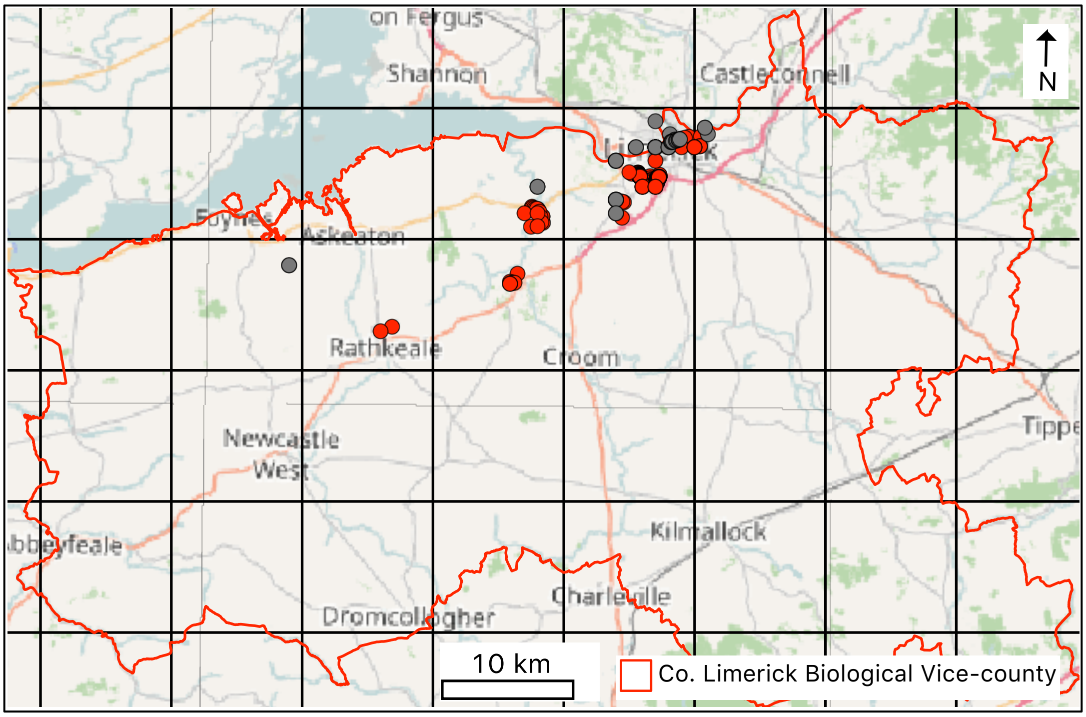
Figure 3.1. Distribution of *Groenlandia densa* in County Limerick (NPWS data)



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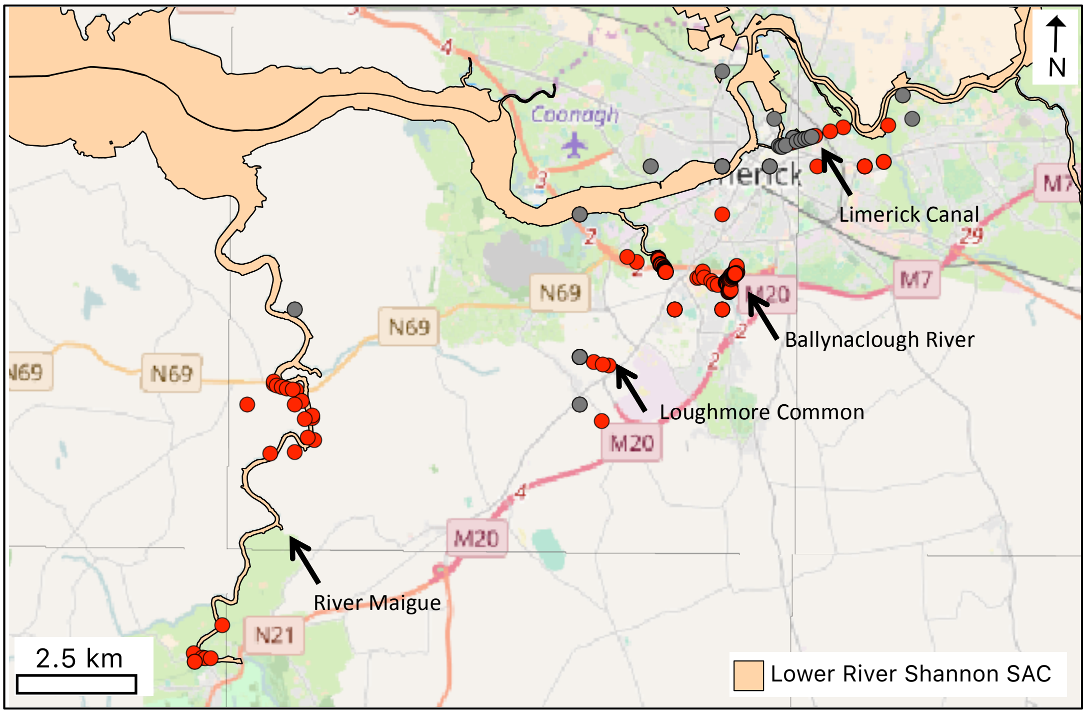
Grid = hectad boundaries (10 x 10km squares). Red circles = post-2000 records; Grey circles = pre-2000 records. Records at hectad level only, excluded.

Figure 3.2. Distribution of *Groenlandia densa* in Lower River Shannon in Co. Limerick (NPWS data)



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Red circles = post-2000 records; Grey circles = pre-2000 records. Records at hectad level only excluded.

Table 3.1. Summary of 2006 NPWS Rare plant survey results for keys sites of *Groenlandia densa* in Co. Limerick (Reynolds et al., 2006)

Site	Waterbody type	Population	Associated submerged aquatics	Management & threats
Adare, near River Maigue	Ditch with relatively clean water	Frequent in the ditch along a 200m stretch with locally dense patches	*Callitriche* sp., *Lemna minor, Elodea canadensis*	No recent dredging or vegetation clearance. Threats include natural infilling by vegetation growth
Ballynaclough River and area, east of Dooradoyle	On tidal mud in Ballynaclough River and in a number of drainage ditches behind the high river embankments	Several areas along a 1km stretch or river and abundant in ditches on both sides of the river	*Callitriche obtusangula Elodea canadensis, Lemna minor, L. trisulca, Myriophyllum verticillatum, Potamogeton berchtoldii, P. pectinatus, Zannichellia palustris*	Ditches had not been cleared recently but were not overgrown. No apparent threats.
Ferry Bridge, east of Kildimo	Deep drainage ditch through pasture	Five patches along a c 500m section of ditch	*Callitriche* sp., *Lemna minor, L. trisulca*	Adjacent grazing and some alluvial mud removed recently. No apparent threats.
Glascurram, south of Ferry Bridge	Deep drainage ditch parallel to the river behind the river embankment at the edge of grazed pasture	Two patches <5m in extent	*Myriophyllum verticillatum*	Adjacent grazing, no recent dredging. Population small and could be impacted by ditch cleaning.
Limerick Canal	Canal, mostly in 1-2m of water	Eight locations along a c1.5km stretch of the canal	*Myriophyllum verticillatum, and Callitriche obtusangula, charophytes, Nuphar lutea, Potamogeton crispus, P. natans, P. pectinatus*	Some recent dredging. Lack of regular clearance could lead to infilling.
Loughmore Common, south-east of Mungret	Wide (>6m) and deep drainage ditch	Dominant and abundant along 300m length of the ditch in shallow water, in places directly on mud not covered by water	Extensive patches of *Callitriche sp.*	No recent drainage work but vegetation sparse suggesting regular cleaning must be undertaken. No apparent threats.
North-east of Patrickswell	Drainage ditch with soft bottom and shallow water	A few plants in one location	Sparsely vegetated. Some *Lemna minor.*	Ditch appeared to have been recently cleared. No apparent threats.
Reboge, north-east Limerick City	Drainage ditches across flat grazed pasture	One small patch of plants (ditch nearly dried out by hot weather at time of survey)	*Callitriche* sp., *Elodea canadensis, Lemna minor, Chara* sp.	No recent clearance. Lack of regular clearance could lead to infilling.
River Shannon at Shannon Bridge, Limerick City	Rivulet and seepage area across tidal mud at edge of River Shannon. Freshwater clear and fairly fast flowing.	Few small patches each in rivulet and seepage areas	*Zannichellia palustris and Callitriche* sp.	No specific management. Decline in plants in this area likely to be due to drainage works leading to changes in water quality, substrate and vegetation on river margins

3.1.3 Relevant ecology

3.1.3.1 Growth and regeneration

Groenlandia densa is a perennial hydrophyte (perennating buds submerged during winter) (Hill et al., 2004). It can grow up to 0.65m, with unbranched to highly branched stems and submerged leaves only (Preston, 1995). It has far-creeping rhizomes (Hill et al., 2004), which lie on or just beneath the substrate surface (Preston, 1995). The rhizomes are white when under the substrate surface, but have a greenish colour when exposed to light (Preston, 1995). Unlike many broad-leaved *Potamogeton* species, the rhizomes are not highly differentiated from the stem and stems often root at the lower nodes (Preston, 1995). It does not produce turions (specialised vegetative propagules found in some *Potamogeton* species) and overwinters as leafy shoots (Preston, 1995). It can reproduce both by seed and vegetatively by sending out rhizomes (Greulich & Bornette, 1999) and irregularly fragmenting (Hill et al., 2004).

Groenlandia densa is considered to have an intermediate secondary ecological strategy: Competitive-Ruderal (C-R) (Greulich & Bornette, 1999). This strategy is adapted to habitats that are productive (which suits competitors), but intermittently disturbed (which suits ruderal species) e.g. eutrophic to mesotrophic ditches, streams and rivers that are subject to vegetation clearance or other disturbance. C-R strategists are able to spread rapidly by vegetative means (e.g. rhizomes) and can efficiently colonise temporary vegetation gaps (Grime, 1979). *G. densa* is outcompeted if tall vegetation becomes dominant and a high abundance of *G. densa* may indicate that a waterbody has been recently disturbed (Greulich & Bornette, 1999).

Groenlandia densa can grow in any season, including winter, but peak growth (including horizontal spread and new ground colonisation) occurs early in the growing season (Haslam, 1997). One study found that the highest production rate was during spring-early summer (end of April to mid-June); growth was then reduced by half in the summer (end of June to mid-August) and reduced further in late summer (end August to end September) (Greulich & Bornette, 1999). Whilst the cover of individual plants was low, *G. densa* had a high growth rate due to fast and abundant production of new, densely packed individuals (Greulich & Bornette, 1999). Damage to plants is followed by regrowth, but this will be slow at certain times of year (e.g. winter) (Haslam, 1997). If damage occurs prior to the peak growing season then the population will recover if some plants remain (Haslam, 1997). *G. densa* can then rapidly invade bare areas by spreading from adjacent undisturbed vegetation, with plants appearing in disturbed areas within a few weeks (Barrat-Segretain & Amoros, 1996; Chiarello & Barrat-Segretain, 1997). However damage at the end of the annual growth period can leave the population sparse and susceptible to further damage (Haslam, 1997).

In addition to vegetative spread by rhizomes, *G. densa* is considered to spread by plant fragments, which are easily detached (Preston & Croft, 1997). It produces flowers (which are self-pollinated), seed-set is normally very high (Preston & Croft, 1997). It has been shown to occur in the propagule bank of a riverine channel as both seeds and rhizomes (Combroux, 2004). However, it is not known to what extent it reproduces by seed and it rarely colonises new habitats (Preston & Croft, 1997).

When *G. densa* plants are newly established the small plants cannot trap silt efficiently (Haslam, 1997). Therefore this species does not regenerate well on coarse or low nutrient substrates unless bands of temporary silt are present (Haslam, 1997). Rhizome growth is in all directions in still water or low flows, but rhizome growth tends to be mainly across the channel, with little upstream growth, in channels with faster flow (Haslam, 1997).

3.1.3.2 Ecological requirements

The Ellenberg values for *Groenlandia densa* from PLANTATT (Hill et al., 2004) are summarised below:

- Light (L) – light-loving plant, rarely found where relative illumination in summer is less than 40%
- Moisture (F) – submerged plant, permanently or almost constantly under water
- Reaction (R) - found on calcareous or other high-pH soils

- Nitrogen (N) – indicator of sites of intermediate fertility
- Salt (S) – slightly salt-tolerant species, rare to occasional on saline soils but capable of persisting in the presence of salt – includes dune and dune-slack species where the groundwater is fresh, but where some inputs of salt spray are likely

(Haslam, 1997) also states that *G. densa* occurs where flow is still to moderate, in eutrophic to moderately mesotrophic water with high alkalinity, in usually shallow, clear, unpolluted water.

3.1.3.3 Habitat

Groenlandia densa has a European temperate element (Preston et al., 2002). At a European level, the EUNIS habitat classification system lists the following habitats for *Groenlandia densa*:

- C1.232 - Small pondweed communities
- C2.1A - Mesotrophic vegetation of spring brooks
- C2.27 - Mesotrophic vegetation of fast-flowing streams
- C2.33 - Mesotrophic vegetation of slow-flowing rivers
- C2.43 - Mesotrophic vegetation of tidal rivers

The habitats for *G. densa* are described as being moderately rich in nutrients.

The vegetation has affinity with the Annex I habitat: 'Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation [3260]' (EC, 2007). In the Lower River Shannon SAC, the Conservation Objectives list a high-conservation value sub-type of 3260 with *Groenlandia densa*. This is described as being associated with the tidal reaches of rivers (NPWS, 2012a). Whilst drainage ditches are mentioned as a habitat for *Groenlandia densa* in the area, the focus on *Groenlandia densa* in 3260 habitat is the tidal rivers and Limerick Canal.

Within Britain and Ireland, PLANTATT (Hill et al., 2004) lists the main habitats for this species as 'standing water and canals' and 'rivers and streams'. The New Atlas of the British and Irish Flora (Preston et al., 2002) states that it is found in '*shallow, clear, base-rich water which may grow in lakes and rivers but is more frequent in smaller waters such as streams, canals, ditches and ponds. It rarely colonises newly available habitats, although it is sometimes found as an introduction in ponds.*' *Generally lowland*.' In addition, Preston and Crofts (1997) mention that it is particularly characteristic of streams flowing from calcareous springs (e.g. growing with *Callitriche obtusangula)* and Preston (1995) that it can occur in calcareous water over an acidic substrate (e.g. peat or sandstone). Haslam (1997) describes *G. densa* as being typical of the lower reaches of chalk streams, or watercourses on hard limestone or mixed-limestone clay, in semi-eutrophic to eutrophic waters and not flow limited.

In Ireland, Parnell and Curtis (2012) list the habitat of *G. densa* as being rivers, canals and estuarine muds. This corresponds to the Habitat Survey classification habitats (Fossitt, 2000): Depositing/lowland rivers (FW2); FW3 Canals (FW3); Drainage ditches (FW4); and, Tidal rivers (CW2).

In Co. Limerick, the habitat of *G. densa* comprises ditches, rivers and canals (Reynolds et al., 2006). This includes the Limerick Canal, tidal rivers and tidal mud by the River Shannon (Reynolds et al., 2006). It particularly thrives in drainage ditches in the area, which act as an important refuge for some aquatic plants (Reynolds, 2013). The ditches that support this species are often deep and regularly cleared of vegetation (Reynolds, 2013). But it is also found in ditches with shallow water (e.g. back drains of the Ballynaclough River; Ní Bhroin, 2007) and on mud (e.g. Loughmore Common; Reynolds, 2013).

Groenlandia densa tends to occur in sites that are in an early to mid-successional stage and free from heavy shading by tall monocots and bankside trees (e.g. back drains of the Ballynaclough River; Ní Bhroin, 2007). *G. densa* is sensitive to eutrophication (Preston, 1995) and is usually found in waterbodies with low turbidity. It survives regular maintenance, as long as some vegetation is left from which it can recolonise (Reynolds et al., 2006). Without this regular maintenance, ditches in particular can become shaded and overgrown, with a build up of sediment and associated reduced water flow, and become unsuitable for *G. densa* (Ní Bhroin, 2007). The main current threats to *G. densa* habitats in Co. Limerick are lack of maintenance leading to succession; decreases in water quality or quantity; and disturbance of the substrate and complete removal of vegetation.

3.1.3.4 Associate species

There are a number of associate species that have been recorded growing with *Groenlandia densa*. In Ireland these include:

Azolla filiculoides (non-native)
Berula erecta
Callitriche species
Callitriche obtusangula
Callitriche stagnalis
Ceratophyllum demersum
Charophytes
Elodea canadensis (non-native)
Elodea nuttallii (non-native)
Lemna gibba
Lemna minor
Lemna minuta (non-native)
Lemna trisulca
Myriophyllum verticillatum
Nuphar lutea
Potamogeton berchtoldii
Potamogeton coloratus
Potamogeton crispus
Potamogeton lucens
Potamogeton natans
Potamogeton pectinatus
Ranunculus circinatus
Ranunculus trichophyllus
Schoenoplectus triqueter
Spirodela polyrhiza
Veronica beccabunga
Veronica catenata
Zannichellia palustris
(Sources: Deegan, 2004; Ní Bhroin, 2007; Reynolds, 2013; Reynolds et al., 2006)

3.2 Ditch survey results

Refer to Appendix A for full details of the field survey. This includes a site map, location of mapped *Groenlandia densa*, transect grid reference, representative photographs, ditch physical characteristics and species composition.

3.2.1 Ditch section with *Groenlandia densa*

The ditch section with *Groenlandia densa* had relatively clear water with low overall algal cover at the time of survey. Aquatic macrophytes were abundant in the channel and the ditch had a shallow eastern bank, grading into wet grassland to the east. There was no shading by scrub or tall vegetation and the ditch was in mid-successional stage with small amounts of open water and a mixture of submerged, floating and emergent vegetation.

The following 11 native aquatic macrophyte species (refer to reference list in JNCC, 2005) were recorded from the ditch:

- *Chara vulgaris**
- *Callitriche* cf *obtusangula*[1]
- *Equisetum fluviatile*
- *Glyceria maxima*
- *Groenlandia densa**
- *Iris pseudacorus*
- *Lemna minor*
- *Ranunculus* cf *trichophyllus*[1]
- *Sparganium* sp.
- *Veronica beccabunga*
- *Veronica catenata*

*Macrophyte species considered to be ‘Ditch Quality indicators’ (JNCC, 2005).
[1]not possible to confirm species as non-flowering at time of survey

Chara vulgaris, Callitriche cf *obtusangula* and *Groenlandia densa* are typical of highly calcareous water (in Ireland). The pH recorded from the ditch during survey (using handheld pH device) was pH 8.24 to 8.43. Subsequent water sampling by Limerick County Council (Appendix B) gave three sampling points with pH 8 and one point near the end of the transect with pH 7.5 (see Appendix B for a table with the results of the detailed water chemistry sampling). Both the species composition and water chemistry data therefore show that the water in the ditch is highly calcareous. It is interesting that the lower value was recorded near the end of the recorded distribution of *Groenlandia densa* and it may be that it depends on a high pH for its abundance in this location.

Chara vulgaris, Callitriche cf *obtusangula* and *Groenlandia densa* can also tolerate brackish conditions. Electrical Conductivity measurements were collected in the field using a handheld device (value range of 650-820 µS/cm recorded) and also measured during the water sampling by Limerick County Council (327-540 µS/cm recorded, Appendix B). A conductivity of >2000 µS/cm indicates either brackish water or highly polluted water (JNCC, 2005). As the recorded values are <1000 µS/cm, this shows that the ditch is neither brackish or highly polluted.

There is little/no data available on the water chemistry of ditches in Ireland. However, some comparison can be made with the data collected from calcareous springs across Ireland by Lyons (2015). Dissolved calcium ranged from 57.59 to 102.7 mg/l in this ditch section (Appendix B), which is comparable with the data recorded from calcareous springs in Ireland (mean of 87.80 mg/l; Lyons, 2015). Nitrate (as NO_3 mg/l) was <0.62 in the ditch section, which is low compared to the data collected from calcareous springs (mean 5.09; range <0.07-44.05 mg/l; Lyons, 2015). However phosphate in the ditch section 0.032-0.082 mg/l is at the upper end of that recorded from calcareous springs (mean 0.016; range 0.002-0.14; Lyons, 2015). This suggests low nitrate pollution, but possibly some input of phosphates in this ditch section. It would also be expected that the water in a ditch with input from surface (and possibly river water) would be more eutrophic than calcareous spring water. It is perhaps surprising that the levels of nitrate and phosphates are not higher.

3.2.2 Adjacent ditch sections without *Groenlandia densa*

In addition to the detailed study of the ditch section with *Groenlandia densa,* the remaining ditches on King's Island were walked to look for *Groenlandia densa* and to compare characteristics:

- The ditch to the south of the ditch section with *Groenlandia densa* (outside but adjacent to the SAC, on the western side of the Island) did not support *Groenlandia densa.* The channel was overgrown by tall monocots and scattered scrub, with little open water and the surface of any open water present was dominated by Lemna *spp.* This ditch section is considered to be mid to late successional. The pH in this area was 7.3 (Appendix B). It was not brackish (484 µS/cm, Appendix B). The highest values of nitrate and phosphate were recorded from this area (0.71mg/l NO_3 and 0.087 PO_4, Appendix B) and calcium was slightly higher (Appendix B). The main difference between this area and the *Groenlandia densa* section appears to be the successional stage, increased eutrophication and pH. It is not clear whether conditions would be suitable for *Groenlandia densa* if the ditch was cleared to provide the early to mid-successional habitat favoured by *Groenlandia densa,* as the pH is lower. As the ditches are connected, it is also not clear why there should be such a difference in pH or successional stage (there were no obvious signs of past management). It is possible that the ditch section with *Groenlandia densa* has a different water source (e.g. a spring), which creates and maintains the high pH and perhaps reduces/ slows competition and succession within the ditch section.
- The ditch to the north of the *Groenlandia densa* ditch section was overgrown with scrub, had little open water and frequent litter from dumping. It was not suitable for *Groenlandia densa.*
- The ditches on the eastern side of King's Island are located within the SAC. *Groenlandia densa* was not recorded from any of the ditches. In addition, macrophyte species richness was generally lower in these ditches, many areas were overgrown with scrub or tall monocots and water was frequently turbid. Water sampling of the area with the most open and clear water, gave a pH reading of 7.4. As above, the ditch was not brackish (603 µS/cm, Appendix B). Nitrate and phosphate levels were similar to those within the *Groenlandia densa* ditch section (Appendix B). As above, it is not clear whether conditions would be suitable for *Groenlandia densa* if the ditch was cleared to provide the early to mid-successional habitat favoured by *Groenlandia densa,* as the pH is lower.

4 TRANSLOCATION REVIEW

There have been a small number of projects involving the translocation of *Groenlandia densa* in Ireland (under licence). These have generally involved removing plants whilst maintenance work was undertaken and replacement of the plants back in their original habitat/ site. In addition there is one study in France that involved translocation of *Groenlandia densa* to a new site as part of an experiment to assess competitive ability of four aquatic macrophyte species (see Section 4.5). The key methods and outcomes of these projects are summarised below.

4.1 *Groenlandia densa* in canal at Meelick, Co. Galway

Refer to unpublished reports prepared by S.Heery for ESB (Heery, 2011a & 2012a) for full details. Key points from these report summarised below.

- Removal of *Groenlandia densa* from canal prior to cement grouting of an embankment and in-situ protection of *Groenlandia densa* populations in areas not directly impacted by grouting.
- Canal c3m wide, constructed in 1929 to prevent flooding of callows to the west of the River Shannon as part of Ardnacrusha Hydro-electric Scheme.

- *Groenlandia densa* first recorded at site in 1991, in 2010 it was recorded from a 130m section of the canal.
- The vegetation within the canal was cut by ESB as part of annual maintenance
- Plants of *Groenlandia densa* from a 6m section of the canal were removed under license and placed in a planting basket in a nearby trench. Two 1.5m wide JCB buckets of silt from the same area (presumed to contain *Groenlandia densa* propagules and fragments) were removed and deposited in a nearby clean skip.
- Translocated material was **stored for 43 weeks** in three different receptors: skip, two wicker hanging-baskets and a small plastic bowl. *Groenlandia densa* grew in abundance in all receptors.
- After completion of the works, **some *Groenlandia densa* remained** in unimpacted sections of the canal.
- Material was **translocated back** into the canal in **September** 2011.
- **Long-term survival of plants** individually relocated (in small receptacles) **uncertain** (no plants recorded in 2012)
- **Plants from skip found to be severely limited by competition** from *Elodea canadensis* (only a single plant recorded in this location in 2012)
- However, there is now a well-established population in an area that was re-profiled (presumably regeneration from dormant propagules or rhizomes). This area had only ever had one plant recorded from it.
- The lack of success of transplantation was not considered to be due to the timing of re-planting (autumn), but most likely that that the roots needed to grow in very loose silt and they could not function in the substrate at the transplant site.

Outcome of translocation: Low survival and growth of translocated plants and competition from non-native macrophyte species. However *Groenlandia densa* regenerated from dormant propagules in less disturbed areas.
Potential issues: Not possible to replant material back into loose silt to promote establishment of roots and rhizomes.

4.2 *Groenlandia densa* at Shannon Harbour, Co. Offaly

Refer to unpublished reports prepared by S.Heery for OPW (Heery, 2011b & 2012b) for full details. Key points from these report summarised below.

- **Removal** of *Groenlandia densa* from 300m section of drain prior to maintenance (**October** 2011).
- *Groenlandia densa* plants removed from 7 recorded locations. One location was not dredged and at four other locations, the plants were left in situ.
- Plants were removed from digger bucket during maintenance work at these 7 locations.
- Plants **replaced back into drain immediately after dredging**. Method: '*After consideration the following method was used. The rooted rhizomes were encased by hand in a compressed ball of silt/marl/soil, with as much as possible of the green leafy stems free. This was then dropped carefully into the water at a point close to the edge of the newly profiled drain. Examination with a spade indicated that there was a dense suspension of silt at the bottom and it was expected/hoped that the Groenlandia material would embed itself in this. The depth of water into which the Groenlandia was replaced (on 12th October 2011) was about 60-70cm but will be significantly less during the growing season*.'
- It was **difficult to remove *Groenlandia densa* long rhizomes fully**, without breaking or removing different plant species. Therefore the amount of material removed at each location was less than expected.

- Monitoring in 2012 showed that **no plants of *Groenlandia densa* were recorded at 5 of the 7 translocation locations**. Plants were recorded at the remaining 2 locations, but it was unclear if this was growth of translocated plants or regeneration from rhizomes.
- It was suggested that translocated material should ideally be replanted into very loose silt, into which the roots and rhizomes can establish. This was not possible at the subject site.

Outcome of translocation: Low survival and growth of translocated plants (did not survive at most locations. At 2 sites where *Groenlandia densa* did persist, it is possible that this was from dormant propagules rather than translocated plants.
Potential issues: Difficult to fully remove long rhizomes; not possible to replant material back into loose silt to promote establishment of roots and rhizomes.

4.3 *Groenlandia densa* in the Grand and Royal Canals, Co. Dublin

Refer to unpublished reports prepared for Waterways Ireland by BEC Consultants (Baron, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013, 2014 & 2015) for full details. Key points from these report summarised below.

1) Monitoring of *Groenlandia densa* in Grand and Royal canals to assess population growth post-dredging (undertaken in 2010-2011). Dredging found to have a positive effect on *Groenlandia densa* populations post-dredging (significant increase in the number of individuals, area covered, and range of the populations), presumably by removing competition.

- Some plants were present in areas where they were not recorded immediately post-dredging, but where there were historic records (suggesting regeneration from dormant propagules).
- Observations from the Grand Canal suggest that despite the stem and leaves of *G. densa* dying back when exposed above the water level for a sustained period, the root-stock remained viable, with the stem and leaves re-growing once the rootstock was submerged again.
- Considered that **recolonisation of areas where *Groenlandia densa* had been recorded** immediately prior to dredging was **most likely from extant rootstock** remaining within the dredged canal levels (in combination with recruitment from seed and development of plants from floating stems).

2) Rescue translocation and reinstatement of *Groenlandia densa* populations in the Grand Canal

- Survey for *Groenlandia densa* plants undertaken in May 2012 (pre-dredging survey). Location of plants recorded using GPS.
- Locations where *Groenlandia densa* plants had been recorded were relocated in **October** 2012 and marked with weighted floats.
- The initial translocation of plants was undertaken from a dewatered section of canal. A base layer of approximately 300mm was removed and loaded into sacks. Where plants were present, the plant and surrounding sediment was either lifted using an excavator (or using shovels if accessible from the bank) and transferred into a sack.
- The sacks with sediment and plants were then submerged in an area of canal that was not going to be dredged. The sacks were held in place (and open) by 1m bars.
- In another location (Ringsend), the sacks were placed in watertight skips filled with water from the Grand Canal. The plants were only stored for 17-18 days so there was no requirement for weeding.
- Plants **returned to the canal** (after dredging) in **December** 2012.
- Sacks were lifted to 0.5m above sediment surface and then bottom of sack opened to allow contents to fall out.

- The **time of year and short storage time mean that there was little/ no growth of plants during the storage phase**. It was expected that even if the plant foliage was lost during storage, that plant rhizomes and propagules would persist in the sediment.
- Monitoring in 2013 recorded growth of plants at some of the translocation location sites and also the appearance of plants in locations where none had previously been recorded (and no translocation had taken place).
- Monitoring in 2014 showed that at the main translocation site, whilst plant numbers had initially increased in 2013 (from 12 to 24), only 9 plants were recorded in 2014. However there was an increase the number and area of records at the second site.
- **Monitoring in 2015 recorded no plants of *Groenlandia densa* at the main site**. Only two plants were recorded at the second site and it was not possible to determine if these were translocated plants.
- It was considered that the **growth of the non-native aquatic macrophytes** *Elodea* sp. and *Crassula helmsii* may have had an **impact** on *Groenlandia densa* populations.
- The conclusion was that the translocation was not successful and that careful consideration should be given to alternative approaches to conservation of *Groenlandia densa* during future dredging projects.

Outcome of translocation: Low survival and growth of translocated plants (did not survive at main translocation site) and competition from non-native macrophyte species. At 2nd site where *Groenlandia densa* did persist, it is possible that this was from dormant propagules rather than translocated plants.
Potential issues: Difficult to fully remove long rhizomes; not possible to replant material back into loose silt to promote establishment of roots and rhizomes.

4.4 *Groenlandia densa* at Rossbrien and Ballykeefe, Co. Limerick

Refer to unpublished reports prepared by BEC Consultants for White Young Green and Direct Route (Baron, 2007 & 2010c) for full details. Key points from these report summarised below.

- Mitigation measures to protect *Groenlandia densa* plants during crossing of watercourses for the Limerick City southern ring road.
- *Groenlandia densa* recorded in Rossbrien ditch (drainage channel that runs parallel to Ballynaclogh River); within the main channel of the Ballynaclogh River and Ballykeefe ditch (drainage ditch that runs parallel to the Ballinacurra Creek). All three sites were subject to tidal cycles.
- Plants **conserved both in situ and ex situ** from the two ditches.
- Plants were removed manually with a substantial volume of sediment with which they were growing. The plants were then transferred to porous planting baskets lined with hessian sacking (biodegradable). The baskets were held within solid containers and transferred to Trinity Botanic Gardens.
- **In situ plants increased after dredging** in 2009 and then **subsequently declined** as *Groenlandia densa* is intolerant of shade. **Plants stored ex situ in good condition**, although regular weeding of non-target species required. The most successful growth is from floating stems which were manually rooted into the sediment in one crate. As the in situ plant populations were healthy, it was not considered necessary to translocate the ex situ plants back to the donor sites.

Outcome of translocation: Plants not translocated back to subject site as in situ conservation was successful.
Potential issues: Although mitigation measures were successful in protecting in situ vegetation, long-term management (regular vegetation clearance) required to maintain healthy *Groenlandia densa* populations.

4.5 *Groenlandia densa* competition field experiment, Upper Rhone River (France)

Refer to published paper for full details (Greulich & Bornette, 1999). Key points from this paper summarised below.

- Competition experiment involving four macrophyte species in an intermediately disturbed, species-rich macrophyte habitat in the Upper Rhone River (France)
- Individual plants removed from nearby habitat and translocated to cut-off channel where they had **not previously been recorded**. This channel had similar water and sediment characteristics to the original habitat.
- **Small plants** chosen for translocation.
- Plants placed in plastic containers (30 x 40 cm, with a depth of 18 cm), filled with sediment from the translocation site. The distances between neighbouring boxes placed perpendicular to water flow were about 5 cm. Since plants tend to bend with water flow, distances in this direction were larger (about 20 cm), to limit interferences with plants from neighbouring boxes.
- Planting (**translocation**) took place in **April** 1996. Experiment continued to end of October 1996.
- **Losses of translocated plants** appeared mainly due to **insufficient anchorage** after transplantation and occurred mainly at the beginning of the experiment.
- There was an unexpected flooding event during the experiment, which did not impact on the abundance of translocated *Groenlandia densa.*
- There was a large variation in how individual *Groenlandia densa* plants performed. However, this species produced the highest number (and high density) of new clonal individuals (ramets) of all species during the experiment.
- **Growth** of *Groenlandia densa* was **particularly high between end April to mid-June**; reduced by half between end June to mid-August and then further decreased between end August to end September.

Outcome of translocation: Plants successfully translocated to a new site and grew well in first season (experiment did not continue more than one season so no long-term data).
Potential issues: Loss of plants after translocation appeared to be due to anchorage in sediment.

4.6 Summary of translocation outcomes

In all of the Irish translocation projects, there was low long-term translocation success. This is despite the plants being translocated back to their original habitat and sometimes only being stored for a short period and/ or growing well during storage.
The main issue described is the lack of loose silt to promote establishment of roots and rhizomes of *Groenlandia densa*. Most of the projects involved dredging or re-profiling of the original habitat, which would have removed silt and impacted the substrate present. Timing of translocation was not considered to be an issue with any of the Irish projects. However, as described in Section 3.1.3.1 and 4.5, *Groenlandia densa* exhibits peak growth in spring to early summer (e.g. end April to mid June). The Irish projects removed and translocated material during late autumn/ winter (when growth is much reduced). The French experiment (Section 4.5) translocated small *G. densa* plants prior to the peak growing season (early April) and had a high translocation success rate.
The results of this review suggest that if translocation is undertaken for this project (King's Island), it is important that: the translocation site has loose silt for root and rhizome establishment (i.e. not recently completely dredged/ some sediment retained after dredging) and that translocation of living plants prior to the growing season is undertaken in addition to (or instead of) removal and translocation of late season plants and rhizomes)

5 REVIEW OF PROJECT OPTIONS

5.1 Review of measures

An initial review of measures to protect *Groenlandia densa* at this site (King's Island) are outlined in Table 5.1.

5.2 Potential impact to SAC from loss/ disturbance of the project ditch

One of the Conservation Objectives of the Lower River Shannon SAC is 'To maintain the favourable conservation condition of Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation in the Lower River Shannon SAC' (NPWS, 2012a; 2012b). *Groenlandia densa* is listed as one of three high conservation elements (sub-types) of 3260 within the SAC (NPWS, 2012a). The mapped distribution for the *G. densa* sub-type within the SAC is 1.6 km; this is considered an underestimate, as the species is likely to be more widespread than current records suggest (NPWS, 2012a). This is shown by the new records from this project at King's Island, a site that has botanical records from the wetland and ditch areas but had no previous records of *G. densa* in the east.

Within the SAC the key management objectives for *G. densa* are:

- to maintain the provision of appropriate substrata;
- maintain river flow variation and tidal regime;
- maintain freshwater seepage areas that diffuse onto tidal mud;
- undertake suitable vegetation clearance in canals and drains (regular clearance whilst leaving some plants in situ to allow re-growth); and,
- maintain sufficiently low concentration of nutrients in the water column to prevent changes in species composition or habitat condition (*G. densa* is sensitive to eutrophication).

The project ditch is located outside of (but adjacent to) the Lower River Shannon SAC. It does not appear to be hydrologically connected to the River Shannon. In addition, as a small drainage ditch, it is not considered to be an example of the Annex I habitat 3260 Floating River Vegetation (see also Section 3.1.3.3 and Appendix A).

The nearest population of *G. densa* within the SAC is in Limerick Canal, where it was recorded along a 1.5km stretch in 2006. The project ditch is not hydrologically connected to the Canal. Therefore it is not considered that the loss of *G. densa* from the project ditch would have a direct affect on *G. densa* populations within the River Shannon or Limerick Canal. Although *Groenlandia densa* is abundant within the project ditch along a 200m stretch, it is also abundant elsewhere within Limerick City and environs, within and outside of the SAC. Some key populations outside of the SAC include Loughmore Common, NE of Patrickswell, adjacent to the Ballynaclough River and adjacent to the River Maguire (Figure 3.2 and Table 3.1). Therefore it is not considered that the loss of *G. densa* from the project ditch would lead to a negative impact on the Conservation Objectives of the SAC. However, *G. densa* has shown a decline in Co. Limerick in recent years and also shows a national decline (e.g. Reynolds, 2013; Reynolds et al., 2006 and Preston et al., 2002). The project ditch has a healthy population of *G. densa* with a relatively high quality associated ditch flora. It is therefore considered that the loss of *G. densa* and associated species from the project ditch would have a local negative impact on biodiversity in Limerick City and that the project should include options to either retain the ditch or translocate the key species to a suitable alternative ditch/ site.

Table 5.1. Possible options to protect *Groenlandia densa* as part of flood defence works

Possible option	Positive features	Negative features
1) Retain ditch and relocate new embankment to eastern side of bank	Existing ditch retained with *Groenlandia densa* and additional macrophyte species.	Design footprint may mean that a large amount of wet grassland to the east of the ditch would be lost. May be limitations on whether embankment can feasibly be re-located here. **Best option. However, this is not considered to be feasible within project design constraints.**
2. Create new ditch and translocate *Groenlandia densa* prior to losing old ditch	*Groenlandia densa* can be translocated to new ditch (recipient site) immediately after removal from donor site (existing ditch). No storage of plants required. If time permits then it may be possible to assess whether translocation has been successful prior to the loss of the existing ditch. However, this would require at least one growing season between translocation and loss of the existing ditch. This method creates new ditch habitat (cf option 4).	It may be difficult to recreate the hydrological conditions in the existing ditch (and physical characteristics such as sediment amount and type which are key to *Groenlandia densa* establishment). The water in the present ditch is highly calcareous and may potentially be spring-fed, which would be hard to recreate. Studies on translocation of *Groenlandia densa* back to existing sites after dredging have had limited success (see Section 4). As this would be a new ditch site, successful translocation of *Groenlandia densa* plants cannot be guaranteed.
3. Translocate to holding area and then translocate into new ditch	The existing ditch can be removed prior to the new ditch being created, which may be more practical depending on the works design and timing.	As for no. 2, it may be difficult to recreate the required ditch conditions. Although plants appear to survive in storage areas (see Section 4), this may reduce the success of translocation to the new ditch.
4. Translocate plants into existing ditch system on site (e.g. a ditch that will be retained, inside or outside of the SAC).	The ditches are already present and therefore there will be no issue of high fertility from disturbed soil as for a newly created ditch. Management to remove tall vegetation etc. will improve biodiversity of SAC ditches in the area, even if *Groenlandia densa* translocation not successful. It may be that *Groenlandia densa* was present in these ditches before they became overgrown with tall monocots and scrub with little open water (although there are no historic records).	There may be legal restrictions on introducing a plant to ditches within the SAC system (as *Groenlandia* densa is not currently present in these ditches and there do not appear to be any historic records for King's Island). These may be the only ditches that are retained post-works. Ditch section would need to be dredged to remove tall monocots/ scrub and to provide the open water conditions required by *Groenlandia densa.* The pH of the water in the ditches where *Groenlandia densa* was not recorded was lower than the *Groenlandia densa* area. Even where open water was present (e.g. within the SAC), *Groenlandia densa* was not recorded. It may be that there is a different water source (e.g. spring), which feed the ditch with *Groenlandia densa* and helps to maintain open conditions. This option does not create new ditch habitat to replace that being lost (cf options 2 and 3). **Best option if feasible (legal restrictions) as SAC ditches within same area as project ditch and SAC ditch management would improve biodiversity as the SAC ditches are overgrown and currently have lower biodiversity than the project ditch.**

5.3 Conclusions

This report has reviewed the desktop data for *Groenlandia densa* in relation to its distribution, growth and ecology in Ireland and Europe (Section 3.1). A field survey of the project site on King's Island assessed the ecological value of the project ditch and the population of *G. densa* that it supports (Section 3.2 and Appendix A).

The project ditch on King's Island supports a healthy population of *G. densa* in addition to several other macrophyte species that are indicators of good water quality and ditch conditions. Whilst it is not considered that the loss of this ditch would impact on the Conservation Objectives of the Lower River Shannon SAC (see Section 5.2), the ditch is of biodiversity importance for macrophyte vegetation and *G. densa*. It is therefore important that, if retention of the ditch is not possible, that ditch creation and/ or translocation of *G. densa* is undertaken. Translocation attempts for *G. densa* have not been shown to be successful in Ireland in the long-term (see Sections 4.1, 4.2, 4.3, 4.4 and 4.6). However, whilst it cannot be certain that translocation would be successful in this case, there are amendments to the translocation protocols used thus far (e.g. timing of replanting) that are likely to increase the chance of successful translocation (e.g. see example in Section 4.5). A review of project options (Section 5.1 and Table 5.1) concludes that if ditch retention is not possible, the best alternative option is translocation to the ditch on the eastern side of King's Island (within the SAC). The potential benefits and disadvantages of this option are discussed in Table 5.1. Whilst this ditch system would require some management (e.g. vegetation clearance) to make them suitable for *G. densa* (and this cannot be guaranteed), it is more likely that they will be suitable than a newly created ditch (e.g. due to lack of suitable substrate for *G. densa* root into and potential water quality issues). The feasibility of this translocation option should be discussed with a macrophyte ecologist, NPWS and the project team.

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