Wide-scale predator control for biodiversity conservation: a case study from Hawke's Bay, New Zealand

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Abstract

Invasive predators are controlled to protect native fauna in many parts of New Zealand. However, this is usually localised within conservation reserves, wildlife sanctuaries or remnants of native habitat; predators are rarely controlled across multi-tenure landscapes. We controlled invasive predators by trapping over 6,000 ha of farmland adjacent to a conservation reserve where intensive predator control had been in place for over a decade. The trapping targeted feral cats (*Felis catus*) and mustelids (*Mustela* spp.), but other invasive mammals (particularly hedgehogs *Erinaceus europaeus*) were also captured. We aimed to promote recovery of native fauna in a pastoral landscape with fragments of native bush. Since 2011, low-cost predator control has been conducted using a network of kill traps, supplemented by live trapping when required. Predator populations were monitored using large tracking tunnels, which also detected native lizards. Invertebrates were monitored using artificial shelters (weta houses). Site occupancy rates of cats and mustelids, as well as hedgehogs, were significantly lower than those in an adjacent non-treatment area. Occupancy of invasive rats was higher in the treatment area, while occupancy of mice showed no difference between treatments. There was evidence of positive responses of some native biodiversity, with occupancy rates of native lizards increasing significantly in the treatment area, but not in the non-treatment. Counts of cockroaches were higher in the treatment area, but other invertebrates were detected in similar numbers in both areas. Our results show that low-cost predator control in a pastoral landscape can reduce invasive predator populations, with apparent benefits for some native fauna.

Keywords: Feral cat; invasive predators; invertebrates; landscape-scale; lizards; mustelids; rodents

Introduction

Invasive predators are controlled to protect native fauna in many parts of New Zealand (e.g. Innes et al. 1999; Reardon et al. 2012; Russell et al. 2015). However, this is usually localised within conservation reserves, wildlife sanctuaries or remnants of native habitat; predators are rarely controlled at a landscape scale. Controlling species in the landscape between conservation reserves can restore functional connectivity, with benefits for a range of native species and ecological processes (Glen et al. 2013).

Although landscape-scale predator control is desirable, financial and logistical challenges often prevent it. Tools and techniques used to control predators at localised scales (e.g. exclusion fencing (Innes et al. 2012; Hayward et al. 2014)) may be prohibitively expensive at the landscape scale (Norbury et al. 2014). Managing wildlife across different land tenures can also be challenging, both logistically and socially (Epanchin-Niell et al. 2009; Glen et al. submitted). Practical and affordable methods are therefore needed to reduce the impacts of invasive predators across large, multi-tenure landscapes.

We controlled invasive predators over 6,000 ha of farmland adjacent to a conservation reserve where intensive predator control had been in place for over a decade. The primary targets of the trapping were feral cats (*Felis catus*) and mustelids (*Mustela* spp.); however, large numbers of other invasive mammals, particularly hedgehogs (*Erinaceus europaeus*), were also captured. By removing invasive predators we aimed to promote recovery of native fauna in a pastoral landscape with fragments of native bush. Here we describe the results (changes in predator populations) and outcomes (trends in native biodiversity) of this landscape-scale intervention.

Methods

Study area

Our study took place on four adjacent pastoral properties in Hawke’s Bay, North Island, New Zealand: Opouahi, Rangiora, Toronui and Rimu stations (39^0 10’ S; 176^0 46’ E). These sheep and cattle stations are vegetated mainly by introduced pasture grass with fragments of native beech forest (*Nothofagus solandri*). Fragments range in size from about 10 to 100 ha. Adjoining the study area to the north is Boundary Stream Reserve, which is managed by the Department of Conservation (DOC). Elevation in the study area ranges from about 300 to 1000 m, and climate varies accordingly from coastal to montane. Invasive predators have been controlled over 800 ha in Boundary Stream since 1996 as part of DOC’s Mainland Island programme (Saunders & Norton 2001; Abbott et al. 2013). There was no recent history of predator control on the adjacent pastoral properties. Predator control was applied on Opouahi and Rangiora stations, as well as three adjacent farms on which we did not monitor. Toronui and Rimu stations served as a non-treatment area for comparison (Fig. 1).

[Figure 1 hereabouts]

Predator control

Invasive predator control was conducted by Hawke’s Bay Regional Council (HBRC). In November 2011, 680 kill traps were deployed across an area of 6,000 ha and left in place year-round. These included 550 DOC-250 traps (Department of Conservation, Wellington) for mustelids, and 130 Timms traps (KBL Rotational Moulders, Palmerston North) for cats. Traps were spaced 100 m apart in bush fragments or 200 m apart on cleared farmland, and baited with various combinations of fresh rabbit meat, a rabbit-based paste (Erayz®, Connovation Ltd, Auckland) or a synthetic, rat-scented lure (Goodnature Ltd, Wellington). To minimise labour costs, traps were set in locations that were easily accessible by an all-terrain vehicle (ATV). Traps were checked every three weeks until November 2014, and thereafter four times a year (January, April, June and November).

Kill trapping was supplemented in May and August each year with pulses of cat control using a combination of live traps (cage (Havahart Traps, Lititz, Pennsylvania), leg-hold (Victor #1$^{1/2}$ soft-catch, Oneida Victor, Cleveland, Ohio)), and other kill traps (Timms and Possum Master traps (Possum Master Industries, Tauranga)), as well as opportunistic shooting. Live traps were checked daily and captured predators were euthanased. This additional 'specialist control' targeted areas of high rabbit (*Oryctolagus cuniculus*) activity as rabbit abundance is a strong predictor of cat abundance (Norbury & McGlinchy 1996; Norbury et al. 2002; Cruz et al. 2013). After the first year, the Timms traps were removed from the permanent trap network as the specialist control proved more effective for cats. The DOC 250 traps remained in place throughout the study.

Monitoring

In October 2011, we established 15 monitoring lines in the treatment area and 14 lines in the non-treatment area. However, due to access restrictions, the number of monitoring lines in the non-treatment area was reduced to 12 from Spring 2014 onwards. Each line consisted of five tracking tunnels (see below) spaced 100 m apart, spanning the interface between a native bush fragment and the adjacent pasture. The first point was inside the bush fragment, 200 m from the edge, the third point was on the edge of the fragment, and the fifth point was in cleared pasture, 200 m outside the fragment. Where possible, monitoring lines were at least 1 km apart to maximise spatial independence; however, steep topography made this impracticable in some cases. The shortest distance between any two monitoring lines was 500 m.

We monitored mammalian predators using large tracking tunnels (20 x 20 x 100 cm) with a removable floor, as described by Pickerell et al. (2014). Tracking ink (Black Track, Pest Management Services, Wellington) was applied to the floor in the middle of each tunnel, and sheets of tracking paper (18 x 30 cm) were fastened to the tunnel floor at each end with bulldog clips and drawing pins. Each tunnel was baited with a cube of fresh rabbit meat in the middle of the tracking ink. Tracking papers were retrieved after three days and labelled with tunnel number and date; tunnels were left in place year-round. Footprints left on the tracking papers were identified using field guides (Agnew 2009; Gillies & Williams unpubl; www.pestdetective.org.nz). Tracking tunnels also detected native skinks.

The first and third point on each monitoring line also had an artificial shelter (weta house) for monitoring invertebrates. Weta houses were 10 cm x 50 cm, with six galleries, a clear Perspex cover and a wooden door. These were attached to tree trunks at approximately chest height and left in place year-round. By opening the wooden door we were able to count and identify invertebrates through the Perspex cover.

Monitoring lines were checked twice per year (spring and summer) from 2011–2014, after which we sampled only once per year (in summer).

Data analysis

We analysed the tracking tunnel data using an occupancy modelling approach (MacKenzie et al. 2006). Within a monitoring line, each tracking tunnel was treated as an independent survey so that each monitoring line yielded a detection history with five ‘occasions’ per season. For example, if a species was detected in the first and last tunnel in a line, this yielded a detection history of ‘10001’. We used a multi-season dynamic occupancy model to estimate site occupancy separately for each species in each area and sampling season. Probabilities of colonisation, extinction and initial occupancy were allowed to vary between treatment and non-treatment. Analyses were conducted using the ‘unmarked’ package in R (Fiske & Chandler 2011). Differences between treatments were inferred visually using 95% confidence intervals ('inference by eye'; Cumming 2009).

For invertebrates, we calculated the mean number per monitoring line of each taxon counted in the weta houses in each sampling season. Values for each season were compared between the treatment and non-treatment areas using paired t-tests.

Results

The kill traps captured cats, mustelids, hedgehogs, ship rats (*Rattus rattus*), rabbits and possums (*Trichosurus vulpecula*). Specialist control removed a large number of additional cats, as well as some ferrets (Table 1).

[Table 1 hereabouts]

The tracking tunnels detected a range of invasive mammals, including cats (*n* = 45 detections), stoats (*Mustela erminea*; *n* = 8), ferrets (*M. furo*; *n* = 5), weasels (*M. nivalis*; *n* = 2), hedgehogs (*n* = 218), rats (*Rattus* spp.; *n* = 142), mice (*Mus musculus*; *n* = 202) and possums (*n* = 47).

Because cats and mustelids (the primary targets of the predator control) were detected in low numbers, data for these species were pooled. Site occupancy estimates for cats and mustelids (Fig. 1a) and hedgehogs (Fig. 1b) were similar in both areas during the first sampling season, before predator removal began. However, wide 95% confidence intervals indicate high uncertainty in these initial estimates. After predator removal, site occupancy estimates for these species remained low in the treatment area, but increased in the non-treatment area. Low overlap in the 95% confidence intervals shows that these differences were statistically significant.

Site occupancy of rats was initially higher in the treatment area, and remained so for the duration of the study (Fig. 1c). Mice showed no difference in site occupancy between the two treatments (Fig. 1d). Skinks (Fig. 1e) were not detected in either area before predator removal began. However, skink site occupancy estimates increased rapidly in the treatment area, while remaining near zero in the non-treatment area. Due to low numbers of detections, we did not estimate site occupancy for possums.

[Figure 2 hereabouts]

Taxa observed in weta houses included tree weta (*Hemideina* spp.), cave weta (Rhaphidodophoridae), cockroaches (Blattodea), spiders (Araneae) and slaters (Isopoda). During the pre-treatment period, no invertebrates had yet occupied the weta houses. During subsequent seasons, counts of cockroaches were higher in the treatment area ($p = 0.001$). No differences were observed between treatments for any other invertebrate taxon (Table 2).

[Table 2 hereabouts]

Discussion

Our results show that extensive trapping in a pastoral landscape was associated with lower site occupancy of invasive predators, with apparent benefits for some native fauna. Detections of feral cats, mustelids and hedgehogs were all lower than in the adjacent non-treatment area, while detections of native skinks and cockroaches were higher. Invasive rats were more frequently detected in the treatment area; however, this was true before predator control began. While control of larger predators can lead to mesopredator release of rats (Ruscoe et al. 2011), this does not appear to have been the case here. The difference in rat occupancy estimates between the treatment and non-treatment areas remained consistent throughout the study.

While previous studies in New Zealand have also reported biodiversity responses to predator control (e.g. Norbury 2001; Reardon et al. 2012), our case is unusual in that it covered a larger area than most predator trapping programmes (but see Dilks et al. 2003; Whitehead et al. 2008), and was focused on a predominantly pastoral landscape. The spatial coverage of our trapping effort was made possible by placing traps in accessible locations where they could be checked rapidly by staff on an ATV. This maximised the number of traps that could be checked in a day, thereby increasing the area that could be trapped within the available budget. There may be a trade-off between maximising the number of traps set and optimising capture probability for each individual trap. Our approach may be effective when the management goal is to reduce predator populations over a large area. For example, extensive predator control in areas of mixed land-use may allow vulnerable native species to move between more intensively managed patches of remnant habitat, increasing functional connectivity of the landscape (Glen et al. 2013). More labour-intensive trapping methods may be preferable when the aim is to reduce predators to zero or near-zero density.

Another likely factor contributing to the successful suppression of predators in our programme was the use of a long-life lure. After comparing relative effectiveness of various lures (HBRC, unpublished data) meat-based baits were withdrawn from use, and were replaced with the rat-scented oil lure, which maintains its attractiveness for weeks or months. This allowed traps to be checked relatively infrequently while maintaining their attractiveness to predators. By contrast, fresh rabbit meat loses attractiveness after about a week (Garvey et al. 2016; Garvey et al. submitted).

Our network of kill traps also used mechanical signals that allowed the trapper to see whether a trap had been triggered without dismounting the ATV. This allowed more traps to be checked per day, reducing labour costs. Recent developments in wireless sensor networks (Jones et al. 2015) may further reduce costs of trapping by alerting managers when a trap is triggered.

Our study is also among the first to confirm the effectiveness of large tracking tunnels for detecting cats and mustelids (see also Pickerell et al. 2014). However, tracking tunnels detected low numbers of animals at both sites during the first sampling season. This may have been due to neophobia as the tunnels had been in place for only a few days. Detection rates were much higher after three months, suggesting that this was sufficient time for animals to become habituated to the tracking tunnels. It is likely that predator occupancy was under-estimated in the first sampling session; the apparent increase in predator occupancy in the non-treatment area may be an artefact of this. We believe predator occupancy at both sites during the pre-treatment period was likely much higher than our estimates suggest, and probably declined in the treatment area while remaining relatively stable in the non-treatment area. Future trials should compare the efficacy of large tracking tunnels with other tools for detecting predators, e.g. camera traps and wildlife detector dogs (Glen et al. 2014; 2016). Studies using large tracking tunnels should include a longer period of repeated sampling in the pre-treatment period to reduce the effect of neophobia and generate more reliable estimates of pre-treatment occupancy or abundance.

Another limitation of the present study is lack of replication. Although predator site occupancy was lower and native lizard detections increased in the treatment area, we cannot rule out the possibility that these changes were unrelated to predator control. Spatial replication is a cornerstone of experimental design (Underwood 1994), but is often unaffordable for large-scale adaptive management programmes such as ours. One solution would be to apply a treatment reversal (e.g. Innes et al. 1999) in which the treatment and non-treatment areas are switched. However, stopping predator control in our current treatment area would be contrary to the aims of this conservation intervention. Another alternative may be to apply a 'treatment extension' in which predator removal is applied to both areas. If similar results and outcomes were observed in the former non-treatment area, this would increase confidence that the observed changes were due to predator removal.

A secondary aim of our intervention was to decrease reinvasion by predators into the neighbouring Boundary Stream Reserve. We lacked resources to monitor predator abundance in the reserve. However, the potential benefits within Boundary Stream of predator control in the surrounding landscape warrant further investigation.

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Figure captions

Fig. 1. Map of the study area showing the treatment and non-treatment areas relative to Boundary Stream Reserve. The locations of kill traps are indicated by dots.

Fig. 2. Site occupancy (with 95% confidence intervals indicated by grey shading) of (a) cats (*Felis catus*) and mustelids (*Mustela* spp.), (b) hedgehogs (*Erinaceus europaeus*), (c) rats (*Rattus* spp.), (d) mice (*Mus musculus*) and (e) skinks (Scincidae) in the treatment and non-treatment areas during each sampling season. Predator removal began in the treatment area after the first sampling season.

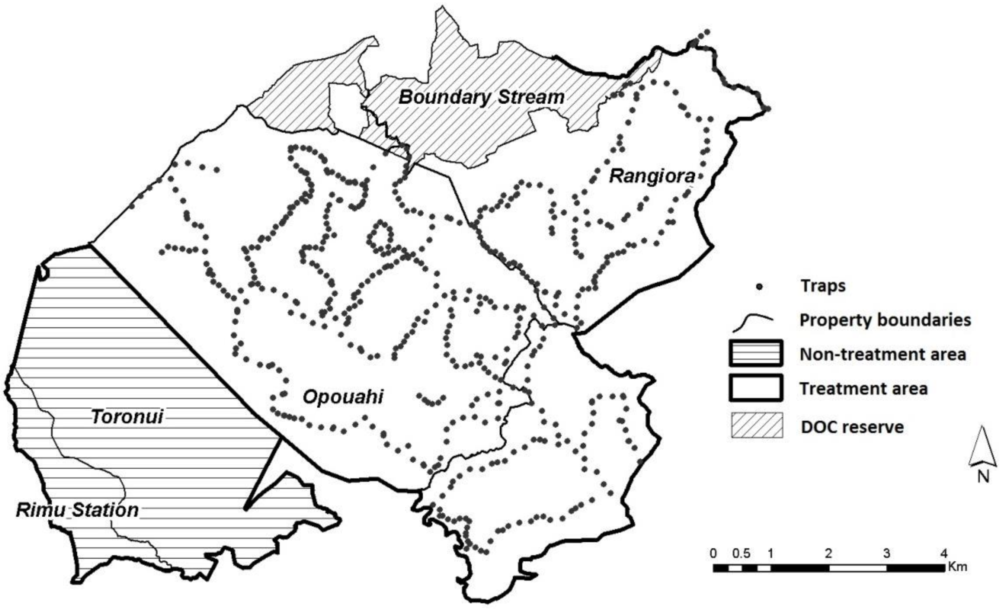
Table 1. Numbers of animals removed by kill trapping and specialist control on pastoral properties in Hawke's Bay, North Island, New Zealand, November 2011 – November 2015.

Species	Number removed	
	Kill trapping	Specialist control
Cat (*Felis catus*)	111	134
Ferret (*Mustela furo*)	51	21
Stoat (*Mustela erminea*)	90	
Weasel (*Mustela nivalis*)	2	
Hedgehog (*Erinaceus europaeus*)	748	
Rabbit (*Oryctolagus cuniculus*)	431	
Ship rat (*Rattus rattus*)	463	

Table 2. Mean numbers of invertebrates recorded per monitoring line in weta houses in the treatment and non-treatment area. *P*-values are for 2-tailed, paired t-tests.

Taxon	Mean count (± SD) per monitoring line		*p*
	Treatment	Non-treatment	
Cockroaches (Blattodea)	1.3 ± 0.7	0.3 ± 0.3	0.001
Spiders (Araneae)	1.5 ± 0.4	1.8 ± 0.6	0.21
Cave weta (Rhaphidodophoridae)	1.5 ± 0.7	1.0 ± 0.6	0.14
Tree weta (*Hemideina* spp.)	1.5 ± 0.5	1.9 ± 0.9	0.3
Slaters (Isopoda)	0.1 ± 0.2	0 ± 0	0.35

361 **Fig. 1**


Boundary Stream
Rangiora
Opouahi
Toronui
Rimu Station
Traps
Property boundaries
Non-treatment area
Treatment area
DOC reserve
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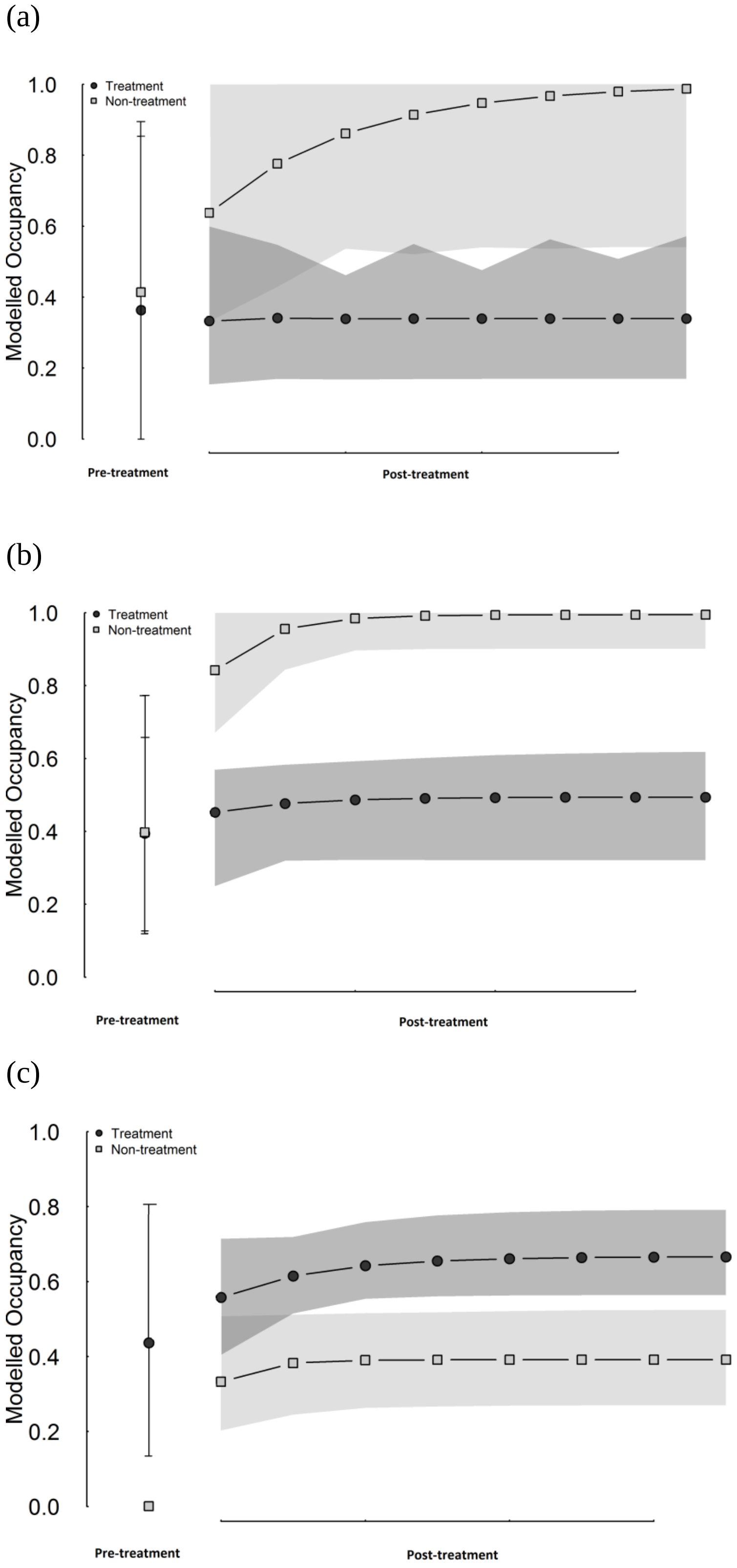
362

Fig. 2


(a)
Treatment
Non-treatment
Modelled Occupancy
1.0
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Pre-treatment
Post-treatment
(b)
Treatment
Non-treatment
Modelled Occupancy
1.0
0.8
0.6
0.4
0.2
0.0
Pre-treatment
Post-treatment
(c)
Treatment
Non-treatment
Modelled Occupancy
1.0
0.8
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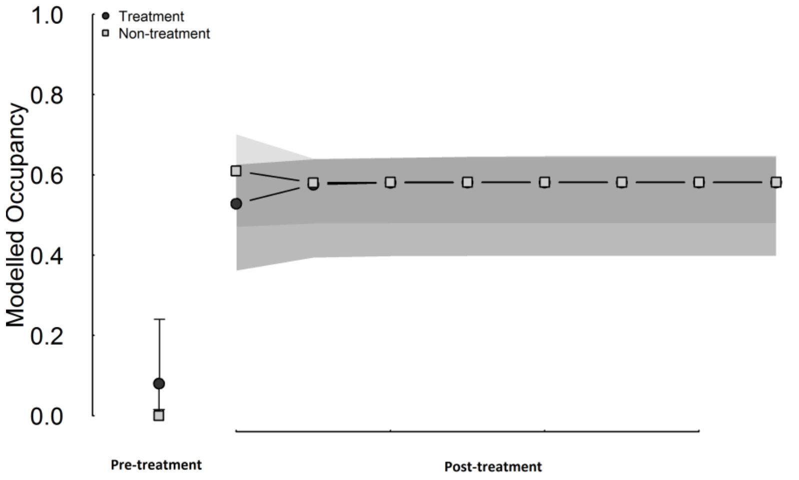
Pre-treatment
Post-treatment

(d)



Treatment
Non-treatment
Modelled Occupancy
1.0
0.8
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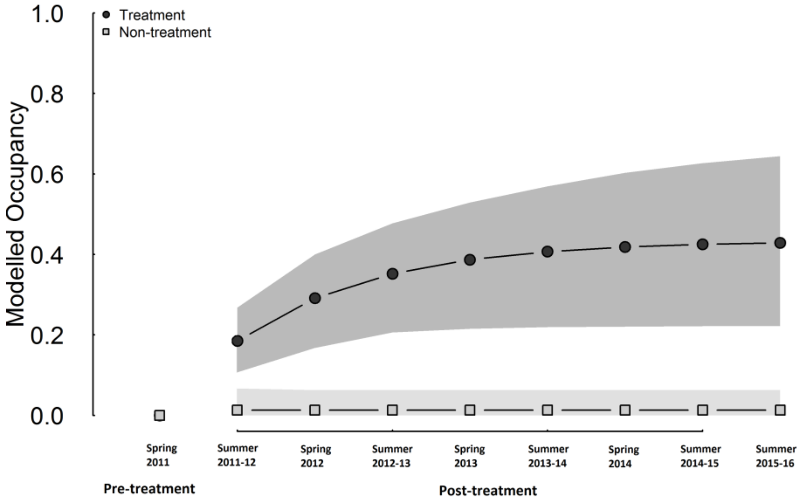
Pre-treatment
Post-treatment

(e)



Treatment
Non-treatment
Modelled Occupancy
1.0
0.8
0.6
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0.2
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Spring 2011
Summer 2011-12
Spring 2012
Summer 2012-13
Spring 2013
Summer 2013-14
Spring 2014
Summer 2014-15
Summer 2015-16
Pre-treatment
Post-treatment