NPWS

Connemara Bog Complex SAC

(site code 2034)

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

Version 1

October 2015

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1. Introduction

1.1 *Najas flexilis*

Najas flexilis (Willd.) Rostk. & W.L.E. Schmidt (species code 1833) is a small, annual, submerged macrophyte of freshwater lakes that is listed on Annex II and IV of the Habitats Directive. In Ireland, the species is also protected under the Wildlife Acts (1976 and 2000), being listed on the Flora Protection Order (S.I. 94 of 1999).

Globally, *Najas flexilis* 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) and since then it has been recorded in approximately 65 lakes in counties Donegal, Leitrim, Mayo, Galway and Kerry. Since the review of its distribution in 2013 (NPWS, 2013b), it has been found in four additional lakes in Connemara, two of which are in the Connemara Bog Complex SAC (Roden, 2014; Roden and Murphy, 2014). Connemara appears to be the species' Irish stronghold, having records from approximately 36 lakes (see Figure 1). Most of the known *Najas flexilis* lakes are located near the western fringe, with the exception of some of the larger lakes such as Loughs Glenade, Corrib (Upper) and Leane. NPWS (2013b) concluded that the species was extinct from three of the known lakes. Roden and Murphy (2014) provided new information indicating that the species has been lost from an additional three lakes.

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 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, 2004). Catchment geology may influence the distribution 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.

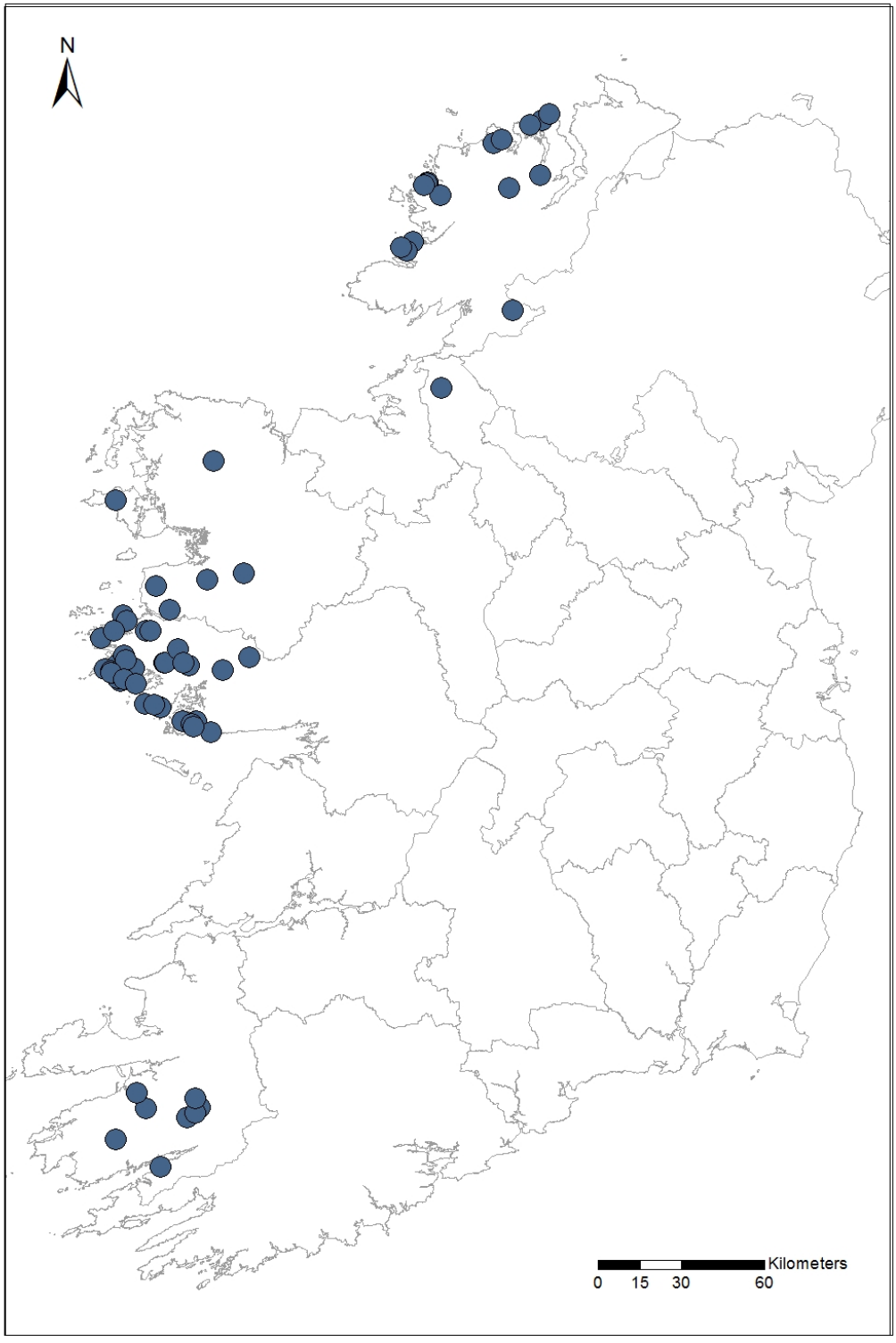

Figure 1. **The distribution of *Najas flexilis* in Ireland.** Based on the centroids for the 65 lakes with records for the species.

Najas flexilis is not found in marl or other hard water lakes (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 Habitats Directive Annex I habitat 3130 (Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *Isoeto-Nanojuncetea*).

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). 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).

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). 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/inadequate conservation status as a result of eutrophication and impacts linked to peatland damage (Roden, 2007; NPWS, 2008, 2013b; O Connor, 2013). Diffuse losses from agriculture and domestic wastewater systems (septic tanks) and point sources from urban wastewater treatment plants are considered the principal sources of nutrients in *Najas flexilis* catchments (NPWS, 2013b; O Connor, 2013).

1.2 Connemara Bog Complex SAC

The Connemara Bog Complex SAC (site code 2034) is a large site in County Galway, encompassing much of the south Connemara lowlands. It is dominated by extensive areas of peatland, particularly blanket bog and wet heath, but also has large numbers of lakes and rivers, coastal lagoons and significant areas of woodland. The site is selected for 14 habitats listed in Annex I of the Habitats Directive and four species in Annex II, including *Najas flexilis*.

Connemara Bog Complex SAC has more than 1,100 freshwater lakes and ponds (based on the OSi 1:5,000 IG vector dataset WaterPolygons feature class). There are records for *Najas flexilis* from 11 lakes across the site (at least six catchments), although one population is presumed extinct and the status of records from three other lakes is uncertain (see Table 1). Appendix 1 maps the distribution of the 11 lakes, and each is discussed in turn below, dealing first with those associated with the Roundstone Blanket Bog. It is important to state that the species is likely to be more widespread in the site, as only a small number of the lakes have been surveyed.

Records for *Najas flexilis* from the Roundstone Blanket Bog area of the site are for Derrywaking Lough, Lough Anillaunlughy, Lough Nafeakle, Lough Nalawney, Lough Truska, Lough Sruffauncam and Maumeen Lough. *Najas flexilis* was recorded in Lough Nafeakle in 1977, but is believed to have gone extinct before the Habitats Directive came into force. The cause of the extinction is considered to be eutrophication from a fish farm in the upstream Beaghcauneen Lough. The exact date of the extinction from the lake is unknown, however the species was not found in 1995, 1999 or 2000, and the fish farm was evident in the 1995 orthophotograph. It is considered possible that the species could re-establish in Nafeakle (Jim Ryan, pers. comm.).

Table 1 Lakes with records for *Najas flexilis* in the Connemara Bog Complex SAC

Name	Alternative names	EPA water body code	Status of population
Roundstone Blanket Bog			
Derrywaking Lough	Derrywaking Lough large	32_346	Extant
Lough Anillaunlughy		31_169	Uncertain
Lough Nafeakle		32_318	Presumed extinct
Lough Nalawney		31_35	Extant
Lough Sruffauncam	[unnamed]	32_335	Uncertain
Lough Truska		31_1063	Uncertain
Maumeen Lough	Loch Mháimín	31_189	Extant
Other			
Loch Chluain Toipín	Shannaghcloontippen Lough	31_47	Extant
Loch na Cúige Rua West	Lough Nacoogarrow	31_7	Extant
Loch na Cúige Rua East	Lough Nacoogarrow	31_85	Extant
Lough Bofin	Bofin GY	30_335	Extant

The species was first recorded in Derrywaking in 1989 by Jim Ryan and Caitríona Douglas (Douglas *et al*., 1989). It was surveyed by Cilian Roden on the 28th of July 2004 (see Appendix II for his survey notes). On both occasions *Najas flexilis* was recorded in the south-eastern part of lake. Dr Roden described it as a small population. Derrywaking is in the Derryehorraun River catchment.

Jim Ryan recorded *Najas flexilis* in Lough Anillaunlughy, a lake in the Roundstone blanket bog complex (J.B. Ryan, pers. comm.). He is uncertain of the date the species was found, however it was probably sometime in the 1980s. He is also uncertain of the exact location of the record and suggested to Dr Cilian Roden that it may have been in a neighbouring lake (Roden and Murphy, 2014). Roden and Murphy (2014) surveyed an area of Lough Anillaunlughy, as well as parts of three nearby lakes and did not find *Najas flexilis*. The authors said the vegetation of Lough Anillaunlughy indicated that the lake is too oligotrophic for the species, however they noted the occurrence of *Najas* flexilis in the nearby Lough Nalawney. It appears that Lough Anillaunlughy is in the same

catchment as Loughs Nalawney and Truska, but there is significant uncertainty as to catchment boundaries within the bog complex.

Jim Ryan also recorded *Najas flexilis* in Lough Nalawney on the 1st of August 1977. He described it as widespread over lake bed. Roden and Murphy (2014) surveyed the lake in August 2014 and found a large population (> 100 plants) of *Najas flexilis* in the eastern basin. As noted above, Nalawney appears to be in the same catchment as Loughs Anillaunlughy and Truska.

van Groenendael *et al*. (1979,) recorded *Najas flexilis* in Lough Sruffauncam (page 136) on the 29th of September 1975 and in Lough Truska (page 133) on the 6th of August 1975. Roden and Murphy (2014) conducted thorough surveys of Loughs Sruffauncam and Truska for *Najas flexilis* and the species did not occur in either lake (Roden and Murphy, 2014). The authors noted that neither lake had suitable habitat for the species; the vegetation of both being typical of oligotrophic peaty lakes [Annex I habitat type 3110], with species including *Lobelia dortmanna*, *Eriocaulon aquaticum*, *Isoetes lacustris* and *Nitella translucens* (Roden and Murphy, 2014). Furthermore, there was no evidence of environmental degradation in these remote, Roundstone bog lakes (Roden and Murphy, 2014). Dr Cilian Roden corresponded with Jan van Groenendael during the 2014 project to learn more about the 1975 records. Prof van Groenendael examined original notebooks and relevé data from 1975, and found that the species was recorded in relevé 764 in Lough Truska, but could find no record for *Najas flexilis* in Lough Sruffauncam (J. van Groenendael, pers. comm.). He also acknowledged that the species could have been incorrectly identified. No herbarium was kept from the 1975 survey (J. van Groenendael, pers. comm.).

Najas flexilis was recorded in Maumeen Lough on the 2nd of September 2005 by Cilian Roden. Again, the lake is in the Roundstone blanket bog complex, but is located closer to the coast than the other lakes listed in Table 1. It may form a sub-catchment of the larger catchment containing Loughs Anillaunlughy, Nalawney and Truska. Dr Roden considered Maumeen Lough to have a large *Najas flexilis* population.

The geology of the Roundstone Blanket Bog is complex, being dominated by Ordovician rocks. The 'Delaney Dome Meta-rhyolite Formation' is composed of metamorphosed volcanics of granitic type, however the records for *Najas flexilis* are primarily associated with the more basic metagabbro suite (Connemara Metagabbro and Gneiss Complex). The influence of the bedrock geology on lake ecology is limited, however, by the dominant coverage of Atlantic blanket bog. Roden and Murphy (2014) suggested that topography could play a key role, with extended slopes providing sufficient contact time between outcropping rock and run-off to enrich the hydrochemistry of some lakes. The outcropping on Errisbeg that surrounds Lough Nalawney was a noted example (Roden and Murphy, 2014). It is considered likely, given the ulatrabasic geology, the occurrence of outcrops and the very large number of lakes, that *Najas flexilis* occurs in more lakes within the Roundstone Blanket Bog. The possibility must also be considered that some of these lakes have very small and even intermittent or transient populations that are very difficult to detect.

Najas flexilis was first recorded in Loch Chluain Toipín in 2014 by Cilian Roden (Roden, 2014). Roden (2014) described the population as very large (possibly > 10,000 plants) and its habitat, where examined, as shallow (2 – 2.5 m), soft sediment with extensive beds of macrophytes and having very clear water. The lake appears to lie within the catchment that discharges to the sea at Camus bay.

Roden (2014) also made the first records for the species in Loch na Cúige Rua. This lake is separated into two basins (east and west) by the R340 and *Najas flexilis* was found in each. A very large population (possibly > 10,000 plants) occurred in the eastern basin, and some plants in the western basin (Roden, 2014). Loch na Cúige Rua east and west appear to be within the complex Recess-Ballynahinch system.

Najas flexilis was first recorded in Lough Bofin, within the Owenriff (Corrib) catchment, by lake biologists of the Environmental Protection Agency (EPA) in 2007. The species was found in two positions on transect 5 at the north-western end of the lake on the 31st of July 2007. It was frequent (cover abundance using DAFOR scale) at 1.9 m depth and rare at 1.3 m. EPA lake biologists again recorded *Najas flexilis* in Lough Bofin on the 17th of August 2010, this time on two separate transects on semi-exposed shores. It was occasional on mud substrata at 1.8 m depth on transect 5, again at the north-western end of the lake. It was also occasional at 2.6 m depth on transect 3, about mid-way along the long southern shoreline.

It must be reiterated, however, that given the number of lakes and ponds in the Connemara Bog Complex SAC and the geology of the area, it is probable that the species is far more widespread in the site.

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 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.

2. Population

Population size is a challenging concept for a somewhat cryptic annual such as *Najas flexilis*. Data on the populations in the Connemara Bog Complex SAC are limited, with little known of the population sizes. Roden and Murphy (2014) considered the population in Nalawney to be large, exceeding 100 plants. Roden (2014) recorded very large populations (each possibly > 10,000 plants) in Loch Chluain Toipín and Loch na Cúige Rua East, with 'some plants' in Loch na Cúige Rua West. Roden (2004, 2007) considered Derrywaking Lough to support a 'small' population of *Najas flexilis*, on his five point scale from 'Very Large' to 'Extinct', however, 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 said that accurately measuring plant abundance to assess the condition of the population in deep water communities is extremely difficult.

The problems with estimating the size of *Najas flexilis* populations at lake and national scale 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[1], 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 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)

As a result, it is likely to be impossible to make statistically robust estimates of the number of mature individuals for a population of *Najas flexilis*. This means that using estimates of the number of mature individuals is not an appropriate method for assessing changes in the condition of *Najas flexilis* populations.

Surveying for *Najas flexilis* is challenging, given that it lives fully submerged (no floating or emergent leaves or flowers). 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.

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

2.1 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.

The target for population, extent is: No change to the spatial extent of *Najas flexilis* within each lake, subject to natural processes.

2.2 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 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. min./most shallow to max./deepest) of the *Najas flexilis* population should be considered.

The target for population, depth is: No change to the depth range of *Najas flexilis* within each lake, subject to natural processes.

2.3 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).

The target for population, viability is: No change to the fitness of *Najas flexilis*, subject to natural processes.

2.4 Population abundance

As noted above, it is extremely difficult if not impossible 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 target for population, abundance is: No change to the cover abundance of *Najas flexilis*, subject to natural processes.

3. Range

The known distribution of *Najas flexilis* in the Connemara Bog Complex SAC is discussed in Section 1.2 and shown in Appendix 1. As explained in Section 1.2, it is probable that the species is far more widespread in the site, as few of the lakes and ponds have been surveyed. The conservation objective for *Najas flexilis* range is for the species to continue to occupy all lakes in which it occurs.

The target for the attribute species distribution is: no decline, 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.

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.

The target for the attribute habitat extent is: No decline, 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.

The hydrological regime of the lakes 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.

The target for the attribute lake substratum quality is: Maintain appropriate substratum type, extent and chemistry to support the populations 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. Water quality can be measured by 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 Environmental Protection Agency (EPA) and Local Authorities, however these data are classified in accordance with general environmental (water quality) objectives and do not take consideration of the specific requirements of protected species. 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. In the absence of species-specific variables and thresholds, however, the targets adopted 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 Water Framework Directive. 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^{-1} (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.

Further surveillance of population and habitat condition is necessary to determine whether the WFD quality elements are appropriate measures for the habitat of *Najas flexilis* and whether the WFD boundaries can be used to determine that habitat's condition.

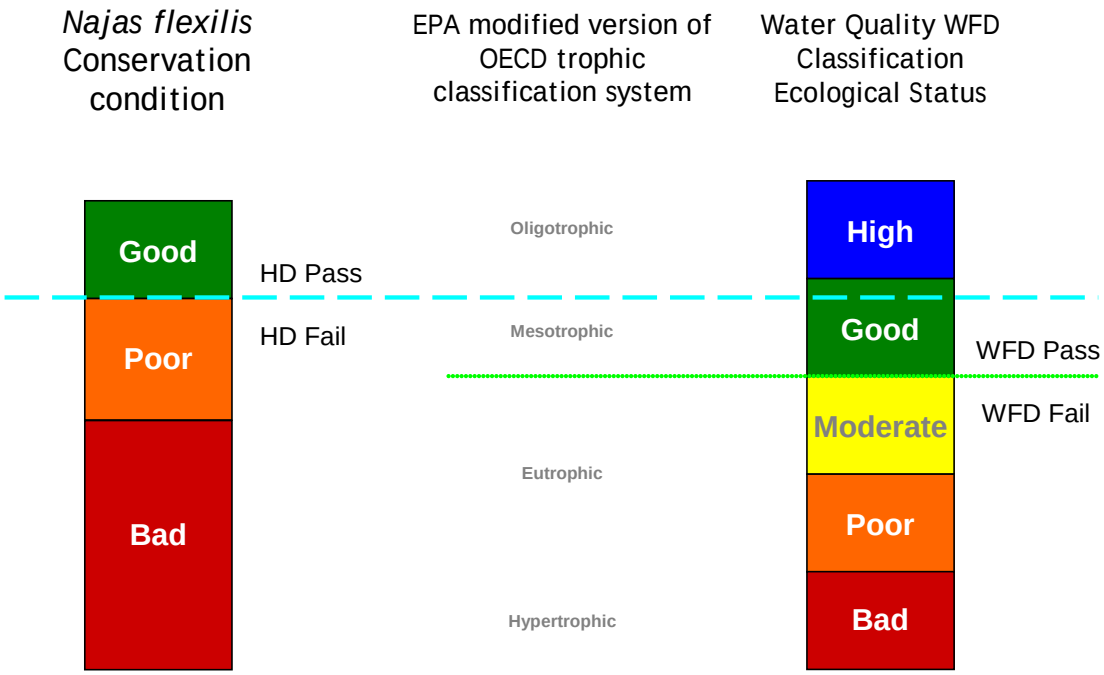

Figure 2. **The use of Water Framework Directive water quality targets for the habitat of *Najas flexilis.*** It is likely that the most appropriate target for *Najas flexilis* water quality lies somewhere below the high-good boundary, within the slightly-mesotrophic band (based on chlorophyll *a* and/or 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.

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 in the water column of the macronutrient phosphorus (Total Phosphorus or TP) and the biomass of single-celled, planktonic algae (chlorophyll *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, 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.

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. pH, alkalinity, 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. Other wastewater discharges
5. Golf courses
6. Forestry

(O Connor, 2013).

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 has used an interim high status value of annual mean total phosphorus (TP) of less than 10 µg l^{-1} for 2007-2009 status classification (Tierney *et al*., 2010). This same threshold was used to as the oligotrophic lake standard in the Phosphorus Regulations (McGarrigle *et al*., 2002). As a result, an annual mean TP of < 10 µg l^{-1} is considered necessary for *Najas flexilis* lakes. Where the mean TP concentrations are lower than this standard, there should be no increase in annual mean, i.e. no upward trends.

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^{-1} or annual 95th percentile of ≤ 0.090 mg N l^{-1}.

The target for the attribute water quality, nutrients is: Maintain average annual TP concentration of ≤10µg l^{-1} TP, average annual total ammonia concentration of ≤ 0.040 mg N l^{-1} and annual 95th percentile for total ammonia concentration of ≤ 0.090 mg N l^{-1}.

4.4.2 Water quality: phytoplankton biomass

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 currently considered to be high status or oligotrophic conditions and, therefore, the mean chlorophyll *a* concentration should be less than 5.8 µg l^{-1} during the growing season (March-October). Where the chlorophyll *a* concentrations are lower than this threshold in a *Najas flexilis* lake, however, there should be no increase in growing season means, i.e. no upward trends.

The target for the attribute water quality, phytoplankton biomass is: Maintain average growing season (March-October) chlorophyll *a* concentration of < 5.8 µg l^{-1}.

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.

The target for the attribute water quality, phytoplankton composition is: Maintain 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.

The EPA monitors the phytobenthos status of Irish lakes for Water Framework Directive purposes. Phytobenthos status can be used as an indicator of increases in attached algal biomass. As discussed above, in the absence of targets for *Najas flexilis*, the default target used here is high status.

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

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 a Ecological Quality Ratio (EQR) of ≤ 0.90.

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

O Connor (2013) used these five indicators ('quality elements') of water quality to assess the national conservation status of the habitat for *Najas flexilis*. For the habitat quality to be in favourable condition in terms of nutrients and eutrophication, the target was for all five elements to reach high status. This use of a lowest common denominator approach was in keeping with classification under the WFD, which is based on the lowest status classes for a range of specified biological, physico-chemical and hydromorphological quality elements (Tierney, *et al*. 2010).

4.5 Acidification status

Acidification is considered 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 <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 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^{-1} (median of 235 µS cm^{-1}) at 42 lakes studied (Wingfield *et al.*, 2004). Alkalinity ranged from 6.71 - 69.71 mg l^{-1} (median of 23.45 mg l^{-1}) at 29 lakes, and calcium concentration in the water had a range of 2.06 - 33.4 mg l^{-1} (median of 9.59 mg l^{-1}) at 30 lakes (Wingfield *et al.*, 2004). Alkalinity data are available for 18 *Najas flexilis* lakes from the Irish EPA 2007-2009 water quality report (Tierney *et al*., 2010) demonstrating a wider range of 2.5 – 106 mg l^{-1}, with a median of 13.2 mg l^{-1} and average of 25 mg l^{-1}. Summary data are provided in Table 2 for five Donegal lakes (Loughs Akibbon, Anure, Derg, Port and Shannagh), having overall averages of pH 7.12, conductivity 133.6 µS cm^{-1} and total alkalinity 24.4 mg l^{-1}. These are based on data provided by Donegal County Council covering the period 2006-2012. Interestingly, 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 status. In line with the other WFD attributes used, the target for WFD Acidification/Alkalisation status is high.

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.

Table 2 **Physico-chemical data for five *Najas flexilis* Donegal lakes.** Data courtesy of Donegal CC.

Lake	Summary	pH	Conductivity µS cm^{-1}	Total Alkalinity mg l^{-1}	Total Hardness mg l^{-1}	Calcium mg l^{-1}
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	
Derg	Range	5.73-7.42	43.2-68.8	1-34		1.3-4.8
	Median	6.57	52	6		1.9
	Average	6.61	53.6	8.4	8.82	2.1
	n	43	43	43	1	30
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	43.2-359	1-94	8.8-120.1	1.3-23.6
	Median	7.21	139	28	50	6.1
	Average	7.12	133.6	24.4	42.9	7.5
	n	125	127	106	9	60

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 over-grazing 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 < 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.

The target for the attribute water quality, colour is: Maintain 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.

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. *Najas flexilis* records have been made in 11 lakes in the Connemara Bog Complex, although the species is likely to be more widespread (see also Sections 1.2 and 3). The known associated species are detailed below.

Appendix 2 includes some of Cilian Roden's notes of his survey of Derrywaking Lough. The following associated species were recorded *Chara virgata, Eriocaulon aquaticum, Isoetes lacustris, Juncus bulbosus, Littorella uniflora, Lobelia dortmanna, Najas flexilis, Nitella confervacea, Nitella flexilis, Nymphaea alba, Potamogeton berchtoldii, Potamogeton natans, Sparganium angustifolium* and *Utricularia* sp., (Roden, 2004).

No data are available on the other macrophyte species associated with *Najas flexilis* at the time the record was made in Lough Anillaunlughy. Roden and Murphy (2014) did not record *Najas flexilis* in the lake, but noted *Isoetes* sp., *Lobelia dortmanna, Eriocaulon aquaticum* and *Juncus bulbosus*, and considered the vegetation community to be too oligotrophic for *Najas flexilis*.

No data are available on the other macrophyte species associated with *Najas flexilis* at the time the records were made by Jim Ryan in Lough Nalawney. Lough Nalawney was surveyed in 1975 by the Dutch ecologists, but *Najas flexilis* was not recorded on that occasion (van Groenendael *et al*., 1979). van Groenendael *et al*. (1979) concentrated on phytosociological classification of the vegetation of the lakes and wetlands studied, and did not use either diving (snorkelling/SCUBA) or grapnels/rakes to survey lake vegetation. The *Isoeto-Lobelietum* vegetation unit was recorded on the western side of Lough Nalawney, with *Phragmites australis* and *Cladium mariscus* (van Groenendael *et al*., 1979). *Potamogeton natans* and *Nymphaea alba* were found on the lake margins. Roden and Murphy (2014) did record *Najas flexilis* with *Utricularia* sp. at depth, as well as *Eriocaulon aquaticum, Lobelia dortmanna* and *Isoetes* sp. in shallower water, *Juncus bulbosus* and occasional *Potamogeton perfoliatus*.

van Groenendael *et al*. (1979) found the *Isoeto-Lobelietum* vegetation unit dominated Lough Sruffauncam, with the emergents *Cladium mariscus, Schoenoplectus lascustris* and *Phragmites australis* also recorded. Roden and Murphy (2014), who considered the lake an unlikely site for *Najas flexilis*, recorded *Lobelia dortmanna, Eriocaulon aquaticum, Isoetes sp*., *Nitella translucens* and *Nitella confervacea*.

In their lake description, van Groenendael *et al*. (1979) noted that the main vegetation type in Lough Truska was the *Isoeto-Lobelietum* in its typical form, and this formed dense mats with *Eriocaulon aquaticum* on the western side of the lake. On the eastern side, the vegetation was more open and dominated by *Lobelia dortmanna* and *Littorella uniflora*. *Cladium mariscus* and *Schoenoplectus lacustris* were also recorded (van Groenendael *et al*., 1979). Roden and Murphy (2014) again recorded *Eriocaulon aquaticum, Lobelia dortmanna, Littorella uniflora* and *Isoetes* sp., as well as *Nitella translucens*.

There are no data available on the species found in association with *Najas flexilis* at Maumeen.

Roden (2014) recorded the following species in Loch Chluain Toipín: *Chara virgata, Equisetum fluviatile, Eriocaulon aquaticum, Isoetes echinospora, Juncus bulbosus, Nitella translucens, Nuphar lutea, Nymphaea alba, Phragmites australis, Potamogeton berchtoldii, Potamogeton natans, Potamogeton obtusifolius, Potamogeton perfoliatus, Schoenoplectus lacustris, Sparganium angustifolium* and *Utricularia cf. australis.*

Roden (2014) recorded the following species in Loch na Cúige Rua West: *Apium inundatum, Baldellia ranunculoides, Chara virgata, Eriocaulon aquaticum, Isoetes echinospora, Isoetes lacustris, Juncus bulbosus, Littorella uniflora, Lobelia dortmanna, Potamogeton berchtoldii* and *Utricularia cf australis.*

Roden (2014) recorded the following species in Loch na Cúige Rua East: *Chara virgata, Elatine hexandra, Eriocaulon aquaticum, Isoetes lacustris, Lobelia dortmanna, Nitella translucens, Nymphaea alba, Potamogeton berchtoldii, Potamogeton perfoliatus* and *Potamogeton* x *zizii*.

Table3 shows the species recorded with *Najas flexilis* in Lough Bofin by the EPA.

Table 3 **Species recorded by the EPA at sampling positions with *Najas flexilis*, along transects in Lough Bofin in the Connemara Bog Complex SAC.** Source: EPA data files. Cover values are provided using a DAFOR scale.

Sample	**Transect 5 Position 5**	**Transect 5 Position 6**	**Transect 3 Position 7**	**Transect 5 Position 6**
Date	31/07/2007	31/07/2007	17/08/2010	17/08/2010
Najas flexilis	R	F	O	O
Fontinalis antipyretica			O	
Isoetes lacustris	F	A	O	F
Nitella sp.		F	O	F
Potamogeton berchtoldii	R	O		
Potamogeton perfoliatus			F	
Sparganium sp.				O
Utricularia sp.				O

Competition from both native and non-native species is a potential threat to *Najas flexilis*. 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 appropriate associated species and vegetation communities to support the populations 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.

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

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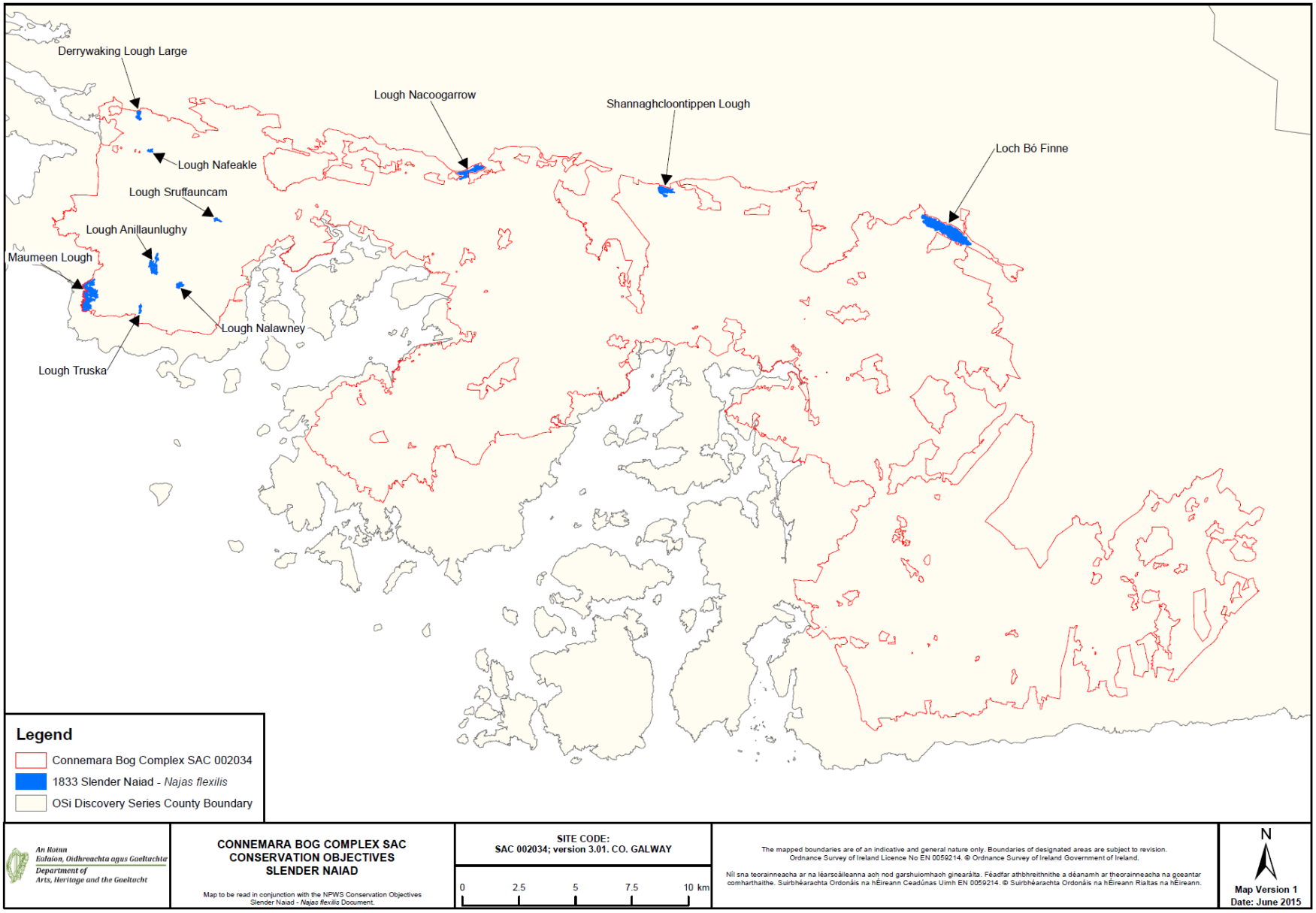
Appendix 1 *Najas flexilis* distribution map



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

Species: *Najas flexilis*	**Discovery series map**: 44	**Grid Reference**: L678493
Locality: Derrywaking Lough, Clifden	**Vice County**: H16	**SAC/NHA code**: 2034
Date: 28/07/2004	**Recorder**: Cilian Roden	**Altitude**: 14 m

Site description: Derrywaking Lough is dumbbell shaped and about 10 ha in size. It lies on Dalradian rock (Streamstown and lakes marble formations) with marble outcrops on the lake shore. The lake is surrounded by blanket bog and a small patch of Oak wood to the east. The shores are either reed bed, rock outcrop or gravel. Below the surface, vertical peat banks suggest flooded turf banks around the lake edge. The centre of the north basin is deep > 8 m. Underwater springs in the marble bedrock may be present (based on plumes of cold clear water encountered below the surface).

Population: The north-eastern shore was examined but *Najas* was only encountered in the eastern section of the southern basin. Here a flooded turfbank had a dense cover of *Juncus bulbosus* near the surface followed at depth by *Nitella flexilis* and *Nitella confervacea*. Occasional plants of *Najas* occurred below this vegetation. The plants grow on loose peat at about 2 m depth. No other species grows below this depth.

Vegetation: A poor flora, most notable for *Najas* and *Nitella confervacea*. The remaining species were present as isolated plants and do not form a sward, except for some isoetids near the surface. Emergents however are extensive (*Schoenoplectrus lacustris* and *Phragmites australis*).

Management:

Threats: No obvious threats

Access: is by a track leading from the Clifden - Galway road and then crossing 300 m of sloping heath and blanket bog.

Conservation: notable only for *Najas flexilis*

Remarks: The adjoining area of Oak wood (*Quercus petrea*) may be of interest.