

Reversing the decline of a threatened aquatic native plant, the Slender Naiad!

Iain Gunn

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What is the Slender Naiad?

Najas flexilis is a rare aquatic annual plant:

- Typically found in submerged & rooted in clear-water, lowland lochs, often with base-rich substrates
- Normally grows > 2m in clear water
- Relatively short plant, usually only growing to *c.* 30 cm
- One of only *c.* 5% of aquatic plants that pollinate underwater
- Obligate user of carbon dioxide (CO₂)

Naiads are a type of Greek mythological female spirit/nymph associated with freshwaters – much celebrated in literature & art



Undine, by John William Waterhouse

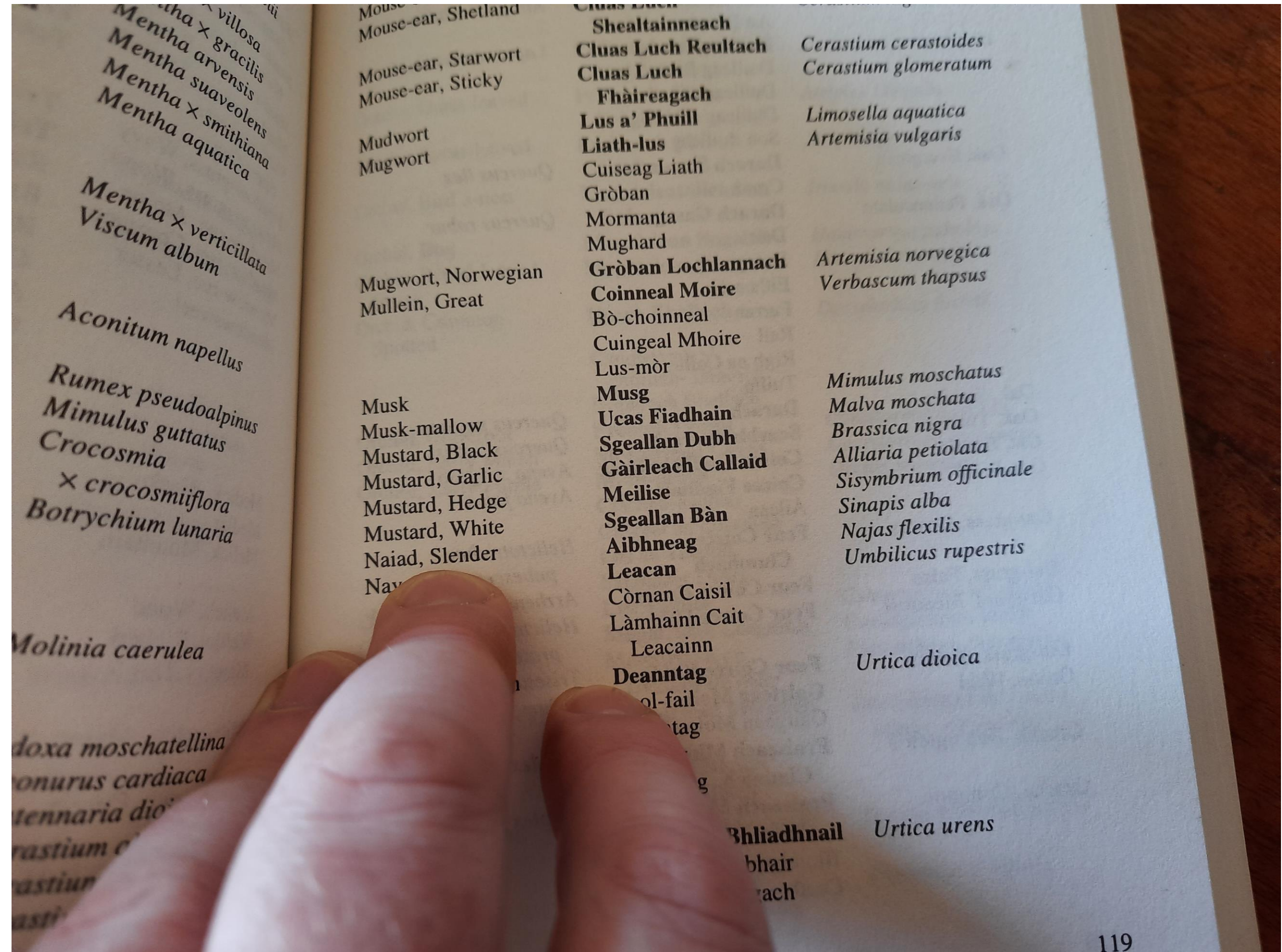
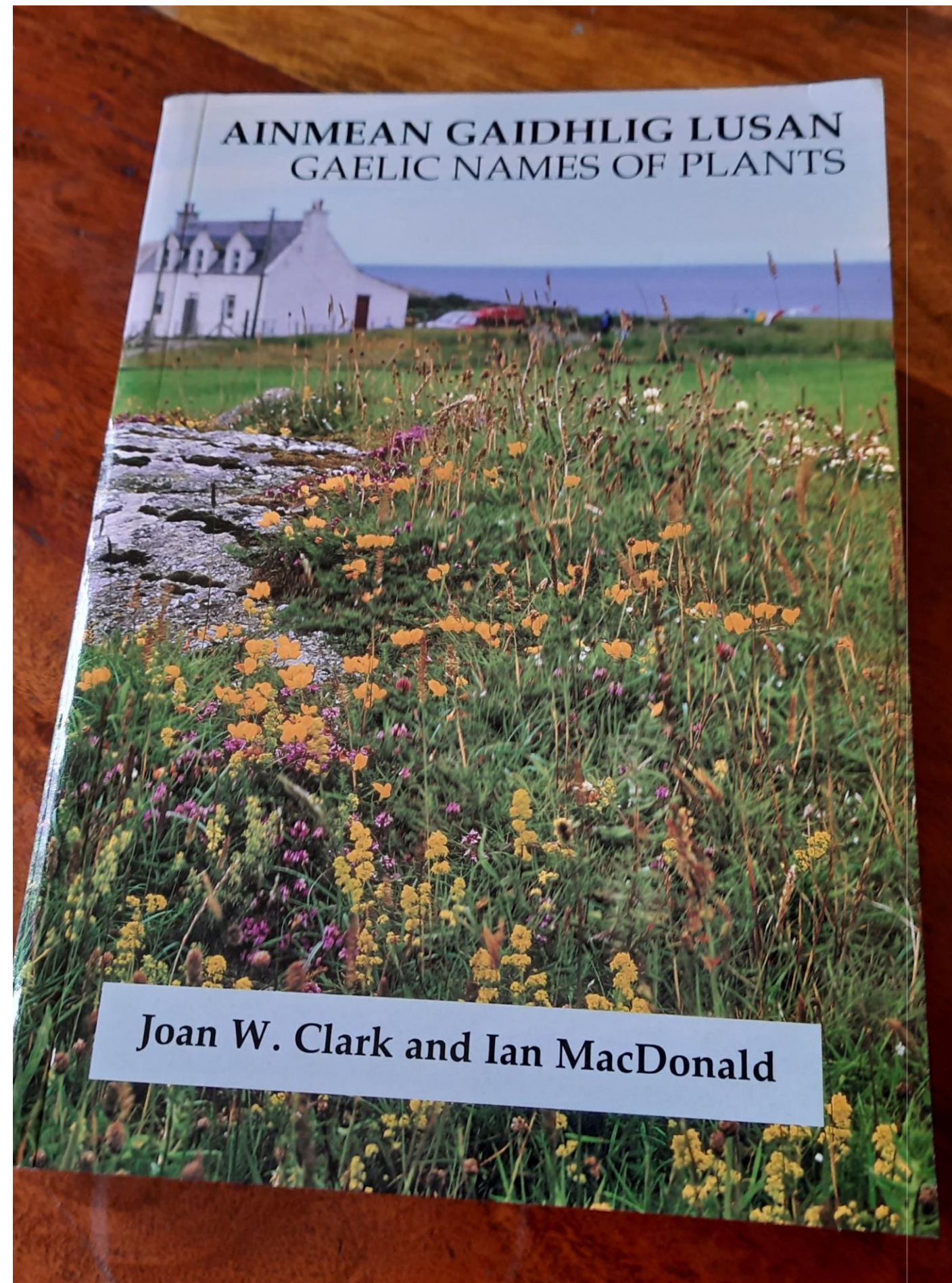


Why conserve it? Conservation importance

- Protected under domestic legislation:
 - Schedule 8 of The Wildlife and Countryside Act, 1981
 - Schedule 4 of The Conservation Natural Habitats Regulations
 - UK BAP species & on the Scottish Biodiversity List

- Scottish sites of international importance
 - Red Data Book species
 - Listed in Appendix 1 of the Bern Convention
 - Listed in Annexes II & IV of the EU Habitats Directive
 - 5 Special Areas of Conservation (SACs) - qualifying interest

Why conserve it? Cultural importance



Where is it?



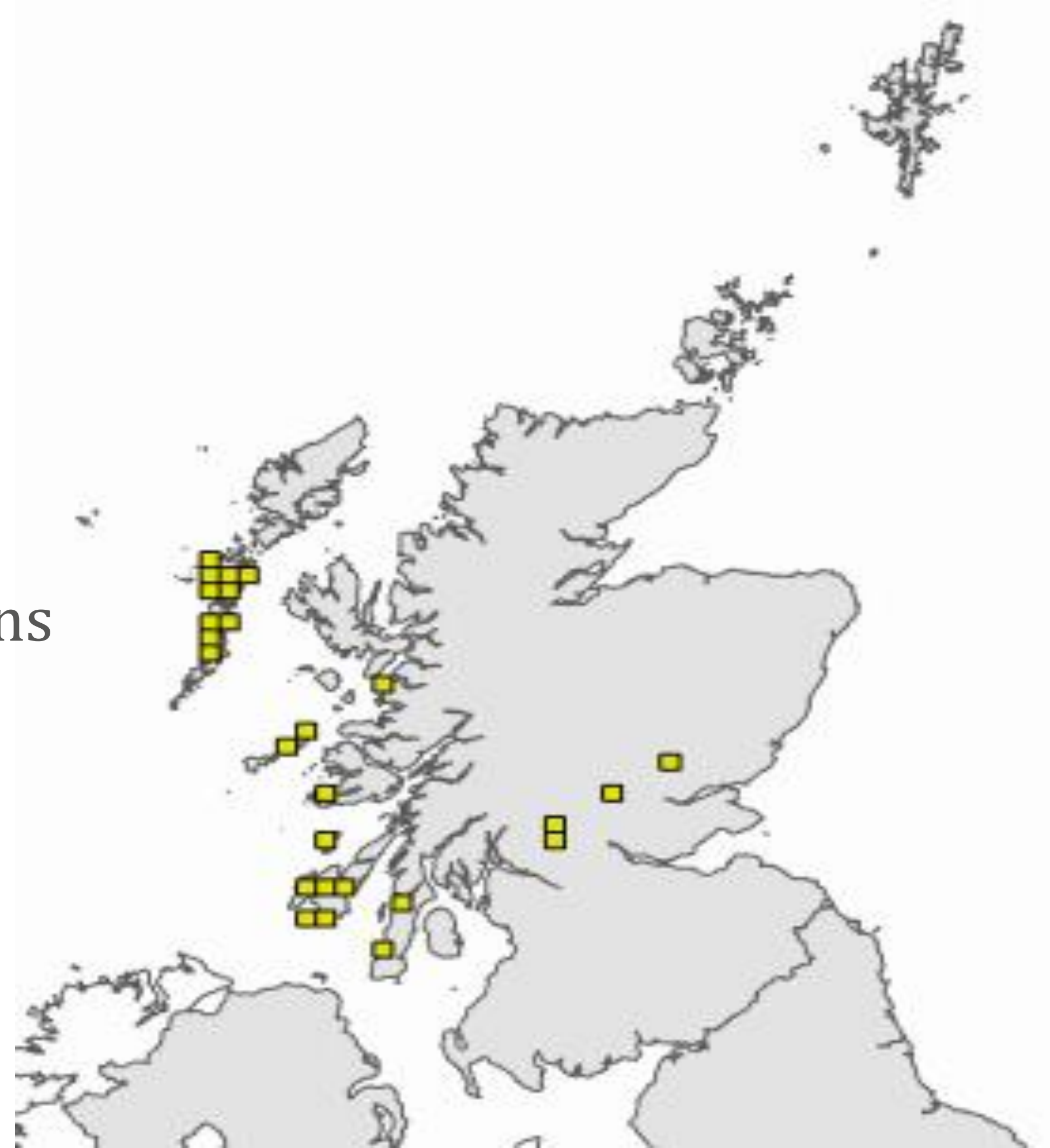
Phil: “Hi Iain, I’m just by Loch Fada in Colonsay, have you ever looked for Slender Naiad here?”

Iain: “I’ve helped organise snorkel surveys for Site Condition Monitoring surveys for Slender Naiad there in 2004 & 2009/10! So keep your eyes open for the elusive Slender Naiad...”



Where is it and why is it under threat?

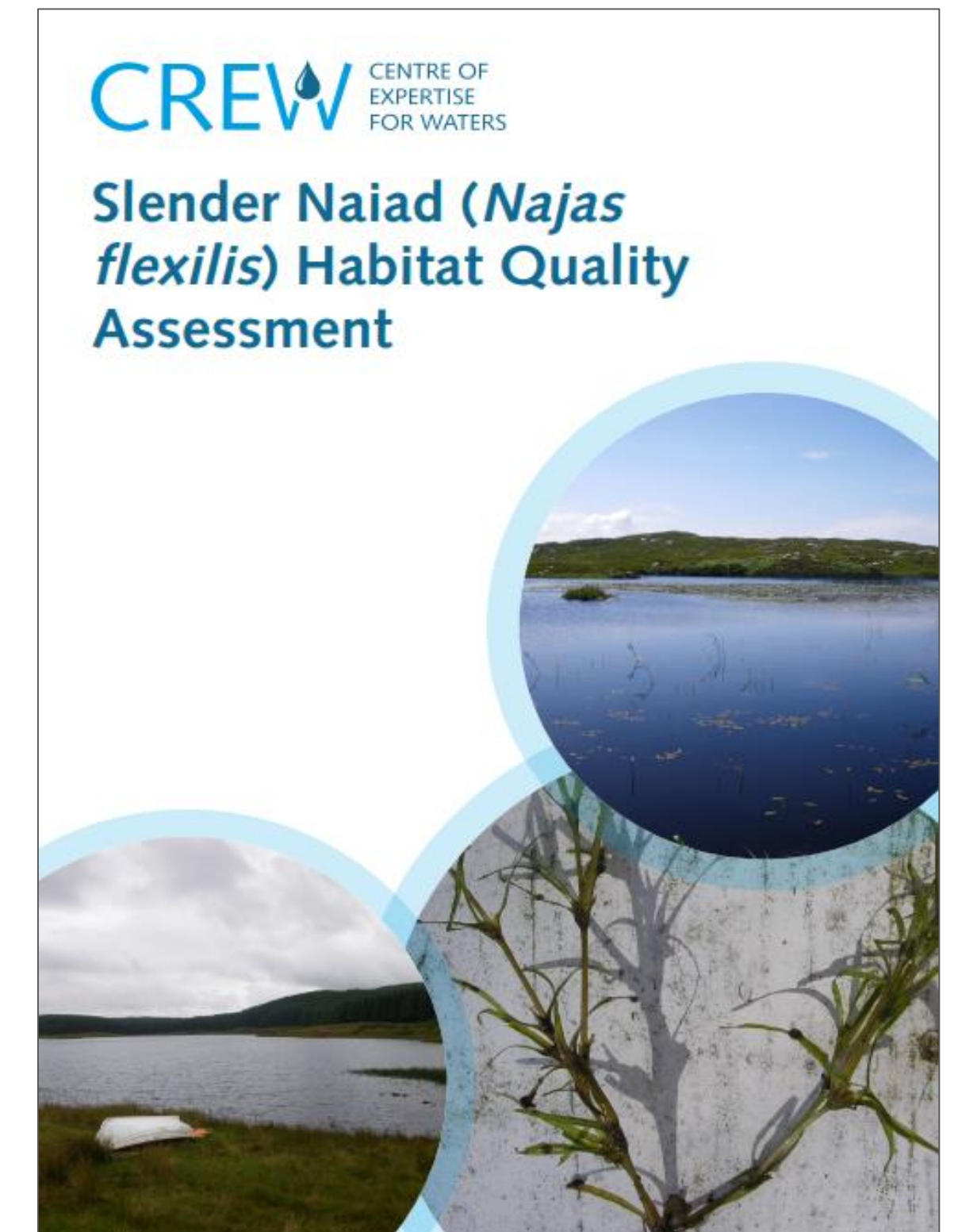
- Strongholds historically in Hebrides, Argyll, Stirlingshire & Perthshire
- Slender Naiad populations under increasing threat in mainland sites with local extinctions
- Factors affecting health of Slender Naiad populations not fully understood:
 - why does the species disappear?
 - where and why it does it fare well in some sites?
 - what needs to be done to ensure habitat quality can support Slender Naiad populations?



CREW Research Project – Phase 1

Phase 1

- Gunn & Carvalho in 2019/20 reviewed existing knowledge & available data on habitat quality requirements of the Slender Naiad
- Three component parts:
 - International expert interviews
 - Literature review
 - Expert workshop
- Highlighted that Slender Naiad particularly sensitive to nutrient enrichment, competition with other plants (e.g. *Elodea* spp.) & mild acidification of circumneutral lochs, primarily because of its physiology as an obligate user of CO₂ (i.e. can't metabolise bicarbonate for photosynthesis)
- Review identified what data are already available, where they are, & how to access them



<https://www.crew.ac.uk/publication/slender-naiad-najas-flexilis-habitat-quality-assessment>

CREW Research Project – Phase 2

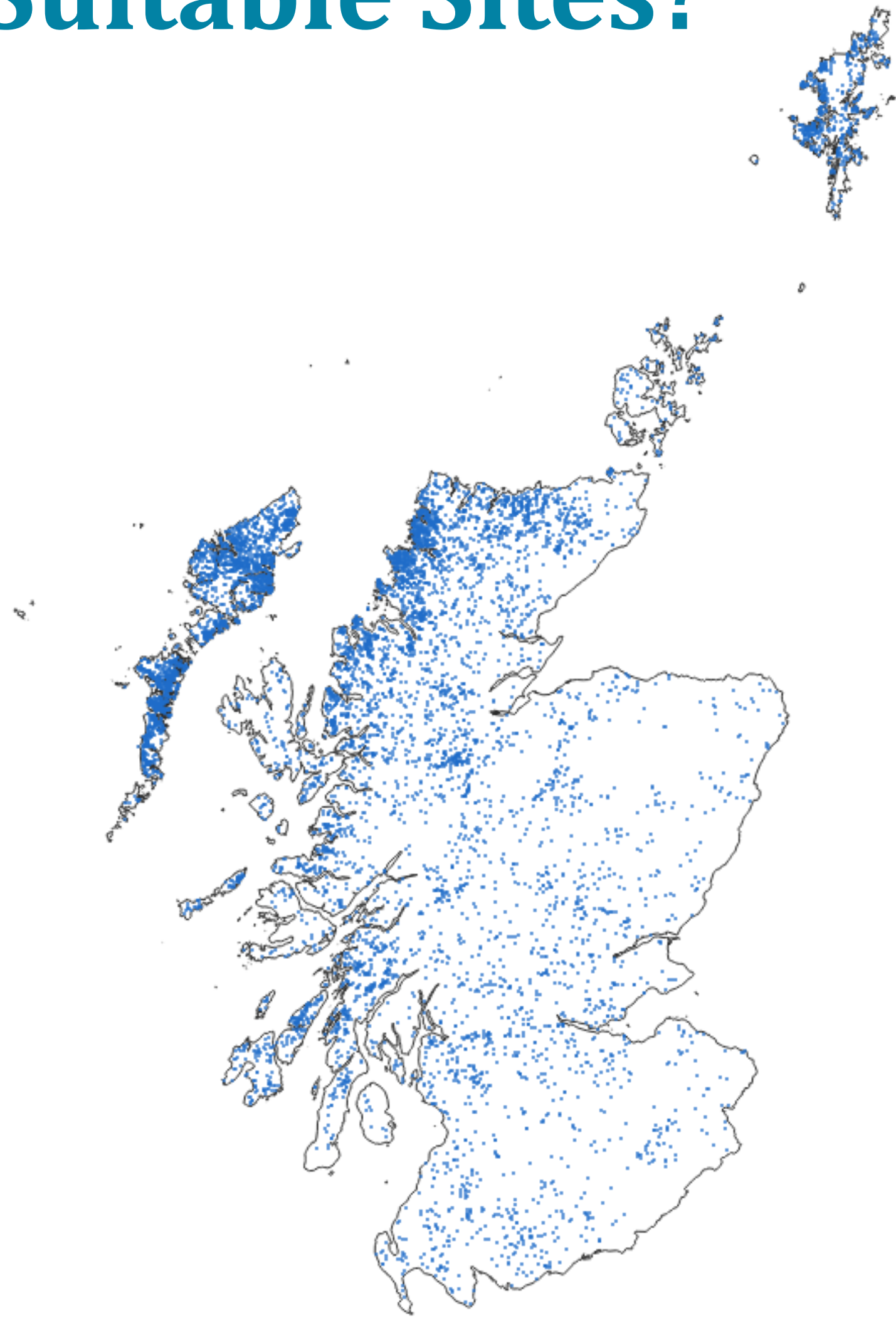
- In Phase 2, Taylor, Carvalho, Gunn & Willby (2021) used Phase 1 findings to identify suitable lochs in Scotland for further investigation of the species' presence and to highlight potential sites for re-introduction
- Develop a prioritisation protocol and apply it to produce a ranked list of the most suitable sites for further field investigations of undiscovered or re-introduction sites for the Slender Naiad

Phase 2



<https://www.crew.ac.uk/publication/slender-naiad-najas-flexilis-habitat-site-prioritisation>

Suitable Sites?



7999 lochs (>1ha)

- Water chemistry (alkalinity & phosphorus concentrations)
- Presence of associated aquatic plant species
- Proximity to known existing Slender Naiad sites



Ideal Water Quality Conditions

Table 3. Environmental thresholds used for assessing habitat suitability for *Najas flexilis*

Factor	Determinand	Ideal Value	Range	UK Lakes Proxy
Free-CO ₂ availability	Alkalinity	120-600 μequiv./L or 6-30 mg/L CaCO ₃	120-1400 μequiv./L or 6- 70 mg/L CaCO ₃	Moderate Alkalinity (MA) lake type with 50-90% siliceous solid geology in catchment
Nutrients	TP as P (μg/L)	<8 (MAD), <=11 (MAS), <=15 (MAVS) <=30 (HA)	<=20 (MA) <=30 (HA)	Modelled TP from NUPHAR project (in UK Lakes database)
Water colour	Colour (mg Pt/L)	<=30	<=60	Clear, Humic or Unknown

Table 4: Number of lochs considered suitable based on alkalinity and nutrient thresholds

Loch Type	Number of Lochs	Number of lochs where <i>N. flexilis</i> known to be present
All lochs	7999	54
Moderate Alkalinity lochs (MA)	1638	27
MA + Low Alkalinity lochs (LA) (alk > 120 μequiv./L)	4315	32
LA + MA + High Alkalinity lochs (HA) (alk < 1400 eqiv./L)	5411	45
LA + MA + HA sites meeting TP standards	4092	36



Identifying habitat suitability for Slender Naiad using aquatic plant species data

- Aquatic plant data used to produce a more targeted short-list of suitable sites at 2 scales:
 - individual water body data from specific loch surveys of aquatic plants (SNH, SCM, SEPA etc.)
 - national-scale 10 km² grid (hectad) data (BSBI, BSS)
- Evaluated set of 80 “associated” aquatic plant species that have previously been recorded at known Slender Naiad sites:
 - for each of 80 species calculated an “Indicator Value” (IndVal) score based on their
 - occupancy & fidelity at sites with & without Slender Naiad (e.g. a species only ever found in association with Slender Naiad would be considered to have 100% fidelity & occupancy)
- IndVal score combined with Water Framework Directive ecological metrics LMNI (Lake Macrophyte Nutrient Index) and LMNI Index score (LMNI scoring taxa) to produce habitat suitability scores

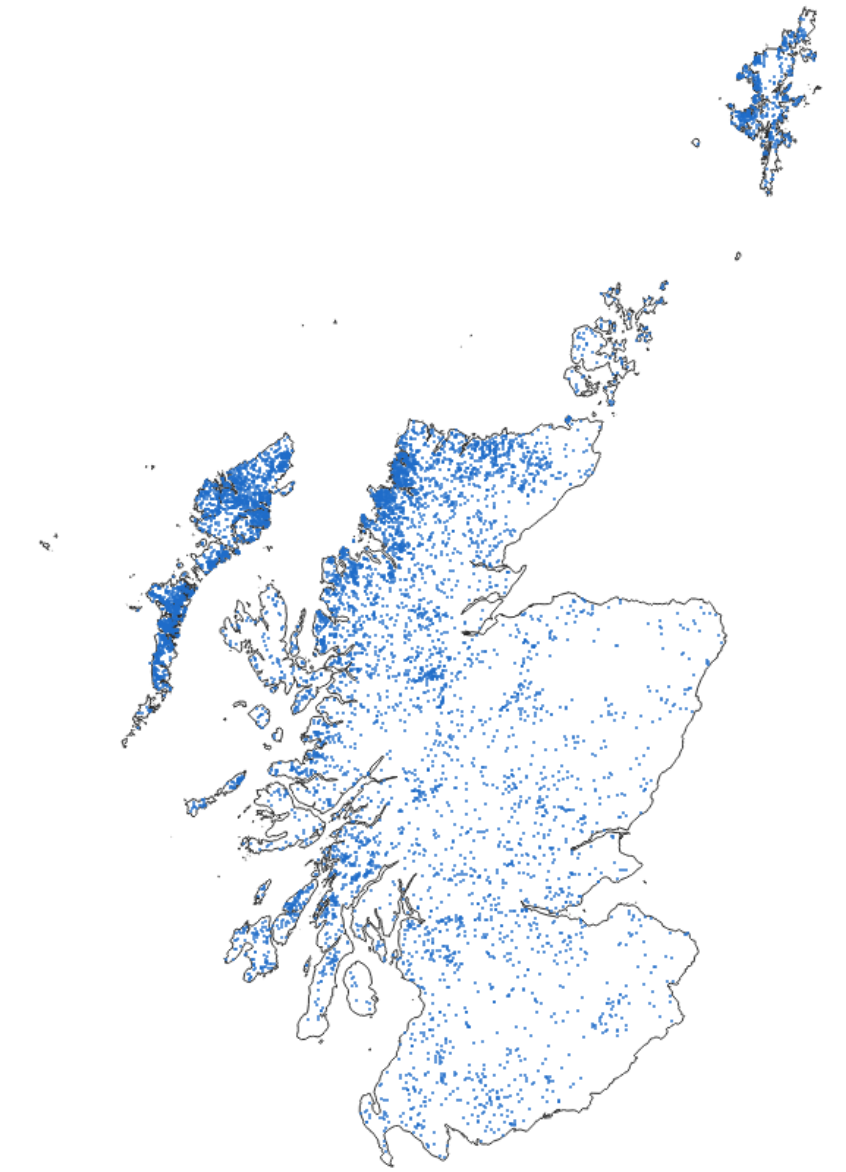
IndVal Analysis

Species	IndVal Score	LMNI Score
<i>Apium inundatum</i>	0.189	4.32
<i>Baldellia ranunculoides</i>	0.302	3.97
<i>Butomus umbellatus</i>	-0.011	7.97
<i>Callitriche brutia</i> subsp. <i>hamulata</i>	-0.143	4.08
<i>Callitriche hermaphroditica</i>	0.139	8.08
<i>Callitriche stagnalis</i> s.s.	-0.106	6.38
<i>Ceratophyllum demersum</i>	-0.015	7.99
<i>Chara aspera</i>	0.301	4.19
<i>Chara globularis</i>	-0.033	6.86
<i>Chara hispida</i>	-0.016	3.95
<i>Chara virgata</i>	0.210	4.29
<i>Chara virgata</i> var. <i>annulata</i>	-0.028	4.07
<i>Chara vulgaris</i>	-0.030	5.56
<i>Elatine hexandra</i>	0.226	3.81
<i>Elatine hydropiper</i>	0.014	5.34
<i>Eleocharis acicularis</i>	0.076	8.68
<i>Eleocharis multicaulis</i>	0.086	3.03
<i>Eleogiton fluitans</i>	0.120	2.03
<i>Elodea canadensis</i>	-0.043	7.45
<i>Elodea nuttallii</i>	0.024	6.19

<i>Fontinalis antipyretica</i>	0.193	4.19
<i>Fontinalis squamosa</i>	0.015	3.09
<i>Hippuris vulgaris</i>	-0.039	5.23
<i>Isoetes echinospora</i>	0.097	2.47
<i>Isoetes lacustris</i>	0.315	2.22
<i>Juncus bulbosus</i>	0.236	2.42
<i>Lemna minor</i>	-0.004	8.52
<i>Lemna trisulca</i>	-0.053	7.96
<i>Littorella uniflora</i>	0.195	3.73
<i>Lobelia dortmanna</i>	0.373	2.16
<i>Lythrum portula</i>	0.054	4.31
<i>Menyanthes trifoliata</i>	0.083	5.17
<i>Myriophyllum alterniflorum</i>	0.247	2.66
<i>Myriophyllum spicatum</i>	0.095	6.23
<i>Nitella flexilis</i> agg.	0.101	5.19
<i>Nitella opaca</i>	0.056	2.36
<i>Nitella translucens</i>	0.304	2.73
<i>Nuphar lutea</i>	0.068	7.47
<i>Nuphar pumila</i>	0.030	4.82
<i>Nuphar x spenneriana</i>	-0.015	3.65
<i>Nymphaea alba</i>	0.078	6.84
<i>Persicaria amphibia</i>	0.087	8.25

<i>Pilularia globulifera</i>	0.015	3.59
<i>Potamogeton alpinus</i>	0.029	4.48
<i>Potamogeton berchtoldii</i>	0.330	6.58
<i>Potamogeton crispus</i>	-0.062	7.5
<i>Potamogeton filiformis</i>	0.046	3.68
<i>Potamogeton friesii</i>	-0.028	4.71
<i>Potamogeton gramineus</i>	0.348	2.85
<i>Potamogeton lucens</i>	0.002	4.37
<i>Potamogeton natans</i>	-0.007	4.71
<i>Potamogeton obtusifolius</i>	-0.013	6.97
<i>Potamogeton pectinatus</i>	0.205	7.19
<i>Potamogeton perfoliatus</i>	0.535	4.42
<i>Potamogeton polygonifolius</i>	-0.027	2.39
<i>Potamogeton praelongus</i>	0.079	3.92
<i>Potamogeton pusillus</i>	0.008	7.54
<i>Potamogeton rutilus</i>	0.134	5.49
<i>Potamogeton x nitens</i>	0.128	3.48
<i>Potamogeton x zizii</i>	0.017	4.04
<i>Ranunculus</i> (sub sect. <i>Batrachian</i>) sp.	-0.011	5.31
<i>Ranunculus aquatilis</i> var. <i>aquatilis</i>	0.057	5.81
<i>Ranunculus aquatilis</i> var. <i>diffusus</i>	-0.020	4.2
<i>Ranunculus circinatus</i>	-0.013	8.7

<i>Ranunculus hederaceus</i>	0.002	8.33
<i>Ranunculus lingua</i>	-0.028	6.79
<i>Ranunculus peltatus</i> *	-0.045	6.485
<i>Scorpidium scorpioides</i> **	0.007	N/A
<i>Sparganium angustifolium</i>	0.264	2.52
<i>Sparganium emersum</i>	0.084	6.06
<i>Sparganium natans</i>	-0.026	2.79
<i>Subularia aquatica</i>	0.022	1.8
<i>Tolypella glomerata</i>	-0.018	5.32
<i>Utricularia australis</i>	-0.023	2.87
<i>Utricularia intermedia</i> s. l.	-0.031	1.61
<i>Utricularia minor</i>	-0.029	2.36
<i>Utricularia ochroleuca</i>	-0.001	1.04
<i>Utricularia stygia</i>	0.022	1.3
<i>Utricularia vulgaris</i>	0.036	4.24
<i>Zannichellia palustris</i>	0.018	8.69



Applied to:

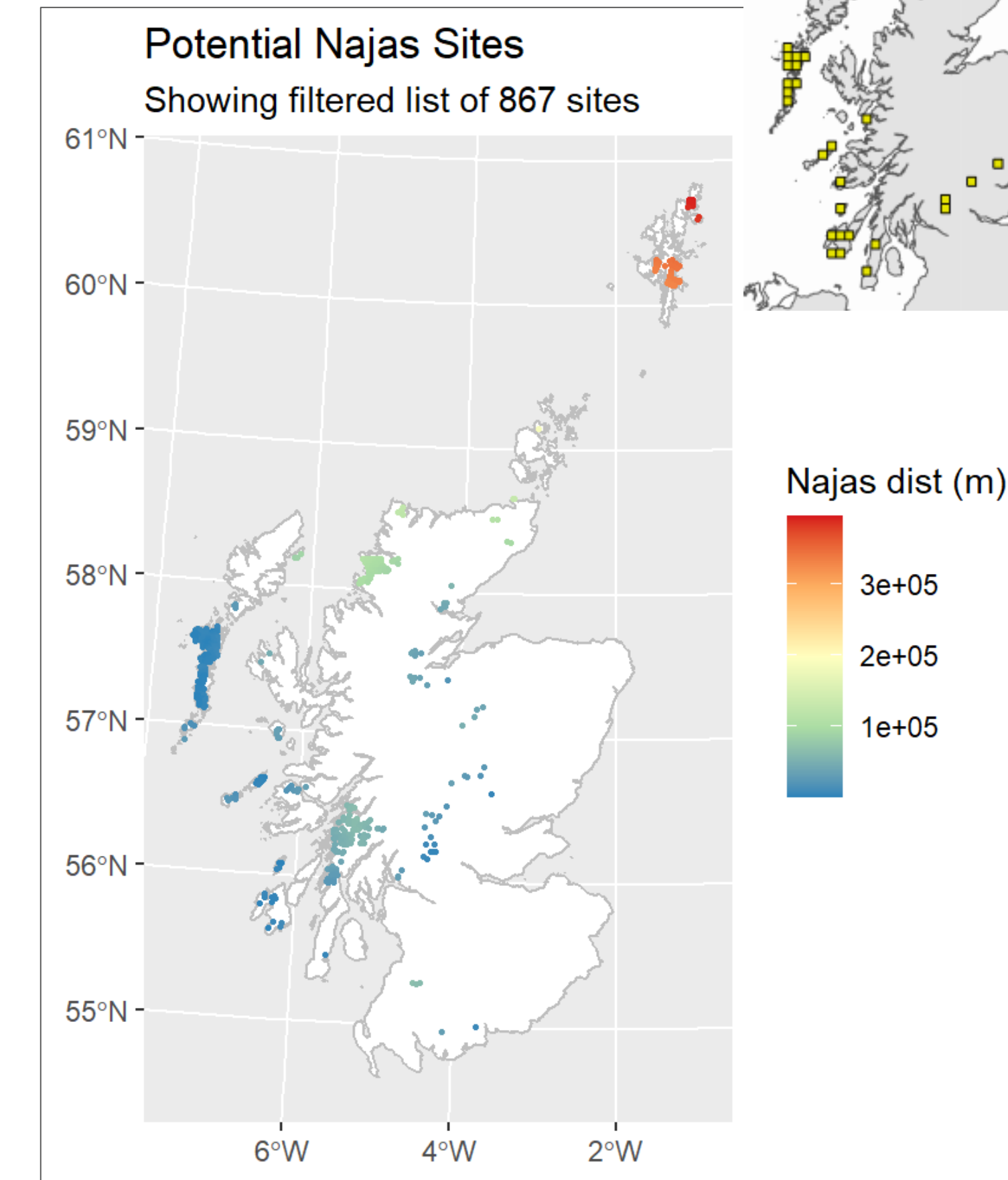
- All surveyed lochs
- All lochs using BSBI / BBS hectad data

Results

4092 sites ranked:

Table 5: The Top 20 ranked sites following prioritisation protocol

Rank	WBID	NAME	UKCOUNTY	WB Latitude	WB Longitude	Distance to nearest Najas site	Elodea canadensis records in hectad	Elodea nuttallii records in hectad	Crassula helmsii records in hectad	Hectad suitability score - total	Site survey suitability score - total
1	20481	Loch Pityoulish	Highland	57.2006	-3.7835	39.5	42	NA	3	3	3
2	20742	Loch an Eilein	Highland	57.1469	-3.8242	44.5	36	NA	NA	3	3
3	28189	Loch Arthur	Dumfries and Galloway	55.0027	-3.7135	7.4	26	NA	NA	2.5	3
4	12995	Loch Migdale	Highland	57.8882	-4.3022	41.5	2	NA	NA	2.5	3
5	24770	Loch na Beiste	Argyll and Bute	56.1955	-5.5235	44.2	38	NA	2	2.5	3
6	24025	Loch Awe	Argyll and Bute	56.3077	-5.2235	47.7	30	12	1	2.5	3
7	24293	Dubh Loch	Argyll and Bute	56.3273	-5.5591	48.5	20	NA	2	2.5	3
8	23515	Loch Tay	Perth and Kinross	56.5067	-4.1644	21.0	8	NA	1	3	2.5
9	24509	Loch a Phearsain	Argyll and Bute	56.2682	-5.4637	50.3	24	NA	NA	3	2.5
10	25179	Loch Coille Bharr	Argyll and Bute	56.0522	-5.53	32.2	24	NA	NA	2.5	2.5
11	28271	Lochenbreck Loch	Dumfries and Galloway	54.9665	-4.1217	32.3	16	12	NA	2.5	2.5
12	12578	Loch an Lagain	Highland	57.9294	-4.2674	45.5	2	NA	NA	2.5	2.5
13	24852	Lochan Fearphorm	Argyll and Bute	56.176	-5.4836	45.3	38	NA	2	2.5	2.5
14	24399	Loch na Sreinge	Argyll and Bute	56.3002	-5.3528	58.0	12	NA	NA	2.5	2.5
15	24830	unnamed	Stirling	56.2076	-4.3036	3.5	104	2	1	3	NA
16	24820	Lochan Balloch	Stirling	56.2099	-4.2719	4.0	104	2	1	3	NA
17	24822	unnamed	Stirling	56.2094	-4.3233	4.3	104	2	1	3	NA
18	24965	unnamed	Stirling	56.1528	-4.3633	5.1	32	NA	NA	3	NA
19	24934	Lochan Spling	Stirling	56.173	-4.4129	7.2	104	2	1	3	NA
20	24623	Glen Finglas Reservoir	Stirling	56.2529	-4.3838	8.9	104	2	1	3	NA

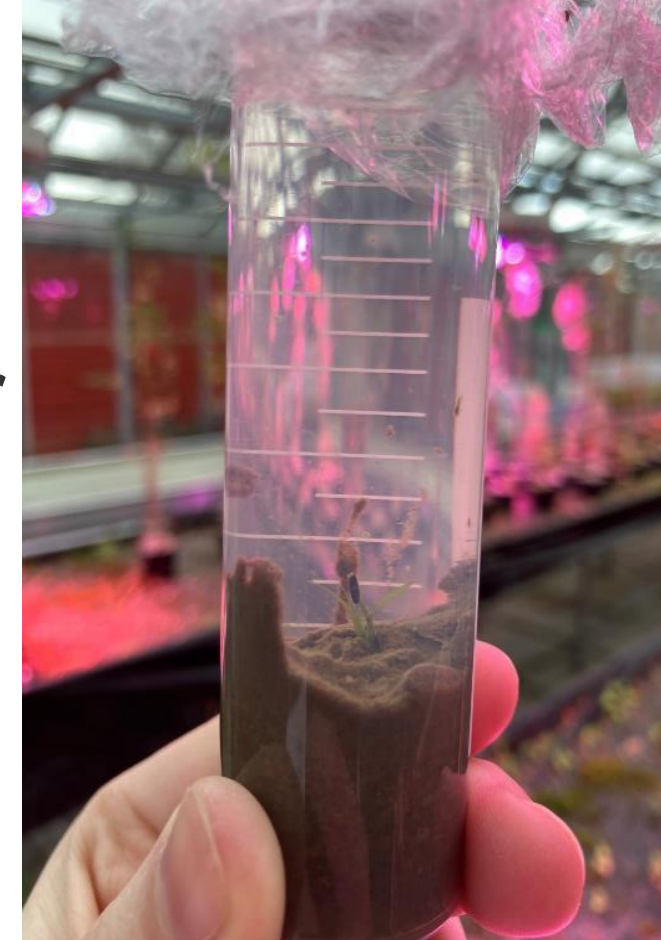


Phase 3?

- Next stage of Slender Naiad recovery story is to potentially carry out field surveys to check whether the identified top-ranked lochs do hold previously undiscovered Slender Naiad populations:
 - aquatic plant surveys
 - sampling loch sediments to check for Slender Naiad seeds
 - novel survey methods, e.g. eDNA techniques, may be option to detect presence of Slender Naiad populations at selected sites
- Species introduction programme?

Slender Naiad propagation

- NatureScot funding to establish Slender Naiad stock from seed in UKCEH greenhouse
- Seed collected from stock population in October 2020
- Viability tests (red stain) showed 50% of seeds viable, 40% partially viable & 10% unviable
- 75% of Slender Naiad 2020 seeds from stock population produced seedlings in small-scale germination trials
- Success in germinating a proportion of seeds collected in 2018 & 2019
- Collected c. 1,500 seeds from stock Slender Naiad population in 2021 for upscaling



Take home messages

- Slender Naiad is a rare plant of European importance
- There are many more sites where it potentially could exist
- Novel IndVal approach brings new habitat suitability understanding
- If upscaled propagation of Slender Naiad successful - offers potential to translocate plants into new loch sites identified in site prioritisation exercise
- Potentially help redress the contraction in Slender Naiad's distributional range in mainland Scotland