Rivers as obstacles to home range expansion by the brushtail possum

Briar Cook1*, Nick Mulgan1 and Helen Nathan1

1Zero Invasive Predators, 39 Waiapu Road, Kelburn, Wellington 6012
*Author for correspondence (Email: briar@zip.org.nz)

Published online: 25 November 2020

Abstract: Strategies for defending large tracts of land from mammalian pest incursion are urgently needed. We report on a study investigating whether brushtail possum (Trichosurus vulpecula) range expansion into a controlled area was restricted by a watercourse. The true left of the Orongorongo River valley was treated with 1080 poison baits, and a 250 ha area bordering the river on the true right was excluded from treatment. Non-toxic cereal bait containing pyranine biomarker was sown repeatedly over half of the excluded area for nine weeks after poisoning. Traps installed on the true left of the river caught no marked possums. This outcome suggests that the river acted as an obstacle to possum movement, specifically, home range expansion into an area of low conspecific density. Our study contributes to the body of evidence that watercourses can inhibit possum movement, supporting operational practice that aligns eradication boundaries with rivers to slow the rate of possum reinvasion.

Keywords: braided rivers, home range movement, pyranine, Trichosurus vulpecula, vacuum effect

Introduction

The brushtail possum (Trichosurus vulpecula, hereafter possum) has long been a major environmental and agricultural pest in New Zealand (Nugent 1995; Payton 2000, Cowan 2001a; Glen et al. 2012). It is widely agreed that possum populations have negatively modified the composition of most New Zealand forests (Owen & Norton 1995) and play a major role in the spread of bovine tuberculosis (TB) into cattle and deer herds in New Zealand (OSPRI 2019).

The ecological and economic impacts of the brushtail possum (Wright 2011) provide strong motivation to eradicate the pest from New Zealand, and progress towards the larger goal of a Predator Free New Zealand (Russell et al. 2015). To do this at landscape scale requires robust methods to defend eradicated sites and prevent re-establishment. Such methods may be enhanced by appropriate use of landscape features that influence pest movements. There is geographic evidence (Julian 1984; Cowan 2001b; Byrom et al. 2015; Etherington et al. 2014) and genetic evidence (Sarre et al. 2014) that watercourses can act as obstacles to possum movement, and so may provide some natural protection to landscape scale eradicated areas.

Possum home range size varies between high-density and low-density populations, with low density populations generally exhibiting larger home ranges (WhYTE et al. 2013; Richardson 2017). After control, previously high-density populations are more likely to exhibit movement behaviour described as home range expansion (Rouco et al. 2017; Margetts et al. 2020) or the vacuum effect (Clinchy 1999), particularly in the absence of landscape constraints (Brockie et al. 1997; Efford et al. 2000; Pech et al. 2010). These changes have been observed to occur within a few weeks of control (Margetts et al. 2020).

We aimed to assess whether the Orongorongo River impeded home range expansion behaviour on the edge of a high-density population, following possum control to low density directly across the river.

Methods

Study Site

The trial was carried out in the Orongorongo Valley, Remutaka Forest Park, 18 km east of Wellington, New Zealand (41°21.3’S, 174°56.8’E). The trial site ranged in elevation from 80−460 m above sea level, was mainly broadleaf/podocarp forest, and had a mean annual uncontrolled possum population density between 6.5−13.7 per ha (Efford & Cowan 2004). Flow data for the Orongorongo River recorded by Greater Wellington Regional Council at Truss Bridge (8 km upstream from our study site) were used to approximate the flow rate at our study site during the trial. The mean daily flow rates during the study period were comparable with the flow rates for the same period in the previous and following years (Fig. 1).

An aerial 1080 toxin operation was undertaken by OSPRI in late July 2017, to control the TB-infected possum population in the Southern Remutaka Forest Park. We secured agreement from OSPRI and the Department of Conservation to establish a 250 ha toxin exclusion zone, covering about 4 km along the true right forest margin of the Orongorongo River (Fig. 2). The boundaries of the exclusion zone comprised an unnamed...
Figure 1. Mean daily flow rates (m³ sec⁻¹) for the Orongorongo River at Truss Bridge from 1 August 2016 to 1 October 2018 (GWRC 2020).

Figure 2. Trial location and layout, Remutaka Forest Park, Lower North Island, New Zealand. Background is Land Information New Zealand (LINZ) Topo50 [ref https://www.linz.govt.nz/land/maps/topographic-maps/topo50-maps] and licensed by LINZ for re-use under the Creative Commons Attribution 4.0]

track from the river to an intersection with Baker Track (left side in the figure), Baker Track itself (upper left), a private land boundary (top left), Cattle Ridge Track (top right) and Browns Track (right). The riverbed habitat was also excluded from 1080 treatment, as per typical 1080 operations.

True right side–boundary traps
For the duration of the trial, possum kill traps (n = 275) (Trapinator™, CMI Springs, Auckland, NZ) were installed at 20 m spacing around the boundary of the exclusion zone, to prevent possums invading the controlled area. A subset of the boundary traps encompassing traps on Baker Track, the private land boundary, and Cattle Ridge Track (n = 215) provided comparative marking distance data to the traps of interest across the river (Fig. 3). For simplicity, this subset is referred to as the ‘ridgetop boundary’. Traps installed on the unnamed track (n = 35) and on Browns Track (n = 25) were excluded due to their proximity to the biomarking zone. All boundary traps were cleared and reset every 7–10 days.

Biomarking
Pyranine (CAS number 6358-69-6) is a non-toxic biomarker which temporarily stains the digestive tract of animals fluorescent green under UV light (Wegmann et al. 2008). Possums that eat bait containing pyranine become marked internally soon after consumption, and green fluorescent flecks can also be found inside the mouth cavity and around the anus (B. Cook, T. Agnew, ZIP, pers. obs.). Pyranine added to cereal pellet bait has an internal marking period of about four days for possums (Cook 2018), requiring regular application to ensure ongoing marking of the target population. Despite this, the relatively low cost and ease of bait production made pyranine
Cook et al.: Rivers may restrict possum movement

Figure 3. Possum captures on the leghold traps and marked captures on the ridgetop boundary traps. Circle size represents the number of captures at that location. Background is Land Information New Zealand (LINZ) Topo50 [ref https://www.linz.govt.nz/land/maps/topographic-maps/topo50-maps] and licensed by LINZ for re-use under the Creative Commons Attribution 4.0]

Table 1. Pyranine application timeline.

| Pyranine application dates | Method of application | Nights since previous application |
|---------------------------|-----------------------|----------------------------------|
| 5/08/2017                 | Aerial                | First application                 |
| 7/08/2017                 | Bait bags             | 2                                |
| 11/08/2017                | Aerial                | 4                                |
| 16/08/2017                | Bait bags             | 5                                |
| 18/08/2017                | Aerial                | 2                                |
| 24/08/2017                | Bait bags             | 6                                |
| 25/08/2017                | Aerial cancelled due to high winds | -  |
| 29/08/2017                | Aerial                | 5                                |
| 30/08/2017                | Bait bagging cancelled due to high river levels | -  |
| 5/09/2017                 | Aerial                | 7                                |
| 7/09/2017                 | Bait bags             | 2                                |
| 12/09/2017                | Aerial                | 5                                |
| 16/09/2017                | Bait bags             | 4                                |
| 19/09/2017                | Aerial                | 3                                |
| 23/09/2017                | Bait bags             | 4                                |
| 27/09/2017                | Aerial                | 4                                |
| 3/10/2017                 | Trial concluded       | 6                                |

our chosen method for marking the possum population in the exclusion area on the true right side of the river. Non-toxic, pyranine-laced (0.2%), 6 g cereal baits (Orillion, Wanganui, NZ) were aerially broadcast over 120 ha of the exclusion zone bordering the river (Figure 2). The first pyranine-laced baits were sown six days after the 1080 operation, at an average rate of 2.25 kg ha\(^{-1}\), and then every 6–11 days throughout the nine weeks of the trial (Table 1). Bait bags containing six of the same pyranine-laced baits were stapled to trees along the true right river edge. These were fixed at about chest height, mostly about 20 m apart, and none more than 50 m apart. The bait bags were deployed between aerial sowing applications to maximise the length of time marked bait was available to possums at the river edge.

**True left side–leghold traps**

Possum leghold traps (n = 205) were installed along an existing 4WD track on the true left of the river, parallel to the exclusion zone on the true right. Traps were set at 20 m spacing, beginning opposite the bottom of Browns Track and ending about 250 m south of Peak Stream (Fig. 2). Each trap set consisted of a PCR #1 leghold trap (Pest Control Research, Christchurch, NZ) within a ZIP PosStop reinforced plastic platform (ZIP, Wellington, NZ) attached to a wooden ramp angled at 60° to the tree. A 9 × 18 cm piece of white corflute was folded in half and nailed to the tree 30 cm above each platform as a visual lure. Each trap set was fitted with an automated reporting transmitter node. This OutPost reporting system, (ZIP, Wellington, NZ) enabled remote monitoring of each trap via VHF transmission and satellite communication (Bell et al. 2019). To facilitate this, a temporary satellite internet system was installed at the Manaaki Whenua - Landcare Research Base, located about 500 m upstream from Paua Hut, and about 200 m upstream of the first leghold trap. The OutPost system and its operation complied with the Animal Welfare Act and Ministry for Primary Industries guidelines
on using remote reporting systems for live capture trapping (Ministry of Primary Industries 2016). Any traps reporting as sprung overnight were manually checked within 12 hours of sunrise, as legally required. Possums caught in the leghold traps were humanely euthanased before examination for traces of pyranine. All possums were examined externally and internally (through dissection) visually and using a UV light. Several detections of external fluorescence (guard hairs, whiskers and fur patches) with no corresponding internal fluorescence prompted trials at the ZIP Animal Behaviour Facility in Lincoln, which confirmed the presence of natural fluorescence in possum fur and urine from animals that had not consumed pyranine baits (Bolliger 1944; P Cowan, pers. comm; ZIP, unpubl. data). Therefore, internal examination was considered the only reliable method of determining pyranine consumption, and any possums with only external fluorescence were recorded as unmarked by pyranine.

Results
Over 59 nights following the first pyranine drop (12 095 trap nights, 5 August–3 October 2017), 44 possums were caught in the leghold traps on the true left side of the river (Fig. 3). None of these showed evidence of pyranine consumption. The ridgetop boundary traps on the true right (n = 215) caught 82 marked possums; these captures are included in results for home range length comparison. Unmarked captures on the ridgetop boundary traps (n = 76) and all captures elsewhere on the boundary traps were excluded from Fig. 3 and further discussion.

Discussion
We did not record any marked possums that had crossed the river during our trial, consistent with previous experimental and anecdotal evidence that possums seldom traverse water bodies.

Residential home ranging
Between 1970 and 1972 in the Orongorongo Valley, the radio-tracked home ranges of four resident possums over a two-year period averaged between 2.1–2.5 ha, and nightly excursions in any direction varied between 0–250 m (Ward 1978). With this in mind, the proximity of the ridgetop boundary traps to the pyranine zone (180–450 m in an uphill direction) makes it likely that most, if not all, of the 82 pyanine-marked possums in these traps are the result of residential home-ranging behaviour. The ridgetop boundary traps were installed as a condition of conducting the study; however, these captures proved useful in eliminating distance to traps and biomarker longevity as limiting factors for our results. The leghold traps were sited 150–500 m across relatively flat terrain from the pyranine zone, a comparable distance to the ridgetop boundary traps.

Braided river habitat effects
The Orongorongo River is usually made up of several small channels separated by wide, exposed areas of gravel. The average flow rate at Truss Bridge between 5 August and 3 October 2017 was 3.21 m$^3$s$^{-1}$, with actual values ranging from 0.88–30.5 m$^3$s$^{-1}$ (GWRC 2017). We would consider both the average rate and the minimum actual rate to be relatively low, and physically possible for a possum to cross. There was very little established vegetation in the riverbed at the time of the study; however, vegetation cover can vary from 5–22%, depending on the frequency and severity of floods (Gibb 1994). The vegetation that was present comprised Raoulia tenuicaulis (seaweed), and sporadic instances of Buddleia davidii and Kanzea ericoides (kānuka) along the margins (B. Cook, pers. obs.). Ward (1978) recorded a single possum making multiple excursions across a small channel into the Orongorongo River over a period of eight months. This behaviour is considered atypical, and while its home range did appear to include part of the riverbed, the possum was not recorded crossing the river and frequenting the opposite side. Because of the lack of vegetation cover and food availability, we consider it likely that any obstacle effect of this river is not solely due to the presence of a water body, but also to the largely unsuitable habitat of the braided river system as a whole.

Possum captures
Of the 44 unmarked possums caught on the true left of the river, 33 were caught inside the 1080 exclusion zones surrounding public huts and were unlikely to have been exposed to the toxin. The remaining 11 possums either survived exposure to the 1080 operation, wandered from nearby exclusion zones, or originated on the true right (but had not consumed pyranine recently) and crossed the river. When reduced to low density, resident possum home ranges can rapidly become larger than average (Sweetapple & Nugent 2009; Whyte et al. 2013). This suggests that possums originating in exclusion zones on the true left were moving around more following density reduction, and therefore encountering the leghold traps. We acknowledge that on some occasions pyranine-laced baits were distributed more than four days after the previous baits (Table 1), meaning it was possible (based on capture dates) for two of the 11 possums to have originated on the true right without showing any signs of marking. However, we cannot assume that all baits were consumed on the night of distribution. Additionally, both possums were caught less than 70 m from the nearest exclusion zone, suggesting they could equally have originated on the true left. The lack of marked possums on the true left, at the very least, indicates that possums rarely inhabit home ranges that span land on both sides of this braided river. At the most it indicates that home range expansion did not occur across the Orongorongo River in the nine weeks following control.

Future research
While home range expansion in adult possums in the Orongorongo Valley appeared to be limited by the presence of the river during our study, this may not be the case for other types of possum movement, or at other times of year. Dispersing sub-adults play a key role in repopulating controlled areas by moving large distances (Clout & Efford 1984, Cowan et al. 1997). Dispersing sub-adult possums are known to sometimes cross the Orongorongo River (Ward 1985). Owing to the constraints imposed by the timing of the 1080 operation, this trial was undertaken outside the peak sub-adult dispersal season. A future trial carried out over several months spanning the sub-adult dispersal period could strengthen the evidence around the use of rivers as obstacles to possum movement or highlight areas for further investigation. In addition, possum crossing rates over narrow rivers with suitable habitat directly bordering such waterways should be investigated, to isolate the effects of different river types. While rivers are used as
boundaries in aerial 1080 operations, the evidence supporting this use is largely anecdotal and qualitative. If successful, these further trials could continue to build evidence for the use of rivers as a key component of a strategy to protect landscapes from possum reinvasion and help to enable large chunks of the country with natural river borders to be targeted for possum eradication.

Acknowledgements

We would like to acknowledge the following for their contribution to this project: Roger Pope, Catchpool Campground Caretaker; Jack Mace, Angus Hulme-Moir, Daryl Stephens, Emma Dunning, Peter Blaxter, Paul Jeffries and Colin Giddy, Department of Conservation, Kapiti Wellington Office; Peter Berben and Phil Cowan, Manaaki Whenua Landcare Research; Nic Gorman, Lyndsay Murray and Hamish Howard, field rangers; Lindsay Chan, DOC GIS Team; OSPRI; Nigel and Lou Thomas; Gray Bamber, Health Protection Officer; Amalgamated Helicopters NZ Ltd; James Ross and Carol West for helpful comments on an earlier draft of this paper, and anonymous reviewers.

References

Bell P, Nathan H, Mulgan N 2019. ‘Island’ eradication within large landscapes: the remove and protect model. In: Veitch CR, Clout MN, Martin AR, Russell JC, West CJ eds. Island invasives: scaling up to meet the challenge Occasional Paper SSC no 62. Gland, Switzerland, IUCN. Pp. 604–610.

Bolliger A 1944. On the fluorescence of the skin and the hairs of Trichosurus vulpecula. Australian Journal of Science 7: 35.

Brockie R, Ward G, Cowan P 1997. Possums (Trichosurus vulpecula) on Hawke’s Bay farmland: spatial distribution and population structure before and after a control operation. Journal of the Royal Society of New Zealand 27(2): 181–191.

Byrom AE, Anderson DP, Coleman M, Thomson C, Cross ML, Pech RP 2015. Assessing movements of brushtail possums (Trichosurus vulpecula) in relation to depopulated buffer zones for the management of wildlife tuberculosis in New Zealand. PLoS One 10(12): e0145636.

Clinchy M 1999. Does immigration “rescue” populations from extinction? Unpublished PhD thesis. University of British Columbia, Canada.

Clout M, Efford M 1984. Sex differences in the dispersal and settlement of brushtail possums (Trichosurus vulpecula). Journal of Animal Ecology 53(3): 737–749.

Cook B 2018. When possums glow: Identifying limiting factors and quantifying pyranine expression in possums. Poster session presented at: New Zealand Ecological Society 2018 Conference, Wellington.

Cowan PE 2001a. Advances in New Zealand mammalogy 1990–2000: brushtail possum. Journal of the Royal Society of New Zealand 31: 15–29.

Cowan PE 2001b. Responses of common brushtail possums (Trichosurus vulpecula) to translocation on farmland, southern North Island, New Zealand. Wildlife Research 28(3): 277–282.

Cowan PE, Brockie RE, Smith RN, Hearfield ME 1997. Dispersal of juvenile brushtail possums, Trichosurus vulpecula, after a control operation. Wildlife Research 24(3): 279–288.

Efford M, Cowan P 2004. Long-term population trend of the common brushtail possum Trichosurus vulpecula in the Orongorongo Valley, New Zealand. In: Goldingay RL, Jackson SM eds. The biology of Australian possums and gliders. Chipping Norton, Australia, Surrey Beatty and Sons. Pp. 471–483.

Efford M, Warburton B, Spencer N 2000. Home-range changes by brushtail possums in response to control. Wildlife Research 27(2): 117–127.

Etherington TR, Perry GLW, Cowan, PE, Clout MN 2014. Quantifying the direct transfer costs of common brushtail possum dispersal using least-cost modelling: a combined cost-surface and accumulated-cost dispersal kernel approach. PLoS ONE 9(2): e88293.

Gibb JA 1994. Plant succession on the braided bed of the Orongorongo River, Wellington, New Zealand, 1973-1990. New Zealand Journal of Ecology 18(1): 29–39.

Glen AS, Byrom AE, Pech RP, Cruz J, Schwab A, Sweetapple PJ, Yockney I, Nugent G, Coleman M, Whithford J 2012. Ecology of brushtail possums in a New Zealand dryland ecosystem. New Zealand Journal of Ecology: 36(1): 29–37.

GWRC Environmental Monitoring and Research 2017. Flow monitoring data: Orongorongo River at Truss Bridge. http://graphs.gw.govt.nz/?siteName=Orongorongo%20River%20at%20Truss%20Bridge&dataSource=Flow (Accessed 6 June 2020)

Julian A 1984. Possum distribution and recent spread in northern Northland: with observations on the vegetation. Wellington, Department of Lands and Survey. 61 p.

Margetts BI, Ross JG, Buckley HL 2020. Measuring home-range changes following density reduction of Australian brushtail possum. The Journal of Wildlife Management. 84: 185–192.

Ministry for Primary Industries. 2016. Remote monitoring of live capture traps for vertebrates: guidelines for good practice. https://www.mpi.govt.nz/dmsdocument/27894-remote-monitoring-of-live-capture-traps-for-vertebrates (Accessed 26 June 2019).

Nugent G 1995. Effects of possums on the native flora. In: O’Donnell CF ed. Possums as conservation pests. Proceedings of a workshop on possums as conservation pests. Wellington, Department of Conservation. Pp. 5–11.

OSPRI 2019. Area Disease Management Plan, North Island. https://ospri.co.nz/assets/Uploads/ADMP-2018-19-NI-002.pdf (Accessed 26 February 2019).

Owen HJ, Norton DA 1995. The diet of introduced brushtail possums Trichosurus vulpecula in a low-diversity New Zealand Nothofagus forest and possible implications for conservation management. Biological Conservation 71(3): 339–345.

Payton I 2000. Damage to native forests. In: Montague TLE ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, Manaaki Whenua Press. Pp. 111–125.

Pech R, Byrom A, Anderson D, Thomson C, Coleman M 2010. The effect of poisoned and notional vaccinated buffers on possum (Trichosurus vulpecula) movements: minimising the risk of bovine tuberculosis spread from forest to farmland. Wildlife Research. 37(4): 283–292.

Richardson KS 2017. Investigating brushtail possum (Trichosurus vulpecula) home-range size determinants in a New Zealand native forest. Wildlife Research. 44(4): 316–323.
Rouco C, Norbury GL, Anderson DP 2017. Movements and habitat preferences of pests help to improve population control: the case of common brushtail possums in a New Zealand dryland ecosystem. Pest Management Science. 73(2): 287–294.

Russell JC, Innes JG, Brown PH, Byrom AE 2015. Predator-free New Zealand: conservation country. BioScience 65(5): 520–525.

Sarre SD, Aitken N, Adamack AT, MacDonald AJ, Gruber B, Cowan P 2014. Creating new evolutionary pathways through bioinvasion: the population genetics of brushtail possums in New Zealand. Molecular Ecology 23(14): 3419–3433.

Sweetapple P, Nugent G 2009. Possum demographics and distribution after reduction to near-zero density. New Zealand Journal of Zoology 36(4):461–471.

Ward G 1978. Habitat use and home range of radio-tagged opossums Trichosurus vulpecula (Kerr) in New Zealand lowland forest. In: Montgomery GG ed. Proceedings of a Symposia of the National Zoological Park on the ecology of arboreal folivores. Washington, DC. Pp. 267–287.

Ward G 1985. The fate of young radiotagged common brushtail possums, Trichosurus vulpecula, in New Zealand lowland forest. Wildlife Research 12(2): 145–150.

Wegmann A, Helm J, Jacobs B, Samaniego A, Smith W, Drake D, Fisher R, Hathaway S, Henry A, Smith J 2008. Palmyra Atoll rat eradication: biomarker validation of an effective bait application rate, 19 June to 5 July 2008. Santa Cruz, Island Conservation. 34 p.

Whyte BI, Ross JG, Blackie HM 2013. Differences in brushtail possum home-range characteristics among sites of varying habitat and population density. Wildlife Research 40(7): 537–544.

Wright J 2011. Evaluating the use of 1080: predators, poisons and silent forests. https://www.pce.parliament.nz/media/1689/pce-1080-2017-web.pdf (Accessed 2 April 2019)

Received 9 September 2019; accepted 1 July 2020
Editorial board member: Tom Etherington