NPWS

Lough Corrib SAC

(site code 000297)

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

Version 1

April 2017

Contents

Please note that this document should be read in conjunction with the following report: NPWS (2017) Conservation Objectives: Lough Corrib SAC 000297. Version 1.0. National Parks and Wildlife Service, Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs.

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 Annexes 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, 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) 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, which considered it likely to be extant in 58 lakes and extinct from three others (NPWS, 2013b; O Connor, 2013), *Najas flexilis* has been found in four additional lakes in Connemara (Roden, 2013; Roden and Murphy, 2014). Roden and Murphy (2014) provided new information indicating that the species has been lost from an additional three lakes and suggesting that records from six may have been erroneous. Currently, therefore, the species is considered extant in approximately 53 lakes. 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.

A fragile, relatively short (rarely >30cm) 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 0.5m and 10m, 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 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.

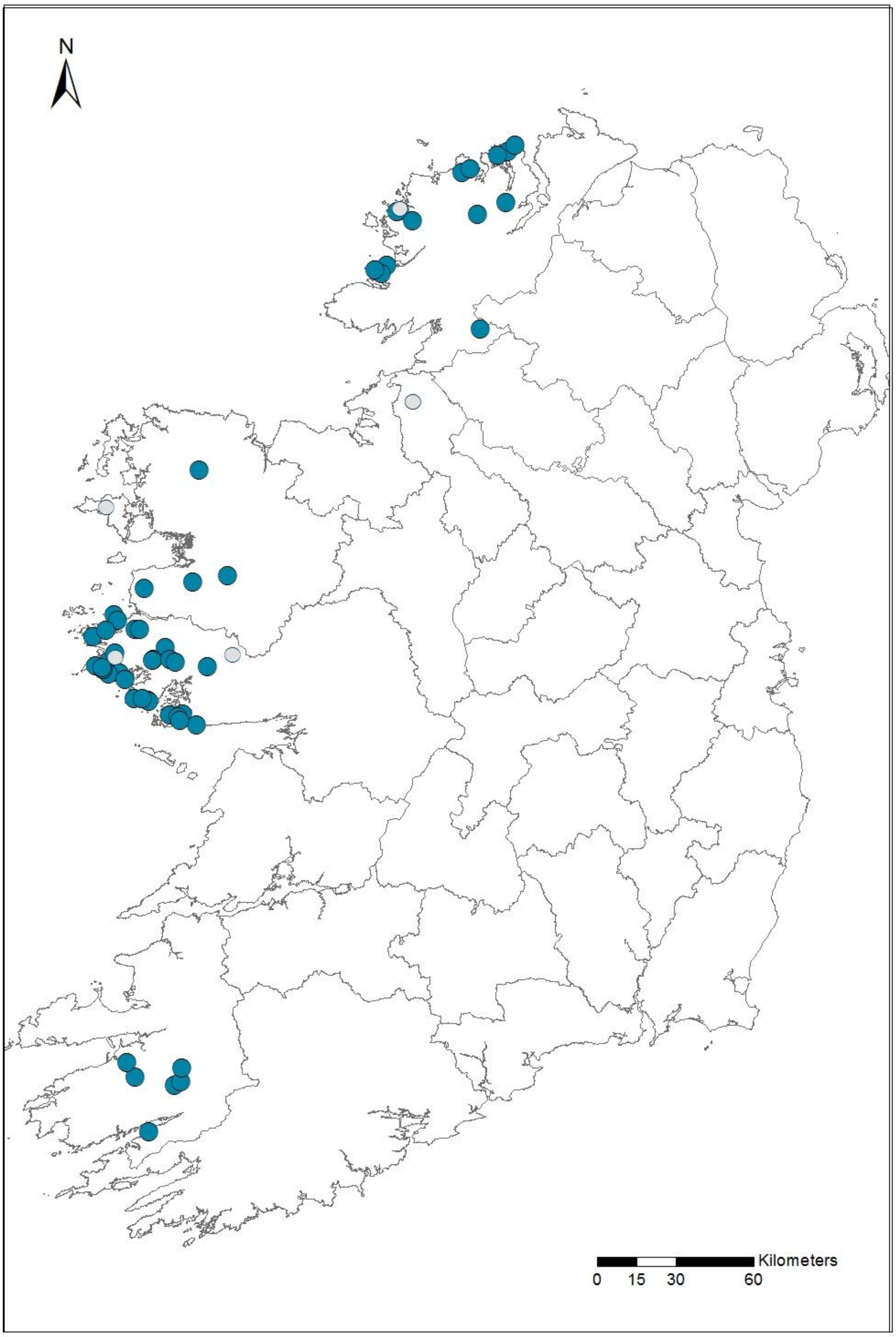

Figure 1. The distribution of *Najas flexilis* in Ireland. Based on lake centroids for 53 lakes considered to hold extant populations of the species (solid blue discs) and six lakes where it is considered extinct (light grey discs).

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 Habitats Directive Annex I habitat 3130 (Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or Isoëto-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). 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*, group 4 had low species richness, low *Najas flexilis* abundance and was found in deeper water.

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 a 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/inadequate conservation status as a result of eutrophication and impacts linked to peatland damage (Roden, 2007; NPWS, 2008; 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 (O Connor, 2013).

1.2 Lough Corrib SAC

Lough Corrib is the second largest lake in Ireland. The lake itself and its catchment cover both acid and basic geologies, resulting in the occurrence of a range of lake habitats. The northern basin is deep and of largely acid geology, while the southern basin is shallower and underlain by Carboniferous limestone. Lough Corrib is of international conservation importance, particularly for its hard-water lake habitat. The SAC also includes a number of rivers of importance for Altantic salmon (*Salmo salar*) and one, the Owenriff, which hosts a large population of freshwater pearl mussel (*Margaritifera margaritifera*). The Owenriff freshwater pearl mussel population is a national conservation priority and of international importance. The SAC also includes a number of smaller lakes and other important wetland and terrestrial habitats, including fen, limestone pavement, grassland, woodland and raised bog. The SAC is selected for 15 habitats listed in Annex I of the EU Habitats Directive and nine species in Annex II, including *Najas flexilis*.

Najas flexilis has been recorded on one occasion from one location in Lough Corrib. The record was made by W. Krause and J.J. King in the north-western bay of the lake between the 7th and the 12th of July 1986 (Krause and King, 1994) (see Figure 2 below for map).

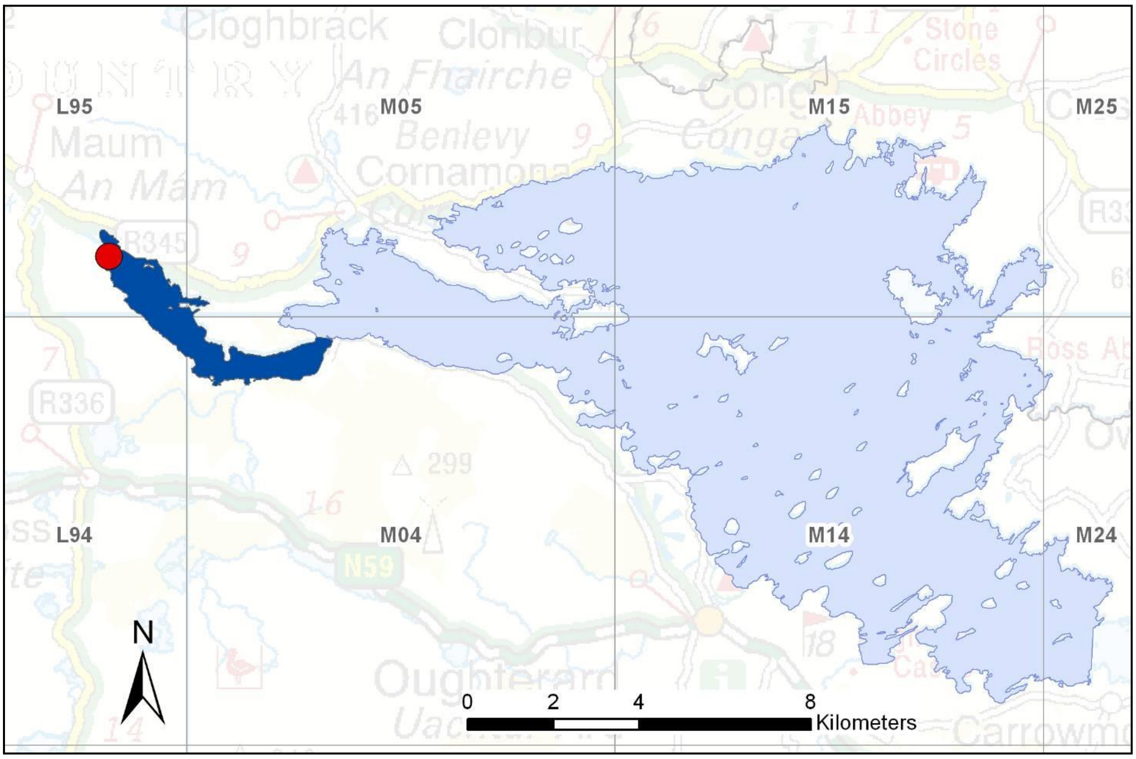

Figure 2. **Location of *Najas flexilis* in Lough Corrib.** The location of the only record for the species in Upper Corrib is shown by the red disc. The north-western bay that is considered to be the habitat for the species on the basis of this record is shown in dark blue, the rest of Upper Lough Corrib is shown in pale blue. It is possible that habitat for the species occurs elsewhere in the upper basin, particularly towards the west.

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*. Roden (2004, 2007) used a 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.

It is possible that the Lough Corrib population of *Najas flexilis* has become extinct since 1986. The single record for the species dates from July 1986 and came from a broad vegetation survey using a boat and grapnel, when it was found at c. 1m depth on stony ground (Krause and King, 1994). It was found only at the mouth of the Bealnabrack river near Maam Bridge (J.J. King pers. comm. to Roden, 2004). The species was not found during a dedicated *Najas flexilis* snorkel survey between 2002 and 2004, however the location surveyed was "about 5 miles" from the site of the original record (Roden, 2004). Routine Water Framework Directive (WFD) macrophyte monitoring has been conducted by the Environmental Protection Agency (EPA) in Lough Corrib since 2007, but again the species has not been recorded. Neither was the species discovered during another snorkel survey of lake habitats and species in 2012 (Roden, 2012). The site of the original record of Krause and King (1994) was targeted for survey in 2014, however, the species was not re-found (Roden and Murphy, 2014).

The large size of Lough Corrib means that the species could easily have been missed by surveys and *Najas flexilis* may persist in some localities. It is likely, however, given the condition of the lake habitat, that the population has declined in number and/or become more fragmented. As a consequence, the conservation objective for *Najas flexilis* in Lough Corrib SAC is to restore the population to at least the north-western bay, as mapped in Figure 2 and Appendix I.

The problems with estimating the population size of *Najas flexilis* 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 10m. 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.

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: Restore the spatial extent of *Najas flexilis* within the lake, subject to natural processes.

2.2 Population depth

Najas flexilis can occur at all depths between 0.5m and 10m, but is frequently associated with the lower depths of macrophyte growth, with scattered plants gradually giving way to bare mud or silt

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

(Preston and Croft, 2001; Roden, 2002). Roden (2007) highlighted that depths between 1m and 5m are particularly important for the species. In Lough Corrib, the species was grapnelled from approximately 1m depth (J.J. King pers. comm. to Roden, 2004). 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.

The target for population depth is: Restore the depth range of *Najas flexilis* within the 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). Note that *Najas flexilis* is protected under the Flora (Protection) Order, 2015 and a Section 21 licence is required to collect specimens of all or part of a plant, as well as to alter or interfere with its habitat. 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: Restore 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: Restore the cover abundance of *Najas flexilis*, subject to natural processes.

3. Range

The known distribution of *Najas flexilis* in Lough Corrib SAC is shown in Figure 2 and Appendix 1. It is likely that the species was formerly more widespread in the large northern basin and with improved habitat condition, that it could recolonize at least some of those localities. The conservation objective for *Najas flexilis* range is to restore the species to at least the north-western bay.

The target for the attribute species distribution is: Restore at least the north-western bay, 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.

Roden and Murphy (2014) recorded vegetation that is typical of *Najas flexilis* habitat but it was in poor condition with isolated plants of the invasive *Lagarosiphon major,* large quantities of zebra mussel (*Dreissena polymorpha*) and shallow euphotic depth (2m). Roden (2012) also documented very low water transparency (Secchi depth), high water colour, peat sediment, shallow submerged vegetation zone, sparse macrophyte vegetation generally and abundant zebra mussels (on exposed hard surfaces) in the north-western bay of Upper Corrib. The 2009-2011 EPA WFD Rolling status placed Upper Lough Corrib in poor status, owing to fish status, however it was at high status for other biological quality elements and general conditions. The trophic status of Upper Lough Corrib has shown signs of enrichment, and was classified as mesotrophic based on the OECD fixed boundary system, owing to chlorophyll *a* (annual maxima exceeded the standard), transparency (average mean Secchi disk depths of < 6m) and Total Phosphorus (TP) (average of 12µg/l for 2007) for the period 2007-2009 (McGarrigle *et al*., 2010).

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: 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 actions leading to re-suspension of find sediment, could decrease light penetration and impact on *Najas flexilis* at the lower depths of growth.

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.

In Lough Corrib, the substratum quality is impaired by peat deposition and likely also nutrient enrichment.

The target for the attribute lake substratum quality is: Restore 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 3 below indicating the likely target for *Najas flexilis* within the water quality classification system required by the Water Framework Directive (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. 4µg/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.

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.

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 (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.

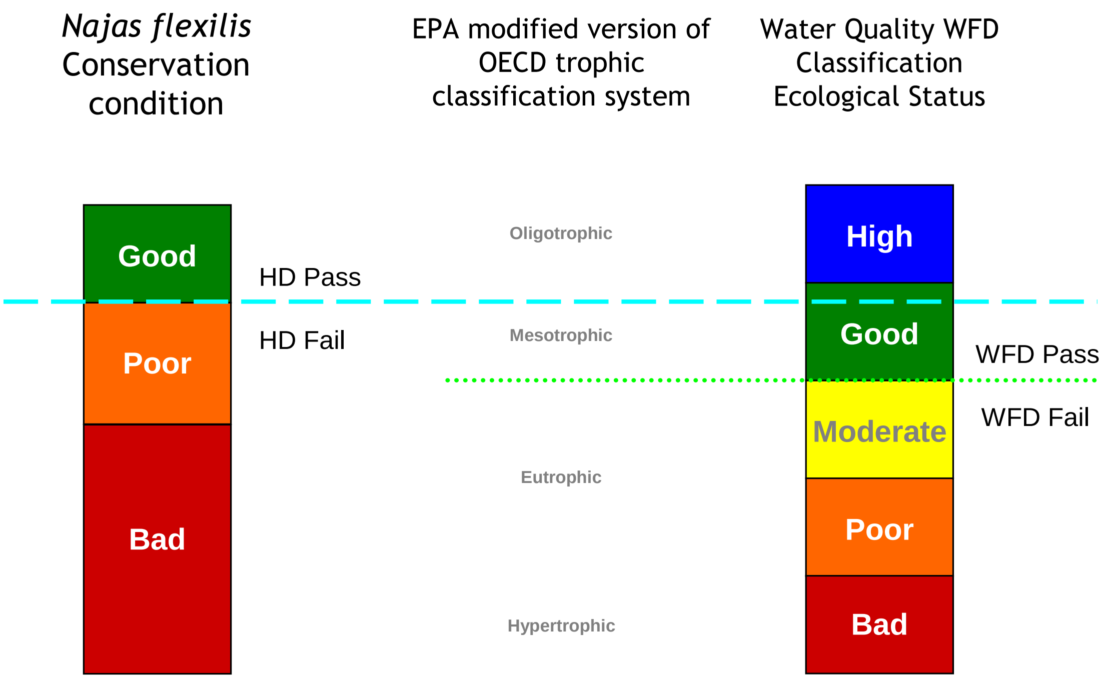

Figure 3. **The use of Water Framework Directive (WFD) water quality targets for the habitat of *Najas flexilis*.** It is likely that the most appropriate target for *Najas flexilis* water quality lies somewhere below the high-good boundary, within the slightly-mesotrophic band (based on chlorophyll *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. 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 10µg/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). As a result, an annual mean TP of less than 10µg/l 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.

As noted above, Upper Lough Corrib has exceeded the TP target on a number of occasions, including 2007 (McGarrigle *et al*., 2010), 2006, 2005 and 2004 (Clabby *et al*., 2008).

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

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

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 5.8µg/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 increase in growing season means, i.e. no upward trends.

Maximum chlorophyll *a* concentrations in Upper Lough Corrib have exceeded the OECD Fixed Boundary System standard for oligotrophic lakes of ≤8.0mg/l in five of the nine monitoring cycles between 1976 and 2009 (McGarrigle *et al*., 2010). Increased phytoplankton growth was noted as a 'recent change' in the upper basin was noted by Toner *et al*. (2005).

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

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 (WFD) 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/restore 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 an 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') (sections 4.4.1–4.4.5) 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 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 235µS/cm) at 42 lakes studied (Wingfield *et al.*, 2004). Alkalinity ranged from 6.71–69.71 mg/l (median of 23.45mg/l) at 29 lakes, and calcium concentration in the water had a range of 2.06–33.4mg/l (median of 9.59mg/l) 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 2.5–106mg/l, with a median of 13.2mg/l and average of 25mg/l. Summary data are provided in Table 1 for five Donegal lakes (Loughs Akibbon, Anure, Derg, Port and Shannagh), having overall averages of pH 7.12, conductivity 133.6µS/cm and total alkalinity 24.4mg/l. 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 (WFD) 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 1 **Physico-chemical data for five *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	
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 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 <50mg/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 41mg/l PtCo and 33mg/l PtCo, respectively.

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.

4.7 Associated species

As detailed in section 1.1, *Najas flexilis* is typically associated with a more diverse range of macrophyte species than found in the more base-poor lakes in peatland catchments. Krause and King (1994) found *Najas flexilis* with the phytosociological association *Eriocauletum septangularis*. While they did not list the species found in the sample containing *Najas flexilis*, they noted that *Eriocaulon aquaticum, Lobelia dortmanna, Littorella uniflora, Isoetes lacustris, Juncus bulbosus, Myriophyllum alterniflorum, Nitella flexilis* and *Nitella opaca* also occurred in the north-western bay (Krause and King, 1994). Adjacent to Maam Bridge, they found *Nuphar lutea, Sparganium angustifolium* and *Juncus bulbosus,* with *Schoenoplectus lacustris* along the shore (Krause and King, 1994). Roden and Murphy (2014) found species typical of the habitat of *Najas flexilis* including *Isoetes lacustris*, *Potamogeton perfoliatus* and *Nitella confervacea*.

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. The occurrence of the non-native *Lagarosiphon major* was noted by Roden and Murphy (2014). 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: 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.

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

5. Bibliography

Allott, N., Brennan, M., Cooke, D., Reynolds, J.D. and Simon, N. (1997) A Study of the Effects of stream Hydrology and Water Quality in Forested Catchments on Fish and Invertebrates: Volume 4, Stream Chemistry, Hydrology and Biota, Galway-Mayo Region. AQUAFOR Report. COFORD, Dublin.

Benthic Solutions Ltd. (2007) *Monitoring of condition, density, location and total extent/population of Slender Naiad (*Najas flexilis*), in the Perthshire Lunan Lochs*. Unpublished report, Scottish Natural Heritage, Perth.

Bilz, M., Kell, S.P., Maxted, N. and Lansdown, R.V. (2011) *European Red List of Vascular Plants*. Publications Office of the European Union, Luxembourg.

Bradley, C., Byrne, C., Craig, M., Free, G., Gallagher, T., Kennedy, B., Little, R., Lucey, J., Mannix, A., McCreesh, P., McDermott, G., McGarrigle, M., Ní Longphuirt, S., O'Boyle, S., Plant, C., Tierney, D., Trodd, W., Webster, P., Wilkes, R. and Wynne, C. (2015) *Water Quality in Ireland 2010-2012*. EPA, Wexford.

Bullock-Webster, G.R. (1920) Some charophyte notes. *The Irish Naturalist* 29(6): 55-58.

Caffrey, J.M. and Rorslett, B. (1989) The macrophytic vegetation of Rusheenduff (Renvyle) Lough, Co. Galway. *Irish Naturalists' Journal* 23(4): 125-128.

Clabby, K.J., Bradley, C., Craig, M., Daly, D., Lucey, J., McGarrigle, M., O'Boyle, S., Tierney, D. and Bowman, J. (2008) *Water Quality in Ireland 2004-2006*. EPA, Wexford.

Duigan, C.A., Kovach, W.L. and Palmer, M. (2006) *Vegetation communities of British Lakes: a revised classification*. Joint Nature Conservation Committee, Peterborough.

Dwyer, N. (2013) The *Status of Ireland's Climate, 2012*. EPA, Wexford.

FitzGerald, R. and Preston, C.D.P. (1994) Preliminary survey of *Najas flexilis*. In: R. FitzGerald, *Kerry - Vc H1 & H2. Report on preliminary survey of threatened & protected species*. Unpublished Report to the National Parks and Wildlife Service, Dublin.

Free, G., Little, R., Tierney, D., Donnelly, K. and Coroni, R. (2006) *A reference-based typology and ecological assessment system for Irish lakes. Preliminary Investigations*. Final Report. Project 2000-FS-1-M1 Ecological Assessment of Lakes Pilot Study to Establish Monitoring Methodologies EU (WFD). EPA, Wexford.

Freshwater Ecology Group (FEG), TCD and Compass Informatics (2007) Conservation assessments of freshwater lake habitats in the Republic of Ireland. April 2007. In: National Parks and Wildlife Service (Ed.) *The Status of EU Protected Habitats and Species in Ireland, Backing Documents, Article 17 Forms, Maps*. Volume 2, 1110-1256.

Godwin, H. (1975) *The history of the British flora. A factual basis for phytogeography.* Cambridge University Press, Cambridge.

Haynes, R.R. (1979) Revision of North and Central American *Najas* (Najadaceae). *SIDA* 8(1): 34–56.

Heuff, H. (1984) *The Vegetation of Irish Lakes. Parts 1 and 2*. Unpublished Report to the Wildlife Service, Office of Public Works, Dublin.

Kelly-Quinn, M., Tierney, D., Coyle, S. and Bracken, J.J. (1997) A Study of the Effects of stream Hydrology and Water Quality in Forested Catchments on Fish and Invertebrates: Volume 3, Stream Chemistry, Hydrology and Biota, Wicklow Region. AQUAFOR Report. COFORD, Dublin.

Krause, W. and King, J.J. (1994) The ecological status of Lough Corrib, Ireland, as indicated by physiographic factors, water chemistry and macrophytic flora. *Vegetatio* 110: 149–161.

McGarrigle, M.L., Bowman, J.J., Clabby, K.J., Lucey, J., Cunningham, P., MacCarthaigh, M., Keegan, M., Cantrell, B., Lehane, M., Clenaghan, C. and Toner, P.F. (2002) *Water Quality in Ireland 1998-2000.* EPA, Wexford.

McGarrigle, M., Lucey, J. and Ó Cinnéide, M. (2010) *Water Quality in Ireland 2007-2009*. EPA, Wexford.

Ní Chatháin, B., Moorkens, E. and Irvine, K. (2013) *Management Strategies for the Protection of High Status Water Bodies*. 010-W-DS-3. Strive Report Series No. 99. EPA, Wexford.

NPWS (2008) The Status of EU Protected Habitats and Species in Ireland. Conservation Status in Ireland of Habitats and Species listed in the European Council Directive on the Conservation of Habitats, Flora and Fauna 92/43/EEC. Unpublished National Parks and Wildlife Service Report, Dublin.

NPWS (2013a) *The Status of Protected EU Habitats and Species in Ireland. Overview Volume 1.* Unpublished Report, National Parks and Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

NPWS (2013b) *The Status of EU Protected Habitats and Species in Ireland. Habitat Assessments Volume 2. Version 1.0*. Unpublished Report, National Parks and Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

NPWS (2013c) *The Status of EU Protected Habitats and Species in Ireland. Species Assessments Volume 3, Version 1.0*. Unpublished Report, National Parks & Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

OECD (Organisation for Economic Co-operation and Development) (1982) *Eutrophication of Waters. Monitoring Assessment and Control*. OECD, Paris.

O Connor, Á. (2013) Article 17 assessment form and audit trail for *Najas flexilis*, the Slender Naiad (species code 1833) – Backing Document. Unpublished Report, National Parks and Wildlife Service, Dublin.

O Connor, Á. (2015) Habitats Directive Annex I lake habitats: a working interpretation for the purposes of site-specific conservation objectives and Article 17 reporting. An unpublished report to the National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Ireland.

Oliver, D. (1851) Notes of a botanical ramble in Ireland last autumn. *Phytologist* 4: 125-128.

O'Sullivan, A. (1997) *A summary report of the rare plants survey of plant species listed on Annex II of the EU Habitats Directive*. Unpublished Report to the National Parks and Wildlife Service, Dublin.

Palmer, M. (1989) *A botanical classification of standing waters in Great Britain; and a method for the use of macrophyte flora in assessing changes in water quality incorporating a reworking of data 1992*. Joint Nature Conservation Committee, Peterborough. Research and Survey in Nature Conservation, No. 19.

Palmer, M. (1992) *A botanical classification of standing waters in Great Britain; and a method for the use of macrophyte flora in assessing changes in water quality*. Nature Conservancy Council, Peterborough.

Preston, C.D. and Hill, M.O. (1997) The geographical relationships of British and Irish vascular plants. *Botanical Journal of the Linnean Society* 124: 1–120.

Preston, C.D. and Croft, J.M. (2001) *Aquatic Plants in Britain and Ireland*. Harley Books, Colchester.

Roden, C.M. (1999) *A survey of the sublittoral vegetation of 15 machair loughs in north-west Ireland*. Report to the National Heritage Council, Kilkenny.

Roden, C.M. (2002) Najas flexilis *in Donegal.* Unpublished Report to the National Parks and Wildlife Service, Dublin.

Roden, C.M. (2003) Najas flexilis *in Connemara.* Unpublished Report to the National Parks and Wildlife Service, Dublin.

Roden, C.M. (2004) *The distribution of* Najas flexilis *in Ireland 2002-2004*. Unpublished Report to the National Parks and Wildlife Service, Dublin.

Roden, C.M. (2005) A new station for *Hydrilla verticillata* in Connemara*. Irish Naturalists' Journal* 28(3): 138-139.

Roden, C. (2007) Conservation Assessment of Slender Naiad (*Najas flexilis* (Willd.) Rostk. & W.L.E.Schmidt) in Ireland. March 2007. Slender Naiad (*Najas flexilis*) (1833) Conservation Status Assessment Report. Backing Document. In: National Parks and Wildlife Service (Ed.) *The Status of EU Protected Habitats and Species in Ireland, Backing Documents, Article 17 Forms, Maps*. Volume 2, 824-840.

Roden, C. (2012) *A report on the sub-littoral environment around selected navigation markers in the north-west sector of Lough Corrib*. Unpublished report to RPS Group.

Roden, C. (2013) *A report on the aquatic macrophytes in 12 lakes along the Maam Cross to Ballynahinch Road*. Unpublished report to RPS Group.

Roden, C. and Murphy, P. (2014) Targeted survey of *Najas flexilis*. Unpublished report to the National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Ireland.

Tierney, D., Free, G., Kennedy, B., Little, R., Plant, C., Trodd, W. and Wynne, C. (2010) Water Quality of Lakes. In: M. McGarrigle, J. Lucey, and M. Ó Cinnéide (eds.) *Water Quality in Ireland 2007-2009*. EPA, Wexford.

Toner, P., Bowman, J., Clabby, K., Lucey, J., McGarrigle, M., Concannon, C., Clenaghan, C., Cunningham, P., Delaney, J., O'Boyle, S., MacCárthaigh, M., Craig, M. and Quinn R. (2005) *Water Quality in Ireland, 2001-2003*. EPA, Wexford.

van Groenendael, J.M., Hochstenbach, S.M.H., van Mansfeld, M.J.M. and Roozen, A.J.M. (1979) *The influence of the sea and of parent material on wetlands and blanket bog in west Connemara, Ireland*. Department of Geobotany, Catholic University, Nijmegen.

van Groenendael, J.M., van Mansfeld, M.J.M., Roozen, A.J.M. and Westhoff, V. (1993) Vegetation succession in lakes in the coastal fringe of West Connemara, Ireland. *Aquatic Conservation: Marine and Freshwater Systems* 3: 25-41.

Wingfield, R.A., Murphy, K.J., Hollingsworth, P. and Gaywood, M.J. (2004) *The Ecology of* Najas flexilis. Scottish Natural Heritage Commissioned Report No. 017 (ROAME No. F98PA02).

Wingfield, R.A., Murphy, K.J. and Gaywood, M.J. (2005) Lake habitat suitability for the rare European macrophyte *Najas flexilis* (Willd.) Rostk. & Schmidt. *Aquatic Conservation: Marine and Freshwater Ecosystems* 15: 227–241.

Wyse Jackson, M., FitzPatrick, Ú., Cole, E., Jebb, M., McFerran, D., Sheehy Skeffington, M. and Wright, M. (2016) *Ireland Red List No. 10: Vascular Plants*. National Parks and Wildlife Service, Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs, Dublin, Ireland.

Appendix 1 Distribution map of *Najas flexilis* in Lough Corrib SAC