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Evaluating The Bude Water Vole Reintroduction Project And The Factors Which Determined The Successes And Failures

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Evaluating The Bude Water Vole Reintroduction Project and The Factors Which Determined The Successes And Failures

by

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Author's Declaration

At no time during the registration for the degree of Research Masters in Biological Science has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

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Abstract

Water voles (*Arvicola amphibius*), once a widespread species in Britain, became the fastest declining British mammal due to habitat fragmentation and North American mink (*Neovison vison*) introduction. Bude catchment (North Cornwall, England) was the location of the first water vole release project in Cornwall and has been closely monitored since the first releases in 2013. Latrines, being the most accurate field sign, were recorded twice a year, alongside burrows and feeding signs, giving an indication to the presence of voles in and around the release locations. In the Bude release catchment the presence of water voles was strongly correlated with static / still water bodies, suggesting that the water voles had moved from lotic (fast flowing) to lentic (still / static) habitat following reintroduction. Comparing this to further releases across England shows that they do not always thrive in static / still water. This was an interesting finding of the project and suggests that water voles are likely to have a plethora of habitat requirements which cannot be easily determined prior to release. Since the cause is unknown this is an area requiring further study. The main objective of the project was to follow up the reintroduction of water voles and latrine numbers show water voles are still active and, therefore, the release can be considered a success due to their short natural lifespan.

Key words: Water voles, mink, reintroduction, habitat features, Cornwall

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Introduction

The European water vole (*Arvicola amphibius*) used to be a widespread species and often considered a pest (IUCN, 2018). By 1989, 97% of the water vole population had declined in Britain and in the late 1990's they were declared extinct in Cornwall and Devon (MacPherson & Bright, 2011). This dramatic decline is thought to be due to predation by introduced North American mink (*Neovison vison*) and habitat fragmentation (MacPherson & Bright, 2011). Due to the significant decline and extinction threat, water voles are fully protected under Sections 5 and 9 of the Wildlife and Countryside Act 1981, however currently there is a quinquennial review of Schedule 5 of the Wildlife and Countryside Act which could alter this if the review sees fit (JNCC, 2021 Derek Gow Consultancy, 2018, Natural England & Defra, 2014). Under this protection it is against the law to capture, injure or kill the voles; damage, disturb, destroy or block their places of shelter and possess, sell, control or transport live or dead wild water voles. In addition, they are a priority species in the UK Biodiversity Action Plan (BAP). The BAP priority species were identified as most at threat from extinction and required conservation action (JNCC, 2019, JNCC, 2016). Due to this, management is carried out to preserve current water vole populations but also to sympathetically manage water bodies for the reintroduction of water voles. Most priority BAP species have a Species Action Plan (SAP), which are mostly county based. As water voles were extinct in Cornwall by this point, there was no Cornwall specific SAP. Water voles are classified as a Red List Species, however the Global IUCN Red List Category for the water vole is Least Concern (LC) (Natural England, 2021).

North American Mink (*Neovison vison*)

1860's in America is the earliest known records of farming North American mink (*Neovison vison*) (hereafter referred to as 'mink') for fur (International Fur Trade Federation, 2011). Mink became a very popular fur species and in the 1920's they were transported far from their native range to many countries, including the UK for fur farming (Rey, 2008; GWCT, 2016). By the 1930's mink were escaping from UK farms; many by releases from animal activists due to fur trade protests (Encyclopedia of Clothing and Fashion, 2009). Over 400 known fur farms were in the UK by the 1950's, with many more suspected undeclared "backyard" farms (Encyclopedia of Clothing and Fashion, 2009). In England, mink were recorded in the wild by 1956 and a lack of natural predators allowed the population to expand rapidly, occupying most rivers in Cornwall and Devon (Canal and Rivers Trust, 2015). Mink expanded into Wales and lowland Scotland by late 1967. In the 1990's mass releases occurred (Table1), however by this time, mink were already widespread in the wild. Mink are now widespread in the UK, all of which are decedents of the mink from the fur farms. It is virtually impossible to gauge the number of mink living in the wild.

Table 1: Two of the larger documented mink releases in England. *Although many were released, a smaller portion actually made it into the wild and survived. (The free library, 1998; The guardian, 1998)*

Location	**Date**	**Description**
Crow Hill Farm, Ringwood, Hampshire	August 1998	Animal Liberation Front (ALF) released 6000 mink and a further 1000 mink 2 weeks later. 2500 were recaptured, 2000 were killed and the rest were unaccounted for
Kelbain mink Farm, Onneley, Nr. Newcastle-Under-Lyme	September 1998	ALF released 7000 mink, 2500- 3000 of which managed to escape the farm. 700 remained unaccounted for, the rest were recaptured, killed or died. It is believed only 200 survived in the wild.

Mink are very effective predators, with anecdotal evidence suggesting they can kill as many as 100 birds in one night (Williams, *et al*., 2010). Their effectiveness as introduced predators, therefore, has had a large impact on native wild animals, devastating populations of local wildlife such as birds, fish and mammals; in particular, the most documented and widely published case, water voles. Water voles are low in the food chain, predated on by many species; however, mink are the only species which are known to enter water vole burrows and kill all inside.

Despite mink populations initially rapidly expanding, over the last 15 years, mink populations appear to have dwindled in Cornwall; coinciding with the time the last water vole populations became extinct, however this could be coincidental. There is no evidence to suggest the water vole decline is the reason, mink could have gone away from water sources in search of food. The exact status of mink populations in Cornwall and Devon is complex and unknown, one reason being because very few organisations have continued mink monitoring and control since the population has appeared to significantly decline.

Biology & Habitat Preferences

Water voles are often misidentified as rats and are frequently referred to as 'water rats'. Although similar, they differ in many ways (Table 2); both species swim, however, neither are obviously adapted for water (The Mammal Society, 2018). Water voles have no webbed feet, a small tail and if submerged for too long, their fur becomes waterlogged (PTES, 2018). Despite this, water voles are known to inhabit riparian habitat. Unlike most animals, water voles dig using their teeth, creating almost perfectly round or "D" shaped burrows (Hill, 2015). Due to this they require a soft earth bank. Water voles eat 80% of their body weight daily and therefore require a large food source (Hill, 2015). They have been recorded to eat 227 different species of plant in Britain, including grasses, common reeds, sedges and rushes. Over summer months they consume roots, tree bark and fruit (PTES, 2018). Pregnant females have also been known to occasionally eat insects, other invertebrates and snails for protein. Water voles will avoid habitat that is overshaded, heavily grazed or trampled due to the lack of bankside ground vegetation for both food and shelter (Water Vole, 2022). They thrive in vegetated banks along rivers, ditches, streams, lakes, ponds, canals, marshland and uplands. Breeding season is between March and September with an average of two to three litters annually, containing between two to eight pups per litter (Hill, 2015). The pups leave their mother at 28 days old to find their own territory.

Table 2: Water vole and rat characteristics (The Mammal Society, 2018)

	Water Vole	**Brown Rat**
Fur	Chestnut brown	Brown/ Grey
Tail	Dark haired Half the body size	Bald Same size as body
Ears	Smaller and barely visible	Larger and prominent
Face	Rounded	Pointed
Size (body)	12-20cm	12 – 27cm
Weight	Max 330g	Usually 200-300g (Max 600g)

Territories

Water voles are primarily solitary; however they live in colonies with individual territories along a watercourse (Discover Wildlife, 2022). Females occupy a 30 to 150 meter territory, marked with latrines, which they fiercely defend (Gow, 2007). Females are most territorial during breeding season, however will sometimes fight if the habitat is overcrowded (YPTE, 2022). Males overlap multiple female territories, covering 60 to 300 meters, and will mostly fight due to overcrowding.

Habitat Fragmentation and Degradation

There has been a shift in farming practices over the years, which has had an effect on the local wildlife. UK farmland has seen a significant increase in intensive farming, with many farmers using land right up to the river's edge which causes a loss in riparian habitat (Rushton, *et al.,* 2001). As well as farming, urbanisation on flood plains has also contributed to the loss of suitable water vole habitat. Intensely farmed and urbanised land is not favoured by water voles due to the lack of a plentiful food source and, thus, suitable water vole habitat has been both reduced and significantly fragmented. Smaller, isolated populations of species experience lower viability due to demographics, and are, therefore, more likely to become locally extinct (Rushton, *et al.,* 2001). The size, quality and connectivity of habitat is all important for water voles to thrive. Increased fragmentation also reduces the likelihood of recolonisation if local extinctions occur (Rushton, *et al.,* 2001).

Ecological Importance

Water voles are an important part of the ecosystem; creating changes in riparian habitat. Water vole burrows dry out soil, promoting microbial activity, which allows more microbes to transform ammonia into nitrogen, regulating nitrogen availability; in turn altering the vegetation (PTES, 2017). The increase in native vegetation promotes native wildlife. They are also an important prey base, being the largest vole in Britain. Bank and field voles are approximately 30g fully grown, an order of magnitude smaller than a fully grown water vole (330g max), which is a significant difference to predators.

Water Vole Reintroductions

Water voles can be released as a 'hard' release, a 'soft' release, or a mixture of hard and soft release. Hard releases involve releasing the voles straight into the wild to fend for themselves. Soft releases involve placing family groups of voles into large cages on the riverbank, these cages are left for three days, allowing the voles to acclimatise. A piece of wood with two holes, approximately 8cm in diameter, known as baffle boards, are attached to the cages, allowing the voles to come and go freely, providing a point of refuge, after a further two days the cages are removed completely.

Since the decline of water voles was made apparent, water vole reintroductions have been a focal point in conservation. Reintroductions have been carried out across the

UK in varying locations, Table 3 shows a few details of some of the notable larger releases prior to the Cornwall releases. These releases have led the way and allowed research for the best practices going into the Cornwall project.

The River Colne water vole reintroduction started in 2009, commencing with extensive mink monitoring (Tansley, 2018 *pers. comm*). In the first year 70 mink were caught. After this, approximately 600 water voles were released between 2010 – 2012 on large sections of the slow flowing river as well as less than 10 voles being released onto a flood plain lake. This release project used mainly soft release cages, incorporating the newer style cages which are dug into the ground to allow water voles to burrow out of, with less than 10 voles being hard released. Since the release, monitoring has shown that the voles have expanded their habitat considerably. One release site was less successful and thought to be due to mink presence further upstream. Mink are still being caught, however in significantly less numbers.

Between 2011 and 2013, a large-scale water vole reintroduction was carried out on Rutland Water Nature Reserve (Mackrill, 2018 *pers. comm*). Water voles were absent from the reserve itself, despite being identified as ideal water vole habitat by Derek Gow Consultancy, leading water vole expert in England. Natural recolonization of the area was highly unlikely as the closest water population was extremely small and approximately 7km away from the site. Over a three-year period, more than 900 water voles were reintroduced in a mixture of hard and soft releases on predominantly ditches and ponds, all static or sluggish flowing water. Since the release, the water voles have shown to be well established in ongoing monitoring work. Water voles have continued to thrive in the areas in which they were released as well as expanding into adjoining habitats, including a stream and reedbeds.

Table 3: Water vole reintroduction sites across England prior to the Cornwall water vole project. *Three water vole release locations in England with a minimum of 600 voles released, in a variety of water bodies. It can be seen that mink monitoring became a priority after the 2010 release in Hertfordshire.*

Location	Site and details	Number of voles
River Colne, Hertfordshire	Sections of the river, released between 2010-2012 by Essex Wildlife Trust	600
Rutland Water, Rutland	Rutland Water Nature Reserve and Oakham Canal. Releases between 2011-2013 Mink Free Release by Leicestershire and Rutland Wildlife Trust	800 Nature Reserve 100 Oakham Canal
Kielder Forest, Northumberland	Mink free/ Low mink count Managed for voles Release by Northumberland Wildlife Trust, supported by Tyne Rivers Trust and Forestry Commission.	965

Northumberland Wildlife Trust (NWT) embarked on "Restoring Ratty", starting in 2016. It is one of the most recent and largest reintroductions in England (Hollings, 2018 *pers. comm*). June 2017 saw 317 voles released in Kielder Forest and August 2017 had 243 voles released in other locations at Kielder, totalling 560 voles. A further 405 voles were released in June and August 2018. These releases were mainly soft releases

(95%) with hard releases only occurring in inaccessible areas, focusing on all habitats. The NWT has discovered that voles prefer the narrow overhanging ditches in Kielder. The water flow at Kielder varies dramatically, which voles appear to be adapting to by creating burrows and latrines a long way back from the banks. This could be an indication that water voles are adaptable to a wide range of habitats. All water voles released in England are sourced by Derek Gow Water Vole Consultancy Limited and the genetical information is documented within his records and not shared to other parties within the release program.

Initial release project & Background

In 2012 Westland Countryside Stewards; a small charity based in North Cornwall, started looking at the possibility of a water vole project in Bude, North Cornwall, England. The Bude catchment is relatively small, draining a combined area of approximately 133.5km^2, comprising of two rivers: The River Neet (10.5 miles long) and the River Strat (12.7 miles long), starting in Week St Mary and Kilkhampton respectively (Figure 1) (Westcountry Rivers Trust, 2006). Both rivers vary in width and flow throughout the entire catchment. The two rivers join at Marhamchurch to form the Bude canal and split at the weir into the River Neet or Strat (Figure 2). The catchment was split into 34 lengths of similar sizes in the vicinity of release locations (Table 4).

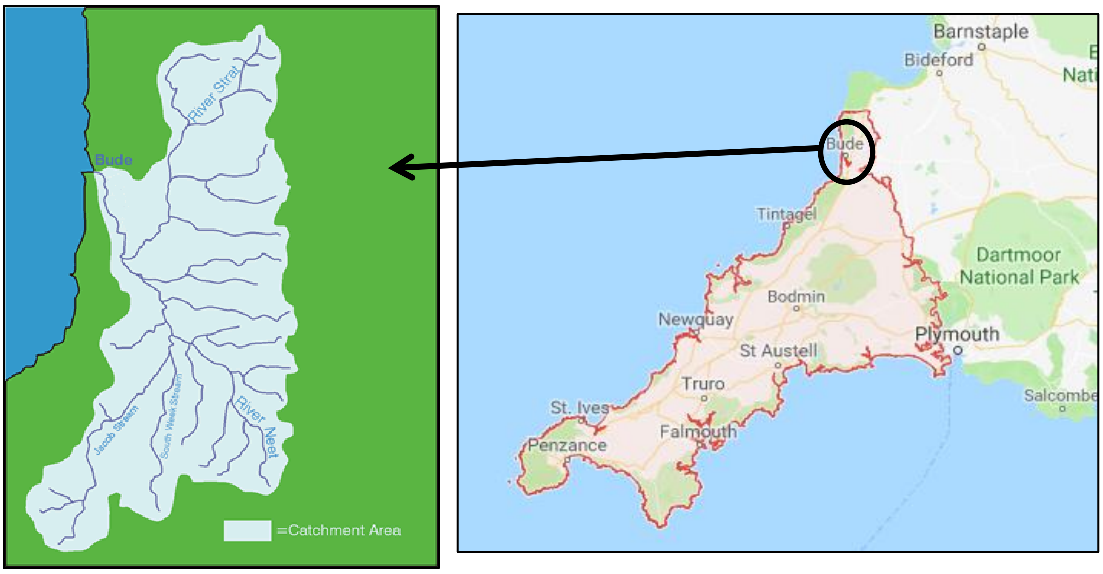

Figure 1: Bude catchment (Westcountry Rivers Trust, 2006). *A catchment,* d*raining an area of approximately 133.5km*^{2}*. The water vole release was focused on the River Neet, River Strat, The River Neet/Strat; which is where the Strat and Neet combine, as well as static water bodies such as the canal and lakes and ponds in close proximity to the main river.*

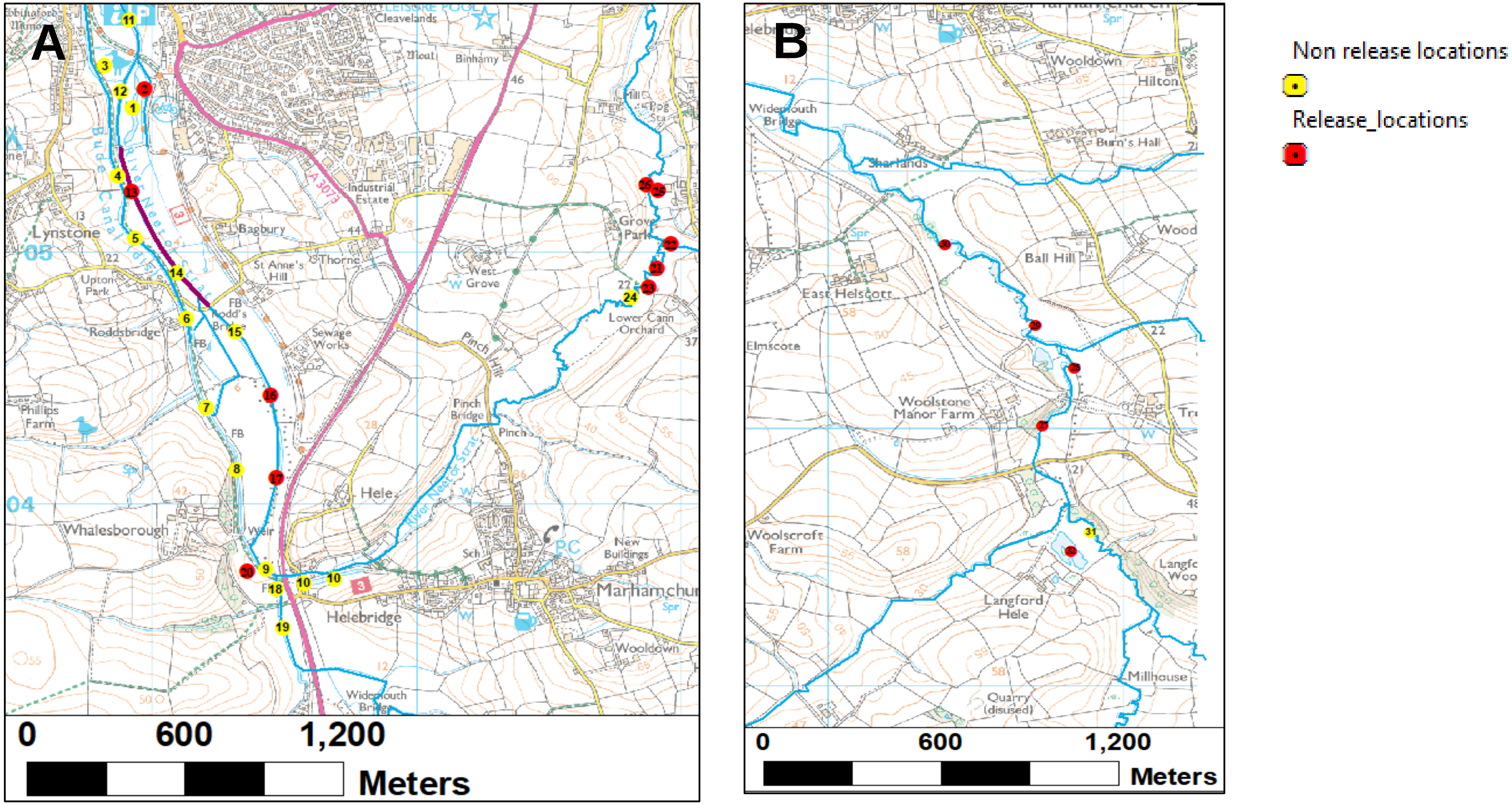

Figure 2: Study area lengths within the River Strat / Neet catchment and the canal. *Map B sits to the south of map A*. *The Bude catchment was split into study areas, separating the water bodies, which were then split into predetermined lengths for ease of surveying and data recording. Lengths varied in size, however the data collected was made comparable by calculating latrines per m^2*

Table 4: Water vole survey sites and length details. *Larger sites and longer stretches of river were split into multiple lengths for easier recording and mapping of data collected. Nine release sites were chosen by Derek Gow Consultancy Ltd based upon their suitability for water voles and landowner permission.*

Site	Location	Grid Reference	Length (L)	Release Site
1	Water body within Bude Marshes Local Nature Reserve	SS 20922 05569	L 1: 280m	No
	Ditch alongside water body 1.	SS 20990 05684 – SS 20977 05447	L 2: 300m	
	Water Body within Bude Marshes (LNR)	SS 20810 05743	L 3: 280m	
2	Lower end of the canal from Bencoolen Road and ending at Rodd's Bridge.	SS 20743 05885 – SS 21098 04830	L 4: 290m L 5: 360m	No
3	Section of the canal, starting at Rodd's bridge and ending at the underpass.	SS 20743 05885 – SS 21487 03717	L 6: 360m L 7: 233m L 8: 365m L 9: 290m	No
4	From Helebridge underpass to the East end of the water body. Includes a ditch and a water body.	SS 21487 03717 – SS 21818 03741	L 10: 290m	No
5	Closest length to the mouth of the River Neet or Strat, from the Bencoolen Bridge to Rodd's Bridge.	SS 20873 06122 – SS 21210 04791	L 11: 310m L 12: 365m L 13: 380m L 14: 338m	Yes

Site	Location	Grid Reference	Length (L)	Release Site
6	Section of river upstream from Site 5, from Rodd's Bridge to the weir/ fish ladder in Marhamchurch	SS 21210 04791 – SS 21375 03842	L 15: 336m L 16: 330m L 17: 360m	Yes
7	Section of river Neet between Site 9 and of Site 14	SS 21481 03598 – SS 21652 03350	L 18: 288m	Yes
8	Section of river adjoining the canal adjacent to The Weir Bistro	SS 21481 03598 – SS 21463 03709	L 19: 390m	No
9	Pond adjacent to The Weir Bistro, Marhamchurch	SS 21385 03721	L 20:360m	Yes
10	Small section of the River Strat in Lower Cann Orchard	SS 22922 05022 - SS 22856 04859	L 21: 380m	Yes
	A tributary flowing into the River Strat,	SS 23220 04975 – SS 22922 05022	L 22: 340m	
	A small pond adjacent to the river.	SS 22888 04832	L 23: 160m	
11	Section of River Strat downstream of Site 11	SS 22856 04859 – SS 22533 04483	L 24: 886m	No
12	Small established pond	SS 22950 05188	L 25: 78.5m	Yes
	River upstream from Site 10	SS 22914 05127 – SS 22892 05214	L 26: 216.5m	
13	Section of the River Neet including the viaduct between Marhamchurch and Box's Shop	SS 22687 01878 – SS 22323 02883	L 27: 308m L 28: 292m L 29: 366m L 30: 653m	Yes
14	Section of the River Neet by Langford Hele pond	SS 22815 01681 – SS 22965 01525	L 31: 365m	No
15	Langford Hele pond	SS 22810 01533	L 32: 390m	Yes
16	Poundstock: A small fishing pond	SS 22503 00016	L 33: 117m	Yes
	Section of the River Neet	SX 22505 99958 – SS 22623 00116	L 34: 237m	

The Bude Water Vole Project commenced with mink surveys and monitoring in summer 2012. Recycled plastic mink rafts were placed around the catchment in and around release locations to detect footprints of animals. Mink being curious creatures, use the rafts as a playground, which has been captured on film. No mink were detected and the charity started running the Bude Water Vole Project in 2013, and releases commenced until August 2014 (Table 5). The project used both hard and soft releases.

June 2013 saw the first water vole release; 100 voles were hard released on a large wildlife pond in Helebridge, adjacent to the Weir Café which was also filmed as part of the BBC 2 documentary “The Burrowers”. In September 2013, a further 177 voles were released in various locations along the River Strat, between Stratton and Marhamchurch. In spring 2014, a comprehensive water vole survey in the Bude catchment was undertaken through funding from BIFFA Landfill Communities Trust. The release sites showed no signs of water voles. The loss of the primary release voles was followed by an expansion of the mink monitoring rafts resulting in the capture and dispatch of two mink; one male and one female. The female had not bred, which was determined by the teat size. Following further mink monitoring, no more mink were detected, suggesting there wasn’t a larger population.

Two more releases took place in June the same year; the first was a small hard release of 10 water voles on the River Neet/ Strat. On the second release, approximately 200 water voles were released using soft release method on the River Neet. The cages were positioned in shaded areas due to the high daytime temperatures occurring during the release period, approximately 50 meters apart where possible directed by Derek Gow Consultancy Limited who provided the voles and expertise.

Two months later, 75 microchipped voles were soft released onto a private lake upstream of the previous release. These voles were then recaptured and scanned in October the same year. Approximately 70% of the voles were recaptured and were all within the same location which they were released, showing a lack of movement. In June 2018, approximately 80 voles were released in four locations; two past failed releases and two new sites. One of the failed releases was thought to be due to the heatwave which occurred after the release, it was not known why the second release failed. Failed releases were determined by the absence of evidence of water voles upon surveying the release site and surrounding area. Approximately, 640 water voles have been released into the catchment in total. Water vole release locations were selected by Derek Gow based upon his knowledge of water vole habitat preferences, however heavily relied on land owner permission.

Table 5: Timeline showing the water vole project. *The Bude Water Vole Project started in summer 2012 with mink rafts being deployed. With no mink detections water vole releases commenced. Water voles were released in stages between June 2013 to August 2014 in five locations. Water vole surveys were carried out in spring and autumn every year.*

Date	Activity
Summer 2012	34 Mink surveys and rafts deployed
June 2013	100 voles hard released at Site 9, length 20
September 2013	177 voles released at Site 10 lengths 21, 22, 23
29th April – 1st May 2014	Water vole survey
7th May 2014	Two mink captured at Site 9
20th June 2014	10 voles were hard released at Site 5, Length 13
24th June 2014	200 voles soft released at site at Site 13, lengths 27, 28, 29, 30
August 2014	75 microchipped voles soft released at site at Site 15 length 32
October 2014	Microchipped voles were recaptured
27th April – 1st May 2015	Water vole survey

Aims and Objectives

The main aims of this research are to find out how to successfully reintroduce the water vole which became extinct in Cornwall in the late 1990's and to analyse the vole's habitat preferences. These aims will be achieved by completing the following objectives:

1. Determine if the water vole reintroduction has been successful by studying and analysing catchment surveys to see if latrine field signs are increasing in numbers. This will allow an estimation of water vole numbers.
    a. Hypothesis: There will be an increase in latrine numbers
2. Analyse field sign numbers for correlation between water vole numbers and different habitat features focusing on water bodies.
    a. Hypothesis: There will be a positive correlation between lentic habitat and latrine numbers
3. Survey locations in and around release sites to determine if water voles have stayed in their reintroduction sites or moved to more preferred habitat.
    a. The water voles will move from the release sites to more preferred habitat.

1. Methods

1.1 Survey Details

The water vole surveys were completed with assistance from a member of staff at Westland Countryside Stewards due to health and safety requirements whilst surveying in and around water bodies (Appendix 1). Surveys were completed biannually in spring and autumn between 2015 and 2017 (Table 6). Surveys are done in spring and autumn to obtain field signs before and after breeding season, as well as to take an average due to the change in bankside vegetation with varying seasonal weather. Prior to surveying, permission to access the riverbanks was obtained from the various land owners.

During the survey, the bankside vegetation was searched for water vole field signs such as burrows, latrines and feeding signs. Other species field signs such as scat, spraint, feeding remains as well as sightings were also recorded. Where possible, the banks were accessed via the river. Where this was not possible however, binoculars were used as well as access from the top of the bank. Field signs were recorded by hand on paper maps, then manually transferred to ARCGIS. The habitat details were recorded using a water vole survey form (Appendix 2), which details habitat information such as bank profile, current, bordering land use and a vegetation frequency using the DAFORN scale. Wildlife information is also included on the form to note any other sightings which may be relevant, such as predator signs and sightings.

Table 6: Dates which water vole surveys were carried out. *Two water vole surveys were carried out per year, one in autumn and one in spring, which is standard practice. Surveys varied in timings depending on weather condition and accessibility.*

Year	Season	Dates	No. of days
2015	Spring	Monday 27th April - Friday 1st May	5
2015	Autumn	Monday 26th - Friday 30th October	5
2016	Spring	Monday 25th - Friday 29th April	5
2016	Autumn	Monday 24th - Wednesday 26th October and Wednesday 2nd - Friday 4th November	6
2017	Spring	Monday 24th - Thursday 27th April and Tuesday 2nd - Wednesday 3rd May	6
2017	Autumn	Monday 23rd - Wednesday 25th October and November 1st - Thursday 3rd November	6

1.2 Field Signs

Water vole burrows are typically ‘D’ or ’O’ shaped, between 4-8 cm in diameter and can be found both above and below the water line (Figure 3). Latrines are used to mark territory and the droppings are unmistakable; “tic tac” shaped, dark in colour and rounded at both ends. Feeding piles consist of vegetation cut at a 45^{o} angle and chewed tuber (A thickened underground part of a stem where new plants arise). Water voles are known to feed on chunky material, especially hemlock water dropwort (*Oenanthe crocata*), where they also consume the tuber (Hill, 2015).

Figure 3: Examples of water vole survey signs (burrow, latrine and feeding signs). *Burrows are "O" or "D" shaped, "Tic Tac" shaped excrement and chunky vegetation cut at a 45^{o} angle*

This study focused on water vole latrines as they are unmistakable and are easy to distinguish between new and old. Burrows recorded have the potential to be unused, historic or be used by rats and feeding signs can vary depending on the available vegetation. Field voles also cut vegetation at a 45^{o} angle; however, they consume less chunky materials compared to water voles (Appendix 3). Despite this, water voles are also known to consume grass alongside chunky vegetation when there is no other food available (Hill, 2015). A female will also eat grass around the burrow when pregnant to limit time spent in the open (The Mammal Society, 2020).

1.3 Statistical Analysis

The data obtained in 2017 was used as this was the last full set of data obtained prior to the end of the water vole project. Due to water voles having a short lifespan, 2017 was 4 years after the first releases and therefore any latrines found would likely be descendants of the voles from the first releases.

The mean latrine number per site was used to give an average between spring and autumn 2017 survey data. The mean latrine number per m^2 was used to allow comparison due to the sites varying in size. The 2017 water vole data was then made comparable by working out latrine per meter due to the varying lengths. The data collected was analysed using a Principle Component Analysis to discover the most significant habitat features, both negative and positive correlation to water vole latrine numbers as well as the data variability. The mean latrine per m^2 data was shown to be not normal after a normality test and checking residuals. An Individual Distribution Identification was done in an attempt to transform the data; however, the data was unable to normalise. A non-parametric test (Kruskal Wallis) was used to compare the average latrines per m^2 between water body types (canal, pond and river) on MINITAB18®. A 2 sample T-Test was used to compare overall mean latrine numbers between 2015 and 2017.

2 Results

Surveys were undertaken twice a year either side of breeding season (spring and autumn) between 2015 and 2017. Each survey ranged from five to six days totalling 44 survey days. Since the first water vole releases in 2013, all sites show either an increase of the latrine numbers, or no change, suggesting the water voles have increased in numbers; accepting hypothesis 1a, which states there will be an increase in latrine numbers (Appendix 4a). Latrines were found to be present at 72.4% of the lengths surveyed, 38.46% of which were release sites, this is an increase in the mean latrines per m^2 of 124.78% between autumn 2015 and autumn 2017 (Table 7).

Table 7: Total percentage increase / decrease in field signs between autumn 2015 and autumn 2017. *Feeding signs and latrine data shows a large increase from the first autumn survey in 2015 to the autumn 2017 survey, with a small decline in the burrow data recorded. Burrows recorded in 2015 have a chance to be historic (prior to the water vole extinction) and over time became clearly unused and therefore not counted in the surveys.*

Field Sign	% Increase/ Decrease
Feeding Signs	71.43
Burrows	-7.47
Latrines	124.78

The Principle Component Analysis (PCA) shows that the first Principle Component (PC1) accounts for 30.6% of the total variance. The variables which correlate positively with latrine numbers are ponds and lakes (0.287), marsh and bog (0.198), submerged weed (0.285) and reeds and sedges (0.210). The variables which correlate negatively with latrine numbers are running water (-0.358), bankside trees (-0.251), bank profile (-0.308), bank depth (-0.353) and current (-0.354) (Figure 4). The biggest positive correlation was between latrines and lentic habitat, accepting hypothesis 2a: There will be a positive correlation between lentic habitat and latrine numbers.

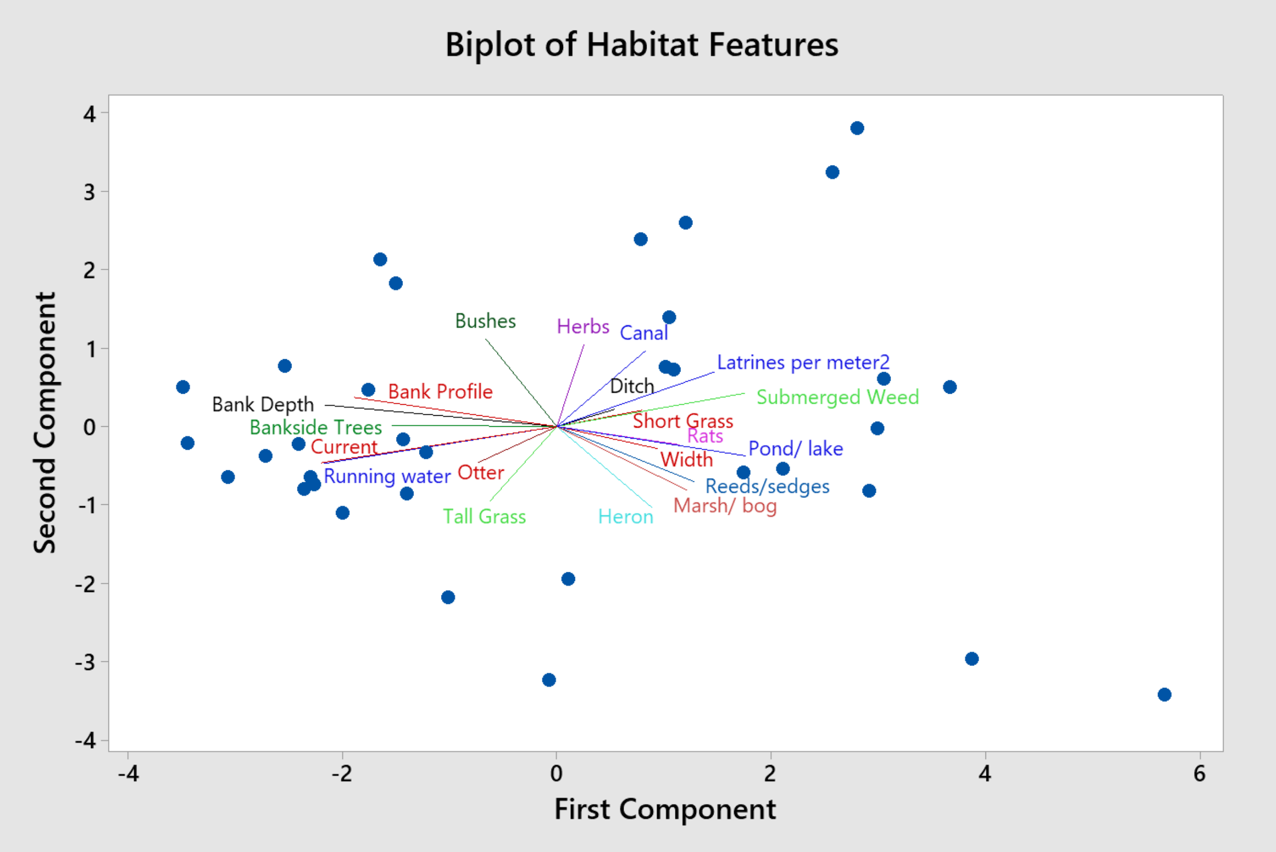

Figure 4: Biplot of Principle Component Analysis (PCA) results for the number of latrines and habitat features. *The first Principle Component (PC1) accounts for 30.6% of the total variance. The second Principle Component (PC2) accounts for 45% of the total variance. Data was collected from release sites and their surrounding areas (8 sites) for three years. Lines show vectors for habitat features and dots denote sample sites.*

Using the Kruskal Wallis test the median number of latrines per m^2 is significantly greater (H= 9.98, df = 2, p =0.007) in the canal compared to the river with a mean rank of 25.7 for the canal, 21.8 for the pond and 12.9 for the river (Figure 5).

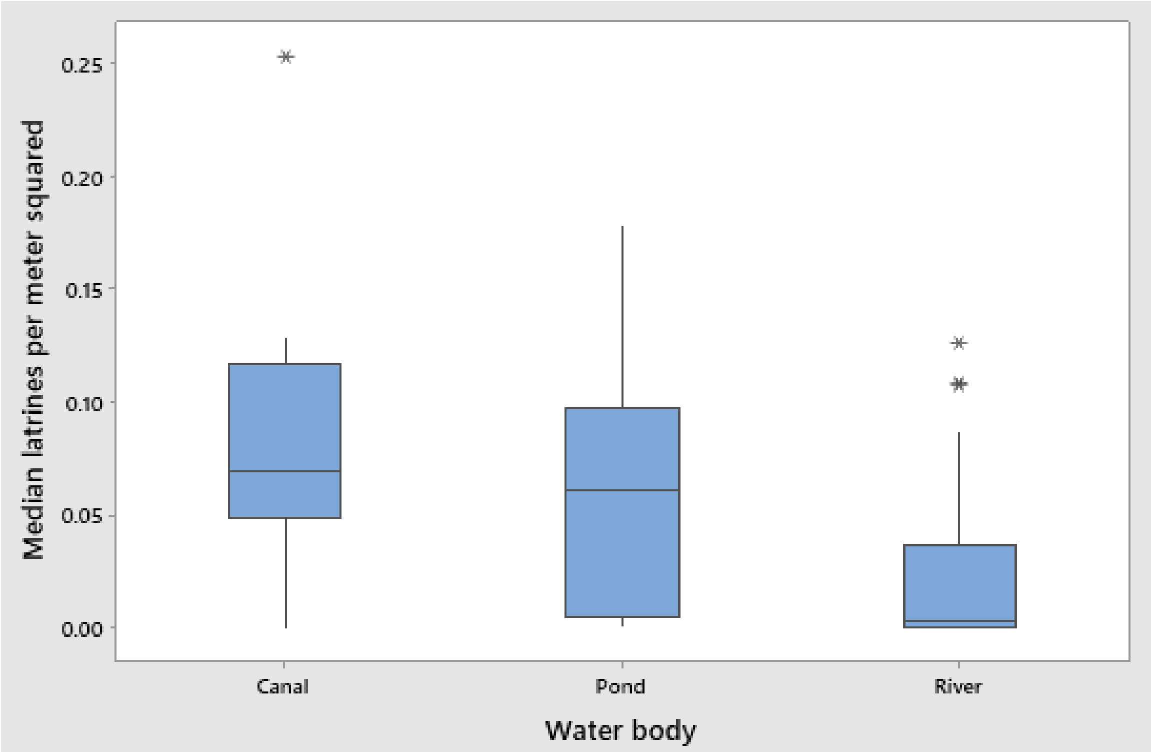

Figure 5: Number of water vole latrines associated with still and running water bodies. *The medians of water vole latrines per m² show that static/ still water bodies contained more water vole latrines than the flowing water of the river (0.0695 latrines per m² in the canal lengths, 0.0609 latrines per m² in the pond lengths, 0.0027 latrines per m² in the river lengths). The asterisk (*) indicates and outlier in the data (data values which are further away than other data values).*

When data for the period autumn 2015 to autumn 2017 were analysed together, there was no significant difference in the number of latrines per m^2 between release and non-release sites (T= -0.35, DF= 13, p = 0.735) (Figure 6). However, when 2017 data were analysed independently, significantly fewer latrines were observed at release sites compared to non-release sites (T=2.90, DF = 14, p = 0.012) (Figure 7). There was a significant negative relationship ($r = -0.622$, $p < 0.001$) between the number of latrines per m^2 and the cover of bankside trees (Figure 8). There was a significant positive relationship ($r = 0.460$, $p < 0.01$) between the number of latrines per m^2 and the cover of submerged weed (Figure 9). These features were chosen as they had the strongest correlation on the Principle Component Analysis.

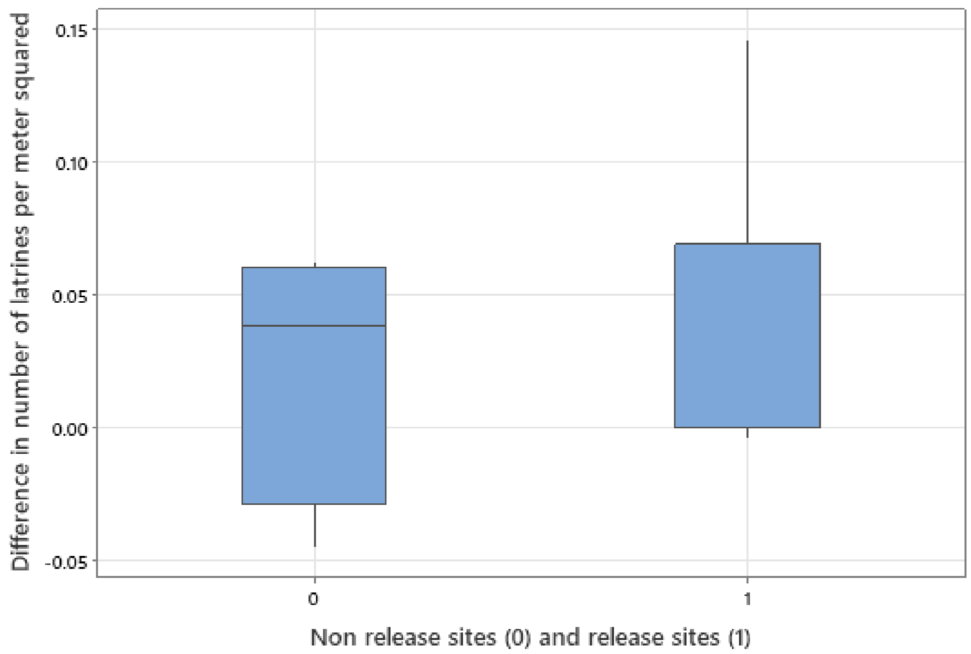

Figure 6: Differences of latrines numbers per m^2 between autumn 2015 and 2017 in release and non-release sites. *The median for non-release sites is 0.038 and 0 in release sites. A two sample T-Test shows that this is not significant (T= -0.35, DF= 13, p = 0.735).*

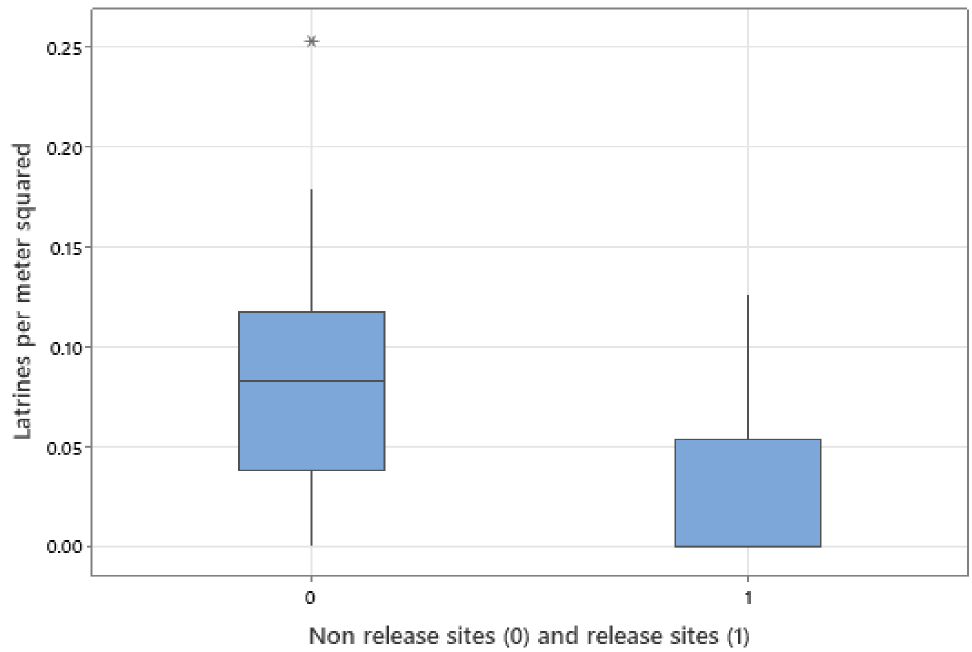

Figure 7: Latrine numbers per meter between release and non-release sites in 2017. *The median for non-release sites is 0.0827 and 0 in release sites showing that water voles appear to be moving away from release sites into the non release sites.*

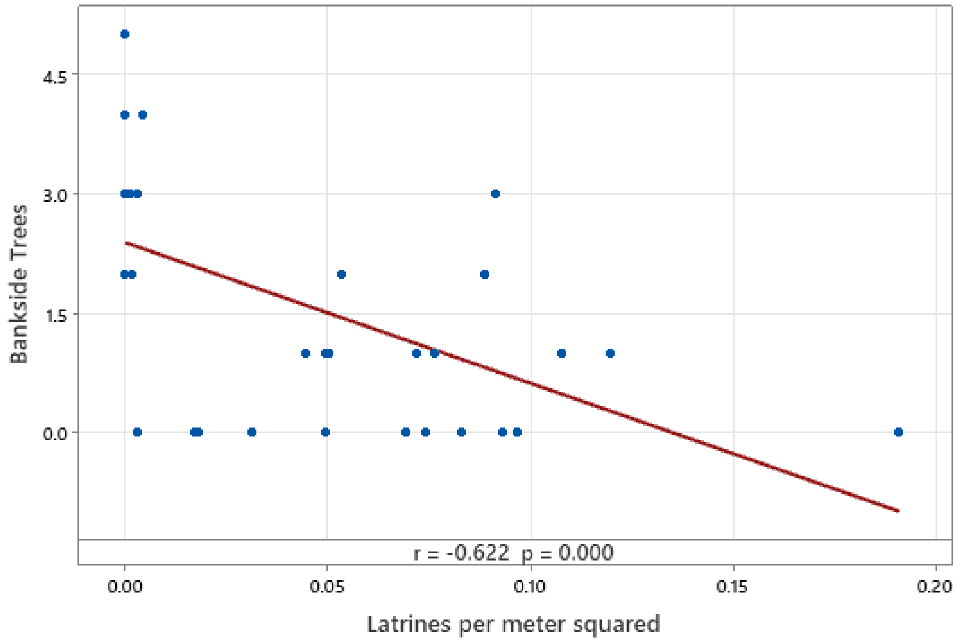

Figure 8: Scatter plot of relationship between latrines per m^2 and bankside trees. *Spearman Correlation shows that increased bankside trees are linked with lower water vole latrine numbers (r = -0.622, p < 0.001).*

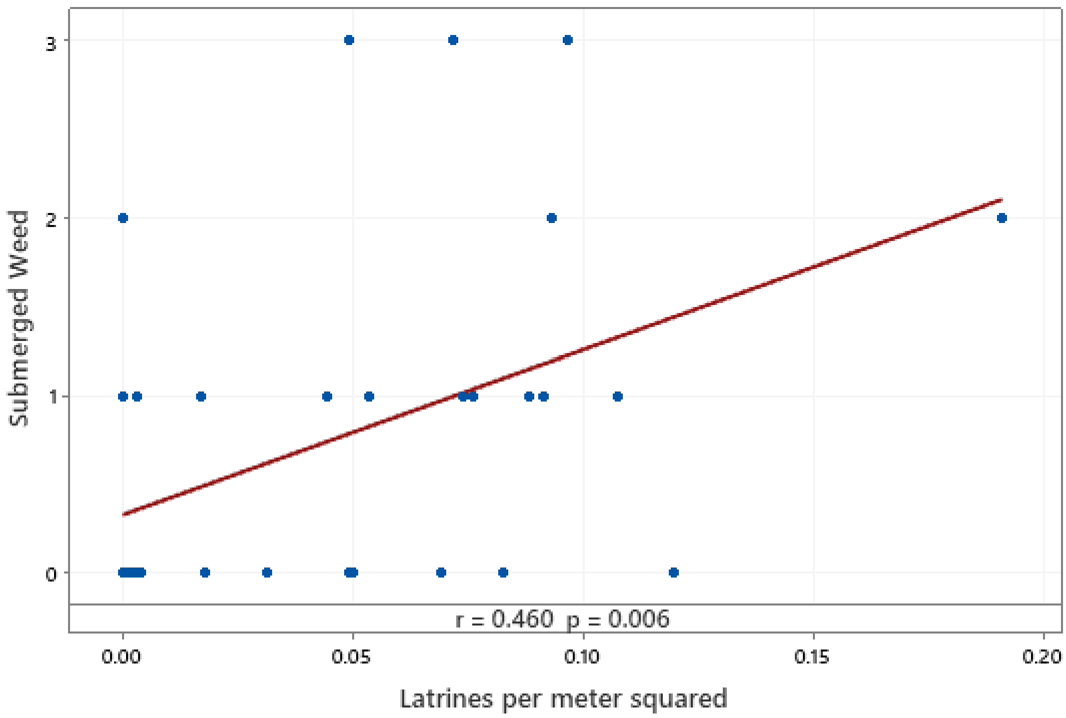

Figure 9: Scatter plot of relationship between latrines per m^2 and submerged weed. *A significant positive correlation is shown between latrine numbers and submerged weed (r = 0.460, p < 0.01).*

3. Discussion

3.1 Reintroduction Results

Latrines in both release and non-release sites increased on average (Hypothesis 1a), but with no significant difference between them. This could indicate that water voles have colonised non-release sites from the release sites. The majority of releases occurred on rivers (flowing water), whereas it can be seen (Figure 5) that voles are more likely to be in still/ static waters, in this case; canals and ponds, which accepts hypothesis 2a. There are many variables which could determine the results, including habitat features, food sources, water levels, predation, breeding requirements and competition. Other factors include human activity around the areas and the release methods.

3.1.1 Vole movement and habitat features

It is clear from the surveys that voles are no longer inhabiting certain release sites. The formation of the River Neet and Strat from the canal was a large release site, along with Site 13, however both of these sites are now almost completely absent of signs (Appendix 4). Bude canal was not a release site for water voles due to a lack of permission, however it is now one of the best locations for people to see water voles and their signs, as opposed to the river, which gives evidence towards hypothesis 3a: The water voles will move from the release sites to more preferred habitat. This movement could be due to many factors.

The static water bodies surveyed all have a consistent depth, whereas the rivers' continuous variation between pools and riffles. Riffles provide no safety for voles, as one of their defences is to dive into deep water and kick up dirt to disguise their location

(Norfolk Mink Project, 2015; PTES, 2021). As well as this, the static water bodies had significantly less tree cover than the rivers. Tree density was linked to a negative correlation in the number of vole latrines. Trees provide shade which causes less ground vegetation growth and a more limited bank cover. Water voles rely on the ground vegetation for food and shelter and therefore would not be as suitable for them to thrive in. Hemlock water dropwort is a plant favoured by water voles on the Bude catchment. They were found to be consuming both the plant and the tuber at all sites containing the plant. Hemlock water dropwort grows best in full sun or partial shade and therefore the increased tree cover would not allow for the growth of this, along with many other species (Royal Horticultural Society, 2021). Hemlock water dropwort prefers a damp environment and the land around site 15 is damp and marshy with large sections of the lake covered in hemlock water dropwort, which could suggest why voles have thrived. Hemlock water dropwort is likely one of the most poisonous plants in Britain, with livestock being the most sensitive to the poison (Downs *et al.,* 2002). Due to this, farmers have been known to control the plant along their land, which could have a knock-on effect to the water voles depending how the plant has been managed. This could be one theory as to why water voles are less likely to be found on the riparian habitat in the Bude catchment.

Submerged weed and sedges provide both cover and a food source for water voles. Both are more likely to be found in deeper water that isn't shaded by trees, which could also explain why water voles prefer unshaded deeper water. Water voles have been recorded to feed on over 227 different plant species (Gow, 2012; Strachan & Moorhouse, 2006; Strachan, 1998), at least 58% of which are located in the catchment, however the feeding signs recorded were mostly reeds, sedges, hemlock water dropwort, Himalayan balsam (*Impatiens glandulifera*).

Habitat fragmentation was one of the two reasons for the decline in water voles. The Bude catchment, although isolated from other catchments, is well connected with two rivers connecting into a river and a canal, along with other smaller streams, ponds, ditches and lakes. Previous studies have shown that water voles are more likely to recolonise good quality habitat without isolation (Telfer, *et al.,* 2001). With the introduction of mink, water voles appeared to be more confined to upper tributaries, whereas previously they were common along the main rivers. Mink were more concentrated along main rivers, likely for the food source, which forced the voles into less suitable habitat (Telfer, *et al.,* 2001).

Prior to the water vole releases a feasibility report was carried out by Derek Gow Consultancy Ltd. The catchment was described as a complexity of riparian habitat with the capability of providing a reliable habitat resource for the voles. The main focus was the suitability of the main water body within the marshes, with expectations of ball nests due to the lack of suitable burrowing bank. Water voles, however, were not recorded on the site until autumn 2016, but they were recorded in the surrounding ditches and smaller water body from Spring 2015, suggesting these provided a more suitable habitat. The ditches contained very little water; however, the vegetation was dense with a dense leaf litter on the surface. Tunnels through the leaf litter were discovered, suggesting the water voles were using this as cover and protection as opposed to water. When these habitats started to show significant numbers of signs, the main water body had signs recorded suggesting that this was the next best habitat available.

It can be assumed that water voles favour different habitats which varies between locations. After studying, and visiting, the Scotland water vole project, Scottish water voles live in entirely different habitats, favouring narrow moorland ditches. The Kielder release project discovered that the voles were preferring narrow ditches with overhanging vegetation, however they are also thriving in the river system which is constantly changing between slow to raging torrents and flooding (Hollings, 2018 *pers. comm*). The River Colne water vole project released voles into the main river system and have only had dispersal upstream due to mink activity (Tansley, 2018 *pers. comm*). The Rutland project has noted that the voles have had limited dispersal from their original release sites, which were predominantly ditches, canal and ponds (Mackrill, 2018 *pers. comm*), which closely mimics the Bude water vole project, with the exception of dispersal. This is likely to be due to the fact water voles were released into the static / slow water bodies in the Rutland project, however, were released into the river systems in the Bude project. The variety in water vole habitats could be due to the availability, or lack thereof, of more suitable habitats (Telfer, *et al.,* 2001). It could, however, be demonstrating the adaptation of water voles to their environment. There appears to be no clear binary distinction between suitable and non-suitable habitats.

There are several factors which could cause changes in field sign numbers: weather, water level, proximity to the sea, predation, vole movement, habitat features, increased breeding and vegetation density. These factors could increase or decrease physical water vole signs.

3.1.2 Weather, water level and proximity to the sea

Weather variations between surveys can often cause fluctuation in the field sign numbers. Rain prior to a survey can wash away latrines and feeding signs close to the water's edge (Sussex Wildlife Trust, n.d.). If the rain is particularly heavy and causes an increase in the water level, burrows previously visible above the water could become submerged, along with latrines and feeding signs on lower ground. As well as this, where possible the river is accessed to get a better look at banks, water levels rising prevents this due to depth and health and safety.

The autumn 2015 survey had significant rainfall, however the following spring survey (2016) had a very similar latrine count, despite most sites showing a decrease in signs, the increases at three sites counteracted it. Sites 4, 6, 7, 12 and 15 all had an increase in latrines in the spring 2016 after the heavy rainfall. All but one of these sites have static – still water movement, with a consistent water depth despite rainfall. Site 6 is a section of river that is heavily shaded with trees in the final length, where no latrines were found, however in the first two lengths in site 6 the river is unshaded, which is where the latrines were recorded. These two lengths have significantly better vegetation on the banks due to the lack of shading, however the river level fluctuates between pools and riffles. The increase of latrines at sites 4, 6, 7, 12 and 15 between the autumn 2015 and spring 2016 surveys plateaued which could suggest that voles were washed downstream from increased water levels, however a more likely theory would be that the limited amount of suitable habitat forces juveniles to travel to better habitats rather than expanding upstream.

In the case of sunshine, water voles, from observation, appear to be less active during the middle of the day (Nick Upton, 2018 *pers. comm*). This could cause a decrease in signs depending on the time of day that the survey was conducted. Due to the Bude catchment being in a tourist location, sunshine also encourages more people to walk along riverside paths. Bude canal is a well-used path by dog walkers, who often let their dogs off lead, and they enter the water. This can be seen to be damaging the bank, but also deters water voles from leaving their burrow systems due to the predation threat. Burrows were recorded along the path where dogs access the water, however more feeding and latrines were recorded on the opposite bank. A lower number of feeding and latrine signs is a knock-on effect of this, the raw data shows that latrine numbers are lower in the spring than in the autumn, however this could be due to a number of factors including winter mortality.

The hot weather also affects the water vole releases as no water is left in the cages. Apples are fed to the voles daily with this being their source of water.. The release at Site 13 occurred during a hot period of weather which meant that the soft release cages needed to be positioned in areas which were shadier as the voles would be too exposed to the heat. Some cages were covered with vegetation, however due to the location, there was little available to cover the cages with. Shaded areas include stretches of watercourses with increased tree cover. The results show that trees had a negative correlation to latrine numbers, this could be due to the shade preventing vegetation growth that the voles require for both food and cover, which could explain the loss of latrine numbers at this site.

With severe winters, the water vole mortality rate can be as high as 70% (Renfrewshire Council, n.d.), which would cause lower field signs during the spring surveys and could bring the average yearly total down significantly. Mild autumns could see the breeding season prolonged and if juvenile water voles do not increase their weight to 60g there is a high chance they will not survive the winter regardless of conditions (Derek Gow, 2012).

The River Neet or Strat has brackish water, which can travel up as far as Rodd’s Bridge (between sites 5 and 6) with bad weather. Water voles were recorded within the brackish waters, mostly upstream where the brackish water only occurred during storms, however latrines were recorded in the furthest downstream section of Site 5 which is brackish on an almost daily basis. This could have been due to voles moving through the area or water voles moving into the area due to overpopulation. This would need further study in order to determine if the voles were living within brackish waters as previous studies have claimed water voles are intolerant to brackish water (Jordan, 1998). Sea surges (brackish waters) do not appear to have affected the voles towards Rodd's bridge, as they were recorded before and after surges which occurred between spring and autumn surveys. It is not clear, however, if the voles recorded after are the same voles or voles which have moved into the area due to the loss of ones potentially affected by the surge. It is also unclear how diluted the salt was by the time it reached site 6.

3.1.3 Predation

Water voles are predated on by a large range of fauna, such as foxes (*Vulpes vulpes*), birds of prey, grey herons (*Ardea* cinerea) as well as the invasive non-native American mink (Forman, 2004; Reynolds *et al.,* 2004). During the reintroductions and surveys, buzzards (*Butero buteo*), foxes, otters and grey herons were recorded as sightings or with field signs. Water voles can make up roughly 15% of a heron's diet (Strachan & Jefferies, 1993), despite this, water voles are still thriving in the area since the capture of the mink, which indicates that mink were likely to have been a more detrimental to the water voles than the herons.

The Bude catchment was once close to the largest mink fur farm in England, closing in 2001 after running for 25 years (Cobbledick, 2012 *pers. comm*.). The farm housed approximately 30,000 mink at any one time and is likely to be one of the main reasons for mink being in the Bude catchment and the subsequent decline in water voles because the farm was constantly under attack from activists. Animal Liberation Front

(ALF) who were affiliated to People for the Ethical Treatment of Animals (PETA) were one of the main activists attacking the farm, as well as many other farms. Activists are well known for their release of the animals, as well as mink escaping.

Water voles have no effective natural defence against mink (MacPherson & Bright, 2011; MacPherson *et al.,* 2003), with female mink being small enough to fit into water vole burrows making them easy prey (Lawrie, 2006). A study on the relationship between mink and water voles concluded that water vole activity increased after mink were absent from an area (Woodroffe *et al.,* 1990). It also concluded that mink depressed the number of water voles, shown in a site previously with a thriving population of water voles which rapidly declined with the presence of mink. This study's conclusion is mimicked in the Bude catchment as the water vole population declined with the increasing number of mink in the catchment, as well with the first water vole release.

The first water vole release was conducted at The Weir wildlife pond near Marhamchurch (Site 9, length 20) in June 2013, where one hundred water voles were released. Prior to this, mink monitoring had taken place with no signs. Mink numbers had dwindled along water courses with the decline in water voles, one of their food sources. In the spring 2014 survey, there were no water vole signs recorded at the release site which led to more intensive mink monitoring and the subsequent capture of two mink. The mink are likely to have come in to the area due to the new, and easy capture, food source, which shows how destructive predation can be on a vole population. Continued mink monitoring, with no detections, and increased water vole reintroductions lead to successful reintroductions along the Bude catchment, as seven years later (2021) water vole field signs and sightings of voles are still being seen along watercourses. Due to water voles' short life span this is a good indication that the reintroduction has been a success since the removal of the mink. This is strong evidence that mink removal is one of the main factors in the success of a water vole reintroduction.

3.1.4 Breeding & Habitat

Water voles have a lifespan of between one and a half to three years in the wild, with an 87% decrease in the population over the winter months (Gow, 2012). Water voles produce anywhere between three to five litters per year, with approximately five young per litter and are weened at 14 days, with early litter females capable of reproduction in the year of their birth (Mammal Society, 2021, Gow, n.d.). With this in mind, it can be assumed that the water voles are breeding due to their short lifespan and the continuing discoveries of fresh signs seven years post reintroduction. This is strong evidence that the water vole reintroduction has been a success.

Water vole nests within burrows and ball nests are made from grasses and rushes; however, the results show long grass has a negative correlation with latrine numbers. The data collected also shows that areas with long grass had less variation in flora species and were predominantly grazed land, often with no fencing stopping livestock accessing the river. From observation when livestock were accessing the river, the banks were often void of vegetation from constant wear, with more erosion occurring. This is likely to be the reason for the lack of vole signs within these stretches for several reasons; water voles are likely to perceive the livestock as a predatory threat, the habitat is fragmented, and the food source is limited and unvaried. Grazing pressure and trampling on banks from livestock causes a loss of riparian vegetation through both erosion and grazing which limits the voles shelter from predation and their food source (Norfolk Wildlife Trust, n.d.). As well as bank erosion, livestock trampling is likely to collapse water vole burrows and cause bank instability, making it unsuitable for digging (PTES, n.d.). Livestock habits could, therefore, result in habitat loss, increased predation, and the eventual dispersal of voles to safer, more suitable habitat. Several release sites that were used for reintroductions due to them being textbook “perfect habitats” were alongside fields containing livestock, which could be the reason for the move from the lotic to lentic habitats as none of the static water bodies had livestock accessibility.

3.1.5 Coexistence & Competition

It has long been debated the coexistence of water voles with rats (*Rattus rattus)* and otters (*Lutra lutra*). Rats are known to utilise disused water vole burrows, which was shown whilst surveying site 12 when a rat emerged from a water vole burrow. As well as this, during water vole trapping along the canal prior to required dredging management, and a trapping on site 15, a rat was captured alongside water voles at each site. Rats have been linked to lower water vole densities, near eradication and water voles have been noted with injuries from rat predation (Neyland, 2011). Water voles have also been witnessed avoiding the scent of rats, perceiving it as a threat, however both sites 15 and 3 with rats recorded are two of the strongest water vole populations in the Bude catchment, suggesting coexistence is entirely possible.

Rats are opportunistic omnivores and therefore could consume the same foods as water voles (Takács & Gries, 2021), however due to the varied diet of both it is unlikely that they would compete for food. They are, however, likely to compete over territory. Rats are often more aggressive than water voles, yet also more adaptable (WWT, 2019). As previously mentioned, rats and water voles appear to be coexisting, this could show that rat populations are smaller than the water vole populations within the areas where water voles reside. Rats can live in almost any habitat, whereas water voles appear to be significantly more selective. The movement of water voles from the rivers could be due to rat populations utilising the shadier less favourable habitat, with only individuals occupying the same habitat as water voles.

Otters are known to predate on water voles as spraint analysis has previously shown water vole remains in variable frequencies (Forman, 2004). Otter spraint has been recorded alongside water vole habitat in the Bude catchment for the Coastal Otter Project. This project has dissected otter spraint to ID the animals consumed, the majority of which were fish bones. Only two spraints out of 223 collected contained identifiable mammal remains, neither being from water voles. There were, however, many unidentifiable bones due to the otters need to chew larger animals and therefore the bones are beyond recognition, which could be water vole. Being opportunistic hunters, there is a chance otters will consume water voles, and the results show a negative correlation between spraints and latrines, however they do not appear to be having a significant negative impact on the water voles as both water voles and otters have been recorded within the same area.

3.1.6 Human disturbances

The Bude Canal (Sites 2 and 3) has significant human disturbances, from Adventure International and members of the public using the watercourse for water sports such as canoeing, kayaking, rowing and supping, as well as dog walkers and fishermen using the path and banks. Water sports, although are often non-invasive on the banks, can cause noise which could deter voles from leaving the burrows for food, which could lead to them spending more time in burrows, and therefore less latrines, or could prevent them from utilising the area completely. This does not appear to be the case on the canal, however more signs have been recorded upstream, where there are less water sports taking place, and therefore less disturbance.

The footpath runs alongside one side of the canal only, alternating at Rodd's Bridge. Water vole activity is greater on the non-path side, shown in the latrines and feeding along the opposite bank to the path. Dogs often jump into the canal, which causes areas of bank erosion and in some cases, bank collapse/ erosion, which as previously mentioned is not beneficial for water voles. As well as this, fishermen often stick rods into the banks, and often place their chairs on the edges, which could also cause the bank to collapse where burrows are situated. This has been noted at site 4, where fishermen have caused burrows close to the surface to collapse. These surface burrows are also heavily excavated by dogs off lead, which could deter voles. More burrows were found on the side where fishermen and dogs are most active, however more latrines were recorded on the opposite bank. This suggests that water voles had to create new burrows due to previous ones being collapsed, however more voles are active on the opposite bank where these pressures are less prevalent.

3.1.7 Release methods

Another factor which may determine the success or failure of a reintroduction is the release methods. Most reintroductions use hard release method, due to the type of animals, for example larger animals are not suitable for a soft release method, and would be more likely to use an enclosure method. With the use of soft release cages for water voles, the process should allow the animals to climatise, and the baffle boards are designed to allow the voles to come and go for safety. Whilst the baffle boards are on the cages, the voles are fed with apple and carrot. From observation on the Bude releases there were no voles actively in the cages after the boards were first attached which suggests as soon as the voles have the freedom, they do not return. Food had not been eaten over the course of the days following the baffle boards being attached. On one occasion a release cage was lifted for removal and a small mammal was seen running from underneath the cage, this could have been a water vole, however due to the animal being under the cage and not within it, still suggests the soft release method with the baffle boards may not be required. The initial release at the wildlife pond (Site 9) was the only major hard release conducted, despite this failure, it is unlikely to be due to the release method, due to the sudden appearance of mink in the area. There is also a chance that some voles moved from the area to other smaller un-surveyed areas when mink were in the area. There were not enough large hard releases to confirm the success / failure of the hard release method, however the hard release voles which were used in later years to add to areas where voles were in small numbers appear to have not only survived, but also thrived.

There is a third method, similar to the soft releases, in which cages are dug into the ground. These allow the voles to dig their way out and therefore having a burrow system before being exposed to the elements. This method was not used in the Bude project, however, has previously been used. This method appears to be more logical if using a soft release, however it requires a lot more work and therefore higher costs. Once the cages are removed there is a likelihood of burrows being exposed without the cover from the cages. All methods have their positives and negatives, however it would appear more research may be required in order to determine the survival rates between all 3 methods. Microchipping voles with a recapture and release programme after the release would provide some evidence, however with voles able to travel easily, it would be hard to monitor and assess fully.

3.2 Limitations

3.2.1 Vegetation

Both the spring and the autumn surveys had dense vegetation which meant that not all parts of the banks could be surveyed. There is a chance for human error when using binoculars for inaccessible sections as well as missed signs that are within the dense vegetation.

3.2.2 Weather Conditions

Prior to the autumn 2017 survey, there was significant rainfall. This would have washed away some latrines, as well as causing more dangerous conditions to survey, including slippery banks and a rise in water level. The water level could have hidden lower field signs, as well as preventing surveyors to access the water as much as normal. This could cause an underestimate in data collected.

3.2.3 Misidentification

Four years of water vole surveying training was completed prior to the surveys taking place. Latrines were the chosen field sign for analysis as burrows and feeding signs have a higher chance of misidentification. Historical burrows could be utilised by rats, or just be historic burrows which have become visible due to bank erosion. Burrows identified by binoculars could also be shading by uneven bank faces. When surveying, burrows are felt to determine depth, which confirms if it is coincidental erosion or a used burrow. Where burrows could not be physically accessed there was an element of guess work as to whether or not the perceived hole was a burrow or not...

Feeding signs can be accurate due to the chunky vegetation preferred by the water voles, as opposed to the smaller vegetation consumed by field voles (Hill, 2015). Pregnant females, however, will consume the vegetation which is around their burrows, which includes grasses and flowers; water voles have also been known to eat snails for their protein content (Oliphant, 2003). As well as this, in locations such as Bude Marshes, there are less available food options. Bude Marshes vegetation is primarily grasses, brambles, submerged weed, and one patch of tall reeds. Feeding signs within the marshes were mostly grasses which could be field vole or water vole. It can be assumed that feeding signs near to water vole latrines are water vole feeding stations, however this cannot be confirmed. Although feeding signs and burrows were recorded, latrines were the certain identification for the presence of water voles.

3.2.4 Genetics

Water vole genetics could determine the habitat preferences, voles from colder climates may gravitate towards a different habitat than ones from warmer climates. The voles were all released from Derek Gow's breeding programme, and therefore the genetical data is from a single source. The origin of the voles was not looked at for this project.

Conclusion

In conclusion the Bude water vole project has been a successful reintroduction, with water voles thriving in the catchment. In the Bude catchment water voles appear to have moved from lotic (fast flowing) to lentic (still/ static) habitats post reintroduction due to the strong correlation between water vole presence and still / static water bodies. There appears to be no singular habitat feature which can be definitively used to define “perfect” water vole habitat as comparable sites across the UK appear to all have different experiences in water vole habitat. This suggests water voles have a plethora of habitat requirements, which could depend upon several factors such as predation and human activity. Since the cause is unknown this is an area requiring further study. Mink appears to be the most significant negative impact upon water vole populations which could prevent future reintroductions in any location, however it can also be concluded that water voles will migrate to more suitable habitat should they require.

Water voles in Cornwall had a relatively short local extinction prior to reintroduction and this may play a part in how successful the reintroduction was. The longer a species is extinct, the higher the chance they will be unable to adapt to new surroundings. Water voles have a significant impact on the banks, and therefore change the vegetation which grows. If they had been gone from the land for a longer period of time, the vegetation would likely change and potentially be no longer suitable for the voles to thrive in.

Appendix

Appendix 1: Risk Assessment

Date:	04/10/17	Assessed by:	Teagen Hill	Activity/Location	Water vole field sign survey on the Bude Catchment

Work Activities	Hazards	No. at risk	Controls in place at present	L (1 – 2)	M (3 – 4)	H (6 – 9)	(List additional controls as required) Comment
Travel to and from site	Road traffic accident	2	Plan route carefully, drive within speed limits with due care and attention, do not drive when tired, wear seat belts, do not use mobile phones when driving, allow sufficient time for journey.		X		All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974
General movement around the waters edge to access banks	Slips, trips and falls. Falling into the water	2	Do not take risks All persons working around the water must have competent swimming ability. Always work in pairs when working near to water. Ensure a mobile phone with emergency contact numbers, including the nearest hospital is accessible to alert help in an emergency. Enter water and marshland only where it is safe to do so with the correct PPE- checking depth of water and substrate with a prod stick prior to entry. Do not enter wetland if depth unclear. Never enter deep water.		X		All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974

			Ensure second person remains on the bank at all times. Person on bank must provide sturdy pole to assist with rescue from water and have throw line available. In emergency call 999. Wear correct footwear for the terrain				
Working in public areas	Abuse, personal attack	2	Work in pairs, keep communication devices to hand for assistance, withdraw from hostile situations.	X			Be aware of dog mess on the ground. Look before kneeling/ placing hands and bags All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974
Working with dangerous habitat (rivers, lakes and ponds, wetlands, farmland)	River levels creating dangerous survey condition, marshland being flooded.		Work in pairs, adhere to no access areas, take communication device at all times, know where water is and the depths. If the river is in spate, rearrange survey when access is safer.		X		Be aware of barbed wire, electric fencing and livestock. All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974
Plant related injuries	Stings, rashes and cuts	2	Ensure first aid is accessible. Visit a doctor if irritation continues. Wear gloves and cover forearms	X			Antihistamines should be carried by individuals likely to suffer reactions. These should not be issued to other surveyors. All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974
Insect related injury	Stings, bites, tic bites, lymes disease	2	Ensure first aid kit is accessible. Ensure surveyors are aware of allergies each other suffer from.		X		Antihistamines should be carried by individuals likely to suffer reactions. These should not be issued to other surveyors.

			Carry contact details for the nearest hospital. Check for tics after surveying. If tics are found they must be removed safely. Seek medical attention if feeling unwell after tic bite. Insect repellent should be carried in case of wasps, midges, horseflies. Avoid wasp nests.				All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974
Working in extreme weather conditions	Hyperthermia, Hypothermia	2	Wear clothing representing of the weather. In heat wear a hat, and carry plenty of water. In cold/ rain wear waterproofs and warm clothing. Bring a hot drink if possible.		X		Check weather forecasts. All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974
Searching vegetation	Injury to eye from vegetation	2	Goggles should be worn to prevent injury to eyes Take care when looking down/ bending down.		X		All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974
Working in and around water	Water borne diseases (Weils, Lymes) Pollution	2	Do not go near the water if pollution is present Check sites for warning signs of pollutants. Wash hands before eating, drinking or smoking Cover cuts and abrasions		X		All work will be completed within the current legislations and rules for: • Report of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR) • Health and safety Act 1974

SIGNATURE: ______________________________ *(Responsible Person)*

PRINT: __***Teagen Hill***______________________

SIGNATURE ___________ ___________ (Head of School/Dept)

PRINT: _____***Jurie Intachat***____________________

DATE: ______09/10/2017____________________________________

REVIEW DATE: _______09/10/2018______________________________

Conduct Risk Assessment in conjunction with Code of Practice

Risk Rating Matrix			Likelihood (see Table 3)		
			Unlikely	Likely	Almost Certain
			1	2	3
Severity (see table 2)	Major	3	M	H	H
	Moderate	2	L	M	H
	Minor	1	L	L	M

	Priority	Action requirements
L	*Low* *1 – 2 rating*	*Risk acceptable without further controls/actions. No need to report*
M	*Moderate* *3 – 4 rating*	*Need for further measures to treat this issue. Requires routine monitoring*
H	*High* *6 – 9 rating*	*Urgent need to mitigate against adverse consequences, and formal reporting/managed communication*

Appendix 2: Water vole survey form.

WATER VOLE SURVEY FORM

BACKGROUND INFORMATION

Site name/river [ ]

Site number [ ] 10km square [ ] Grid ref [ ]

County [ ] Water Authority [ ]

Recorder [ ] Date [ ]

HABITAT INFORMATION (mark features on map)

Survey distance [km]

Habitat
- [ ] Ditch
- [ ] Dyke
- [ ] Gravel pit
- [ ] Pond
- [ ] Lowland lake
- [ ] Upland loch
- [ ] Reservoir
- [ ] Running water
- [ ] Marsh/bog
- [ ] Canal

Shore/bank
- [ ] Boulders
- [ ] Stones
- [ ] Gravel
- [ ] Sand
- [ ] Silt
- [ ] Earth
- [ ] Rock cliffs
- [ ] Earth cliffs
- [ ] Canalized
- [ ] Poached
- [ ] Reinforced (man-made)

Bordering land use
- [ ] Upland grass
- [ ] Permanent/temporary grass
- [ ] Mixed broadleaf woodland
- [ ] Conifer wood
- [ ] Peat bog
- [ ] Arable crop
- [ ] Salt marsh
- [ ] Urban/industrial
- [ ] Park/garden
- [ ] Heath
- [ ] Fen
- [ ] Cattle/grazing
- [ ] Bank fenced?

Vegetation (DAFORN)
- [ ] Bankside trees
- [ ] Bushes
- [ ] Herbs
- [ ] Submerged weed
- [ ] Reeds/sedges
- [ ] Tall grass
- [ ] Short grass

Disturbance:

Bank profile
- [ ] Flat < 10°
- [ ] Shallow < 45°
- [ ] Steep > 45°
- [ ] Vertical/undercut

Depth
- [ ] < 0.5m
- [ ] 0.5–1m
- [ ] 1–2m
- [ ] > 2m

Width
- [ ] 1m
- [ ] 1–2m
- [ ] 2–5m
- [ ] 5–10m
- [ ] 10–20m
- [ ] 20–40m
- [ ] > 40m

Current
- [ ] Rapid
- [ ] Fast
- [ ] Slow
- [ ] Sluggish
- [ ] Static

WILDLIFE INFORMATION

Water voles
- [ ] Sightings (count)
- [ ] Latrines (count)
- [ ] Burrows (count)
- [ ] Footprints
- [ ] Pathway in vegetation
- [ ] Feeding remains
- [ ] Cropped grass around tunnel entrance

Rat
- [ ] Sightings
- [ ] Droppings
- [ ] Footprints/runs

Otter
- [ ] Sightings
- [ ] Droppings
- [ ] Footprints/runs

Mink
- [ ] Sightings
- [ ] Droppings
- [ ] Footprints/runs

Other wildlife
- [ ] Coot
- [ ] Moorhen
- [ ] Kingfisher
- [ ] Heron
- [ ] Waterfowl
- [ ] Dipper

Identified plants from feeding remains:

Appendix 3: Water vole and field vole signs

<u>Latrines</u>

Water vole: Tic Tac Shaped

Field vole: Rice sized

<u>Feeding Signs</u>

Water vole: 45° chunky material and tubers

Field vole: 45° – Thin material (Grass)

<u>Burrows</u>

Water vole: O or D shaped (larger)

Field vole: o shaped (smaller)

Appendix 4

Appendix 4a: Autumn 2015 and autumn 2017 latrine data with % increase / decrease

Site (Lengths)	Autumn 2015	Autumn 2017	% Increase/ Decrease	Release Site?
1 (1, 2, 3)	33	85	158	No
2 (4, 5)	19	29	53	No
3 (6, 7, 8, 9)	89	167	87.6	No
4 (10)	23	10	-57	No
5 (11, 12, 13, 14)	3	81	2600	Yes
6 (15, 16, 17)	41	12	-71	Yes
7 (18)	10	25	150	Yes
8 (19)	0	42	Increase	No
9 (20)	0	22	Increase	Yes
10 (21, 22, 23)	4	1	-75	Yes
11 (24)	0	0	0	No
12 (25, 26)	0	0	0	Yes
13 (27, 28, 29, 30)	0	0	0	Yes
14 (31)	0	0	0	No
15 (32)	4	34	750	Yes
16 (33, 34)	0	0	0	Yes
Totals	226	508	125	

Appendix 4b: Autumn 2015 and autumn 2017 burrow data with % increase / decrease

Site (Lengths)	Autumn 2015	Autumn 2017	% Increase/ Decrease	Release Site?
1 (1, 2, 3)	66	153	132	No
2 (4, 5)	147	156	6	No
3 (6, 7, 8, 9)	224	249	11	No
4 (10)	356	139	-61	No
5 (11, 12, 13, 14)	50	61	22	Yes
6 (15, 16, 17)	15	9	-40	Yes
7 (18)	22	17	-23	Yes
8 (19)	0	6	Increase	No
9 (20)	0	27	Increase	Yes
10 (21, 22, 23)	12	2	-83	Yes
11 (24)	4	0	-100	No
12 (25, 26)	4	5	25	Yes
13 (27, 28, 29, 30)	19	11	-42	Yes
14 (31)	4	0	-100	No
15 (32)	93	104	12	Yes
16 (33, 34)	2	3	50	Yes
Totals	**1018**	**942**	**-7.47**	

Appendix 4c: Autumn 2015 and autumn 2017 feeding sign data with % increase / decrease

Site (Lengths)	Autumn 2015	Autumn 2017	% Increase/ Decrease	Release Site?
1 (1, 2, 3)	28	120	329	No
2 (4, 5)	26	9	-65	No
3 (6, 7, 8, 9)	37	64	73	No
4 (10)	20	4	-80	No
5 (11, 12, 13, 14)	20	42	110	Yes
6 (15, 16, 17)	0	0	0	Yes
7 (18)	0	8	Increase	Yes
8 (19)	0	1	Increase	No
9 (20)	0	10	Increase	Yes
10 (21, 22, 23)	3	3	0	Yes
11 (24)	0	2	Increase	No
12 (25, 26)	0	1	Increase	Yes
13 (27, 28, 29, 30)	2	1	-50	Yes
14 (31)	1	0	-100	No
15 (32)	66	83	26	Yes
16 (33, 34)	0	0	0	Yes
Totals	203	348	71.43	

Appendix 5: Kruskal Wallis test results

Water body	N	Median	Mean Rank	Z-Value
Canal	6	0.0826760	25.7	2.21
Pond	9	0.0534483	21.8	1.52
River	19	0.0016930	12.9	-3.05
Overall	34		17.5	

Null hypothesis	H_0: All medians are equal
Alternative hypothesis	H_1: At least one median is different

Method	DF	H-Value	P-Value
Not adjusted for ties	2	9.85	0.007
Adjusted for ties	2	9.98	0.007

Appendix 6: Tables within text

Table 1: Two of the larger documented mink releases in England. *Although many were released, a smaller portion actually made it into the wild and survived. (The free library, 1998; The guardian, 1998)*

Location	Date	Description
Crow Hill Farm, Ringwood, Hampshire	August 1998	Animal Liberation Front (ALF) released 6000 mink and a further 1000 mink 2 weeks later. 2500 were recaptured, 2000 were killed and the rest were unaccounted for
Kelbain mink Farm, Onneley, Nr. Newcastle-Under-Lyme	September 1998	ALF released 7000 mink, 2500- 3000 of which managed to escape the farm. 700 remained unaccounted for, the rest were recaptured, killed or died. It is believed only 200 survived in the wild.

Table 2: Water vole and rat characteristics (The Mammal Society, 2018)

	Water Vole	**Brown Rat**
Fur	Chestnut brown	Brown/ Grey
Tail	Dark haired Half the body size	Bald Same size as body
Ears	Smaller and barely visible	Larger and prominent
Face	Rounded	Pointed
Size (body)	12-20cm	12 – 27cm
Weight	Max 330g	Usually 200-300g (Max 600g)

Table 3: Water vole reintroduction sites across England prior to the Cornwall water vole project. *Three water vole release locations in England with a minimum of 600 voles released, with a variety of water bodies. It can be seen that mink monitoring became a priority after the 2010 release in Hertfordshire.*

Location	Site and details	Number of voles
River Colne, Hertfordshire	Sections of the river, released between 2010-2012 by Essex Wildlife Trust	600
Rutland Water, Rutland	Rutland Water Nature Reserve and Oakham Canal. Releases between 2011-2013 Mink Free Release by Leicestershire and Rutland Wildlife Trust	800 Nature Reserve 100 Oakham Canal
Kielder Forest, Northumberland	Mink free/ Low mink count Managed for voles Release by Northumberland Wildlife Trust, supported by Tyne Rivers Trust and Forestry Commission.	965

Table 4: Water vole survey sites and length details. *Larger sites and longer stretches of river were split into multiple lengths for easier recording and mapping of data collected. Nine release sites were chosen by Derek Gow Consultancy Ltd based upon their suitability for water voles and landowner permission.*

Site	Location	Grid Reference	Length (L)	Release Site
1	Water body within Bude Marshes Local Nature Reserve	SS 20922 05569	L 1: 280m	No
	Ditch alongside water body 1.	SS 20990 05684 – SS 20977 05447	L 2: 300m	
	Water Body within Bude Marshes (LNR)	SS 20810 05743	L 3: 280m	
2	Lower end of the canal from Bencoolen Road and ending at Rodd's Bridge.	SS 20743 05885 – SS 21098 04830	L 4: 290m	No
			L 5: 360m	
3	Section of the canal, starting at Rodd's bridge and ending at the Underpass.	SS 20743 05885 – SS 21487 03717	L 6: 360m	No
			L 7: 233m	
			L 8: 365m	
			L 9: 290m	
4	From Helebridge underpass to the East end of the water body. Includes a ditch and a water body.	SS 21487 03717 – SS 21818 03741	L 10: 290m	No
5	Closest length to the mouth of the River Neet or Strat, from the Bencoolen Bridge to Rodd's Bridge.	SS 20873 06122 – SS 21210 04791	L 11: 310m	Yes
			L 12: 365m	
			L 13: 380m	
			L 14: 338m	

Site	Location	Grid Reference	Length (L)	Release Site
6	Section of river upstream from Site 5, from Rodd's Bridge to the Weir/ fish ladder in Marhamchurch	SS 21210 04791 – SS 21375 03842	L 15: 336m L 16: 330m L 17: 360m	Yes
7	Section of river Neet between Site 9 and of Site 14	SS 21481 03598 – SS 21652 03350	L 18: 288m	Yes
8	Section of river adjoining the canal adjacent to The Weir Bistro	SS 21481 03598 – SS 21463 03709	L 19: 390m	No
9	Pond adjacent to The Weir Bistro, Marhamchurch	SS 21385 03721	L 20:360m	Yes
10	Small section of the River Strat in Lower Cann Orchard	SS 22922 05022 - SS 22856 04859	L 21: 380m	Yes
	A tributary flowing into the River Strat,	SS 23220 04975 – SS 22922 05022	L 22: 340m	
	A small pond adjacent to the river.	SS 22888 04832	L 23: 160m	
11	Section of River Strat downstream of Site 11	SS 22856 04859 – SS 22533 04483	L 24: 886m	No
12	Small established pond	SS 22950 05188	L 25: 78.5m	Yes
	River upstream from Site 10	SS 22914 05127 – SS 22892 05214	L 26: 216.5m	
13	Section of the River Neet including the Viaduct between Marhamchurch and Box's Shop	SS 22687 01878 – SS 22323 02883	L 27: 308m L 28: 292m L 29: 366m L 30: 653m	Yes
14	Section of the River Neet by Langford Hele pond	SS 22815 01681 – SS 22965 01525	L 31: 365m	No
15	Langford Hele pond	SS 22810 01533	L 32: 390m	Yes
16	Poundstock: A small fishing pond	SS 22503 00016	L 33: 117m	Yes
	Section of the River Neet	SX 22505 99958 – SS 22623 00116	L 34: 237m	

Table 5: Timeline showing the water vole project. *The Bude Water Vole Project started in summer 2012 with mink rafts being deployed. With no mink detections water vole releases commenced. Water voles were released in stages between June 2013 to August 2014 in five locations*

Date	Activity
Summer 2012	Mink surveys and rafts deployed
June 2013	100 voles hard released at site 9, length 20
September 2013	177 voles released at site 10 lengths 21, 22, 23
29th April – 1st May 2014	Water vole survey
7th May 2014	Two mink captured at site 9
20th June 2014	10 voles were hard released at site 5, length 13
24th June 2014	200 voles soft released at site at site 13, lengths 27, 28, 29, 30
August 2014	75 microchipped voles soft released at site at site 15 length 32
October 2014	Microchipped voles were recaptured

Table 6: Dates which water vole surveys were carried out. *Two water vole surveys were carried out per year, one in autumn and one in spring. Surveys varied in length depending on weather condition and accessibility.*

Year	Season	Dates	No. of days
2015	Spring	Monday 27th April - Friday 1st May	5
2015	Autumn	Monday 26th - Friday 30th October	5
2016	Spring	Monday 25th - Friday 29th April	5
2016	Autumn	Monday 24th - Wednesday 26th October and Wednesday 2nd - Friday 4th November	6
2017	Spring	Monday 24th - Thursday 27th April and Tuesday 2nd - Wednesday 3rd May	6
2017	Autumn	Monday 23rd - Wednesday 25th October and November 1st - Thursday 3rd November	6

Table 7: Total percentage increase / decrease in field signs between autumn 2015 and autumn 2017. *Feeding signs and latrine data shows a large increase from the first autumn survey in 2015 to the autumn 2017 survey, with a small decline in the burrow data recorded. Burrows recorded in 2015 have a chance to be historic and over time became clearly unused and therefore not counted.*

Field Sign	% Increase/ Decrease
Feeding Signs	71.43
Burrows	-7.47
Latrines	124.78

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