NEW ZEALAND JOURNAL OF ECOLOGY

RESEARCH

Rivers as obstacles to home range expansion by the brushtail possum

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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

DOI: https://dx.doi.org/10.20417/nzjecol.45.5

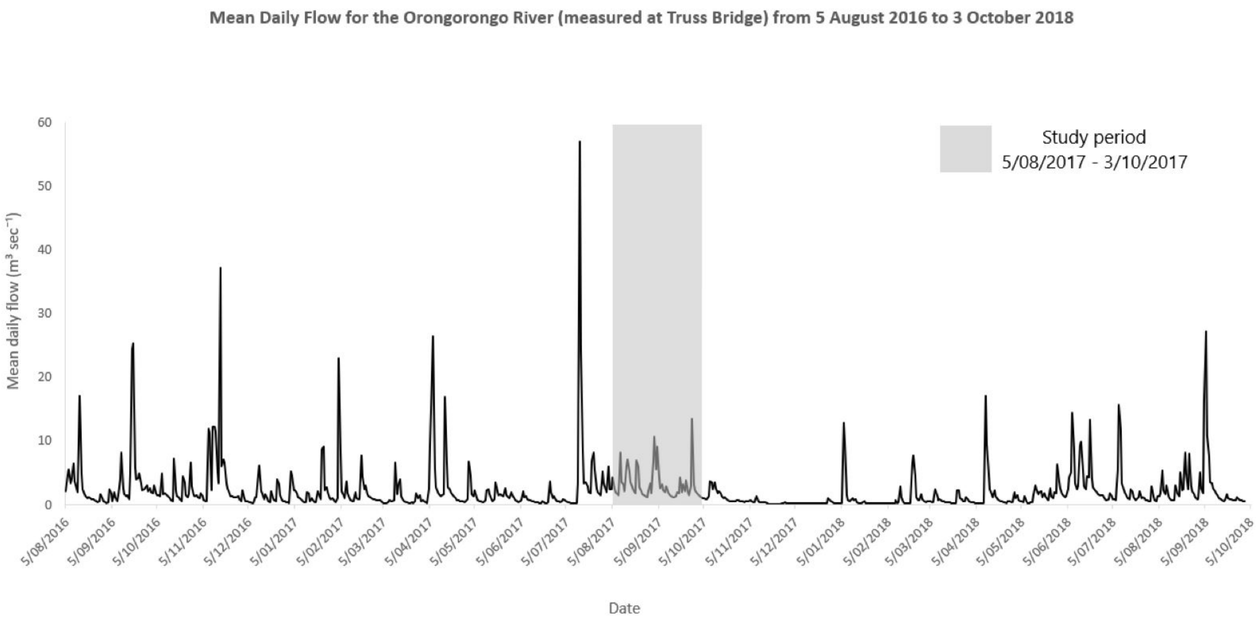

Figure 1. Mean daily flow rates (m³ sec^{-1}) for the Orongorongo River at Truss Bridge from 1 August 2016 to 1 October 2018 (GWRC 2020).

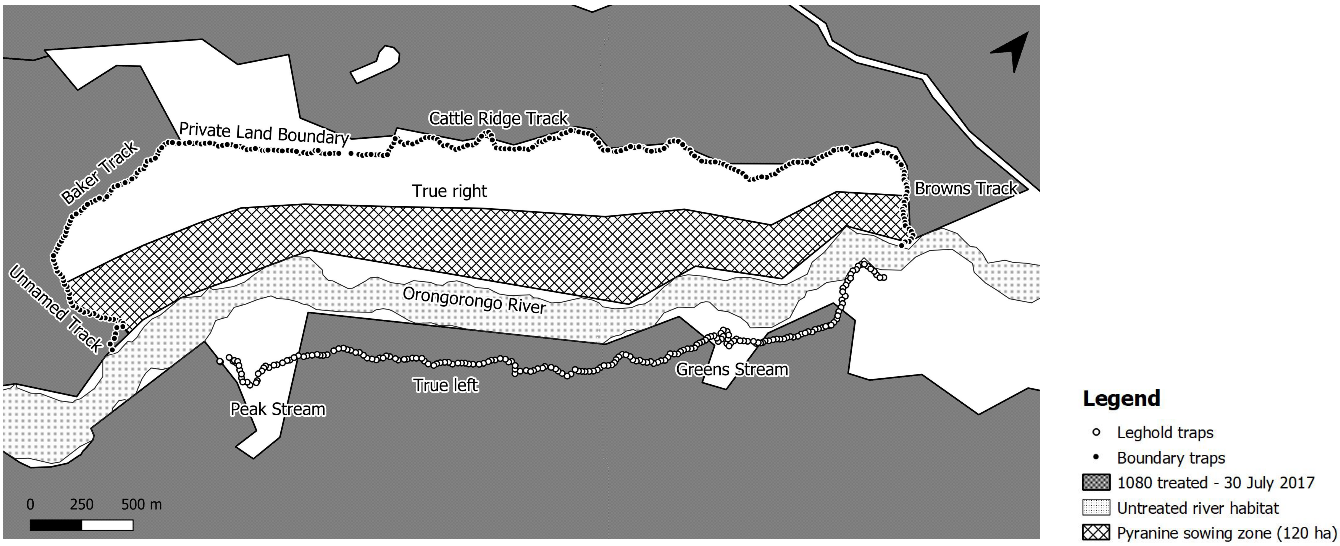

Figure 2. Trial location and layout, Remutaka Forest Park, Lower North Island, New Zealand. Background is Land Information New Zealand (LINZ) Topo50 [ref https://www.linz.govt.nz/land/maps/topographic-maps/topo50-maps] and licensed by LINZ for re-use under the Creative Commons Attribution 4.0]

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

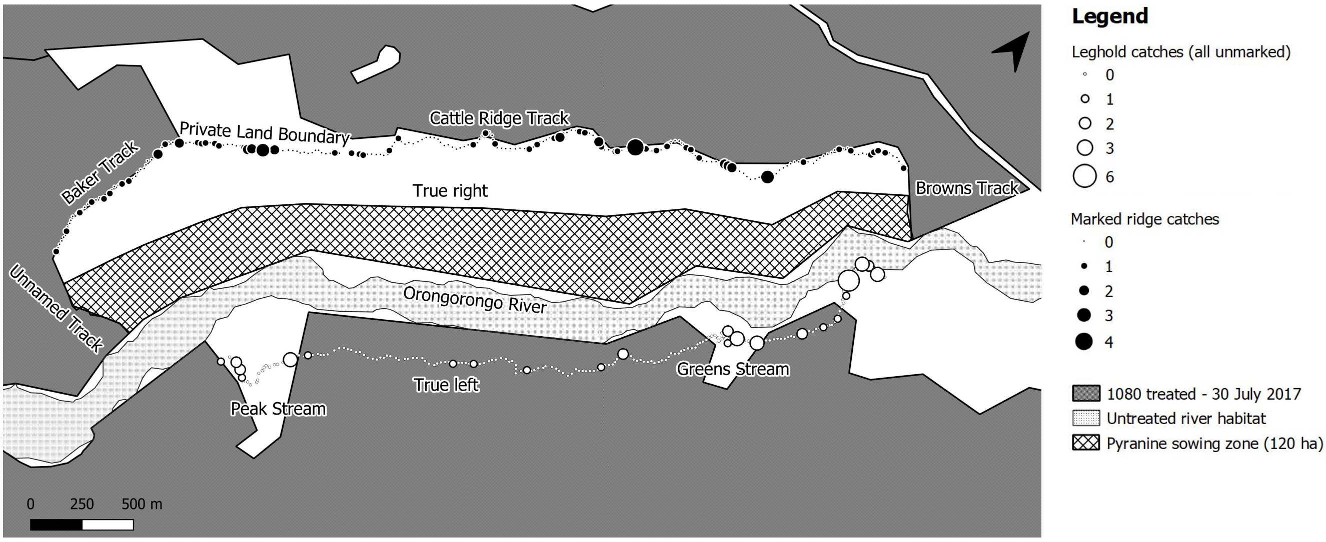

Figure 3. Possum captures on the leghold traps and marked captures on the ridgetop boundary traps. Circle size represents the number of captures at that location. Background is Land Information New Zealand (LINZ) Topo50 [ref https://www.linz.govt.nz/land/maps/topographic-maps/topo50-maps] and licensed 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 pyranine-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 150–550 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* (scabweed), and sporadic instances of *Buddleia davidii* and *Kunzea 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 riverbed 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.

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