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Assessing the long-term abundance of water voles (Arvicola amphibius) in Great Britain using a standardised citizen science monitoring framework

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Abstract

Water voles (*Arvicola amphibius*) underwent one of the steepest declines of any native British mammals during the 20th century. In 2015, the National Water Vole Monitoring Programme (NWVMP) was launched to collect long-term data on water vole status and support recovery efforts for this species. NWVMP uses standardised 500m transect surveys, subdivided into 100m sections, which produces both occupancy- and abundance-sensitive metrics. Here we review previous surveys, analyse the results of the first ten years of NWVMP (2015–2024) including different modelling approaches, and advise future monitoring efforts. All four NWVMP models indicated consistent national declines despite increasing survey effort. The 100m section-level presence/absence analysis provided the most stable and reliable indicator, with narrow confidence intervals and resilience to survey inconsistencies. Latrine counts revealed the steepest and most persistent declines, with mean values falling from 1.32 per 100m in 2019 to 0.48 in 2023, and proportions of occupied transect sections halving to just 10% by 2023. These results demonstrate that the NWVMP provides a consistent, standardised citizen science framework for monitoring water vole populations at national scale, allowing the tracking of distribution and occupancy trends. Ongoing volunteer support and survey delivery will enable tracking the fate of this species alongside eradication efforts for invasive American mink (*Neogale vison*), but it is likely that urgent habitat improvements are also needed to halt and reverse the long-term and ongoing water vole declines in Britain.

Introduction

The water vole, also called Eurasian water vole, is a well-known and adaptable rodent species, widely distributed across Europe, from the British Isles in the west to Siberian Russia in the east. They occupy a range of habitats, primarily rivers with well vegetated banks (Strachan & Jefferies, 1993), riparian grassland and forest areas (Gazzard, 2023). They are sometimes abundant and can reach pest status in parts of their continental range, impacting agricultural crops and fruit trees (Fischer et al. 2013). Water voles have also been described as ecosystem engineers due to their complex impacts on riparian vegetation composition and structure, both within and among habitat patches, driven by herbivory, burrowing and creation of bare patches of soil (Bryce et al., 2013).

Despite their wide distribution and adaptability, in Great Britain water vole populations were already considered to be in decline by 1989 due to river pollution, habitat loss driven by post-war agricultural changes and, later, predation from invasive American mink (Jefferies et al. 1989). Many of the water vole preferred habitats, semi-natural vegetation along river systems, have suffered progressive intensification, turning into arable fields or improved pasture and resulting in large scale fragmentation and vulnerable populations, while simultaneously predation increased due to the rapid expansion of mink in the 1950s in Britain (Rushton et al., 2000). Early water vole surveys indicate they declined by approximately 78% between two national surveys conducted from 1989 to 1990 and 1996 to 1998, with a further estimated reduction of 50% occurring between 1998 and 2016 (Matthews et al. 2018). However, the authors noted that the quality and consistency of available data for water vole populations varied considerably, indicating the need for additional and more standardized national surveys (Matthews et al. 2018).

The two initial national water vole surveys in Britain were conducted by the Vincent Wildlife Trust (VWT) between 1989 and 1998 and provided a critical benchmark for assessing water vole distribution (Strachan et al., 2000;

Vincent Wildlife Trust, 1998). The first survey (1989–1990) established a systematic national baseline using approximately 2,000 pre-selected 1km² sites distributed evenly across mainland Britain to sample a representative range of waterways. Each site was visited by trained surveyors - mostly professionals, supported by staff and volunteers of local Wildlife Trusts (a federation of wildlife conservation charities covering the whole of the UK) - and used searches for 600m along a single waterway bank. Standardised recording forms noted evidence of water vole presence, including latrines, burrows, and feeding signs, and the survey was complemented by a directed search of over 1,000 historical sites drawn from historic water vole records. In total, 2,970 sites were examined as part of this initial national survey, of which 47.7% showed signs of water vole activity. The re-survey conducted in 1996–1998 repeated the same methodology across the same sites, thus allowing direct comparison over time, and revealed a dramatic 78% decline in the number of occupied sites (Vincent Wildlife Trust, 1998). Losses were particularly severe in lowland England, where American mink predation and habitat degradation had the greatest impact, while remnant strongholds were mainly confined to upland areas and parts of Scotland. These findings provided clear evidence of the scale and speed of the species' decline and were instrumental in triggering national concern and the development of subsequent conservation initiatives. However, these surveys were not designed as an ongoing monitoring programme but rather as fixed points in time to collect snapshot information.

Subsequent data from the more recent Wildlife Trust's National Water Vole Database Project (previously called the National Water Vole Database and Mapping Project and henceforth called the WV Database Project), used volunteer surveys and indicates that, despite a short period of stabilisation between 2014 and 2018, water vole occupancy has since resumed its downward trajectory (Hampshire & Isle of Wight Wildlife Trust, 2024). The WV Database Project draws on presence and absence records for water voles and American mink, collected from a range of contributors including Local Environmental Records Centres (LERCs), People's Trust for Endangered Species (PTES), Wildlife Trusts, and other organisations. For the most recent reporting period, data was sourced solely from surveys in England, though previous updates (2011–2020) also incorporated Welsh data. Incoming data are verified, formatted, and prepared into a Geographic Information System (GIS) to facilitate spatial analysis of water vole distribution using 10km grid squares as their primary unit of assessment. Additionally, the WV Database Project produces three tiers of mapped areas known as Alert Areas, Local Key Areas, and Regional Key Areas, each based on water vole records buffered by specified distances, e.g., 2km for Alert Areas, and classified by potential for sustaining or recovering populations. The latest project report indicated that, between 2013 and 2022, an estimated 652 10km grid squares across Britain were occupied by water voles. This is the lowest figure recorded since the baseline was set in 2006 and represents a 39% decline in distribution compared with the revised 2006 baseline of 1,071 occupied grid squares. In England alone, where more consistent data is available, there has been a 31% decline, from 826 occupied squares in 2006 to 574 in 2022 (Hampshire & Isle of Wight Wildlife Trust, 2024). However, the WV Database Project relies on inconsistent survey methodologies across different data providers, ranging from structured monitoring and targeted habitat assessments to incidental records of water vole presence collected during development surveys or conservation projects, all of which are collated and standardised before being analysed spatially. This survey variation results in limitations including spatial data gaps, variability in survey effort and quality across regions, as well as differences in data availability between years. For example, although water vole distribution has declined for decades across Britain, the largest apparent losses in the WV Database Project are often recorded in areas with limited or inconsistent long-term data (Hampshire & Isle of Wight Wildlife Trust, 2024). This highlights a common issue in citizen

science datasets, where uneven recording effort across regions and years can affect the ability to detect true trends (August et al., 2020).

The national IUCN Red List for Great Britain (Mathews & Harrower, 2020) now categorises water vole status as Endangered in England, Wales, and Great Britain overall, while they remain Near Threatened in Scotland, though this may reflect data gaps rather than a true difference in status at the national level. The rapid and ongoing decline of water voles in Britain has led to numerous conservation initiatives, including the development of a definition for Favourable Conservation Status (FCS) for the species (Mousley, Van Vliet, & Cork, 2023). FCS is a legal concept adopted for England under the Habitats Regulations that defines when a species is considered to be thriving in the long-term, and it is based on three key parameters: range, population, and available habitat. Preliminary assessments indicate that water voles in England are not currently in favourable condition based on these criteria. Robust assessments of population trends are therefore vital for tracking their current distribution and informing future FCS and other targets, as well as for supporting direct conservation actions including habitat restoration or reintroductions.

While previous surveys indicate substantial water vole declines, recent advances in affordable and effective American mink eradication, particularly via the use of smart trap technology and novel lures, offer new opportunities for large-scale water vole recovery (Martin & Lea, 2020). Combined with targeted habitat restoration and carefully managed reintroductions, there is now increasing potential to support population recovery across Britain for this declining species. Yet, some reintroduction projects have been criticised for limited data transparency and lack of clear success criteria (Dean & Gelling, 2019). A consistent understanding of water vole distribution and relative abundance - particularly at the metapopulation scale - is therefore essential for evaluating the impact of both mink eradications and water vole reintroductions, and for guiding future conservation planning.

Both the VWT surveys and the Wildlife Trusts' National WV Database Project have generated invaluable data on water voles in Britain, yet neither provides the kind of standardised, repeatable framework required to monitor long-term trends with confidence. The VWT surveys were pioneering but conducted over a fixed time window, meaning that no mechanism was put in place for systematic follow-up once the project ended. The WV Database Project, by contrast, is ongoing and spatially extensive but is inherently limited by lack of standardisation, which makes it difficult to determine whether apparent declines represent true population changes or artefacts of inconsistent recording.

To address this need, the National Water Vole Monitoring Programme (NWVMP) was developed. The programme was designed to provide a simple, standardised and repeatable annual framework that could be used by volunteers nationwide to robustly detect changes in both the distribution and relative abundance of water voles across Great Britain. The survey builds on the VWT national surveys by resurveying approximately 850 1km² sites which included all sites previously found to support water voles as well as 150 negative sites. By resurveying these historical locations, the NWVMP allows direct comparison with earlier datasets, providing a means to assess changes since the 1990s as well as to detect future trends. Volunteers participating in the programme can select one of these pre-identified sites to survey after registering online, or they can register their own existing monitoring sites to ensure that ongoing local or regional efforts are captured within wider water vole analyses.

In this study we present the analysis of results from the 10 years of NWVMP implementation to evaluate how the methodology and the results are achieving the stated aims and to discuss current water vole population trends.

Methodology

Survey methods

NWVMP surveys are carried out annually between 15th April and 15th June. This coincides with peak post-winter water vole activity and precedes late summer juvenile dispersal to ensure the data reflects established adult territories. However, although surveys are intended to take place within this fixed spring survey period, occasional variation occurs due to weather conditions, site access, or volunteer availability, resulting in some surveys falling outside the main window. In some cases, monitors also undertake multiple surveys from April through to September along the same transect to observe changes in water vole activity throughout the active season. Before carrying out surveys, all volunteers are encouraged to visit their sites to obtain landowner permission and gather key contextual information about the habitat type, accessibility, reintroduction history and mink control or eradication efforts. This data supports the interpretation of the results and helps to identify factors influencing water vole occupancy.

Surveys are undertaken by trained citizen scientists, supported by PTES. Volunteer training includes the identification of water vole field signs, such as the morphology of droppings and dropping deposits (latrines), feeding signs and burrows, alongside the NWVMP survey methodology and data submission procedures. Each spring, registered volunteers are contacted with a reminder to carry out their surveys and to submit their data. Survey data are uploaded by the volunteers to the NWVMP portal, verified by PTES staff, and prepared for analysis.

At each NWVMP site, volunteers survey a 500m stretch of riparian habitat, referred to as a transect. Most sites consist of a single transect, but some larger or more complex sites may include multiple transects. For example, a wetland nature reserve might contain several interconnecting or parallel streams, ponds, or drainage channels, which may be surveyed as separate transects under the umbrella of one site. Every 500m transect is further subdivided into five consecutive 100m sections, a scale that approximates the territory size of a female water vole and provides finer spatial resolution. Within each section, surveyors record field signs of water voles as well as signs of American mink and otters *(Lutra lutra)* throughout their transect, as predator presence is a key factor that can influence water vole recovery. All field signs are to be photographed alongside a ruler for scale. Water vole field signs are divided into three main categories:

- Latrines: water voles deposit distinctive cylindrical droppings, typically 8–12 mm in length with blunt ends, in discrete piles known as latrines. Surveyors also note whether latrines appear trampled or untrampled, as trampled latrines are a behavioural sign of ongoing territorial activity and provide additional evidence of current occupancy. Each latrine along a 500m transect is georeferenced and assigned to its corresponding 100m section.
- Feeding signs: water voles characteristically feed by gnawing stems of vegetation at a 45° angle, leaving behind clean-cut ends. Feeding remains are often grouped into small piles or “feeding stations”, particularly in proximity to burrows or latrines. The number of such feeding stations in each 100m section is recorded.

- Burrows: water vole burrow entrances are usually 4–8 cm in diameter and may occur in vertical banks, among dense vegetation such as reedbeds, or within tussocky grass. Entrances can be positioned at the waterline, just above it, or in adjacent grassland, and may be associated with grazed “lawns” or runways leading down to the water. The number of visible burrow entrances within each 100m section is recorded.

Analytical approaches

To assess the effectiveness of the NWVMP as a standardised citizen science framework for monitoring water vole abundance trends in Great Britain, four analytical approaches were applied:

1. Site-level presence/absence (binary logistic regression): i.e. whether water voles were detected at a site each year. As each site may comprise multiple 500m transects, detection on any single transect at one site is considered presence for the site overall.
2. Transect-level presence/absence: whether water voles were detected along an individual 500m transect. Sites with multiple transects therefore contributed more than one record.
3. 100m section-level presence/absence: uses the proportion of occupied 100m sections within a transect (e.g., two out of five sections occupied) to provide fine-scale resolution of distribution and abundance along a transect.
4. Latrine count analysis (Poisson model): uses the number of latrines per 100m section as a proxy for the intensity of habitat use and relative abundance.

All models employed Generalised Additive Models (GAMs) fitted with the Fewster method, incorporating site-level bootstrapping to generate robust confidence intervals and reduce sensitivity to Generalised Linear Model assumption violations. Analyses were conducted using GenStat software (VSN International, 2022). To prevent bias, only transects of consistent length across survey years were included, which removed approximately 2% of records. Sites surveyed only once were excluded from trend analysis, as they provided no information on temporal change. This resulted in the omission of 63% of sites for more reliable and stable trend detection.

Survey sites were divided into two groups: (i) standard NWVMP transects (n = 2,462 surveys across 653 unique sites), which form the basis of national trend analyses; and (ii) research sites (n = 1,097 surveys), which were primarily surveyed between 2015 and 2017 (Fig. 1). Research sites were excluded from trend analysis due to uneven geographical coverage and potential bias. The research sites comprised data collated from universities, ecological research institutions, and partner organisations undertaking water vole studies that used similar but not identical methodologies to the NWVMP. These sites were primarily surveyed between 2015 and 2017 and tended to be geographically clustered, often forming part of academic or project-based monitoring in specific regions rather than evenly distributed across Britain. As a result, their inclusion could introduce geographical bias and overrepresentation of certain areas, so they were excluded from national trend analyses, although they remain valuable for understanding local population dynamics.

Results

Between 2015 and 2024, a total of 2,462 NWVMP transects were surveyed across 653 unique sites (Table 1). A further 1,097 transects were recorded from “research” datasets, but these were excluded from trend analyses due to their spatial clustering and temporal bias towards the years 2015-2017 (Figure 1). Overall survey effort

was greatest in 2015, with 392 transects surveyed, and lowest in 2020, when only 73 transects were completed, largely due to COVID-19 travel and social restrictions. Numbers rebounded thereafter, reaching 264 transects in 2023 and 210 in 2024. Across all years, 7,251 individual 100m sections were surveyed (Table 2c). The number of sites surveyed in combinations of years, with total site counts shown along the diagonal is included (Table 3). The distribution indicates that trend estimation would be improved by a higher frequency of site revisits, not necessarily on an annual basis but at intervals of several years. At present, the comparatively low values off the diagonal demonstrate that relatively few sites are resurveyed between years. However, there has been notable progress, with more than 60% of sites surveyed in 2024 having been surveyed in at least one previous year, representing a substantial increase in revisitation rates compared with 2023.

Table 1: Number of transects per year across NWVMP and research datasets.

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	All years
Source											
NWVMP	392	295	302	225	228	73	253	220	264	210	2462
Research/Other	261	318	363	69	82	4	0	0	0	0	1097
All	653	613	665	294	310	77	253	220	264	210	3559

Despite increased survey effort, results indicate a consistent decline in water vole presence since 2016, across all four analytical approaches:

1. Site-level presence/absence: at the site level, presence/absence analysis (binary logistic regression) indicated a statistically significant decline in occupancy relative to the 2016 baseline (Figure 2a). While occupancy estimates fluctuated annually, the overall trend remained downward, with the upper 95% confidence interval consistently below the baseline from 2018 onwards. However, site-level models were sensitive to inclusion criteria, with small changes in survey date range affecting estimates. Given this instability, site-level results provide only a coarse indicator of population status.
2. Transect-level presence/absence: transect-level analysis, which considers occupancy of individual 500m transects, also shows a decline relative to the 2016 baseline (Figure 2b). The fitted GAM trend suggested decreasing occupancy between 2016 and 2020, followed by relative stabilisation from 2020 to 2023 but with a downward curve in 2024. Although the transect-level model was more precise than the site-level model, confidence intervals remained broader than at the section level, and results were somewhat sensitive to inconsistencies in transect definition.
3. 100m section-level presence/absence: section-level analysis, based on the proportion of occupied 100m sections per transect, provided the most consistent and stable indicator of occupancy trends (Figure 2c). This model also showed a decline in occupancy since 2016, with narrower confidence intervals compared with site- and transect-level models. The section-level approach reduces the risk of bias from variable transect definitions (e.g. splitting of 500m stretches into different configurations) and provides finer spatial resolution. In practical terms, occupancy at this scale fell from around one in five sections containing signs in 2016-2019 to closer to one in ten by 2023 (Table 4a).

4. Latrine counts: analysis of latrine counts using a Poisson model with transect length as an offset showed the steepest and most persistent decline of all four approaches (Figure 2d). The mean number of latrines per 100m section fell from 0.94 in 2016 and 1.32 in 2019 to just 0.48 in 2023 - the lowest recorded value in the dataset (Table 4a). Similarly, the percentage of 100m sections containing latrines decreased from 20.1% in 2019 to 10.3% in 2023. In 2024, the mean number of latrines per 100m section increased to 0.86 and the percentage of 100m sections containing latrines increased slightly to 13.8%. Unlike the presence/absence models, which suggested a levelling off after 2020, the latrine count trend did not show evidence of stabilisation. This may highlight a reduction not only in distribution but also in the intensity of habitat use.

Table 2: Total number of sites, transects, and 100m sections surveyed by month and year.

a) Sites surveyed by month and year

year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	All yrs
month											
1	0	0	0	0	0	1	0	0	0	0	1
3	1	0	1	0	0	0	1	0	1	0	4
4	6	8	3	11	13	1	6	14	9	17	72
5	151	144	138	70	57	5	59	46	91	44	489
6	26	17	15	33	30	2	29	25	68	40	225
7	8	1	2	0	4	1	15	2	2	5	35
8	2	0	1	0	1	3	1	0	1	0	9
9	6	4	7	12	4	9	6	7	0	7	36
10	5	13	0	0	1	2	2	1	1	1	19
All months	195	174	161	115	104	20	111	90	169	110	653

b) Transects surveyed by month and year

year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	All yrs
month											
1	0	0	0	0	0	1	0	0	0	0	1
3	1	0	1	0	0	0	1	0	1	0	4
4	7	11	4	12	16	3	6	29	11	20	119
5	247	212	240	136	106	8	123	105	152	73	1402
6	62	27	16	36	58	14	37	44	96	64	454
7	11	1	3	0	4	3	30	2	2	19	75
8	4	0	4	0	1	3	3	0	1	0	16
9	55	31	34	41	35	32	43	34	0	24	329
10	5	13	0	0	8	9	10	6	1	10	62
All months	392	295	302	225	228	73	253	220	264	210	2462

c) 100m sections surveyed by month and year

year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	All yrs
month											
1	0	0	0	0	0	2	0	0	0	0	2
3	6	0	1	0	0	0	1	0	6	0	14
4	31	35	16	55	74	15	31	72	44	70	443
5	843	736	729	400	337	36	362	265	511	226	4445
6	148	97	78	161	137	50	168	134	359	209	1541
7	41	1	4	0	20	15	77	6	6	35	205
8	14	0	4	0	1	12	9	0	4	0	44
9	62	35	46	73	36	56	45	34	0	24	411
10	25	66	0	0	8	13	11	6	4	13	146
All months	1170	970	878	689	613	199	704	517	934	577	7251

Table 3: Overlap of sites surveyed in pairs of years; total sites per year on diagonal (e.g. 58 sites were surveyed in 2015 and 2017). Numbers on the diagonal (italics) are total sites surveyed in each year.

2015	*195*									
2016	71	*174*								
2017	58	92	*161*							
2018	45	73	72	*115*						
2019	25	42	49	50	*104*					
2020	9	10	10	11	13	*20*				
2021	19	33	33	33	43	12	*111*			
2022	24	21	23	25	28	9	34	*90*		
2023	33	32	30	31	38	10	31	41	*169*	
2024	17	18	18	15	20	5	25	26	45	*110*
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

The total number of water vole field signs recorded each year - specifically latrines, feeding signs, and sightings - along with the number of 100m sections where signs was also declining (Table 4). While there is some natural variation between years, the 2023 figures stand out as particularly low. The mean number of latrines and feeding signs per 100m section in 2023 was the lowest recorded since the survey began, excluding 2020. The final column shows that this drop is primarily due to fewer 100m sections containing any signs at all, rather than a decline in the number of signs within occupied sections. Feeding sign mean values rose to a peak of 2.49 per 100m in 2019 but fell to 0.89 in 2023 (Table 4b). The percentage of occupied sections also decreased, from 21.4% in 2019 to 12.3% in 2023. Direct sightings of water voles were consistently rare across all years (<3% of sections; Table 4c), providing little additional information beyond indirect field signs.

Table 4: Total numbers of water vole signs (latrines, feeding signs, and sightings), including mean signs per 100m and percentage of sections with signs.

a) Latrines (trampled and untrampled)

	N transect	N 100m	Total signs	Mean per 100m	Mean excl zeros	N 100m with	% with signs
2015	392	1170	926	0.79	4.5	205	17.5
2016	290	950	890	0.94	6.0	148	15.6
2017	292	802	941	1.17	5.0	190	23.7
2018	204	589	505	0.86	4.4	116	19.7
2019	228	613	811	1.32	6.6	123	20.1
2020	73	199	114	0.57	9.5	12	6.0
2021	253	699	644	0.92	5.8	111	15.9
2022	220	517	502	0.97	5.5	92	17.8
2023	264	921	443	0.48	4.7	95	10.3
2024	210	574	492	0.86	6.2	79	13.8

b) Feeding signs

	N transect	N 100m	Total signs	Mean per 100m	Mean excl zeros	N 100m with	% with signs
2015	392	1170	1288	1.10	6.1	210	17.9
2016	290	950	1679	1.77	10.1	166	17.5
2017	292	802	1582	1.97	8.0	197	24.6
2018	204	589	936	1.59	7.3	128	21.7
2019	228	613	1525	2.49	11.6	131	21.4
2020	73	199	218	1.10	7.8	28	14.1
2021	253	699	1605	2.30	11.5	140	20.0
2022	220	517	830	1.61	7.3	113	21.9
2023	264	921	816	0.89	7.2	113	12.3
2024	210	574	1157	2.02	10.5	110	19.2

c) Sightings

	N transect	N 100m	Total sightings	Mean per 100m	Mean excl zeros	N 100m with	% with sightings
2015	392	1170	20	0.02	1.2	17	1.5
2016	290	950	10	0.01	1.1	9	0.9
2017	292	802	22	0.03	1.2	19	2.4
2018	204	589	14	0.02	1.4	10	1.7
2019	228	613	9	0.01	1.1	8	1.3
2020	73	199	1	0.01	1.0	1	0.5
2021	253	699	27	0.04	1.7	16	2.3
2022	220	517	13	0.03	1.3	10	1.9
2023	264	921	18	0.02	1.3	14	1.5
2024	210	574	31	0.05	1.6	20	3.5

Discussion

The NWVMP is the first consistent, standardised framework for annual monitoring of water vole distribution and abundance across Britain using a citizen science approach. Its design allows for comparability across sites and years and scalability across a national volunteer network. All four analytical approaches included here showed similar trends for water vole populations across Britain since the NWVMP began but the comparative analyses demonstrate that 100m section-level presence/absence provides the most stable occupancy metric, reflecting established water vole territories, while latrine counts can provide additional information on habitat use intensity. Together, these metrics strengthen the ability of the NWVMP to report not only where water voles persist, but also how strongly populations occupy those habitats. Site-level and transect-level analyses confirmed broad patterns but were less stable than the 100m section-level model.

The 100m section-level analysis provided the narrowest confidence intervals, was least sensitive to inconsistencies in transect definition, and offered finer spatial resolution by capturing variation within transects. This makes it more robust for tracking changes over time and across sites, meaning the 100m section-level model is recommended as the most reliable headline indicator of national water vole trends. However, the most recent data show occupancy at historic lows, with less than 15% of sections containing signs in 2023, highlighting the continuing decline of water voles.

Latrine counts, although informative on intensity of use and providing a pragmatic index of intensity of use and relative abundance, showed greater variability between years and wider confidence intervals. Higher latrine densities typically coincide with multiple occupied sections and an increased number of feeding signs, indicating locally higher activity. As such, latrine counts can be used alongside occupancy-based metrics. However, their interpretation requires caution, as individual voles may maintain a single latrine or deposit multiple latrines within a territory. Latrine detectability also fluctuates with season and vegetation cover (Strachan & Moorhouse, 2006;

Strachan et al., 2011). These factors likely contribute to the steeper declines and greater interannual variability observed in latrine-based analyses compared with occupancy models.

Despite these limitations, the value of abundance-sensitive measures should not be underestimated. Presence/absence alone can mask deteriorating population health, especially where a species remains widespread but increasingly sparse. For locally abundant species, robust population sizes are a clearer indicator of long-term resilience and capacity for recolonisation (Isaac & Pocock, 2015; Lindenmayer & Likens, 2010; Petrovan et al., 2025). This is particularly relevant in the context of FCS, where population parameters are a core criterion alongside range and habitat. Monitoring frameworks that incorporate abundance indices therefore offer greater power to detect meaningful changes and to assess progress towards statutory conservation targets. This is particularly relevant for water voles given that all the analyses of NWVMP show clear ongoing evidence of declining populations since the programme began.

The NWVMP's reliance on citizen scientists is both a major strength and an inherent challenge. Volunteers collect data across a wide geographic range - including nature reserves, farmland, urban fringes, and remote waterways - at a scale and cost that would be unattainable through professional surveys alone. This aligns with broader findings that citizen science can dramatically expand ecological datasets while promoting public participation in conservation (Dickinson et al., 2010; Bonney et al., 2014; Chandler et al., 2017). While it is important to consider that citizen science projects are not cost-free, requiring training, coordination and data management (Lawson et al., 2015), the associated costs are typically greatly reduced compared with fully professional monitoring and wildlife monitoring using citizen science also has other benefits such as increased public education, nature-relatedness and wellbeing (e.g. Pocock et al., 2023).

The NWVMP shares similarities with other structured wildlife monitoring schemes such as the Bumblebee Conservation Trust's BeeWalk (Carvell et al., 2016) and the Bat Conservation Trust's Waterway Survey within the National Bat Monitoring Programme (Barlow et al., 2015). These surveys show that simple and repeatable citizen science survey methods can generate reliable long-term population trends of a quality comparable to professional monitoring and involve large volunteer networks but also that the strengths and challenges found in the NWVMP are common to many volunteer-based monitoring programmes.

As with other large-scale volunteer programmes, differences in surveyor experience, site selection and volunteer retention introduce heterogeneity (August et al., 2020). For the NWVMP, this is reflected in the high proportion of sites surveyed only once (63%), which reduces the statistical power of trend models. Such challenges are likely magnified for declining species where volunteers might get disheartened by the lack of positive survey results, but can be mitigated through standardised training, user-friendly data entry tools, and targeted strategies to encourage long-term site stewardship. Increasing repeat surveys at fixed sites would particularly improve temporal consistency and trend reliability while strategic expansion into under-sampled regions would reduce spatial biases.

Although imperfect, the NWVMP is currently the most robust national-scale framework available for monitoring water vole status in Britain. The dataset is already delivering valuable evidence for conservation planning and policy, particularly at a time when water voles remain classified as Endangered on the IUCN Red List in Great Britain (Mathews & Harrower, 2020). Our results confirm that occupancy and activity have continued to decline since 2016, with the proportion of occupied 100m sections falling to historic lows by 2023. However, this decline must be viewed within the context of major current conservation developments. Mink do not specialize on

predating water voles, but they can rapidly eradicate water vole populations (Strachan, 1998), are highly mobile and can recolonize areas from which they have been removed. Limited control and habitat management were traditionally the only practical conservation actions for water voles in Britain (Rushton et al., 2000), but that all changed in recent years, when innovative approaches made mink eradication a realistic option. Much of the period analysed here precedes the recent rollout of landscape-scale mink eradication, which has expanded rapidly since 2020 (Harrington et al., 2020; Martin & Lea, 2020). These NWVMP results therefore provide a vital baseline against which to measure the effectiveness of ongoing and future coordinated mink control and eradication programmes alongside riparian habitat restoration and reintroduction efforts (Reynolds et al., 2019) for restoring water vole populations. With mink eradication now being implemented across Britain, and targeted water vole reintroductions and habitat restoration becoming increasingly common, the conditions are in place to support large-scale water vole recovery. The NWVMP is uniquely positioned to detect the transition from decline to recolonisation and offers a standardised metric for comparing outcomes across sites and regions.

Looking forward, the key priorities for strengthening the NWVMP are: (i) increasing repeat surveys at existing sites to improve temporal resolution; (ii) expanding targeted coverage in under-represented regions; and (iii) maintaining long-term volunteer engagement. These improvements will enhance the reliability of long-term trends and ensure that the NWVMP remains central to assessing progress towards FCS and other conservation targets under the Habitats Regulations.

Recommendations and conclusion

The first decade of the NWVMP demonstrates the value of this structured, citizen science-based framework for tracking national trends in water vole occupancy and activity. Although all models identified ongoing declines, the 100m section-level presence/absence metric proved the most stable and reliable indicator of national status, with latrine counts offering complementary insights into intensity of use. Ongoing surveys should continue to include and focus on this metric to provide robust trend estimations for this species across Britain. This provides a crucial baseline for evaluating emerging conservation strategies, including coordinated mink eradication, habitat restoration, and reintroduction programmes. Continued investment in volunteer training, survey continuity, and site retention will further improve its power to detect population change. As conservation efforts intensify, the NWVMP is well positioned to document future stabilisation or recovery, ensuring that water vole conservation remains evidence-led and responsive to national-scale trends.

Declarations

Conflict of Interest:

the authors have no conflict of interest.

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Author Contribution

Author contribution: Emily Luck: conceptualization (co-lead), data acquisition, writing – original draft preparation (co-lead). Steve Langton: analysis and visualisation. Emily Marnham: writing – review and editing. Nida Al-Fulaij: project conceptualization, project funding, writing – review and editing. Silviu O. Petrovan: conceptualization (co-lead), supervision, writing – original draft preparation (co-lead), review and editing.

Data Availability

all data are shared with local record centres and are freely available for non-commercial usage

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Figures

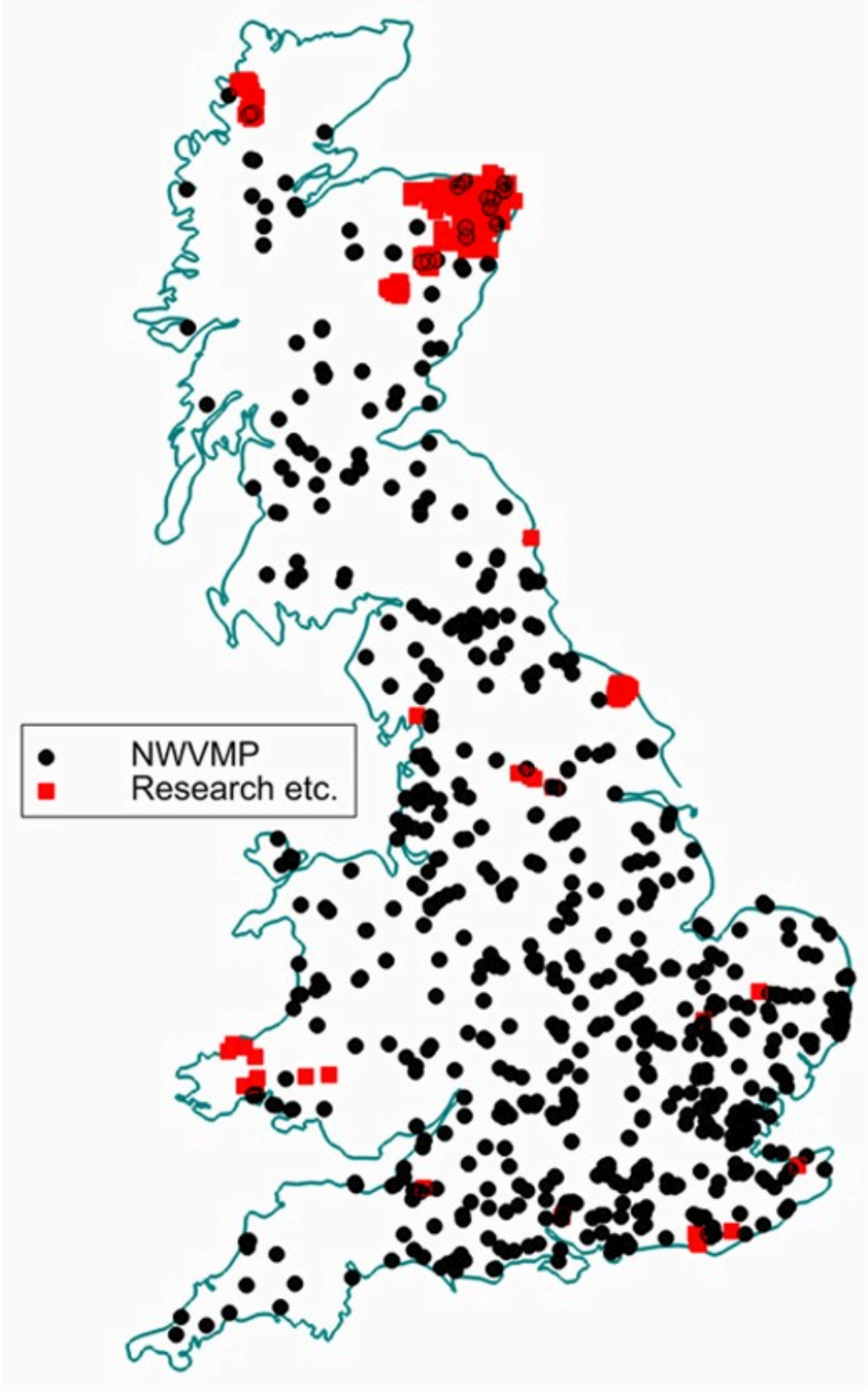


Figure 1

Map showing spatial distribution of NWVMP (grey) and excluded research sites (red), surveyed between 2015 and 2024.

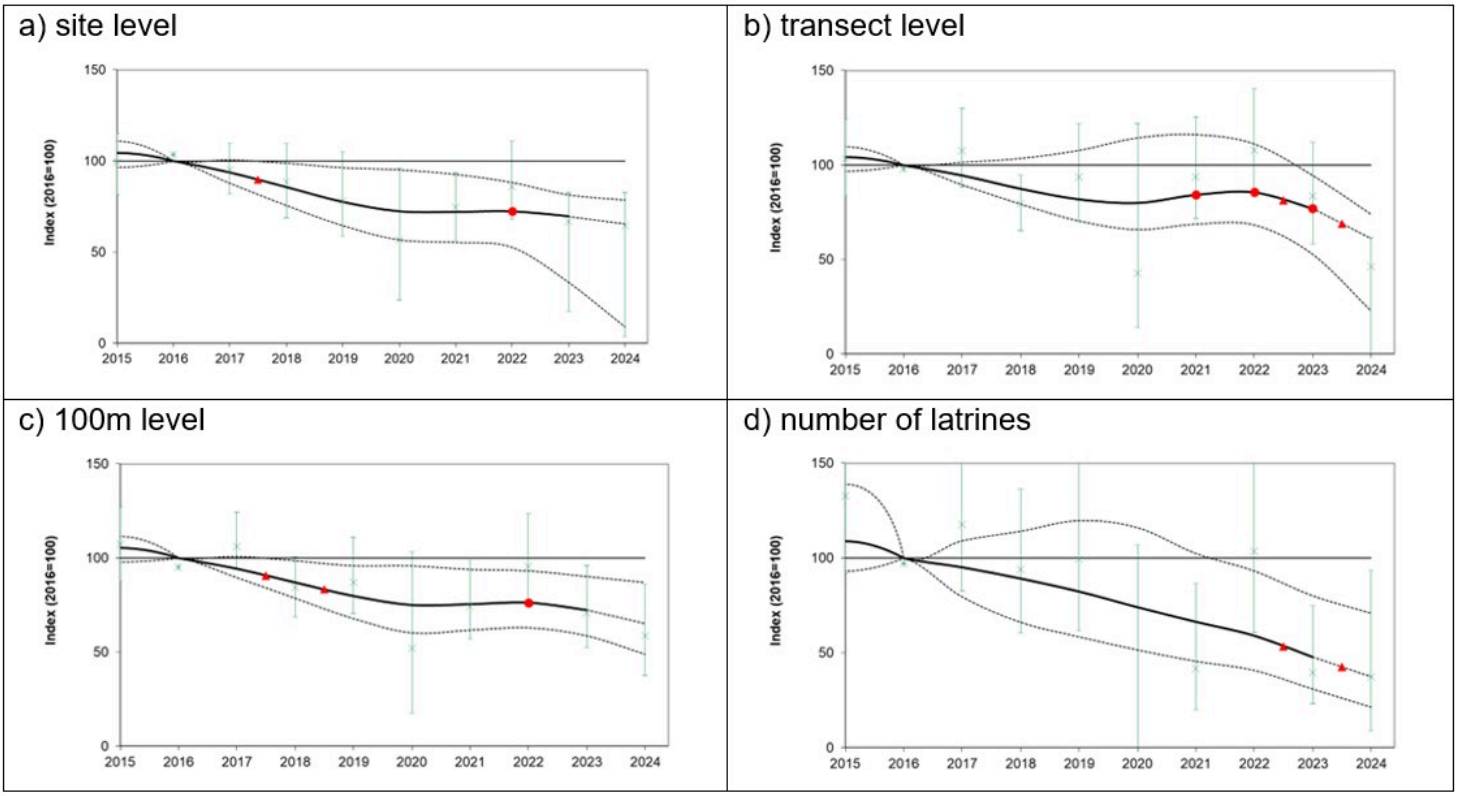


Figure 2

GAM results. The black solid line is the fitted GAM trend (the final year is dotted to indicate its provisional nature) and the dotted lines are 95% confidence limits for the trend. Green points are annual estimates and indicate the variation around the smoothed line. Red points indicate significant (P<0.05) change points, where the slope of the smoothed trend line changes. Red triangles indicate that the upward or downward trend is significant between years. 2016 is taken as the base year. See text for details