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The habitat suitability of the Studland heaths dune system for the natterjack toad *Epidalea calamita*

A dissertation submitted as part of the requirement for the BSc Ecology and Wildlife Conservation.

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Abstract

Amphibians are facing widespread decline on a global scale due to habitat loss, climate change, trade and the spread of emerging diseases. In the UK, the natterjack toad *Epidalea calamita* had declined up 70-80% by the 20th century due to widespread habitat loss caused by urbanisation, afforestation and the cessation of traditional land management practices, resulting in ecological succession. Translocations of natterjack spawn enabled the reintroduction of the species to 19 sites between 1975 and 2010, however, recent species status assessments highlight a lack of habitat in sufficient quantity and quality. This study seeks to address the shortage of suitable areas of habitat for the natterjack by assessing the habitat suitability of the Studland heaths dunes system. The Studland dune system was identified as a possible area suitable for the translocation of natterjacks, in light of recent works to reduce the succession stage of vegetation through the reinstatement of traditional grazing and the creation of temporary ponds. A natterjack habitat suitability index (HSI) was formed by identifying critical population limiting factors from a literature review including aquatic vegetation coverage %, conductivity, pH, pond shading, pond area, pond network, terrestrial vegetation structure, pond drying and predator risk. Several field trips were undertaken in April 2022 and March 2023 to collect data which was analysed in QGIS and Graphab. The result was the identification of two ponds rated as 'excellent' and nine ponds rated 'good'. Management options to improve habitat suitability for natterjacks and limitations and improvements of the HSI are discussed.

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Contents

1 Introduction

1 The decline of amphibians

A recent global biodiversity review shows that amphibians are the most threatened group of animals on the planet; of all assessed amphibian species by the International Union for the Conservation of Nature, 41%, 1,957 species, are categorised as Vulnerable, Endangered or Critically Endangered, (Monastersky 2014). Amphibians are ectothermic and are reliant on water for reproduction as well as survival due to their highly permeable skin, making them vulnerable to abiotic factors such as water quality and desiccation (Halliday 2008). The global decline in amphibian populations has been noted since the 1950s, although significant recognition only came in the 1989 First World Congress of Herpetology (Barinaga 1990). By this time in the UK, the natterjack toad *Epidalea calamita* had faced widespread decline and the threat of local extinction from habitat loss, which have been somewhat reversed through translocation projects (Beebee et al. 1990).

1.2 The natterjack toad: ecology and its habitat

The natterjack toad, *Epidalea calamita* (Laurenti 1768), is a medium-sized (<10cm) true toad in the order Anura (figure 1). It has a European distribution, it is a niche specialist in habitats featuring friable soils, short turfs, bare ground and ephemeral pools. The main habitats across its range include Mediterranean temporary ponds, coastal marsh, lowland heathlands and coastal sand dune systems (Ruhí et al. 2012; Reyne et al. 2019). Open habitats are essential foraging grounds, where it feeds upon invertebrates; unlike other toads it does not typically hop, ambulating with a curious gait referred to in its Spanish common name, *sapo corredor* - the 'runner toad' (Beebee 1979). Their shortened limbs are an adaptation for digging, retreating to burrows during the winter and daytime, and emerging in the evening to feed and breed (Denton and Beebee 1994). The ability to burrow and thrive on areas of sparse vegetation represents niche separation from the sympatric competitor species *Bufo bufo*, despite significant dietary overlap (Denton and Beebee 1994). Like most other true toads, this species is sexually dimorphic, with females (<10cm) being typically larger than males (<8cm), with both sexes attaining a reduced maximum size in the northern part of its distribution. This variation may be substrate-dependent, reflecting resource availability and selective pressure in maturation size (Marangoni et al. 2021).

Figure 1: The natterjack toad, with characteristic horizontal pupils and yellow dorsal stripe (Brown 2012).

Breeding occurs within warm, rapidly drying ephemeral pools in open habitats; the rapid development of tadpoles enables predator escape and allows the natterjack to survive outside the niche of competitively dominant sympatric species such as *Bufo bufo* during the development stage (Reques and Tejedo 1997). Adaptation to this habitat makes the developing tadpoles especially vulnerable to pond desiccation during years of low rainfall (Sinsch 1992), however deeper pools, less prone to desiccation, come with the trade-off of increased predation pressure from macroinvertebrates *Notonecta* spp. and Odonata larvae (Banks and Beebee 1998). Pond habitats with significant niche crossover with other amphibians are unsuitable for natterjacks, with reduced growth rates or total predation of the spawn (Banks and Beebee 1987).

The powerful call of the male natterjack attracts both females and other males to the breeding pools during the breeding season from April to July (1971). Some studies show a female preference for more powerful calls, however half of the observed females mate with the first male encountered, a behavioural adaptation that reduces the time spent in the pool and thus reduces her predation risk (Arak 1988). Female natterjacks typically produce a single pair of spawn strings containing around 4000 eggs, although incidences of a second smaller string later in the season have been observed on some occasions (Beebee and Denton 1996; Trochet et al. 2014). As a result of their scramble breeding behaviour, the majority of offspring will carry the genetics of a few dominant males, contributing to lower genetic diversity in small or isolated populations (Wells 1977; Ficetola et al. 2010).

1.2.1 Threats

Changing land use within the range of the natterjack has led to the extinction of some populations and presents increasing pressure on remaining populations throughout Europe (Beebee 1977). The anthropogenic development and homogenisation of natural landscapes to supply the growing human population and associated economic activity have resulted in extensive habitat degradation and fragmentation. Research by Foley et al. (2011) showed that 38% of the Earth's ice-free terrestrial land surface is utilised for agricultural purposes, with increasingly intensive farming methods employed. The global distribution of agricultural intensity is not equal, however, as in England the used agricultural area increases to 69% of total land cover, an area of 8.9 million hectares. The shift away from traditional, less impactful methods of land stewardship in favour of intensive methods has been cited as a key driver for the habitat loss of amphibians in Europe along with urbanisation (Curado et al. 2011; Smith and Skelcher 2019). The cessation of traditional grazing practices, along with increased agroforestry within the natterjacks heathland and dune habitats, has led to vegetative succession and thus the loss of suitable breeding pools and areas of short swards and bare ground for foraging and burrowing (Beebee 1977). Overall, the population of natterjacks in the UK had declined by 70-80% at the beginning of the 20th century, particularly in the South of England, which was reduced to one surviving population in Woolmer forest (Beebee 1977; Beebee et al. 1990).

1.2.2 Legal protections

The natterjack toad is protected both at an EU and national (UK) level, with overlapping designations protecting both the species and its habitats. In the UK, they are protected as a European protected species in Schedule 2 of the Conservation (Natural Habitats, &c.) Regulations 1994, making it unlawful to kill, capture, disturb or destroy their breeding places. This legislation adopted the designations of the European Council Directive 92/43/EEC, also known as the Habitats Directive, which established both Special Areas of Conservation (SAC) and Special Protection Areas (SPA), collectively known as Natura 2000 sites. Under Articles 11 and 17 of this directive, as an Annex IV species, a pan-EU status assessment was undertaken, in which it is clear that the natterjack is under threat in most of its European range (figure 2). This is in contrast to its status of Least Concern as assessed by the IUCN amphibian specialist group (IUCN 2022). In post-Brexit UK, the nature network established under Natura 2000 is replaced by a National Nature Network under ministerial authority through the 2019 amendment to the Conservation of Habitats and Species Regulations 2017. Natterjacks also have protection in England and Wales from disturbance, obstruction and sale under section 9(4)(b), (c) and (5) of the Wildlife and Countryside Act 1981 (as amended).

The 1971 International Ramsar Convention on Wetlands also covers many dune and wet heath habitats favoured by natterjacks, although as an international framework of guidance focusing on protection and sustainable use, it lacks the enforcement options available under national directives and acts. Similarly, an earlier form of habitat protection in the UK, the designation of a Site of Special Scientific Interest (SSSI) also protects many natterjack populations, increasing from 60% coverage in 1970 to 83% by 1990 (Banks et al. 1994). The level of protection offered by SSSI designation was upgraded in the Wildlife and Countryside Act 1981, allowing the Nature Conservancy Council, now defunct, to prevent damaging activities on SSSIs (Banks et al. 1994). Site designations do not cover all populations in the UK however, and agricultural improvement has led to damage and population declines in the 1980s, although this situation has since stabilised through conservation interventions (Banks et al. 1994; JNCC 2019).

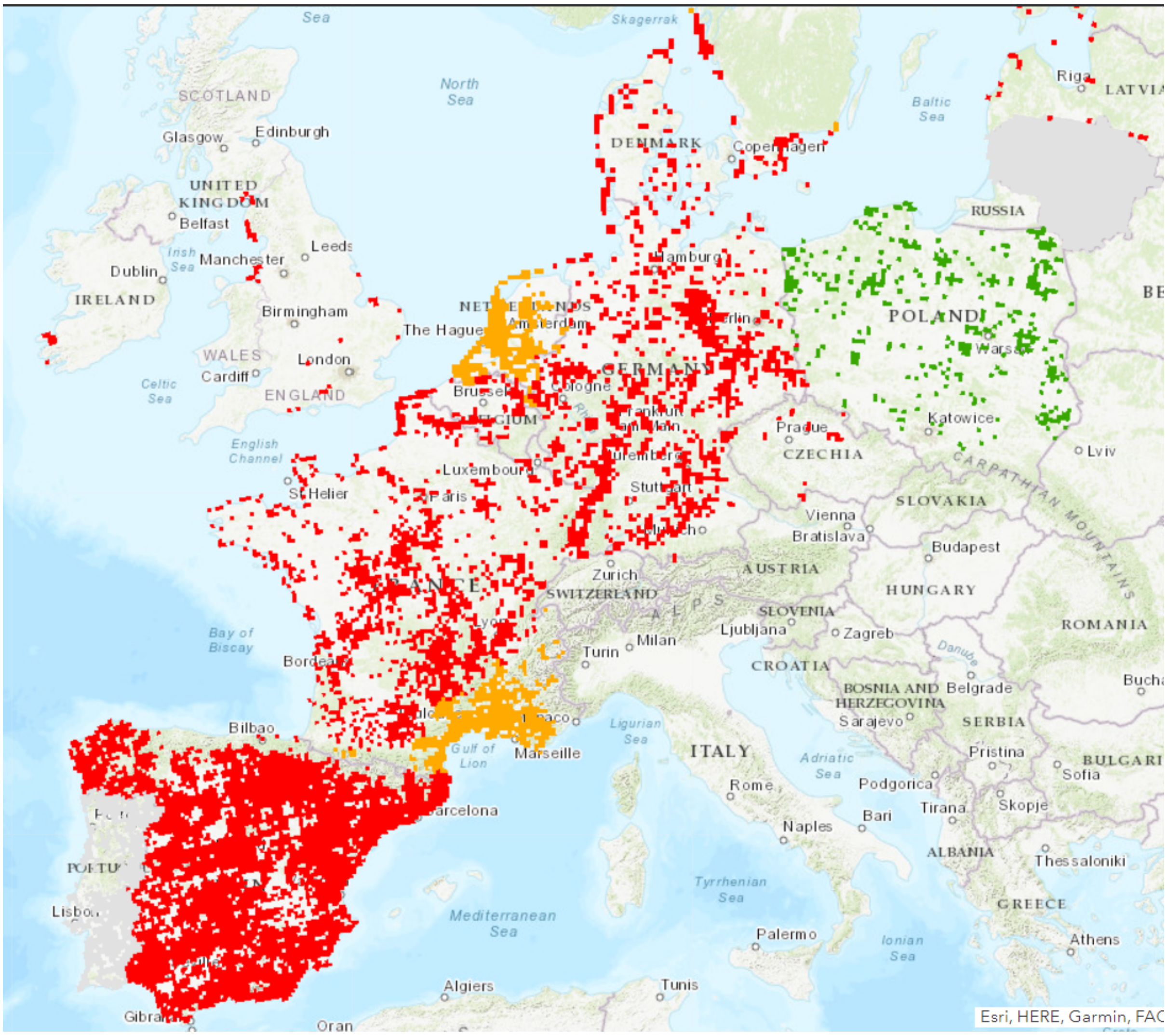

Figure 2: Habitat Directive Article 17 status assessment of *Epidalea calamita* within Europe. Green = Favourable, Orange = Inadequate, and Red = Bad (European Environment Agency 2018).

1.2.3 Translocations and conservation action in the UK

Translocations are the restoration of populations via the intentional movement of flora or fauna, with the aim of improving the conservation status of a species or its habitat through the restoration of ecological function (Seddon et al. 2014). Translocations, alongside sympathetic management practices, were identified as a key tool for the restoration of natterjacks to their former range in a UK biodiversity action plan (JNCC 2010). An attempt to form and reinforce natterjack population strongholds through the translocations of natterjacks began in the 1970s, although the initial attempts were unsuccessful. Later projects in the 1980s proved more successful due to the experience gained and method improvement from the 1970s, highlighting the importance of the accumulation of knowledge in behavioural ecology, feasibility analysis and economic management when conducting translocations (Banks et al. 1994, Berger-Tal et al. 2020, Ewen et al. 2014). A review by Griffiths et al. (2010) assessed the reintroduction of natterjacks to 29 sites between 1975 and 2010, of which 19 (70%) were successful in the medium term.

As an R-selected species with masses of offspring, and due to the homing and territorial instincts of adult natterjacks, translocations are attempted using the spawn, which enables the efficient transportation of many thousands of individuals at a time (Banks and Beebee 1988). Translocation of spawn may also confer immunological benefits, as the succession of protective symbiotic bacteria is able to develop in the context of the release environment (Conlon 2011; Prest et al. 2018). The release of many individuals at once is important, as a low-density population may succumb to the Allee effect, whereby inverse density dependence leads to issues with finding mates and negative population growth (Courchamp et al. 1999).

1.2 Habitat Suitability Indices (HSI)

Habitat Suitability Indices (HSI) are a standardised assessment, typically employed as a predictive tool to model areas of ecologically suitable and unsuitable habitat for the target species and to assess the ecological impact of other factors, such as climate change and invasive species (Hirzel et al. 2006). The adoption of HSI in species translocation projects allows the identification and characterisation of potential release sites, as well as the ability to model the carrying capacity and occupancy of the species within the chosen site (Macdonald et al. 2000). The typical output of a HSI is a numerical value between 0, representing unsuitable habitat, and 1 indicating optimal habitat (Oldham et al. 2000). The selection of HSI parameters is critical, as the exclusion of population limiting factors may result in no correlation between HSI outcome and species abundance (Layher 1985). There is currently no HSI focusing on the natterjack toad.

1.3 Natterjack UK status summary

Reintroduction efforts over the last 50 years have managed to re-establish the natterjack toad to 19 sites in the UK, reversing some of the historic declines. Led by the Herpetological

Conservation Trust, now Amphibian and Reptile Conservation, these efforts continue to the present, with a reintroduction currently taking place in Hampshire (ARC 2022). However, the latest Article 17 report from the JNCC (2019) finds that England, which holds 76% of the UK natterjack population, does not have sufficient quantity or quality of habitats for the species to achieve Favourable Conservation Status.

2 Aims

This study aims to meet the need for the identification of appropriate translocation receptor sites by investigating the suitability of the Studland Heath dune system for a natterjack toad translocation project.

Objective 1

Produce and critically assess the feasibility of a habitat suitability index for the natterjack toad. This will be achieved by reviewing relevant literature to form a workable index that allows a comparative assessment of habitat suitability.

Objective 2

Accurate collection of spatial, biotic and abiotic measurements in the field, enabling calculation of the HSI, and mapping of habitat suitability and connectivity.

Objective 3

Critically discuss the habitat suitability of the Studland Heath dune system for translocation of the natterjack toad.

3 Survey methods and natterjack toad HSI development

3.1 Survey site: Studland Heath

The Studland heaths, designated as part of the Studland and Godlingston heaths (SSSI), has a remarkably detailed documented history of its formation, much of which has occurred in the last several hundred years (Diver 1933). Recent work by Howlett et al. (2022) investigated a palaeoenvironmental dataset obtained from sedimentary cores, which show highly unstable environmental conditions during the early development of beaches and sand bars from ~1150–1470 AD and the subsequent formation of the dune system. The dune system is comprised of three primary ridges, beginning with the formation of the confusingly named Third Ridge in the 1700s, followed by the Second and Firstridges between the late 1700s and 1849 (Diver 1933). Diver (1933) noted the ecological attraction of the area for its fauna and flora, in addition to the relative absence of human influence.

In subsequent years, the cessation of traditional grazing has led to extensive ecological succession and fixation of the dunes, the restoration of which was the subject of a recent management plan (Mahdi 2015). Cattle were brought onto the site after an absence of 90 years as part of the Dynamic Dunescapes project, which aims to increase bare ground cover to 10% from the current 2% (Dynamic Dunescapes 2021).

3.2 Survey Methods

Following the engagement and permission of the National Trust at Studland, a site visit was conducted to identify any existing pond sites. The survey was conducted twice: in late April 2022 and March 2023. The timing of the survey was targeted to be within the timeframe in which the ponds would be utilised as breeding pools by natterjacks. Habitat mapping as well as the approximate locations of where 'wet scrape' conservation works were recently carried out were provided by the National Trust.

Identification of suitable water bodies was determined by digitally drawing the bounds of the water margin within Qfield, an open-source project provided by QGIS (Team 2016). Any islands within the pond margin were also traced and cut out of the pond area. The pond survey was timed to map pond areas at their fullest extent, with the expectation that they would reduce over time due to evaporation. The device used was a Sony Xperia XZ2, which has an onboard GPS with an inaccuracy of up to 5m, however comparison with visual landmarks on satellite imagery revealed greater accuracy (<3m) in practice. Each pond was given an individual identification number or name to allow analysis and data association in follow-up surveys.

The pond water quality parameters of conductivity and pH were measured using a Hach Multimeter HQ40D according to the manufacturer's instructions.

The invertebrate community within the pond was assessed with a standardised approach adapted from the national pond survey method (Biggs et al. 1998). A 1.5mm mesh telescopic pond net for maximum reach, using the 'shuffle' technique to capture both benthic and pelagic specimens. These were then identified visually within a white tray and counted or approximated where appropriate. The invertebrate community was assessed three times from opposing margins to capture the diversity of each pond. Aquatic vegetation was noted, both species and approximate percentage cover.

3.3 Natterjack HSI construction

The HSI adapted for this study is the great crested newt (GCN) *Triturus cristatus* HSI, which was developed with the aim of offering a simple assessment of GCN habitat with the premise that habitat quality is significantly correlated to GCN population size (Oldham et al. 2000). The survey data were collated per pond, and the Natterjack HSI was applied to the results to produce the scores in the below categories and numerical scales. Some data points were unobtainable in the first year due to drought conditions. Also, typical aquatic floras were also absent in 2022 as they had not yet had time to establish themselves.

3.3.1 Aquatic vegetation

A coverage of approximately 40% of aquatic plants growing on the pond substrate is significantly linked to natterjack presence (Reyne et al. 2021). However, management aims for natterjack conservation include the maintenance of early succession phase aquatic vegetation, a reduction in emergent vegetation and the creation of bare soils (Reyne et al. 2021; van der Loop et al. 2023). The natterjack HSI reflects this by favouring a balance between both states (table 1). Flora should be identified at the species level as a matter of record as they are important for indicating the succession phase, however, these do not figure in the HSI calculation due to a lack of available baselines for comparison. Invasive species should also be noted for reporting to site management. Consideration of the inclusion of these in the SI was given, however, research points to a mixed picture of the impact on natterjack toads for example in the case of *Crassula helmsii* (van der Loop et al. 2023).

Table 1: Aquatic flora SI

Pond substrate aquatic flora	Score
<10%	0.33

11-29%	0.67
30-50%	1
51-75%	0.67
76-100%	0.33

3.3.2 Salinity

Natterjacks are more tolerant of higher levels of salinity than other native amphibians and their macroinvertebrate predators, however, a salinity level of greater than 6000-10000ppm leads to exponential mortality rates in various ontogenetic stages (Gomez-Mestre and Tejedo 2003). The same study also found significant variability in tolerances amongst populations sourced from freshwater and saline environments, indicating localised adaptation to high salinity levels. Beebee (1985) found that experimental exposure to increased salinity levels of 4000-5500ppm resulted in the destruction of spawn. Both studies concluded that increased tolerance correlates with the development stage of tadpoles. The formulation of a salinity score for natterjacks is thus complex and has to consider both the benefits and drawbacks of salinity levels (table 2). Sources of salinity should also be noted, with special regard to the inundation of seawater.

Table 2: Salinity SI

Salinity ppm	Score
> 4000	1
4000-5999	0.67
< 6000	0.01

3.3.3 pH

Natterjacks are tolerant of acidic conditions, however hatch, growth and survival rates are significantly impaired in a linear relationship with low success rates at pH >4 and the best outcomes at pH 7 (Banks and Beebee 1988). The suitable range of pH has some overlap with ponds that have been shown to be unproductive for natterjacks due to other interacting factors such as temperature and disease, although most sources agree that a pH of 6-8 is desirable (table 3) (Baker et al. 2011; Banks and Beebee 1987; Banks and Beebee 1987; Smith and Skelcher 2019).

Table 3: pH SI

pH	Score
<4.5	0.01
4.5-5.99	0.50
6-8	1

3.3.4 Shade

Long-term pond temperature data offers the best insight into natterjack growth rates and breeding success, with metamorphosis occurring after 88 days at 20°C, decreasing to 23 days at 22.5-25°C, and considerably slowing or failing at 15°C or less (Sanuy et al. 2008). Direct pond temperature measurements over time were not possible in this study due to time and resource constraints, however, the quantification of shade cover on a pond serves as an informative proxy for temperature data and is useful information for the conservation and biodiversity management of ephemeral pools (Hill et al. 2017, Raffel et al. 2010). Methods for quantifying shading exist with the aid of a clinometer (Hamer and Parris 2011),; however, the visual estimation method employed in the GCN HSI was chosen as it has the benefit of speed, less equipment as well as being weather-independent in contrast to direct temperature measurements. The aim is to estimate average pond shading at noon in April/|May.

Table 4: Pond shading SI

Shade	Score
76-100%	0.01
26-75%	0.33
6-25%	0.67
<6%	1

3.3.5 Pond surface area

Natterjack breeding activity and presence in Ireland were associated to ponds with a large surface area (219.0 ± 572.5m^2) and less associated with smallerto smaller ponds (73.0 ± 44.5m^2)(Reyne et al. 2021). However, other research shows natterjacks can breed successfully in a variety of contexts, from artificial pools <10m^2 to lakes measuring >1000m^2

(Banks and Beebee 1998; Sinsch et al. 1999). Thus, like the GCN HSI, quantification of pond surface area and its scoring seeks to reflect breeding success potential, acknowledging that although smaller ponds may support natterjacks, larger ponds are more likely to sustain populations in the long term (figure 3) (Oldham et al. 2000). However, due to a lack of available data on suitability, ponds exceeding 1200m^2 should not include the pond surface area SI in the HSI calculation.

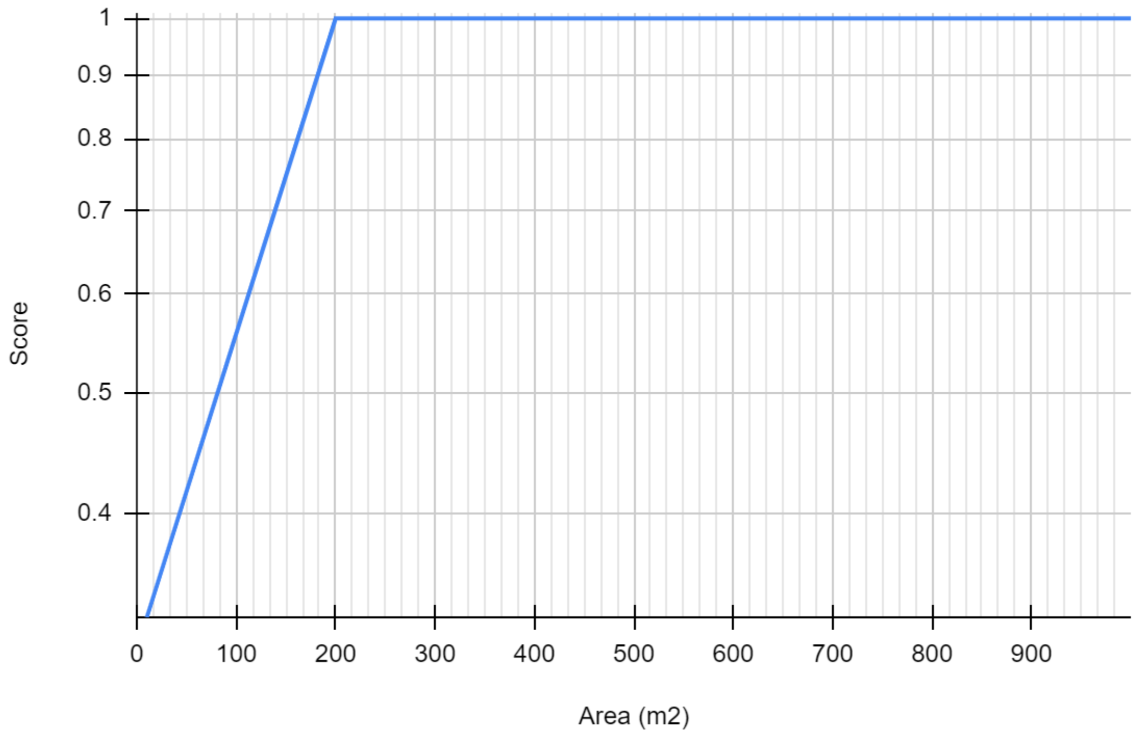

Figure 3: SI for pond area is read from the graph. Ponds up to 1200m^2 should score 1.

3.3.6 Pond network connectivity

Across its range, the natterjack has a mean dispersal distance of 2.46km, with a minimum of 567m (Trochet et al. 2014). The value of 500m was given as the recommended minimum distance between ponds for natterjacks in the UK by Amphibian and Reptile Conservation (Personal communication, 7 November 2022), with a maximum of 2km to allow genetic crossover between metapopulations and avoid the negative effects of inverse density dependence (Courchamp et al. 1999; Muir et al. 2020). The natterjack HSI, as designed for the UK context, thus values pond networks with intervals of 500m, up to 2km. Therefore, as ponds up to 2km distant are important for the long-term sustainability of the population, a high density of ponds is less valued over extended networks.

The connectivity score per pond is derived from presence/absence within distance range categories (table 5). The presence of a pond within the range categories is marked Y or N for presence/absence, with the number of categories present contributing to the score.

Table 5: Pond Network SI.

<250m	**250-749m**	**750-1249m**	**1250-1749m**	**1750-2000m**	
Y/N	Y/N	Y/N	Y/N	Y/N	**Score**
Ponds present in all categories OR all categories 250-2000m					1
Ponds present <250m and any 3 other categories					0.9
Ponds present in any 3 categories					0.81
Ponds present in any 2 categories					0.73
Ponds present in any 1 categories					0.66

3.3.7 Terrestrial vegetation structure

Natterjack presence is associated with short swards <5cm within 100m of breeding ponds, important for toadlet dispersal and feeding grounds (Reyne et al. 2021). Ten quadrat locations for each pond were generated as random points in polygons within QGIS with the following criteria: within 100m of the pond margin; within suitable habitat as determined in subchapter 3.4. Vegetation height was measured from each quadrat corner and the centre using the direct measurement method (Hodgson et al. 1971 cited by Stewart et al. 2001). An area estimation of vegetation below 5cm was also recorded per quadrat and averaged to calculate a score per pond (table 6). As unsuitable habitat areas were excluded, the result is not representative of all habitats within 100m of the ponds. The total potential area of suitable habitat is calculated per subchapter 3.4.

Table 6: Terrestrial vegetation SI.

Terrestrial vegetation height <5cm within 100m of pond	**Score**
>80%	1
50-79%	0.67

20-49%	0.33
<20%	0.01

3.3.8 Pond permanence

The natterjack is a specialist of temporary ponds, therefore the natterjack SI for ephemerality is the inverse of the GCN SI, which favours pond permanence (table 7) (Oldham et al. 2000). This should ideally be understood on a multi-year cycle, although this is not possible for newly constructed ponds.

Table 7: Pond permanence SI.

Drying cycle	Score
Never	0.01
Rarely	0.33
Sometimes	0.67
Annually	1

3.3.9 Predation risk

The likely predation risk and threat to natterjack recruitment and survival were assessed following a review of the relevant literature focused on the following taxa: Amphibia, Dytiscidae, Notonecta, Odonata (table 8) (Banks and Beebee 1988; Portheault et al. 2007; Rowe and Beebee 2005). The presence and relative abundance of these species indicate limited success or total failure potential of translocated natterjack spawn.

Table 8:Predator risk SI.

Presence of predators (Amphibia, Dytiscidae, Notonecta, Odonata)	Score
None	1
2 or fewer taxa with several (1-5) individuals	0.67
Diverse assemblage with abundant individuals, or other amphibians present	0.33

3.3.10 Scoring

Habitat suitability is determined as a geometric mean - the n^{th} root of the product of all indices. The benefit of this formula in calculating the HSI is the smoothing of large fluctuations in values, producing a score which is representative of the weight of all independent values. The natterjack HSI is calculated as follows:

$$HSI = (I_1 * I_2 * I_3 * I_4 * I_5 * I_6 * I_7 * I_8 * I_9)^{1/n}$$

In this formula: I_1 = SI for aquatic vegetation; I_2 = salinity; I_3 = pH; I_4 = shade; I_5 = pond area; I_6 = pond network; I_7 = terrestrial vegetation structure; I_8 = pond permanence; I_9 = predation risk. The value of $n = 9$ when all HSI parameters are applied.

The scores are attributed as per the categories suggested by the GCN HSI. However, analysis by Buxton and Griffiths (2022) shows that the delineation of GCN HSI scores as per the default unweighted scoring system both underestimates lower values whilst overestimating higher values, resulting in false positive scores. This issue was predicted in the initial work that produced the GCN HSI, and recent research has addressed this post-hoc, with technology not widely available in 2000 (Oldham et al. 2000; Buxton and Griffiths 2022). Buxton and Griffiths (2022) suggest a revised system based on the median score, whereby 40% of values fall within the 'average' category, to more accurately reflect habitat suitability. Their study, however, was based on analysis of an extensive (*n.* > 5300) eDNA dataset alongside years of GCN HSI data collection. The initial natterjack HSI will be based on the default categories suggested in the GCN HSI, and can be readily modified when benchmarked against real-world usage (table 9).

Table 9: HSI pond suitability categories.

Natterjack HSI	Pond suitability
< 0.5	poor
0.5-0.59	below average
0.6-0.69	average
0.7-0.79	good
> 0.8	excellent

3.4 Habitat mapping and patch identification

Alongside the HSI, which focuses on individual pond habitats, habitat suitability was assessed on a larger scale to better understand the connectivity of the wider landscape and its ability to sustain a natterjack population.

The suitability of habitats was assessed from published studies, focusing on terrestrial classifications which were then related to the JNCC Phase 1 habitat map provided by the National Trust (Beebee 1977, Beebee 1979, JNCC 2010, Reyne et al. 2021). The habitat classes present in the Phase 1 survey were assessed and categorised as either favourable or unfavourable, with the resulting dataset allowing computation of patch sizes with 8-connectivity in Graphab (Foltête et al. 2021). The smallest area of suitable patch size of 4.1ha was determined from research by Miaud and Sanuy (2005), though variables such as prey abundance and natterjack burrow site availability lend some ambiguity to this determination as applied to novel sites where no natterjacks are currently present. The 'unfavourable' classification is a designation reflecting the secondary importance of these habitats for natterjack toads only, as structural diversity and habitat heterogeneity are important for maintaining overall site biodiversity (table 10) (Báldi 2008; Schirmel et al. 2010; Schirmel and Fartmann 2014). The area of habitats identified should be seen as of potential suitability, as realised suitability is dependent upon vegetation structure within these patches.

Table 10: Habitat classes grouped by favourability for natterjacks.

Habitat Group	**JNCC Phase 1 habitat class**
Favourable habitats	Bare sand - J4.1 Dune heath - H6.6 Dune slack - H6.4 Open dune - H6.8

Unfavourable habitats	Bracken - continuous - C1.1 Broadleaved woodland - semi-natural - A1.1.1 Coniferous woodland - plantation - A1.2.2 Cultivated/disturbed land - amenity grassland - J1.2 Dry dwarf shrub heath - acid - D1.1 Dune scrub - H6.7 Intertidal - boulders/rocks - H1.3 Intertidal - mud/sand - H1.1 Marsh/marshy grassland - B5 Not Surveyed - K1 Saltmarsh - dense/continuous - H2.6 Scrub - dense/continuous - A2.1 Standing water - G1 Swamp - F1 Wet dwarf shrub heath - D2

4 Results

Although no ponds scored in the 'excellent' category in 2022, the majority of ponds show an improvement in scores from 2022 to 2023 (table 11). This is driven primarily by increases in pH, aquatic vegetation cover and predation risk, however, caveats with the latter are discussed below.

4.1 Natterjack HSI results

Table 11: Natterjack HSI results from April 2022 & March 2023.

Pond ID	Geometric mean April 2022	Geometric mean March 2023	δ
1	0.46	0.71	0.25
3	0.71	0.71	0.00
5	0.48	0.48	0.00
9	0.59	0.67	0.07
10	0.43	0.76	0.32
11	0.27	0.30	0.02
13	0.48	0.52	0.04
14	0.68	0.76	0.09
16	0.45	0.47	0.01
17	0.60	0.70	0.10

19	0.68	0.79	0.11
20	0.68	0.73	0.05
21	0.71	0.68	-0.03
22	0.63	0.79	0.17
23	0.67	0.89	0.23
24	0.60	0.83	0.22
Boomerang	0.47	0.73	0.26
Dune	0.72	0.77	0.05
Pear	0.40	0.68	0.27
Score key:	< 0.5 poor	0.5-0.59 below average	
0.6-0.69 average	0.7-0.79 good	> 0.8 excellent	

Table 12: All SI scores for 2022. (*)Water quality parameters for ponds 23 and 24 were unfortunately unrecoverable due to data loss.

Natterjack HSI 2022

Pond ID	Aquatic vegetation SI	Conductivity SI	pH SI	Shade SI	Pond area SI	Pond network SI	Vegetation structure SI	Pond drying SI	Predator risk SI	Geometric mean
1	0.33	1	0.01	1.00	1	0.81	0.33	1	1.00	0.46
3	0.33	1	0.50	1.00	1	0.81	0.33	1	1.00	0.71
5	0.33	1	0.50	1.00	1	0.81	0.01	1	1.00	0.48
9	0.33	1	0.50	1.00	0.7	0.73	0.33	1	0.33	0.59
10	0.33	1	0.01	1.00	1	0.73	0.67	1	0.33	0.43
11	0.33	1	0.01	1.00	1	0.81	0.01	1	0.33	0.27
13	0.33	1	0.50	1.00	1	0.81	0.01	1	1.00	0.48
14	0.33	1	0.50	1.00	1	0.81	0.33	1	0.67	0.68
16	0.33	1	0.50	1.00	1	0.73	0.01	0.67	1.00	0.45
17	0.33	1	0.50	1.00	1	0.81	0.33	0.67	0.33	0.60
19	0.33	1	0.50	1.00	1	0.81	0.33	1	0.67	0.68
20	0.33	1	0.50	1.00	1	0.81	0.33	1	0.67	0.68
21	0.33	1	0.50	1.00	1	0.81	0.33	1	1.00	0.71
22	0.33	1	0.50	1.00	1	0.81	0.33	1	0.33	0.63
23	0.33	-*	-*	1.00	1	0.81	0.67	1	0.33	0.67
24	0.33	-*	-*	1.00	1	0.81	0.33	1	0.33	0.60
Boomerang	0.33	1	0.01	1.00	1	0.81	0.67	1	0.67	0.47
Dune	0.33	1	1.00	1.00	0.58	0.81	0.33	1	1.00	0.72
Pear	0.33	1	0.01	1.00	1	0.81	0.33	1	0.33	0.40

Table 13: All SI scores for 2023.

Natterjack HSI 2023

Pond ID	Aquatic vegetation SI	Conductivity SI	pH SI	Shade SI	Pond area SI	Pond network SI	Vegetation structure SI	Pond drying SI	Predator risk SI	Geometric mean
1	0.33	1	0.50	1.00	1	0.81	0.33	1	1.00	0.71
3	0.33	1	0.50	1.00	1	0.81	0.33	1	1.00	0.71
5	0.33	1	0.50	1.00	1	0.81	0.01	1	1.00	0.48
9	0.33	1	0.50	1.00	1	0.73	0.33	1	0.67	0.67
10	0.33	1	0.50	1.00	1	0.73	0.67	1	1.00	0.76
11	0.33	1	0.01	1.00	1	0.81	0.01	1	0.67	0.30
13	0.33	1	1.00	1.00	1	0.81	0.01	1	1.00	0.52
14	0.33	1	1.00	1.00	1	0.81	0.33	1	1.00	0.76

16	0.33	1	1.00	1.00	1	0.73	0.01	0.67	0.67	0.47
17	0.67	1	1.00	1.00	1	0.81	0.33	0.67	0.33	0.70
19	0.67	1	1.00	1.00	1	0.81	0.33	1	0.67	0.79
20	0.33	1	1.00	1.00	1	0.81	0.33	1	0.67	0.73
21	0.33	1	0.50	1.00	1	0.81	0.33	1	0.67	0.68
22	0.67	1	1.00	1.00	1	0.81	0.33	1	0.67	0.79
23	0.67	1	1.00	1.00	1	0.81	0.67	1	1.00	0.89
24	1	1	1.00	1.00	1	0.81	0.33	1	0.67	0.83
Boomerang	0.33	1	0.50	1.00	1	0.81	0.67	1	0.67	0.73
Dune	1	1	1.00	1.00	0.52	0.81	0.33	1	0.67	0.77
Pear	0.33	1	0.50	1.00	1	0.81	0.33	1	0.67	0.68

4.1.1 Aquatic vegetation

Typical aquatic vegetation was absent during the April 2022 survey (table 12), although some strands of bladderwort *Utricularia sp*. were noted in July of that year. Habitat suitability was increased in March 2023 (table 13) as several species of plants were found colonising the ponds: bog pondweed *Potamogeton polygonifolius*; marsh pennywort *Hydrocotyle vulgaris*; marsh St. John's wort *Hypericum virginicum*; marsh bedstraw *Galium palustre*; and rushes *Juncus spp.* Although present on site, the invasive stonecrop *Crassula helmsii* was not noted in any of the ponds, however, a small mat was observed outside of the southern margin of pond 16.

4.1.2 Salinity

Salinity levels in 2022 show a higher range of 253 PPM, and a mean of 236 PPM, in comparison to measurements in 2023, with a range of 134 PPM and a mean of 125 PPM. There was a significant difference in salinity values between the years (t-test, $t=2.253$, d.f. = 34, $p < 0.05$) (figure 5). All measurements were within the highest scoring category of the salinity SI (<4000).

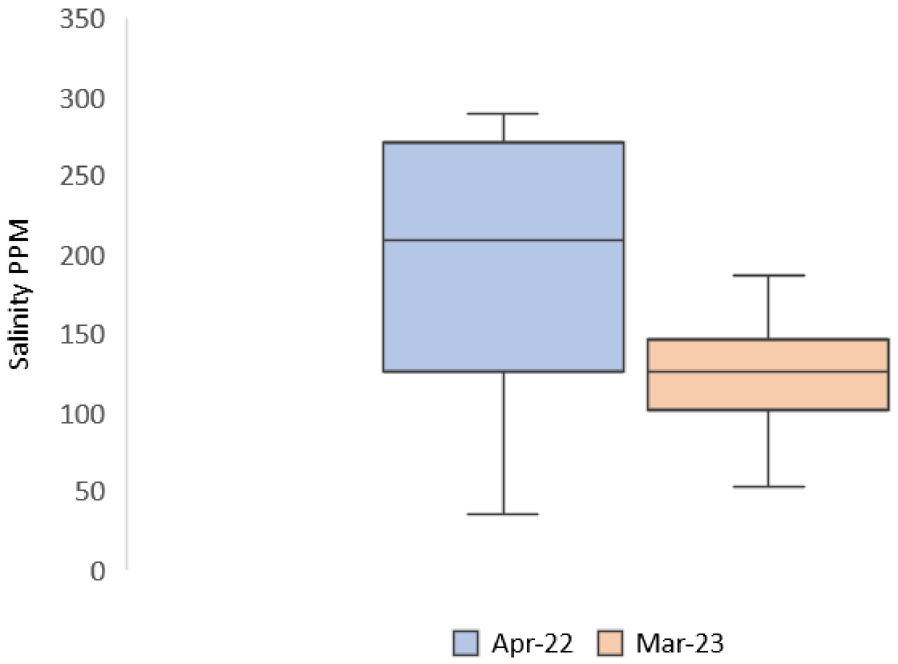

Figure 5: Year-on-year comparison of salinity levels across both years of the study showing an overall decrease in salinity.

4.1.3 pH

The pH levels in 2022 indicate acidic conditions, with some ponds falling below the tolerable range for natterjacks. There was a significant difference between 2022 and 2023 (t-test, t=-2.612, d.f. = 34, $p < 0.05$), with levels in 2023 less acidic than the year before (mean pH 5.09 vs 5.83) (figure 6), scoring more highly overall (table 13).

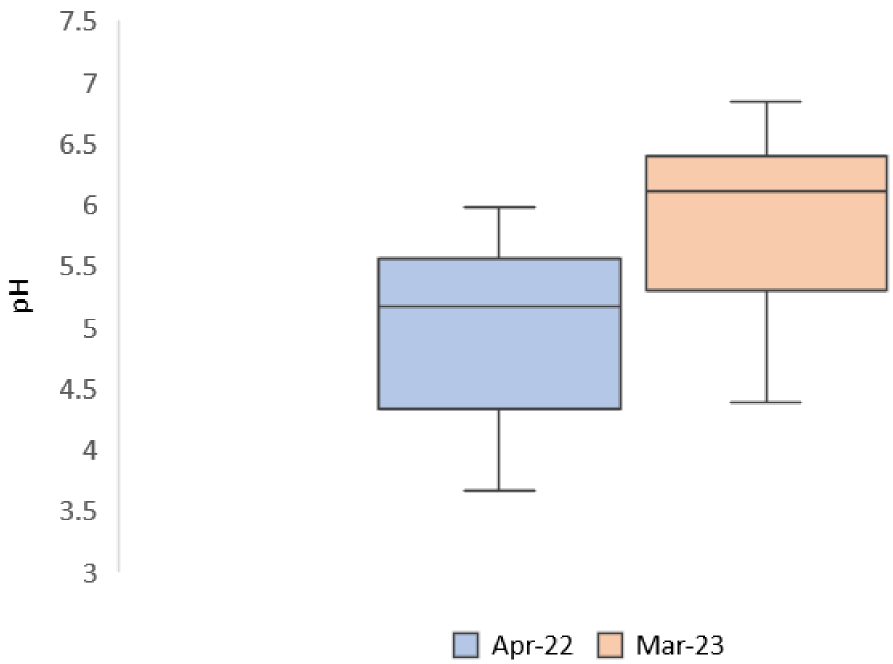

Figure 6: Year-on-year comparison of pH levels, with a significantly favourable increase in 2023.

4.1.4 Shade

Due to surrounding scrub clearance, it was assessed that no ponds had any significant shading effects from the surrounding vegetation, therefore all ponds scored in the highest category.

4.1.5 Pond surface area

Pond areas increased from 2022 to 2023 (average 349-401m^2). Only pond 9 increased in the SI as all other ponds were already at the maximum score. Due to inaccessibility, the area of pond 3 for 2023 was visually estimated, and judged to be within 5% of the 2022 value (table 14).

Table 14: Pond areas in April 2022 and March 2023. *estimated value.

Pond ID	Pond area 2022 m^2	Pond area 2023 m^2	Pond area 2022 SI	Pond area 2023 SI
1	214	280	1	1
3	552	552±5%*	1	1
5	404	455	1	1
9	146	315	0.7	1
10	411	341	1	1
11	431	403	1	1
13	355	402	1	1
14	305	282	1	1
16	407	586	1	1
17	319	568	1	1
19	258	373	1	1
20	524	666	1	1
21	372	456	1	1
22	325	423	1	1
23	367	372	1	1
24	267	239	1	1
Boomerang	576	527	1	1
Dune	112	88	0.58	0.52
Pear	290	295	1	1

4.1.6 Terrestrial vegetation structure

In total, 190 randomly generated vegetation structure quadrats were surveyed (figure 7). Despite being random, the quadrats were representative of the various vegetation types and landscape features such as bare ground dry scrapes, gorse stands, and heathers from pioneer to degenerate. The integrity of the <5cm estimated values was tested by examining the relationship between % coverage <5cm and average vegetation height per pond as measured from 5 points per quadrat. The relationship shows a weak negative correlation (Figure 8), though this is not significant when tested with Pearson’s correlation ($p = .135$; $r^2 = -.356$; $N = 19$).

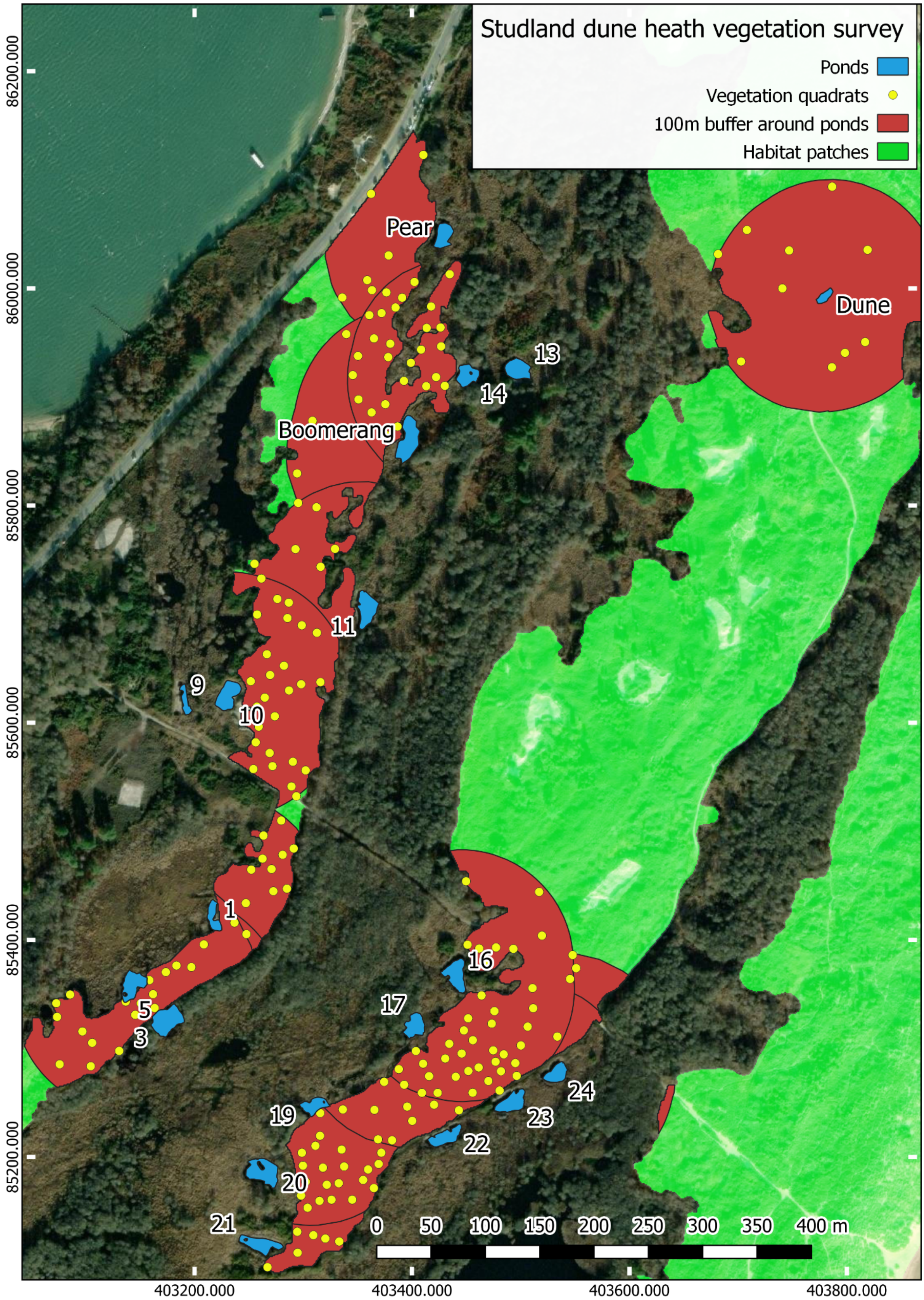

Figure 7: Vegetation survey points as plotted randomly in QGIS.

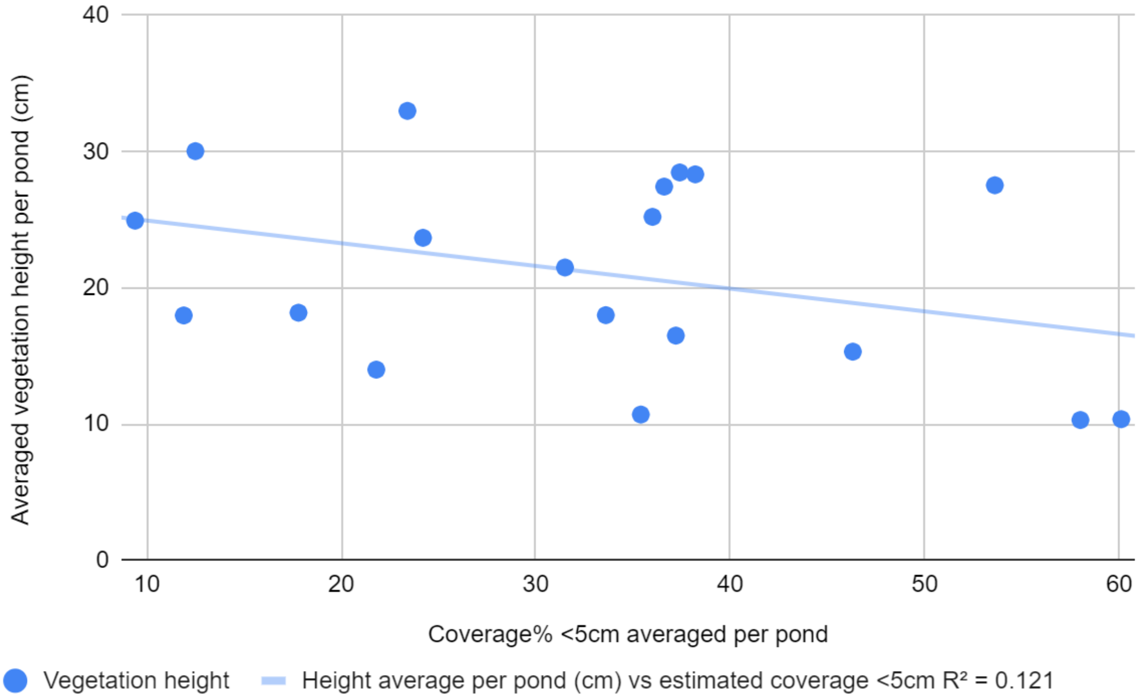

Figure 8: The relationship between average vegetation height and estimated vegetation coverage <5cm shows a weak correlation.

4.1.7 Predator risk

Five main predators of natterjack spawn and tadpoles were captured during the netting sessions: *Notonecta glauca*, *Corixa punctata*, *Acilius sulcatus*, *Dytiscidae sp*. larvae and *Lissotriton vulgaris*. Dragonfly adults were observed around the pools, along with egg-laying behaviour but no nymphs were recorded at any stage. Far fewer predators were detected in 2023 (Figure 8 & 9).

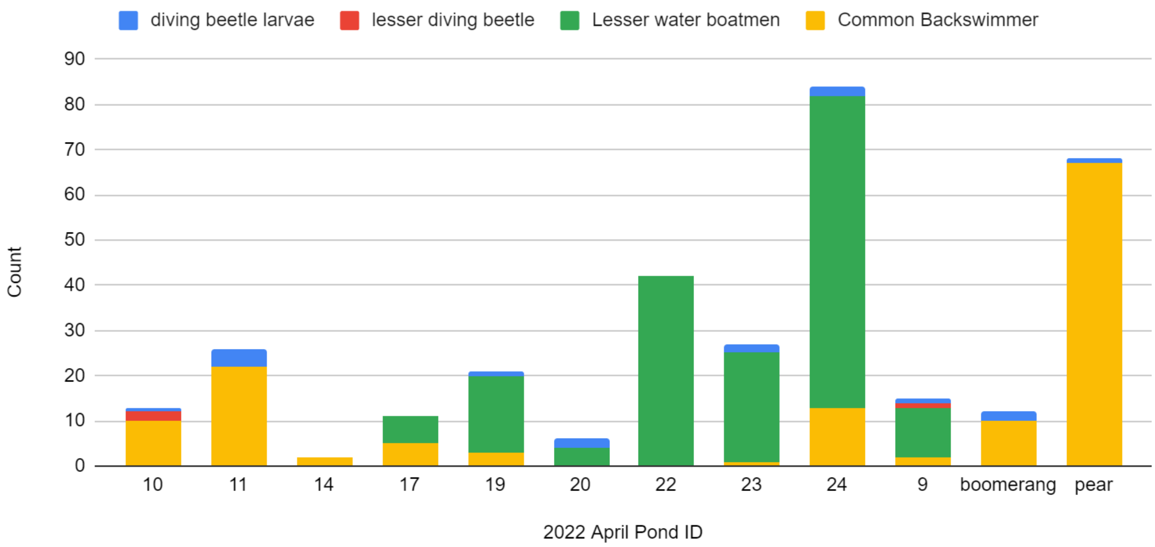

Figure 8: Count of individual predators netted within the ponds in 2022. Ponds with 0 predators netted are omitted.

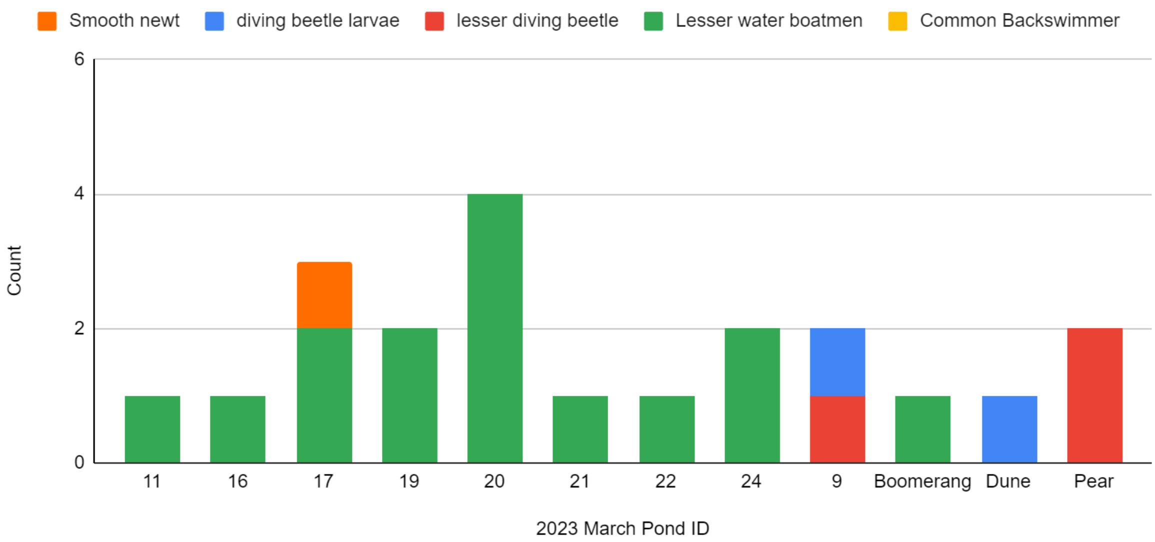

Figure 9: Count of individual predators netted within the ponds in 2023. Ponds with 0 predators netted are omitted.

4.1.8 Pond permanence

A follow-up site visit in August 2022 found that all ponds had dried during the summer, with the exception of ponds 16 & 17 (figure 10), although they had reduced in area to 16% and 6% of their April 2022 maximum extent respectively.

Figure 10: Surviving ponds and their margins in August 2022. All other ponds had desiccated most likely by mid-late July 2022.

4.2 Pond locations

A total of 19 ponds were identified to have potential suitability for natterjacks, all of which were the result of wet scrape pond construction on the margins or within dune heath habitat (figure 11). Pictures of each pond were taken for future reference (Appendix 9.4)

Figure 11: All surveyed ponds at their maximum extent in April 2022.

4.3 Habitat patches and pond network

Two patches of favourable habitat of sufficient size were identified (figure 12), one measuring 7.38 ha, and a more extensive patch measuring 72.68 ha, with a minimum dispersion effort distance of 128m between the patches.

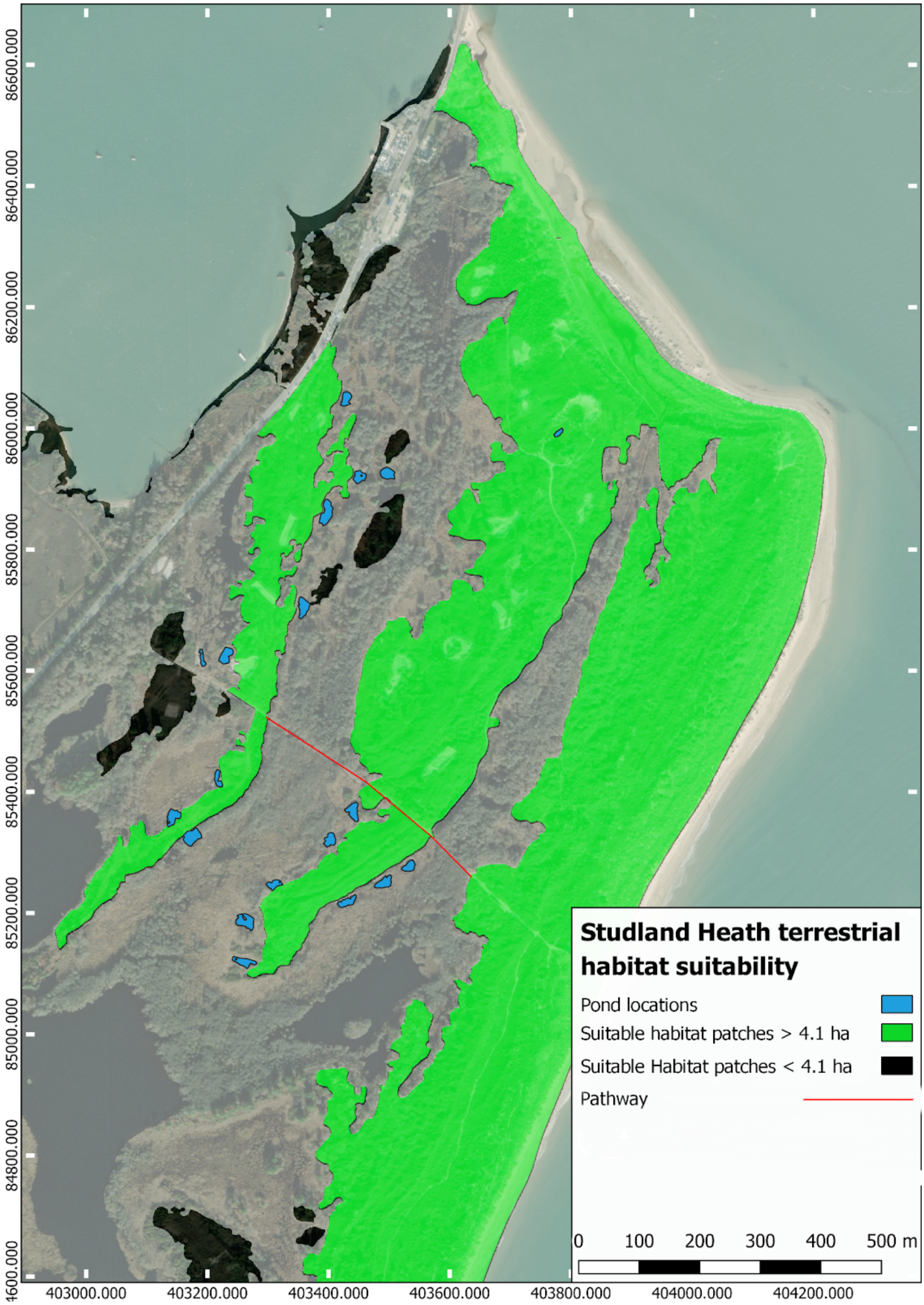

Figure 12: Habitat-type patches favourable for natterjacks are highlighted black (< 4.1 ha) and green (> 4.1 ha).

5 Discussion

5.1 Natterjack HSI outcomes

The results of the HSI show an improvement in the number of ponds scoring 'good' or more between 2022 and 2023 (16% vs 57%), driven largely by favourable changes in aquatic vegetation, pH and predator risk SIs. The conductivity means and range were significantly lower in 2023 as compared to 2022, suggesting stabilisation within this metric, likely due to the release of salts as a result of soil disturbance during the creation of the ponds, subsequently leaching back into the soil or groundwaters (Olmo et al. 2016). Aquatic vegetation was absent in 2022, therefore the increased vegetation cover in 2023 resulted in higher scores for all ponds. Two large patches of contiguous dune heath were identified, both of sufficient area to sustain natterjack populations, however, the results of the terrestrial vegetation survey indicate high structural heterogeneity in some areas. All ponds had dried either completely or extensively in the summer of 2022, with low levels of shade and groundwater contributing to this.

5.2 Application of the HSI

The natterjack HSI could be applied both pre and post-translocation, to assess habitat quality and changes, and inform management decisions during the process. Identification of the drivers of low SI scores can reveal management options that will increase habitat suitability for the natterjack.

5.2.1 Terrestrial habitat suitability

Both pond network and terrestrial vegetation SI scores are sub-optimal across all ponds, however could be improved through the implementation of favourable management decisions for natterjacks. Two large areas of suitable habitat classes were identified, separated by willow-birch carr which has developed in the fixed dune slacks. Movement through forest presents a 3-5x cost barrier to the species, however, a public pathway (Figure 12) is maintained as a thoroughfare and offers the path of least resistance between the units (Stevens et al. 2004). The structure of the vegetation within the identified patches is naturally influenced by grazers, including naturalised sika deer *Cervus nippon* and rabbits *Oryctolagus cuniculus*. Rabbits are particularly influential in the maintenance of short sward patches, and the reduction of heather succession through trampling and browsing of heather by deer and cattle will enable rabbits to increase their area of impact (Bokdam 2001; Lees and Bell 2008). Indeed, the decline of rabbits following the spread of myxomatosis in the 20th century may have contributed to vegetative succession at Studland, as was the case in other dune habitat sites (Ranwell 1960). Natural warrens exist within areas of protective scrub, where the grazing impact of rabbits can be clearly seen (Figure 13), however these areas of gorse score negatively on the terrestrial vegetation SI, highlighting the need to revise this calculation. The creation of artificial warrens on south-facing slopes such as those on the dune ridges has been shown to boost rabbit numbers and increase the area of grazed vegetation (Godinho et al. 2013).

A small herd of cattle were released on-site by the National Trust with the goal of reducing vegetation to an earlier successional stage. Their movements are tracked and managed with a virtual fencing GPS system, both for the protection of visiting members of the public and to limit the amount of time the cattle can spend in each area, thus limiting their impact. Trampling of vegetation is evident around several of the ponds, predominantly by cattle, although deer tracks and rabbit grazing signs were also noted. Trampling is significant on the heath adjacent to pond 21, and cattle were observed using the area as a safe space to rest, resulting in the creation of bare ground and the disturbance of much of the pioneer heather growth (Figure 14), however, this area was not captured by the random sampling. Areas of mature and degenerate heather were also visibly impacted by the presence of cattle, reducing vegetation height and increasing areas of vegetation <5cm (Figure 15). Further monitoring of these areas will quantify the long-term impacts of *Calluna* disturbance, as trampled stems may regenerate from the base of the plant, however, continual impacts may lead to path formation or areas of pioneer growth and create desirable mosaics of habitat (Schirmel et al. 2010; Schellenberg and Bergmeier 2022).

Figure 13: A patch of rabbit-grazed short sward, partially enclosed by gorse, approximate to pond 24 (Deakin 2023).

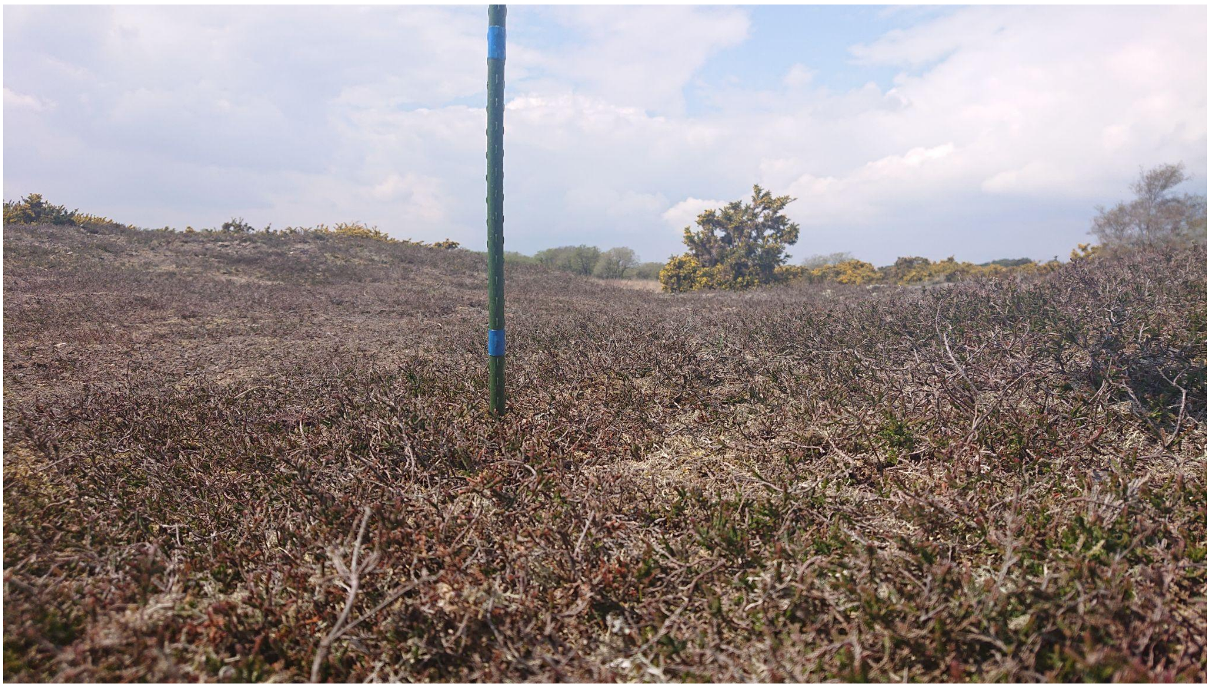

Figure 14: Area of trampled and rabbit-grazed heather *Calluna vulgaris* adjacent to the southeast of pond 21. The midpoint of the lower blue tape marks 10cm (Deakin 2023).

Figure 15: Patch of cattle trampled mature and degenerate heather (Deakin 2023).

The creation of multiple dry scrape areas within the survey area (figure 11) has reset vegetative succession and generated zones of bare sand which have signs of early colonisation by sand sedge *Carex arenaria*, as well as invertebrate bare ground specialists such as the green tiger beetle *Cicindela campestris.* Large-scale habitat management to maintain early succession conditions for the conservation of rare species is commonly undertaken on dune systems and heathlands, however, it should be acknowledged that there are arguments against this management paradigm. Cooper and Jackson (2021) argue that artificial interventions on dune systems are effective 'gardening' and that this damages the systems' resilience to climate change, whilst acknowledging the importance of protecting endangered species. Consideration of the impact on other protected species, such as the smooth snake *Coronella austriaca*, is critical as intensive grazing may harm their populations (Reading and Jofré 2015). A balanced approach whereby landscape heterogeneity is maintained through dynamic disturbance alongside the retention of valuable fixed habitats will achieve the best results for biodiversity and system resilience (Bird et al. 2017).

5.2.2 Intra and inter-site pond network

Artificially dug wet scrapes are valuable for natterjack conservation as demonstrated by Smith and Skelcher (2019), with scrapes forming a high proportion (57%) of successful breeding sites in dry years. There are opportunities to create new ponds to fill gaps in the pond network, e.g. the gap between pond dune and pond 16 (790m), as well as expand the network along the eastern and southern sides of the site, where large areas of rabbit grazed dune exists alongside natural pools subject to tidal inundation (figures 16 & 17). The creation of new scrapes on a periodic basis would also ensure a dynamic landscape supporting a metapopulation of natterjacks and allow the natural dynamics of extinction and colonisation to take place (Griffiths 1997). Creation of new ponds along with grazing regimes will ensure the provision of suitable habitat as vegetative succession renders ponds unsuitable after 3 years (Banks et al 1993)

Despite the provision of good habitat, Studland is functionally and geographically disconnected from the nearest colonies of natterjack at Vitower (6km) and Hengistbury head (15km), due to significant barriers including roads, forests, development and ocean (McGrath and Lorenzen 2010). A translocation is likely the only feasible route for the colonisation of natterjacks at this location.

Figure 16: Dune slack pool subject to tidal inundation 180m northeast of the pond dune (Deakin 2023).

Figure 17: Area of rabbit-grazed dune adjacent to the dune slack pool (Deakin 2023).

5.2.3 Translocation potential

Ponds 23 and 24 scored ‘excellent’ suitability in the natterjack HSI, and therefore are the starting point for investigating translocation potential. Though scoring very well in most SI categories, like much of the site, the terrestrial vegetation score is not in the highest category and should be improved to maximise the success of a natterjack translocation due to the significant relationship between short swards and natterjack presence (Reyne et al. 2021).

5.3 Feasibility of the natterjack HSI

The scarce results of the 2023 aquatic fauna survey, occurring a few weeks earlier than in 2022 and following a cold spell of weather, are called into question by these factors. However, the removal of predator risk SI from the 2023 survey did not change the average HSI score (.68-.68) although the status of ponds 22 and 19 changed from ‘good’ to ‘excellent’. As a population limiting factor, the accuracy of this SI is reliant upon the detection of predation threats therefore both the timing and method employed should reflect best practices in the detection of natterjack predators. Griffiths (1985) recommends torching or bottle trapping as methods of detecting newt presence, though other rapid, though more expensive methods such as eDNA detection exist (Rees et al. 2014).

There is a degree of subjectivity in three of the nine SI; shade, aquatic vegetation cover and terrestrial vegetation cover <5cm. Adoption of intensive methods would reduce subjectivity, however, increase the survey burden with potentially limited benefit. In the absence of high-resolution data regarding the sensitivity or tolerance range for all abiotic parameters, e.g. conductivity, some degree of arbitrariness is incorporated into the categorisation of these SI, at the risk of miscategorisation. Some SI from the GCN HSI were deemed irrelevant or of little value to natterjacks, e.g. waterfowl, which is of debatable importance for the GCN HSI itself, whilst other SI were newly created (Seccombe and Salguero-Gomez 2022). The creation of new SI for terrestrial vegetation structure and pond networks rather than simple density was formed to address species-specific population limiting factors. It is possible that some population limiting factors were not included in the HSI, for example, grazing intensity, public disturbance or pond-habitat connectivity, therefore there is a risk that the HSI score does not correlate to natterjack presence or abundance (Layher 1985). It should also be noted that all ponds surveyed at Studland have shallow margins due to the nature of their construction, and although this is an important feature, it is also difficult to quantify, therefore it is omitted from the natterjack HSI (Banks and Beebee 1987). Furthermore, the natterjack HSI was not benchmarked against existing sites, relying on a literature review to assess the most critical limiting factors, therefore weaknesses in the weighting of the SI or methods have not been exposed. In addition, pond permanence requires quantification over time; the extreme heatwave event during the summer of 2022 may have had an outward influence on pond permanence estimations (Kendon 2022).

6 Conclusion

It is unlikely that newly dug pond scrapes offer a suitable stable environment for the immediate translocation of natterjack spawn, however, invertebrate abundance was high during this period, and pond habitat condition improves to a broadly favourable status for natterjacks after one year. Many of the current and past management practices at Studland are aligned with creating suitable habitats for the natterjack. Areas of favourable terrestrial habitat types at Studland exist in sufficient quantity to support a sustainable population of natterjacks, although more intensive grazing or management of vegetation structure to reduce vegetation succession would improve suitability scores.

7 Recommendations

7.1 HSI improvements

The natterjack HSI successfully delineates good vs poor quality breeding pools within the study area, however, the accuracy of these scores should be assessed against existing natterjack populations and habitats in order to gain an inter-site quantification of their precision. A further review of population limiting factors, when benchmarked against existing natterjack populations, may result in the inclusion of factors such as terrestrial connectivity, pond temperatures, water quality parameters such as dissolved oxygen, and a revision of the terrestrial vegetation survey to better assess the structure and grazing impact. The predator threat SI could also be improved by adopting a better method for the detection of amphibians, such as torching or bottle trapping (Griffiths 1985). Back-ups of all data collection should be made as soon as possible to prevent irrecoverable data loss. Furthermore, the natterjack HSI is seasonally dependent, and best conducted in late April-June whilst the ponds are at maximal depth, vegetation has exited winter dormancy and the presence of predators can be accurately assessed.

7.2 Improving habitat suitability for the natterjack toad

Continuation of the current conservation management direction at Studland will be beneficial for the creation of suitable habitat for the natterjack, although an increase in intensity may be necessary. The dynamic of cattle trampling mature heather and subsequent grazing maintenance of pioneer heather growth by rabbits may produce a shorter sward over time, although quantifying this will require follow-up surveys (Barham and Stewart 2005). This could be achieved by repeating the terrestrial vegetation structure survey at the same points conducted in this survey to assess grazing impact, as in any case follow-up surveys are recommended during the translocation process (Berger-Tal et al. 2020). Artificial interventions such as rotavation, or cutting of dense scrub vegetation would achieve similar results in a shorter time frame (Denton et al. 1997). Although several ponds of good status for natterjacks exist at Studland, the pond network SI could be improved by increasing the pond network range to 2km through the creation of new ponds on the periphery of the existing network. There is potential for this in the less vegetated dunes in the south and east of the site, with the prospect of a pond network several kilometres in length.

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9 Appendices

9.1 Learning Contract

BU Bournemouth University **LEARNING CONTRACT: INDEPENDENT RESEARCH PROJECT**

The learning contract is an agreement between student and supervisor: it should clearly indicate what is expected from both sides. The text in Sections 2 and 3 provides guidance and can be modified to give more details reflecting what has been agreed, such as deadlines for submission of drafts and provision of feedback, word count limits/exclusions and number/timing of meetings.

Importantly, the document checklist helps students to follow the required procedures (e.g. ethical approval and risk assessment) and communicate what has been done to the supervisor.

The student should submit a draft of the completed form to the supervisor and request a meeting to discuss and finalise the content. Both the student and the supervisor are responsible for keeping a signed copy of this document and following what has been mutually agreed.

1. YOUR DETAILS

Student name: Sam Deakin

Degree Programme: Ecology & Wildlife Conservation

Proposed IRP Title or Set Project: The habitat suitability of Studland bay for the natterjack toad (Epidalea calamita)

Supervisor name: Kathy Hodder

2. As the student undertaking the above project I agree to:

- E-mail my supervisor on a fortnightly basis with a progress report
- Meet with my supervisor at least once a month to discuss progress and I understand that it is my responsibility to organise these meetings
- Comply with the terms of this learning contract and the guidance set out in the Guide to Independent Research Projects
- I understand that this is an *independent* project and that I am solely responsible for its completion
- I agree to comply with all ethical, laboratory and fieldwork protocols established by the Faculty.

3. As the supervisor of this project I agree to:

- Meet with the student undertaking this project on at least a monthly basis and to respond to the progress e-mails as appropriate
- To meet formally with the student during the first week in November to undertake the interim interview

- To provide guidance and support to the student undertaking this project bearing in mind that it is an *independent* research project. This is inclusive of commenting on drafts of the final report in a timely fashion.

3. DOCUMENT CHECKLIST

Research Proposal or Plan Attached?	☒ **YES**	☐ **NO**	
☒ **YES**	☐ **NO**	**Risk Assessment for fieldwork and evidence of COSSH assessment for all laboratory procedures (online risk assessment completed)**	
☐ **YES**	☒ **NO**	**Completed booking for all field equipment**	
☒ **YES**	☐ **NO**	**Letters of permission where appropriate providing evidence of access to such things as field sites and/or museum archives**	
☒ **YES**	☐ **NO**	**Completed Ethics Checklist**	

4. INTERIM INTERVIEW – Progress evaluation

By November my field work will be complete, so I aim to be able to present my data, a habitat suitability index for natterjack toads and a map of my survey results incorporating terrain data.

I will also have planned the structure of my write up, and how I will analyse my data in order to assess my objective.

Interim Review Date: Early November

5. Variance from the Independent Research Project Guide
The IRP assessment is normally governed by the guidance provided in the Independent Research Project Guide. Any variance in terms of format (e.g. technical report, scientific paper) and word limit should be agreed and specified here. Submission date cannot be changed unless evidence of mitigating circumstances is provided in accordance with the standard BU Guidelines.
Any changes? ☐ ☒ **NO** If YES please provide details below:

Both of the undersigned parties agree to be bound by this learning contract:	
Student Signature:	Sam Deakin
PRINT NAME:	Sam Deakin
Date:	14/03/2022

Supervisor Signature:	Kathy Hodder
PRINT NAME:	Kathy Hodder
Date:	30.03.2022

9.2 Interim meeting comments

Independent Research Project
Interim Interview - Agreed Comments Form

Student Name: Sam Deakin	Programme: BSc Ecology and Wildlife Conservation
Date: 01.12.2022	IRP Title: The habitat suitability of Studland bay for the natterjack toad (Epidalea calamita)
Supervisor Name: Kathy Hodder	

Agreed comments – to include progress and plans for completion:

- Sufficient data has been collected to form the suitability index, more data may be required and can be collected later.
- Complete extraction of data from maps to characterise the ponds and their surrounding habitat.
- Test and sense check the values in the HSI, present these at the end of December.
- Create a formal document for the IRP.
- Create structure of the IRP document, start entering ideas, references and text.
- Consider testing the HSI at Studland with volunteers, look at feasibility and logistics.

Each student should retain a digital copy of this form once it is completed and signed and include it in the appendices of the IRP. The completed form should also be emailed to the supervisor.

Student signature: Sam Deakin	Supervisor signature: Kathy Hodder

9.3 Risk assessment

About You & Your Assessment

Name	Sam Deakin
Email	s5301567@bournemouth.ac.uk
Your Faculty/Professional Service	Faculty of Science and Technology
Is Your Risk Assessment in relation to Travel or Fieldwork?	Yes
Status	Approved
Date of Assessment	12/03/2022
Date of the Activity/Event/Travel that you are Assessing	04/04/2022

What, Who & Where

Describe the activity/area/process to be assessed	Shallow pond surveying
Locations for which the assessment is applicable	Studland Bay, Dorset
Persons who may be harmed	Student

Hazard & Risk

Hazard	leptospirosis
Severity of the hazard	Medium
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for leptospirosis: Covering cuts, disinfecting	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Hazard	Lone working
Severity of the hazard	Medium
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for Lone working: Avoiding this if possible, otherwise using a buddy system, with someone aware of where I am, when I am due back and who can raise the alarm if I don't make contact.	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Hazard	Tick bites
Severity of the hazard	Medium
How Likely the hazard could cause harm	Medium
Risk Rating	Medium
Control Measure(s) for Tick bites: Checking for ticks, removal of ticks and monitoring of bites	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Hazard	Adders
Severity of the hazard	Medium
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for Adders: Good boots, following my reptile surveying training and avoiding tall vegetation.	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Hazard	dehydration
Severity of the hazard	Low
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for dehydration: Bottled water	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Hazard	Slips/trips
Severity of the hazard	Low
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for Slips/trips: Good walking boots and situational awareness Ensuring I have emergency contact and someone is aware of where I am	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Hazard	Lyme disease
Severity of the hazard	Medium
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for Lyme disease: If there are signs of infection (red ring around bite) or any other symptoms, I will visit the GP for antibiotics. Covering up, awareness of tick bite locations and monitoring them.	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Hazard	Public interactions / dogs
Severity of the hazard	Low
How Likely the hazard could cause harm	Low
Risk Rating	Low
Control Measure(s) for Public interactions / dogs: Carrying proof of permission to carry out study Avoiding confrontation	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	

Review & Approval

Any notes or further information you wish to add about the assessment	In addition to harm to myself, I am aware of mitigation processes to prevent the spread of invasive aquatic plants.
Names of persons who have contributed	
Approver Name	Kathy Hodder
Approver Job Title	Principal Academic
Approver Email	khodder@bournemouth.ac.uk
Review Date	30/04/2022

9.4 Pond photos

Pond 1 (Deakin 2023)


Pond 3 (Deakin 2023)


Pond 5 (Deakin 2023)


Pond 9 (Deakin 2023)


Pond 10 (Deakin 2023)

Pond 11 (Deakin 2023)

Pond 13 (Deakin 2023)


Pond 14 (Deakin 2023)


Pond 16 (Deakin 2023)


Pond 17 (Deakin 2023)


Pond 19 (Deakin 2023)


Pond 20 (Deakin 2023)


Pond 21 (Deakin 2023)

Pond 22 (Deakin 2023)

Pond 23 (Deakin 2023)

Pond 24 (Deakin 2023)

Pond Boomerang (Deakin 2023)

Pond Dune (Deakin 2023)

Pond Pear (Deakin 2023)

9.5 Raw data

Further data including habitat shapefiles will be shared with the National Trust stakeholders.

9.5.1 Appendix table 1: Vegetation quadrat height data

Pond name	H1	H2	H3	H4	H5	Coverage% 5cm >	Height average
1	15	30	40	55	180	5	28.33333333
1	5	1	0	0	1	99	2
1	0	0	38	11	0	92	12.66666667
1	20	0	20	52	0	15	13.33333333
1	110	100	60	50	160	8	90
1	30	25	10	1	30	50	21.66666667
1	15	10	1	2	1	22	8.666666667
1	2	40	180	1	1	45	74
1	3	12	0	8	20	18	5
1	5	30	0	9	0	13	11.66666667
10	2	0	1	2	2	97	1
10	10	14	0	0	1	93	8
10	0	0	0	0	2	95	0
10	8	8	20	0	70	10	12
10	0	0	0	0	0	99	0
10	0	0	2	10	0	95	0.666666667
10	0	12	28	20	25	8	13.33333333
10	60	0	0	45	10	8	20
10	4	3	10	13	13	40	5.666666667
10	1	0	2	2	7	97	1
11	4	60	50	90	49	22	38
11	13	180	30	30	0	15	74.33333333
11	0	70	30	0	10	15	33.33333333
11	0	0	20	0	0	75	6.666666667

11	7	0	30	32	80	2	12.33333333
11	100	40	20	70	60	30	53.33333333
Pond name	**H1**	**H2**	**H3**	**H4**	**H5**	**Coverage% 5cm >**	**Height average**
11	0	0	0	1	12	87	0
11	140	12	45	100	3	15	65.66666667
11	0	28	5	13	2	80	11
11	50	0	53	0	2	27	34.33333333
13	25	15	3	2	31	30	14.33333333
13	30	15	54	13	30	5	33
13	50	10	10	12	70	7	23.33333333
13	20	15	40	10	2	70	25
13	10	1	12	32	11	20	7.666666667
13	30	0	0	0	0	50	10
13	0	13	12	0	80	22	8.333333333
13	30	70	0	30	25	5	33.33333333
13	30	20	0	30	0	30	16.66666667
13	15	28	8	20	13	20	17
14	1	10	55	30	15	30	22
14	0	0	0	0	0	100	0
14	0	50	30	33	10	10	26.66666667
14	15	10	50	30	45	10	25
14	7	34	50	0	20	10	30.33333333
14	33	30	31	50	45	23	31.33333333
14	1	13	62	48	34	7	25.33333333
14	12	45	45	18	15	2	34
14	28	50	45	27	35	20	41
14	40	32	0	12	30	15	24

16	30	40	35	10	40	7	35
16	40	23	28	10	10	7	30.33333333
Pond name	**H1**	**H2**	**H3**	**H4**	**H5**	**Coverage% 5cm >**	**Height average**
16	1	35	20	20	0	30	18.66666667
16	11	0	9	13	30	2	6.666666667
16	13	15	29	7	15	2	19
16	20	0	0	30	20	6	6.666666667
16	2	0	0	3	10	85	0.666666667
16	0	12	0	10	20	25	4
16	0	1	5	0	2	62	2
16	0	0	32	27	0	65	10.66666667
17	12	30	40	30	54	2	27.33333333
17	0	0	0	1	25	95	0
17	26	14	12	30	9	2	17.33333333
17	25	31	160	30	13	0	72
17	4	1	1	3	10	82	2
17	14	26	11	12	28	4	17
17	15	15	29	13	15	3	19.66666667
17	39	11	12	40	2	5	20.66666667
17	0	0	0	0	0	100	0
17	10	10	10	1	10	75	10
19	7	0	9	0	10	55	5.333333333
19	0	0	1	10	0	90	0.333333333
19	10	12	13	11	2	7	11.66666667
19	10	5	10	25	25	2	8.333333333
19	7	200	30	5	7	70	79
19	0	0	0	15	0	85	0

19	10	10	3	35	30	15	7.666666667
19	15	5	9	29	2	38	9.666666667
Pond name	**H1**	**H2**	**H3**	**H4**	**H5**	**Coverage% 5cm >**	**Height average**
19	9	10	18	25	15	2	12.33333333
19	8	10	150	160	20	3	56
20	5	2	10	15	9	45	5.666666667
20	10	2	2	42	20	2	4.666666667
20	27	20	5	10	15	5	17.33333333
20	18	37	35	14	6	2	30
20	25	60	10	30	12	5	31.66666667
20	20	10	13	20	20	7	14.33333333
20	20	48	5	2	11	20	24.33333333
20	30	10	10	12	7	10	16.66666667
20	25	19	20	20	32	10	21.33333333
20	30	1	10	10	53	13	13.66666667
21	12	90	150	14	3	5	84
21	28	12	10	50	0	15	16.66666667
21	5	2	7	0	10	80	4.666666667
21	25	25	15	5	2	6	21.66666667
21	250	150	160	250	2	0	186.6666667
21	7	7	10	12	5	35	8
21	0	35	3	30	12	18	12.66666667
21	25	45	0	11	20	10	23.33333333
21	30	11	10	10	13	5	17
21	10	5	48	10	4	60	21
22	10	20	28	28	10	4	19.33333333
22	0	0	1	0	10	95	0.333333333

22	13	29	20	20	28	3	20.66666667
22	28	17	7	14	8	13	17.33333333
Pond name	**H1**	**H2**	**H3**	**H4**	**H5**	**Coverage% 5cm >**	**Height average**
22	13	11	20	10	18	5	14.66666667
22	33	1	6	10	46	11	13.33333333
22	29	28	34	4	15	7	30.33333333
22	27	0	0	7	30	5	9
22	5	10	8	10	8	20	7.666666667
22	27	10	12	25	30	3	16.33333333
23	31	30	27	19	7	5	29.33333333
23	14	12	15	15	29	8	13.66666667
23	2	3	0	13	21	85	1.666666667
23	27	30	13	28	30	7	23.33333333
23	2	1	11	0	15	20	4.666666667
23	20	51	20	30	15	2	30.33333333
23	20	5	12	18	11	10	12.33333333
23	12	25	25	2	3	2	20.66666667
23	14	15	0	40	10	37	9.666666667
23	30	27	11	26	13	6	22.66666667
24	5	8	9	2	28	10	7.333333333
24	27	30	25	10	20	6	27.33333333
24	20	46	5	40	5	1	23.66666667
24	3	29	30	15	10	4	20.66666667
24	12	42	30	45	32	1	28
24	30	30	35	11	28	3	31.66666667
24	33	45	60	33	90	15	46
24	11	20	11	13	8	12	14

24	20	6	0	30	50	35	8.666666667
24	0	12	0	0	0	70	4
Pond name	**H1**	**H2**	**H3**	**H4**	**H5**	**Coverage% 5cm >**	**Height average**
3	0	12	0	0	7	45	4
3	0	0	0	0	60	85	0
3	5	0	12	0	3	70	5.666666667
3	210	230	180	50	140	10	206.6666667
3	0	0	0	0	0	100	0
3	2	0	0	15	3	25	0.666666667
3	10	0	55	0	2	50	21.66666667
3	0	0	0	1	0	99	0
3	60	0	0	0	0	55	20
3	0	0	150	100	0	30	50
5	100	2	1	10	2	35	34.33333333
5	60	110	0	70	50	2	56.66666667
5	0	0	1	0	30	55	0.333333333
5	3	1	0	30	4	10	1.333333333
5	20	0	30	20	0	40	16.66666667
5	0	0	0	0	0	100	0
5	120	70	140	130	50	0	110
5	100	10	100	0	12	15	70
5	7	2	90	1	0	75	33
5	0	15	45	10	15	30	20
9	25	1	5	15	5	20	10.33333333
9	0	0	0	0	0	100	0
9	0	0	0	0	0	100	0
9	30	40	120	0	10	10	63.33333333

9	0	1	20	0	2	80	7
9	1	1	0	0	2	97	0.666666667
9	6	8	20	0	0	21	11.33333333
9	12	2	28	2	40	50	14
9	7	0	1	0	3	93	2.666666667
9	30	0	30	120	180	12	20
Boomerang	30	0	5	35	0	40	11.66666667
Boomerang	25	25	50	50	27	4	33.33333333
Boomerang	50	50	45	10	2	5	48.33333333
Boomerang	20	40	41	20	38	5	33.66666667
Boomerang	30	15	30	30	3	15	25
Boomerang	52	46	10	13	1	25	36
Boomerang	100	50	50	30	3	5	
Boomerang	30	30	28	0	3	3	29.33333333
Boomerang	50	40	50	55	20	1	46.66666667
Boomerang	0	6	28	25	30	12	11.33333333
Dune	0	30	20	25	30	45	16.66666667
Dune	65	60	28	15	65	1	51
Dune	1	25	1	10	0	45	9
Dune	0	13	3	2	1	75	5.333333333
Dune	40	25	10	12	40	6	25
Dune	5	13	25	10	10	45	14.33333333
Dune	20	0	0	5	0	97	6.666666667

Dune	10	12	0	12	0	35	7.333333333
Dune	40	10	32	25	15	15	27.33333333
Pond name	**H1**	**H2**	**H3**	**H4**	**H5**	**Coverage% 5cm >**	**Height average**
Dune	0	0	0	0	1	99	0
Pear	5	10	1	5	1	45	5.333333333
Pear	10	25	0	0	0	85	11.66666667
Pear	10	20	70	30	65	18	33.33333333
Pear	10	7	30	30	0	65	15.66666667
Pear	1	1	1	50	7	70	1
Pear	20	1	30	20	28	15	17
Pear	30	5	60	20	30	35	31.66666667
Pear	50	45	70	10	15	10	55
Pear	35	12	30	40	1	12	25.66666667
Pear	20	20	30	0	1	55	23.33333333

9.5.2 Appendix table 2: Water quality parameters

Pond ID	US/CM 2022	pH 2022	US/CM 2023	pH 2023
1	350	4.47	196.1	5.29
3	316	5.26	194.1	5.62
5	301	4.69	183.2	4.8
9	88.2	5.97	211.6	5.41
10	124.7	4.03	213.1	5.36
11	266	3.98	141.7	4.38
13	55.4	5.24	231	6.84
14	370	5.17	230	6.21
16	369	5.04	275	6.51

17	435	5.29	195.9	6.33
19	419	5.4	214.4	6.2
20	1552	5.83	279	6.78
21	451	5.07	291	5.83
22	428	5.72	218.1	6.39
23	-	-	168.8	6.1
24	-	-	155.8	6.38
Boomerang	287	3.66	118.9	5.03
Dune	112.9	7.61	80.8	6.69
Pear	326	4.19	148.9	4.66