The effect of using 'displacement' to encourage the movement of water voles *Arvicola amphibius* in lowland England

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SUMMARY

Water voles are nationally protected as one of Britain's most endangered wild mammals. However conflict can arise where works are required along short sections of riverbank. Vegetation removal is commonly used with the aim of displacing water voles towards safety prior to development, despite a lack of evidence demonstrating its efficacy. This study aimed to investigate the movement and fate of water voles in response to vegetation removal, by radio-tracking individuals during spring and autumn at 12 experimental and four control sites. Vegetation was removed to ground level from 50 m of riverbank at experimental sites, and observed home ranges were compared before and after vegetation removal. There was no significant net movement of water voles out of areas where vegetation had been removed in either spring or autumn, although movement of individuals both in and out of the works area did occur. There was no impact of treatment on water vole survival in either season.

BACKGROUND

The water vole *Arvicola amphibius* was formerly a common mammal on waterways throughout mainland Britain. However, the impact of invasive American mink *Neovison vison* (Baretto *et al.* 1998), combined with changes in both land use and riparian habitat management have resulted in catastrophic declines in both site occupancy and population size, leading to the water vole now being considered one of Britain's most endangered wild mammals (Strachan *et al.* 2011).

There is often a need for river managers to undertake works on short sections of riverbank for either maintenance (e.g. to regrade an eroding bankside) or development purposes (e.g. to install a headwall or pipeline), and this has the potential to result in conflict with the conservation of water voles where they are present. Water voles are a protected species under Schedule 5 of the Wildlife and Countryside Act (1981, as amended), meaning that not only the animal itself, but also its burrows and any other structure or place used for shelter are protected. There is no route within UK law to obtain a disturbance licence for such works for the purpose of development, although it is possible to apply for a licence for the purposes of conservation. Nonetheless, Natural England (the Government's adviser for the natural environment in England) historically directed enquirers towards use of the 'incidental result of an otherwise lawful activity' defence under the Wildlife and Countryside Act, indicating that a licence was only required in situations where the water voles present could not be relocated by means of displacement, and therefore needed to be caught (Natural England 2011).

Displacement activities include habitat manipulation such as vegetation removal and/or water draw-down, to encourage relocation of water voles from within the affected area, up to a maximum bank length of 50 m. These activities should be undertaken at a 'suitable' time of year prior to any destructive works of the bank or channel. This approach was initially suggested as a means to encourage water voles to relocate out of the area, but has since become routine practice in areas where movement of voles out of a development area is required. Some studies have attempted to investigate the success or otherwise of displacement with varying results (Dean *et al.* 2016), but further research is required to determine whether the technique was effective in relocating water voles.

Discussion of this approach by species experts and statutory nature conservation organisations in 2013 led to Natural England issuing a class licence for England, which came into effect in January 2016. This licence permits the intentional disturbance of water voles and damage/destruction of water vole burrows by means of 'displacement' to facilitate development activities for extents of river bank that do not exceed 50 m in length. Works are licensed between mid-February and mid-April throughout most of England (the season is extended in some northern counties of England to reflect the later onset of spring), using methods following a specific accepted protocol (Dean *et al.* 2016). Natural England has also issued an organisational licence, primarily for use by Internal Drainage Boards and the Environment Agency, to allow ongoing maintenance of watercourses. Works permitted under this licence are not considered in the research we report here.

This project aimed to experimentally investigate the movement and fate of water voles in relation to the removal of vegetation over 50 m sections of riverbank during spring and autumn. Radio-tracking of water voles was undertaken before and after vegetation removal to establish whether or not water voles do relocate out of areas in which vegetation has been completely removed.

ACTION

Site selection: During each season, eight discrete sites were used: six 'experimental' sites where vegetation was removed, and two 'control' sites with no vegetation removal, to provide baseline data on population dynamics as the seasons progressed. All sites were located on lowland rivers in the Upper

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Thames region (Oxfordshire, Gloucestershire and Wiltshire) in central southern England. Initial surveys were conducted for water vole field signs at sites with ongoing mink control and historically robust water vole populations to estimate relative population densities, with only sites that yielded a moderate or high relative population density being selected for use in the study (Dean *et al.* 2016). Potential sites for the spring season were surveyed during the previous autumn, and surveys to identify sites for the autumn season occurred in early summer. All sites had earth banks with an average water depth of 50-100 cm. None of the sites was managed and all were protected from stock grazing, allowing growth of mixed vegetation including riparian species and some ruderal vegetation, with shading provided by occasional mature trees. In-channel emergent vegetation was present at all sites (see Dean *et al.* 2016, 3.3.5). A site-specific licence from Natural England was sought, with live-capture work commencing in February 2016 at spring sites and August 2016 at autumn sites.

The Water Vole Mitigation Guidelines (Dean *et al*. 2016), and the Natural England class licence both stipulate that there should be sufficient available alternative habitat into which displaced water voles could relocate. Each of our study sites therefore comprised a 300 m length of suitable habitat, and in all cases there was additional suitable habitat both up and downstream of the area of disturbance, with good connectivity to streams, ditches and adjacent lakes. One site had an approximately 200 m stretch of sub-optimal habitat that was fringed and shaded by mature trees immediately downstream, after which optimal habitat was again available. None of the water vole colonies used in this study was deemed to be isolated, as water voles were present over a greater area at all sites.

Water vole capture and tracking: Water voles were live-captured using 20 cage traps over a 300 m section of river at each site for up to 14 days, or until there was a 100% recapture rate. All animals were weighed and had a passive integrated transponder (PIT) tag inserted subcutaneously to allow individual identification throughout the course of the study. Individuals over 130 g were fitted with a PIP 3 cable tie radio-collar with 1 Ag 393 battery, each weighing approximately 3 g (Biotrack, UK) having been anesthetised directly within a handling tube using gaseous isoflourane (Isocare, Animalcare Ltd., York, UK; Mathews *et al.* 2002). Post-release, voles were radio-tracked using Wildlife Materials (USA) TRX 1000s receivers and Wildlife Materials antenna for a minimum of five days to establish observed home range length (the distance between the two furthest capture points following the contours of the watercourse), with a minimum of four fixes being taken per day in daylight hours during that time (Moorhouse & Macdonald 2008). GPS fixes were mapped for every animal using QGIS (2016), to enable calculation of the observed home range both before and after works occurred. Once observed home ranges had been established for each site, a 50 m section of riverbank within the 300 m study site was selected for vegetation removal.

Vegetation removal: Vegetation removal at all experimental sites took place sequentially within one week, in the same order as trapping start date. Burrows were noted prior to vegetation being removed to ground level with brush-cutters. Emergent vegetation was also removed using hand tools and all cut vegetation was raked up and removed from the area. Entrances to vole burrows were cleared of debris to ensure access for animals was not compromised, following the standard displacement protocol (Dean *et al.* 2016).

Post-works tracking and trapping: Radio-tracking continued for an initial five days at each site (after which the licenced destruction of water vole burrows would normally commence), and continued thereafter for a total of 30 days following vegetation removal, to determine the observed home range and fate of collared water voles. Each GPS fix was again mapped using QGIS and used to calculate post vegetation removal home ranges. During the study any animals that were not located within the expected area were searched for, as far as access permissions would allow, in a bid to identify their fate.

At the end of the study, water voles at each site were again live-captured to retrieve radio collars, and to establish survival rates and population estimates. All captured water voles were checked for the presence of a PIT tag to determine whether or not they had previously been captured.

Statistical analysis: We hypothesised that voles would show no significant movement away from the vegetation removal area and instead display high burrow fidelity; that they would show a change in observed range length due to having to travel a greater distance to forage, and that increased exposure from vegetation removal would affect survival rates, both at an individual and population level.

Individual survival was assessed by whether or not animals were present at the end of the study. The percentage population of collared animals that survived through works was used to investigate the impact of works at the population level (population percentages were arcsine transformed).

The effect of season and vegetation removal on changes in observed home range length were assessed using analysis of variance (ANOVA) where the response variable was the observed range length of each individual and the explanatory variables were season (spring or autumn), and whether or not works were undertaken (control or experimental site).

A Before-After-Control-Impact-Pairs (BACIP) design was used to determine the optimal season for vegetation works by looking at the average observed home range length before and after works. This approach determines whether a treatment system differs significantly from the results that would have occurred in a system with no treatment (control). Data were analysed separately for spring and autumn datasets, to investigate any differences between treatment and control sites, and between treatment sites. A BACIP design was then used for each season, with the observed range length of each individual as the response variable, and the explanatory variable was pre- or post- works, analysed using a Generalized Linear Mixed Model with normal error structure in R (2013).

CONSEQUENCES

We trapped and collared a total of 76 voles across both seasons and over all sites (Table 1). During spring all captured animals were over-wintered adults, while in autumn juveniles were also present in the trapped cohort (Figure 1).

Effect of works on vole movement: We first looked at home range data pre- and post-works to establish individual movement as a result of the displacement works. Before works began, over all sites and during both seasons, there were 22 collared voles in the vegetation removal zone (spring = 8 (3 female and 5 male); autumn = 14 (9 female and 5 male)). Thirty five animals were recorded outside the works area at experimental sites (spring = 17 (4 female and 13 male), autumn = 18 (6 female and 12 male). Thirteen voles were monitored at control sites.

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Table 1. Number of water voles caught and collared at each site before and after experimental vegetation removal in either spring or autumn 2016.

Season	Site	Minimum no. alive at start[1]	No. collared[2]	No. collared at start of works[3]	No. collared at end[4]	Minimum no. alive at end[5]	Total no. of animals[6]
Spring	Control 1	4	4	4	1	7	10
	Exp. 1	8	8	7	5	20	24
	Exp. 2	9	9	8	2	15	23
	Exp. 3	3	3	2	1	1	5
	Exp. 4	7	7	3	1	14	23
Autumn	Control 1	12	6	3	1	2	13
	Control 2	3	3	3	3	3	3
	Exp. 1	11	8	8	2	12	21
	Exp. 2	12	9	9	9	12	14
	Exp. 3	24	8	8	7	17	27
	Exp. 4	14	5	3	3	3	17
	Exp. 5	6	6	3	3	6	6

[1]Number of animals captured during the initial trapping session.
[2]Includes individuals weighing at least 130g. All spring animals were over-wintered adults.
[3]Number of radio-collared animals present at the start of removal works.
[4]Number of radio-collared animals present 30 days after vegetation removal (end of study).
[5]Minimum number of animals alive in each site during re-trapping (includes new animals and those only PIT tagged).
[6]Total number of individuals at each site throughout the study.

Individual movement of voles within each site was recorded. During spring, four animals (50%) within the removal area stayed within the area after the vegetation was removed, three (37.5%) moved, and the remaining individual disappeared. In autumn, 12 voles (86%) stayed completely or partially within the works area, with the remaining two animals (14%) disappearing from the study area (Table 2). During spring, 17 animals were not directly affected by works, however post-works two (11.8%) of these voles moved predominantly into the removal section, and one (5.9%) used part of it (Figure 2). One vole (5.9%) previously used part of the zone and continued to do so, whilst another moved completely out, and four (23.5%) voles remained in the area. During autumn, of the 18 animals not directly affected, two (11.1%) moved completely into the removal area after works, and one (5.6%) used part of the removal area. Three voles (16.7%) had partly used the removal area pre-works and moved out completely and one (5.6%) moved in. Of the remaining directly affected, two (11.1%) moved out completely, one (5.6%) used only part of the removal zone, and the remaining 11 (61.1%) continued to show high fidelity to their burrows (Table 3). Season did not significantly affect the proportion of voles remaining either totally or partially within the works area, after vegetation removal occurred ($F = 0.94$, d.f. = 1,10, $p = 0.36$).

Table 2. Number (and %) of individual water voles with home ranges inside the works zone that showed different types of movement after vegetation removal in spring or autumn.

Movement type	Spring	Autumn
Remained in vegetation removal area	4 (50%)	11 (78.8%)
Used part of the vegetation removal area	0 (0%)	1 (7.1%)
Moved out of the area but stayed within study area	3 (37.5%)	0 (0%)
Disappeared	1 (12.5%)	2 (14.3%)

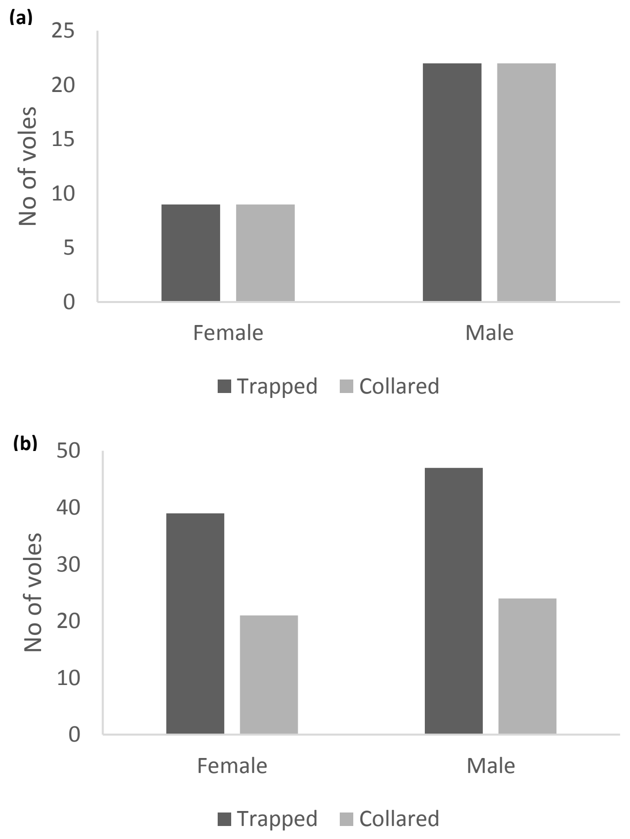
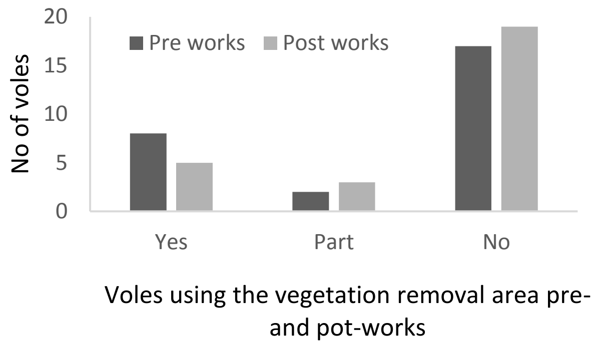


Figure 1. Number of voles trapped vs. those suitable for collaring (i.e. weighing more than 130 g) in (a) spring and (b) autumn. In spring all animals caught were adult, whilst in autumn juveniles were also trapped.

(a)



(b)

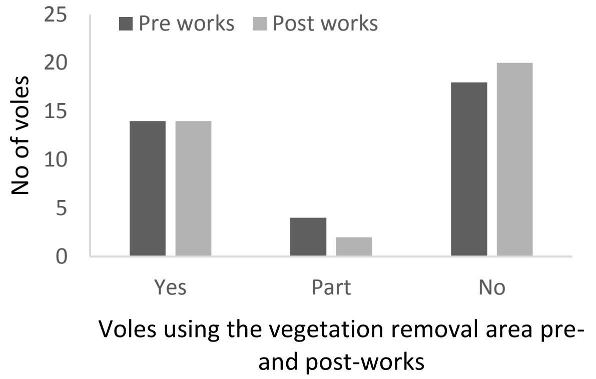


Figure 2. Number of water voles using the vegetation removal area pre- and post-works in a) spring and b) autumn. Voles that used part of the vegetation removal area were considered to be "using" the vegetation removal area.

Effect of vegetation removal on observed range length: We looked at the average observed home range length before and after works, to determine the optimal season for vegetation works in terms of vole movement, looking at. Mean observed range length in spring was 53 m for females and 70 m for males, and in autumn was 52 m for females and 54 m for males. We found no difference in observed range length between seasons or between control and experimental sites, nor was there any impact of the interaction between season and experiment. There was no material difference in these results when only using data from males to determine whether there was a sex bias (Table 4).

No significant difference was found in observed range length between any pair of sites in either season by the BACIP analysis, indicating that neither treatment nor season affected the observed range length of voles in treatment sites.

Table 3. Number (and %) of individual water voles with home ranges outside the works zone that showed different types of movement after vegetation removal in spring or autumn.

Movement type	Spring	Autumn
Moved into the vegetation removal area	2 (11.8%)	2 (11.1%)
Used part of the vegetation removal area	2 (11.8%)	2 (11.1%)
Remained outside vegetation removal area	8 (47.1%)	11 (61.1%)
Moved away	1 (5.9%)	3 (16.7%)
Disappeared	4 (23.5%)	0 (0%)

Effect of works on vole survival: Of the four animals that remained *in situ* during spring works, one was a lone female (ultimately the only individual left at that site), and three were males of which only one survived to the end of the study (the others disappeared after five and 11 days respectively). Of the four animals that moved away, one male disappeared completely, and one male and one female both stopped moving (presumed dead) within three days, as did the remaining female after 18 days.

During autumn, of the 11 animals that showed high fidelity towards their burrows within the removal zone, ten survived until the end of the study (three males, seven females), as did one that continued to use part of the removal area (female). Of the two that moved away, one disappeared completely (female) and the other (male) survived until the end of the study.

To investigate the impact of works at the population level we used the percentage population of collared animals that survived through works. Season had a significant impact on the survival of animals (voles have better survival in autumn; $F = 7.24$, d.f. = 1,8, $p = 0.03$), but there was no impact of treatment on survival rates ($F = 0.13$, d.f. = 1,8, $p = 0.73$), nor was there an interaction between season and treatment ($F = 1.06$, d.f. = 1,8, $p = 0.33$).

In terms of the overall survival of all animals on each site, from the initial trapping session to the final trapping session, the number of animals at the start had a significant impact on the number of animals at the end ($F = 21.5$, d.f. = 1,9, $p = 0.001$).

DISCUSSION

This study has demonstrated that there was no significant net movement of water voles out of areas where vegetation had been removed in either spring or autumn, although movement of individuals did occur. There was no impact of treatment on water vole survival in either season. These findings are in contrast to those of Moorhouse *et al.* (2009), who demonstrated a clear association of habitat quality on water vole density. Water voles perceive higher predation risk and therefore decrease food consumption when they are further from cover (Carter & Bright 2003), with narrow channels and reed beds providing optimal shelter (MacPherson & Bright 2010).

Despite the expectation that voles would have to travel further in order to forage post-vegetation removal, no difference in observed range length was found in relation to either

Table 4. The results of ANOVAs to examine the effect of season, experiment and their interaction on water voles' observed range length for all animals, and for males only to investigate any sex bias.

	Sum sq	F value	d.f.	p-value
Season (All animals)	142.8	0.10	1,7	0.77
Experiment (All animals)	869.5	0.58	1,7	0.47
Season*Experiment (All animals)	1866.2	1.24	1,7	0.30
Season (Male only)	5728.7	1.40	1,7	0.28
Experiment (Male only)	246.6	0.06	1,7	0.81
Season*Experiment (Male only)	429.7	0.11	1,7	0.76

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vegetation removal or season. Male water voles are non-territorial with larger ranges than females, and territories of both sexes often overlap (Efford 1985). Although we expected male range size would be smaller at higher vole densities (Moorhouse & Macdonald 2008), we found no difference in our results when using only data from males.

We did not carry out works in three sites in spring due to a lack of water voles; this was unexpected considering the high level of field signs located during surveys conducted the previous autumn, but had development works occurred at these sites then there would have been no impact on water voles. Our aim was to impact on habitat currently being used by water voles, but had sites been selected by chance (as would be expected during displacement works for development purposes), it is possible that the effectiveness of the habitat displacement on individual movement could be higher (or indeed lower) by chance selection of less optimal habitat.

We noted a high native predator pressure at all sites during spring, notably signs and sightings of barn owl *Tyto alba*, heron *Ardea cinerea*, otter *Lutra lutra* and fox *Vulpes vulpes*, although we were unable to quantify these systematically. Signs of predators, particularly otter, raptors and fox were also noted at all sites during autumn.

These results indicate that there is a risk to localised water vole colonies in spring and that careful consideration of the suitability of individual sites for displacement should include assessment of both relative population size over a large area surrounding the proposed displacement site, and alternative habitat availability and connectivity in the localised area to ensure there is sufficient alternative habitat for displaced animals.

Our findings suggest that it may be necessary to adjust the emphasis on displacement away from the current expectation that vegetation removal will deter water voles from occupying a given area, to an understanding that vegetation removal will expose all burrows in that area, which should then be subject to a careful destructive search using hand tools where possible. There should be a high expectation of locating animals during this period (particularly if undertaken in autumn) and therefore consideration should be given to encouraging exposed water voles to move towards remaining vegetation, with works progressing accordingly. Further restrictions on the use of the displacement technique during spring at sites considered to have vulnerable populations might be appropriate.

Despite our findings of high burrow fidelity for water voles in affected areas, the use of the displacement technique using vegetation removal is still considered to be a pragmatic and proportional response in most situations where works are required over a short (less than 50m) section of river bank. This is due to a combination of factors, including the lack of a cost-effective alternative solution for small-scale impacts, and the drawbacks of trapping water voles in such situations, in terms of both cost and animal welfare. In addition, even if the technique is ineffective or only partially effective, likely impacts on water vole populations should not be significant provided it is only used in the scenarios set out in the Water Vole Mitigation Handbook (Dean *et al.* 2016), and outcomes for individual water voles are likely to be better than the ‘do nothing’ option.

The natural variability of water vole populations renders it impossible to draw firm conclusions on the effectiveness of the technique in all scenarios based on this study alone. Undertaking further monitoring of sites where such works are undertaken, either as a licence condition, or voluntarily by ecological consultants, would allow further refinement of the technique. Such refinements might include consideration of habitat conditions and population density in the wider environment. Evaluation of Natural England licence returns will provide such information, and this next step of research will begin during 2018.

Finally, this study was undertaken on lowland river systems, which may have influenced the effectiveness of the vegetation removal technique being tested, and conclusions cannot be drawn on the likely effectiveness in different habitats. The study did not include water drawdown, as this is not a current requirement of the displacement technique and in many cases can be difficult to achieve, due to the flood risks associated with bunding off and over-pumping, particularly on rivers or canals. It therefore is not possible to draw conclusions as to whether this would have aided effectiveness in this instance.

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REFERENCES

Barreto G.R., Rushton S.P., Strachan R. & Macdonald D.W. (1998) The role of habitat and mink predation in determining the status and distribution of water voles in England. *Animal Conservation*, **1**, 129-137.

Carter S.P. & Bright P.W. (2003) Reedbeds as refuges for water voles (*Arvicola terrestris*) from predation by introduced mink (*Mustela vison*). *Biological Conservation*, **111**, 371-376.

Dean M., Strachan R., Gow D. & Andrews R. (2016) *The Water Vole Mitigation Handbook (The Mammal Society Mitigation guidance Series).* Eds Fiona Mathews and Paul Chanin. The Mammal Society, London.

Efford M.G. (1985) The structure and dynamics of water vole populations. PhD thesis, University of Oxford.

MacPherson J.L. & Bright P.W. (2010) A preliminary investigation into whether grazing marsh is an effective refuge for water voles from predation. *Lutra*, **53**, 21-28.

Mathews F., Honess P. & Wolfensohn S. (2002) Use of inhalation anaesthesia for wild mammals in the field. *Veterinary Record*, pp 785-787.

Moorhouse T.P., Gelling M. & Macdonald D.W. (2009) Effects of habitat quality upon reintroduction success in water voles: evidence from a replicated experiment. *Biological Conservation*, **142**, 53-60.

Moorhouse T.P. & Macdonald D.W. (2008) What limits male range sizes at different population densities? Evidence from three populations of water voles. *Journal of Zoology*, **274**, 395-402.

Natural England (2011) *Water voles and development: licensing policy*. TIN042 2nd Edition. Natural England, Peterborough.

Quantum GIS Development Team (2016) Quantum GIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

ISSN 1758-2067

R Core Team (2013) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Strachan R., Moorhouse T.P. & Gelling M. (2011) *Water Vole Conservation Handbook 3rd Edition.* Wildlife Conservation Research Unit, Oxford.

Wildlife and Countryside Act (1981) online only

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