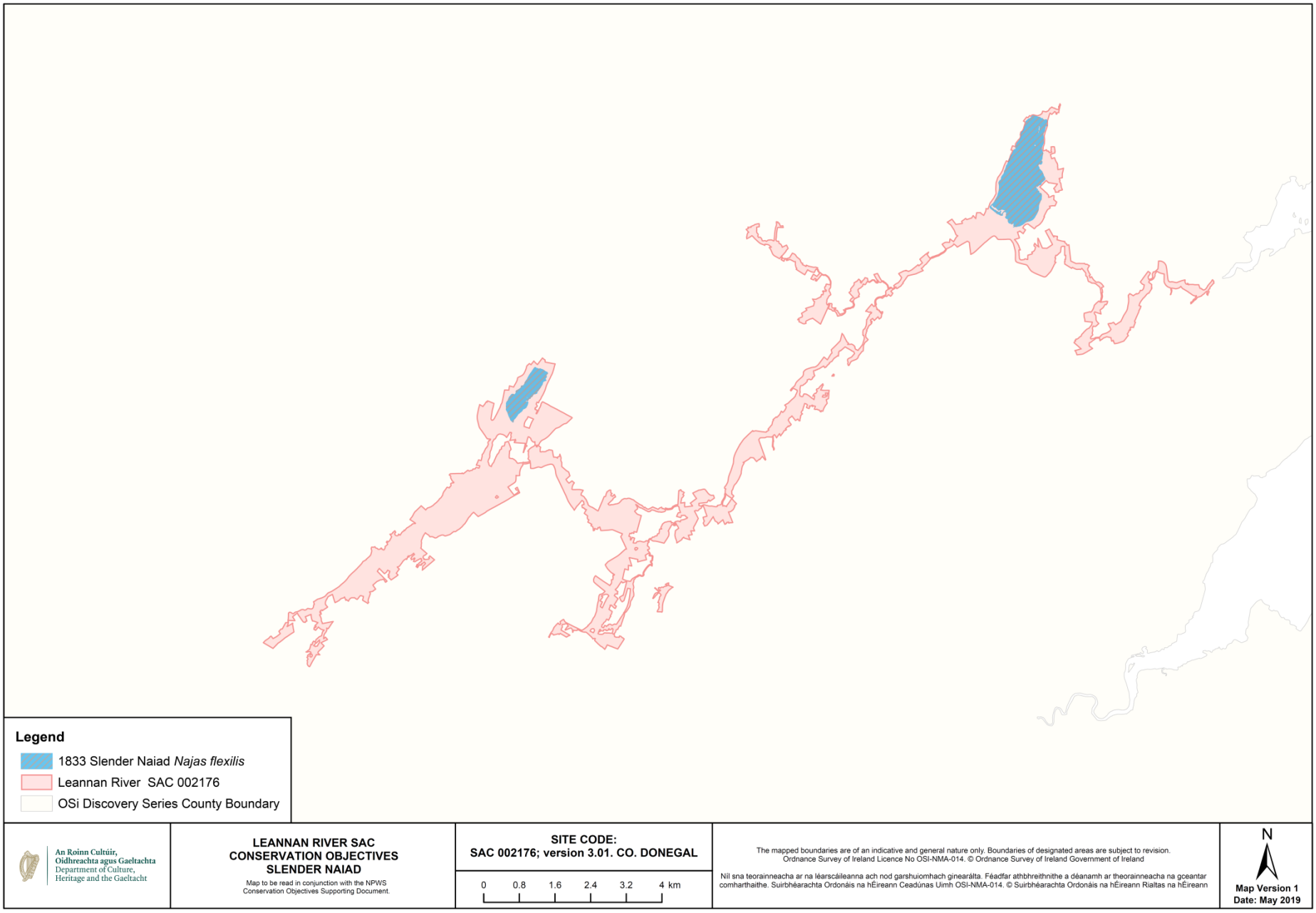
Appendix 1 *Najas flexilis* distribution map within Leannan River SAC



Appendix 2 Notes of *Najas flexilis* surveys of Lough Akibbon by Dr Cilian Roden

Najas flexilis	**Discovery series map:** 6	**Grid reference:** C074190
Locality: Lough Akibbon	**Vice county:** H35	**SAC/NHA name & no: 002176**
Date: 01/08/2002	**Recorder:** Cilian Roden	

Site description: Lough Akibbon is a large dystrophic lake surrounded by hills. The northeast end is floored with sand gravel and silt. The water is strongly stained with bog runoff. The greatest depth recorded was 4 m.

Population: A sparse population was found at the northeast end midway between the east and west shores at a depth of 4 m. Given the large size of the lake, the total population may be large (>1000 plants).

Vegetation: The plant occurs with *Nitella batrachosperma*, *Nitella flexilis*, *Potamogeton berchtoldii* and *Potamogeton perfoliatus*. Only the two *Nitella* species occur in any great density.

Management:

Threats: No obvious threats

Access: By track from the road to the east of the lake.

Conservation: The lake is an unusual habitat for *Najas* which tends to occur in clearer and less oligotrophic sites.

Remarks: The most inland and dystrophic site in Donegal for *Najas*.