The response of water voles *Arvicola amphibius* to 'displacement' when using water draw-down and habitat removal in grazing marsh habitat, lowland England

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SUMMARY

Displacement is a form of mitigation that involves the removal of habitat to relocate water voles *Arvicola amphibius* from <50m sections of watercourse where their presence conflicts with small-scale development works. The technique is permitted under license in England to minimise negative impacts of development on water voles that are protected under UK law. Despite its widespread use, displacement as a mitigation tool is controversial due to the paucity of evidence relating to its effectiveness and disparity in the methods used to remove habitat. This study aimed to investigate the response of water voles to displacement when using a combination of water draw-down and vegetation removal. We radio-collared 20 water voles and used recapture data to monitor the movement and fate of individuals at three displacement sites and two control sites located in grazing marsh habitat in England during spring 2017. We found that all voles moved to alternative habitat following the removal of vegetation and water and no individuals were discovered in the works area following a destructive search of burrows seven days later. There was no significant difference between the fate and movement of displaced and control individuals. We conclude that displacement of water voles was effective when using both water draw-down and vegetation removal, but recommend further research is carried out to investigate other potentially confounding factors including population density and habitat type.

BACKGROUND

Water voles are a conservation priority in the UK where they have suffered one of the greatest documented declines of any British mammal in the 20th century (Strachan & Jefferies 1993. Their decline has mainly been attributed to habitat loss and fragmentation and predation of populations by feral American mink *Neovison vison* (Woodroffe et al. 1990, Macdonald & Strachan 1999). To help safeguard the species in the UK, water voles are afforded full protection under Schedule 5 of the Wildlife and Countryside Act (1981, as amended). This means that it is an offence to intentionally kill, injure or take an animal or disturb, destroy or obstruct its place of shelter.

Water voles are associated with wetland habitats in the UK and their presence along watercourses can often conflict with development and management operations that risk damage to the banks. To avoid the unintentional killing or injury of individuals and ensure compliance with current legislation, a license must be obtained from the relevant Statutory Nature Conservation Organisation to use mitigation measures that would otherwise be considered as unlawful activities. Such activities must be carried out prior to any development works and include either the capture and translocation of water voles to suitable receptor sites or the use of habitat removal to displace individuals from development sites. In England, displacement is permitted under a class license issued by Natural England (relevant Statutory Nature Conservation Organisation) for small scale works that do not impact more than 50m of water vole habitat.

The license allows experienced ecologists to intentionally damage and destroy water vole habitat to encourage the movement of one or a few individuals from a location where their presence conflicts with development to a location where it does not. The protocol for displacement activities is set out in the Water Vole Mitigation Handbook (Dean et al. 2016), which details appropriate timings and methodological approaches to maximise displacement success. The methods comprise the removal of all in-channel and bank-side vegetation down to bare ground and an optional component to also remove water from the channel if doing so does not pose an environmental or flood risk. Individuals are then given a minimum of five consecutive days and nights to relocate, after which a destructive search of all burrows within the works area is usually carried out to ensure that water voles have moved out of their own accord.

Data provided by Natural England obtained from 2017 water vole displacement licence returns, indicates a total of 27 water vole displacements were carried out under personal licences in 2017 with a further 21 displacements carried out under the Environment Agency's organisational licence. Despite the use of displacement as a mitigation technique, the practice remains controversial due to the paucity of evidence demonstrating its effectiveness, or otherwise, at relocating water voles from development sites. In 2017, an experimental study was carried out by Gelling et al. (2018) to investigate the response of water voles to displacement using vegetation removal along lowland rivers in England. They found that water voles continued to use 50m sections of bank following vegetation clearance, but there was no effect of the displacement works on water vole survival. The study, however, did not incorporate water draw-down as part of the habitat removal methodology and other studies have

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suggested that displacement is likely to be more effective when both vegetation and water is removed (Markwell 2008, Dean 2003).

Our study aimed to determine whether water voles can effectively be displaced from 50m sections of ditch when using a combination of water draw-down and vegetation removal. The study formed part of a live project to install new culverts along ditches that were occupied by water voles in south east England. We used radio-tracking and capture-mark-recapture methods to monitor the movement and fate of voles occupying displacement sites and compared this with control sites that were unaffected by the works. We hypothesised that by removing water and vegetation, water voles would relocate from the works area and that this would result in voles from the displacement sites moving further than the control group due to an increased competition for resources.

ACTION

Study area: The study was carried out within lowland grazing marsh habitat located on the Hoo Peninsula, Kent, UK between coordinates 51.47 and 51.48° N and 0.55 and 0.56° W. The area was within higher level stewardship and comprises an extensive ditch network that is under active management for water voles with ongoing mink control. The ditches hold between 50cm and 100cm depth of water, measure 1-2m in width, have steep banks and are fringed with in-channel and bankside riparian vegetation, which extends 2m back from the bank top. To improve connectivity across the site for water voles, and to install new gate crossings for livestock, culverts were to be installed along three ditches in spring 2017. Surveys in autumn 2016 showed water voles to be present at moderate to high relative density (Dean et al. 2016) along the three ditches to be affected by the works and would need to be temporarily displaced from 50m sections of bank using habitat removal. Our study sites included three displacement sites (D1-3) where culverts were to be installed and two control sites (C1-2) where no works were carried out. Each displacement site included a 50m 'displacement zone' where habitat was to be removed and an additional 250m length of suitable adjoining habitat to monitor individuals directly and indirectly impacted by the displacement works. Each of the study sites, therefore, comprised a 300m section of ditch and all formed part of a continuous network of suitable ditch habitat. The three displacement sites were located within 500m of each other and were not considered to support discrete populations of water voles as movement between the sites was observed during the study. The data for these sites were pooled for analyses. The two control sites were located between 1km and 2km of each other and from the displacement sites and whilst this is within the mean dispersal range of water voles (Telfer et al. 2003), they were treated as independent sites as no movement between them was detected. As displacement sites for water voles located <500m apart is not permitted under a Natural England class license, a project license was obtained to carry out the works and included monitoring the movement and fate of individuals using methods outlined below.

Live capture and radio-collaring: Water voles were live captured simultaneously at each of the five sites between 12 March and 20 March 2017 before any habitat removal had been carried out. A total of 10 Greenatyle cage and bedding traps (Wildcare, UK) were secured to floating rafts placed at 30m intervals along the channels at each site. Traps were checked twice per day at dawn and dusk and newly captured individuals from all sites were permanently marked using a Trovan 2.0 x 32mm PIT tag (ID: 162B/1.4). VHF radio collars (Pip Ag 393 cable-tie with whip antennas collars, Biotrack Ltd, Dorset, UK) were fitted to adults that weighed ≥180g that were captured along the three displacement sites and one of the two control sites (C1). Individuals from the remaining control site (C2) were not collared due to license restrictions. All individuals were released at their point of capture.

Displacement method: The displacement works were carried out within each of the three 50m displacement zones on 21 and 22 March 2017. Bankside vegetation was first removed to ground level using brush cutters. Following this, an excavator fitted with a wide tool bucket carefully removed all in-channel vegetation and carried out a surface scrape of the bank (avoiding damage to existing water vole burrows, where vegetation was removed by hand using hand tools) (Figure 1a). This ensured that all vegetation was removed; difficult to achieve when using brush cutters alone. Lastly, water was removed using a submersible pump after installing two earth coffer dams at either end of the 50m works area (Figure 1b). The pumps were left running in-situ for seven consecutive days and nights to ensure that the channel remained dry, after which a licensed ecologist carried out a destructive search of all mammal burrows within the displacement zone. All works were overseen by an experienced licensed ecologist and carried out in-line with current guidance (Dean et al. 2016).

Radio-telemetry: Radio tracking was carried out between 13 March and 18 April 2017 (36 days) and comprised searching all suitable habitat within 2km of the study sites during daylight hours. Location fixes for each collared individual were taken once per day from initial collaring before any displacement works had been carried out (maximum number of fixes = 8) and for seven days after the vegetation and water had been removed. This was to determine if this was an appropriate length of time for water voles directly impacted by the works to move to alternative habitat. Radio-tracking then continued once per week for three weeks to determine longer term movements and fate of collared voles. We were unable to obtain the positions of all individuals for each of the monitoring occasions due to intermittent signals obtained from some collars. In total 13% of all possible detections (n = 329) were classified as false negatives, where failure to detect was followed by a detection during subsequent sampling occasions. All locations were recorded using a Garmin ETrex Summit GPS (<6m accuracy) and were mapped using geographic information system ARCVIEW GIS v10.2 (Environmental Systems Research Institute, Inc, Redlands, CA, USA).

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Figure 1: Displacement Area, a) prior to surface scrape and water drawn down, and b) subject to surface scrape and removal of water. Photographs: Charlie Dwight

Recapture of water voles: Water voles were live captured using the same pre-displacement method, at all five sites between 18 and 26 April 2017 to investigate the fate of marked individuals and retrieve collars. Additional traps were used to recapture collared individuals whose locations were outside of the study sites.

Statistical analyses: We used the average daily distance travelled until seven days after habitat manipulation and the total observed range lengths of collared individuals for the study period to determine the short- and longer-term effects of displacement on movement. The average daily distance travelled was calculated by summing the inter-location distances for each collared individual and averaging them across the number of days for which location data was obtained. Measurements of observed range lengths were calculated by measuring the distance along ditch lines between the two furthest locations obtained for each collared animal (Moorhouse & Macdonald 2005). We used separate generalised linear models to determine if displacement had a differential effect on the average daily distance travelled and/or observed range lengths. For both models, explanatory variables included treatment (whether individuals were from displacement vs control sites) and gender, as male water voles typically range further than females (Stoddard 1970, Efford 1985, Moorhouse & Macdonald 2005). Average daily distance moved and observed range length data were log transformed to meet model assumptions. Values are presented as mean $\pm$ *SD*.

We used recapture data from all marked individuals as a measure of survival on the study sites for the study period. We used binary logistic regression to investigate if the displacement works (whether individuals were from the displacement vs control sites) and/or gender had a significant effect on the probability of survival (recaptured vs not recaptured). Collared individuals that were not recaptured but were still active by the end of the study were assumed to have survived but were not included in the statistical analysis to avoid sampling bias.

All analyses were conducted in Minitab® Statistical Software (version 18.1, Minitab LLC, State College, Pennsylvania, USA).

CONSEQUENCES

A total of 40 adult water voles were captured across all sites during the first trapping session including 17 individuals from the three displacement sites and 23 individuals from the two control sites (Table 1). Twenty individuals (10 females, 10 males) were fitted with VHF radio collars, including eight voles (six females, two males) from control site C1 and 12 voles (five females, seven males) across the displacement sites. Of these, 19 were relocated a maximum of 16 times during the study period (mean = 12.6, *SD* = 3.8 fixes per individual). Before any habitat removal was carried out, four

Table 1. Summary of water vole capture data before and after displacement works where MNA = minimum number known to be alive and No. marked includes individuals that were radio-collared and/or PIT tagged.

	Pre-displacement			Post-displacement		
Site	**MNA**	**No. collared**	**No. marked**	**MNA**	**No. collared**	**No. marked individuals recaptured**
D 1	6	6	6	9	5	5
D 2	3	2	2	2	2	2
D 3	8	4	8	5	2	4
C 1	14	8	14	12	4	8
C 2	9	0	9	8	0	3

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collared voles (two females, two males) from the displacement sites had ranges that included, but were not exclusive to, the 50m displacement zones and the remaining eight individuals had ranges outside.

The displacement of water voles following habitat manipulation: All four voles that were directly using the displacement zone, moved immediately away from the works area following the removal of vegetation and water. One male moved 220m and returned after seven days to overlap his previous observed range and remained outside of the displacement zone. Two individuals (one male, one female) remained in ranges that overlapped their previous range but did not include the displacement zone and one female moved adjacent to the displacement zone and did not move for the remainder of the study. Of the eight collared voles from the displacement sites that were not directly impacted by the works, one vole (12%) used part of the displacement zone two days following vegetation removal but moved out the following day. The remaining seven individuals (88%) remained outside of the displacement zones. The destructive search of burrows, seven days after habitat removal, found no water voles present in the any of the displacement zones.

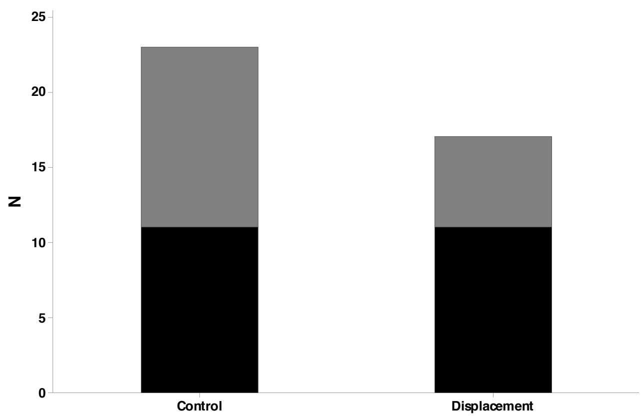

Figure 2: Number (N) of water voles captured at the end of the study and the number of these that were recaptures of marked individuals (black).

The effects of displacement on survival: Ten (83%) collared animals from the displacement sites were alive at the end of the study, of which nine were recaptured and their collars removed. This included three (75%) of the four voles that were directly displaced by the habitat removal, the one female that moved into the displacement zone two days after the works and six other individuals that were not directly impacted by the works. Of the two remaining animals, one female displaced by the works is considered to have either died or slipped her collar after moving adjacent to the displacement zone following habitat removal. The other female was not directly impacted by the works and is assumed to have been predated following the retrieval of her collar in a field two days after the works.

Five (63%) collared animals from the control site were known to be alive at the end of the study. Four individuals were recaptured, whilst one female that was still active on the control site would not re-enter the traps. The remaining three individuals are assumed to have been predated. This included one female whose collar was retrieved in a field 12 days after initial collaring and two females who disappeared, one immediately after collaring and the other 22 days later.

When considering only individuals that were recaptured from the total marked population, 65% of displacement-site voles and 48% of control-site voles survived to be recaptured at the end of the study period (Figure 2). The results of logistic regression found there was no significant effect of treatment or gender on the probability of being recaptured (survival) (Table 2).

The effects of displacement on water vole movement: We found no significant difference in the short-term movement of individuals from the displacement and control sites (Table 3a). The mean average daily distance travelled was 35m (± 33m) for displaced individuals and 30m (± 32m) for control individuals and was highly variable between individuals from both sites (range = displacement: 7-123m, control: 6-97m). The mean daily distance moved by males (43m ± 32m) was nearly twice that of females (23m ± 29m), but this difference was not significant.

Four (40%) of the collared animals from the displacement site reached 100% of the observed range lengths prior to habitat removal and this included two individuals (one female, one male) that were displaced by the works. The mean observed range length for voles from the displacement and control sites was 205m (±195m) and 124m (±132m), respectively. This difference was not significant owing to large variation in observed range length between individuals from both sites. The mean observed range length was significantly larger for males (234m ± 198m) than females (109m ± 126m) (Table 3b, Figure 3).

Table 2: Results of logistic regression analysis showing the effects of gender and treatment (displacement vs control site) and their interaction on the probability of recapture at the end of the study for all marked individuals (n = 40, model R^2 = 9.54%).

Factor	**Coefficient**	**SE**	**d.f.**	**P-Value**
Intercept	0.154	0.556		0.154
Gender (male)	-0.560	0.852	1,36	0.509
Treatment (displacement)	-0.377	0.872	1,36	0.664
Gender: Treatment	2.730	1.520	1.36	0.056

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Table 3: ANOVA results showing the effect of gender, treatment (displacement vs. control site) and their interaction on water voles' average daily distance moved (a) and observed range length (b) for all collared individuals. Data on daily distances and observed range length was log transformed for analysis.

	a) Average daily distance				**b) Observed range length**			
Factor	**Sum sq.**	**F-value**	**d.f.**	**p-value**	**Sum sq.**	**F-value**	**d.f.**	**p-value**
Gender	2.66	4.49	1,15	0.05	2.99	3.80	1,15	0.07
Treatment	0.04	0.07	1,15	0.80	0.71	0.90	1,15	0.36
Gender*Treatment	0.37	0.63	1,15	0.44	0.11	0.14	1,15	0.72

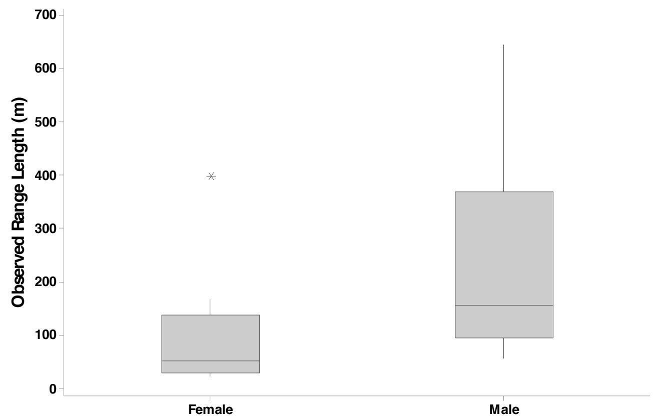

Figure 3: Total observed range length of collared male and female water voles from the control and displacement channels combined.

DISCUSSION

This study found that water voles using the displacement zone prior to any works moved immediately following the removal of vegetation and water. Three of the four voles relocated into suitable habitat that overlapped their initial ranges and survived until the end of the study and one female either died or slipped her collar after moving into suitable habitat adjacent to the works. Our results contrast those reported by Gelling et al. (2018) who found that half of the voles that exclusively used displacement areas in spring exhibited high burrow fidelity and stayed following vegetation removal. As our voles only partially used the displacement zone prior to the works, it is plausible that they were more inclined to move as they had suitable alternative habitat available within their existing ranges. However, one of two voles in Gelling et al.'s (2018) study that partially used their displacement areas in spring, continued to do so following the removal of vegetation. A key difference between our study and Gelling et al.'s (2018) is that we used water draw-down in addition to vegetation removal as a displacement technique. This method was shown by Markwell (2008) to be more effective at displacing water voles in marshland habitat than vegetation removal alone. However, because removing water from rivers is not always feasible due to the increased risk of flooding, it is not a requirement of the displacement technique. Water is a key resource for water voles and research by Bonesi et al. (2002) and accounts from other unpublished reports (Tinsley-Marshal & Boyle 2013, Chen 2010) have shown water voles to be negatively associated with dry channels and will abandon them when they dry out (Strachan & Holmes-Ling, 2003, Crane 2009). Another potential factor that may have contributed to voles moving is the use of a surface scrape of the bank to ensure all vegetation was removed to bare earth. Strimming is currently the recommended approach for removing vegetation for displacement (Dean et al. 2016); however, in our experience, stripping the turf is an effective method that ensures thorough removal of all shoots that is hard to achieve when using strimming alone.

Our method, however, did not completely deter water voles from using the displacement zone as we observed one (12%) of the eight voles not directly impacted by the works move into a burrow two days following habitat removal. Gelling et al. (2018) also found 18% of voles outside of their displacement areas moved either wholly or partially inside after the removal of vegetation. It is unclear from their study how long the voles remained, but our female moved out of the displacement zone the following day. No other voles were recorded inside of the displacement zones for the remainder of the study, nor were any individuals encountered during the destructive search of burrows seven days after the habitat was removed. As water voles have been shown to shift their ranges when adjacent habitat becomes undefended by conspecifics (Moorhouse & Macdonald 2005), there is a risk that voles will move into displacement areas if resident animals relocate.

Despite our expectation that voles from the displacement sites would travel further in response to the displacement works, we found no significant difference in the average daily distance travelled or observed range lengths between the displacement and control sites. The movement of all individuals was highly variable in both populations and, as with previous studies (Stoddard 1970, Efford 1985), we found male range lengths to be significantly longer than females. This suggests that movement was not differentially affected by the removal of short sections of habitat and concurs with the notion set out in current guidance that displacement in spring is most appropriate as water voles are already predisposed to move as they begin to establish breeding territories (Dean et al. 2016)

Displacement techniques aim to avoid negative impacts on water voles foregoing small scale works to watercourses and we found no significant effect of displacement on the apparent survival of voles. The two confirmed predations were on voles that were not directly impacted by the works and despite the temporary movement of one vole into the displacement zone, this did not result in mortality. It is unclear as to the fate of the female that did not move following her relocation into adjacent habitat after works were carried out, but we consider it unlikely that she died as a result of the ground works which were overseen by an experienced water vole ecologist.

Owing to the small number of individuals that were impacted in our study, it is not possible to conclude that displacement, when using water draw-down and vegetation

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removal, will be 100% effective in all situations. Our study site had an extensive system of grazing marsh ditches comprising suitable water vole habitat that supported native predators including grey heron *Ardea cinerea* and foxes *Vulpes vulpes* and was part of an ongoing mink control programme. The work was carried out during a live project where displacement zones corresponded with areas where watercourse works were required and thus the underlying population size and distribution could not be controlled for. As concluded by Gelling et al. (2018), variations in population density and dispersion, habitat quality and habitat type may all have a confounding effect on the outcomes of displacement and further research is needed under different scenarios. The assessment of class license returns that is proposed by Gelling et al. (2018) will be a useful evidence base for directing future guidance.

It is clear from our study, however, that by removing water and vegetation in spring, we were able to permanently relocate individuals into adjacent habitat with no significant impact on their movement and survival. Allowing a minimum of five consecutive days before carrying out a destructive search, as stated in current guidance, was supported by our findings. We conclude that in habitats where water draw-down is a feasible option for the displacement technique, it should be used in conjunction with vegetation removal to encourage the relocation of water voles from short sections (<50m) of bank in spring. Where removal of water is not possible, a surface scrape of the bank, should be considered as a potentially viable method to ensure all vegetation is removed. This will need to be carried out under a watching brief by an experienced water vole ecologist and any vegetation around burrows removed, using hand tools only.

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