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Costs of control of vertebrate predators by New Zealand regional and national agencies: July 2010–June 2015

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1 Client and scope

With a predator-free New Zealand, the costs of post-border predator control will be greatly reduced or eliminated. This should mean significant savings for many organisations and the nation. In early 2016, Landcare Research was engaged by Predator Free New Zealand (PFNZ) to produce a short report detailing the current funds spent on predator control by public agencies nationally. Specific requirements were to:

- focus on costs to the major national and regional predator-control agencies: regional and unitary authorities (RUAs), the Department of Conservation (DOC), OSPRI and the Ngā Whenua Rāhui programme
- cover possums, all rodents (ship/Norway/kiore rats and mice), mustelids (stoats, ferrets and weasels) and feral cats
- cover the direct cost of actual predator control (i.e. method that is being used) not necessarily the cost of best practice. The information from different agencies will subsequently be aggregated to give a total direct cost of control from all those agencies
- include all kinds of predator control (aerial and ground operations, etc.)
- focus on eradication and suppression data for the past 5 years
- include the area of treatment (by predator control method if possible).

Exclusions were:

- economic assessment of the benefits of large-scale predator control
- cost from large-scale predator control contractors (these are assumed to be captured by the key pest control agencies)
- funding received for predator control from 'outside' the specified agencies.
- regulatory costs
- overall research costs.

2 Introduction

The effects of introduced mammalian predators on New Zealand's biodiversity and its economic, social and cultural values are well documented (Diamond & Veitch 1981; Craig et al. 2000; Dowding & Murphy 2001; Innes et al. 2010). The gradual realisation of these impacts has led to the species being considered as pests and included in regional and national management strategies leading to the implementation of widespread programmes aimed at their suppression, eradication, and exclusion from vulnerable landscapes and ecosystems across the country. Most control of invasive mammals in New Zealand is aimed at reducing browse damage to native vegetation and production crops, reducing predation on native species, and controlling disease spread via control of wildlife vectors (Clayton & Cowan 2010).

3 Focal predator species

The brushtail possum (*Trichosurus vulpecula*) is primarily a herbivorous arboreal marsupial that was introduced to New Zealand from its native Australia in 1858 to establish a fur trade and has since become widespread and abundant (Cowan 2005). It has been estimated that there are now over 30 million possums in New Zealand, approximately 60% of which are found in native forest habitat (Warburton et al. 2009). Possums damage crops, carry disease, and cause major changes in native ecosystems (Clout 2006). As a result there are now efforts to control possum populations over approximately 40% of New Zealand. Possums are the main wildlife host of bovine tuberculosis (TB), a zoonotic disease that threatens market access for New Zealand's NZ$16.0 billion beef, dairy and venison export industries (MAF 2010). In addition, DOC, regional councils, community conservation groups, and private landowners control possums to reduce their impacts as folivores on forest composition and structure (including prevention of possum-induced forest canopy collapse) and also as predators of native birds and insects. Control over large areas is achieved by ground or aerial application of toxic baits or by trapping (Warburton & Livingstone 2015).

Domestic cats (*Felis catus*) were introduced into New Zealand by early European colonists and feral populations were first noted in the mid-19th century. Cats are carnivores and, as such, are very capable hunters of small prey typically of body mass ≤100 g, particularly rodents and juvenile rabbits (*Oryctolagus cuniculus*). In spite of this apparent preference for small mammals, cats are opportunistic predators and other small animals will be preyed upon where available. Birds are also eaten frequently, as are small reptiles and invertebrates, although the relative proportions of each prey type varies according to local availability. In New Zealand, feral cats have been associated with significant impacts on native bird populations, particularly on islands (Buller 1905; Fitzgerald & Veitch 1985; Veitch 2001) or where the birds nest on the ground (Karl & Best 1982; Dowding & Murphy 1993; Sanders & Maloney 2002) and with declines in native lizard populations (Stack 1874; Thomson 1922). If local populations of their main prey decline through control or disease, cats may increase their predation on native species (Norbury 2001). Feral and farm cats have been associated with the transmission and spread of toxoplasmosis to livestock. Toxoplasma infection is responsible for significant abortion/resorption of foetuses, particularly in pregnant sheep, goats and pigs on first infection, leading to considerable economic loss to farmers (Hopkins 2013). Control of cats is primarily through trapping supplemented by shooting. Cats are also susceptible to secondary poisoning when consuming rodents or rabbits that have ingested toxic baits, particularly brodifacoum (Gillies & Fitzgerald 2005).

Three species of mustelids are established in New Zealand, all of which were introduced by European settlers from the 1870s onwards in an attempt to exert a natural control over burgeoning rabbit populations. Although the three species vary in their distributions, habitat preferences, and behaviour, all have been implicated in significant impacts on native wildlife (King 1984). The largest mustelid in New Zealand, the feral ferret (*Mustela furo*) is most commonly found in pasture, rough grass and scrubland in association with its primary rabbit prey (Norbury et al. 2002). Ferret predation has been recorded on a range of native species including kiwi (*Apteryx mantelli*), penguins, burrow-nesting Procellariform seabirds, ground-nesting shorebirds and lizards (reviewed in Clapperton & Byrom 2005). Ferrets also play a role in the transmission of bovine TB, primarily through their habit of scavenging

tuberculous carrion although their naturally low population densities generally, but not always, preclude maintenance of the disease without continued reinfection (Byrom et al. 2015; Warburton & Livingstone 2015).

Stoats (*M. erminea*) are widespread across New Zealand's two main and nearer inshore islands and are found in most habitats, although most commonly in forest. They have been identified as key agents in the decline of a range of endemic bird species, including brown kiwi (*A. australis*), mohua (*Mohoua ochrocephala*), and kaka (*Nestor meridionalis*; McLennan et al. 1996; O'Donnell et al. 1996; Wilson et al. 1998). In beech (*Nothofagus*) forests, predation on native birds is correlated positively with stoat population dynamics. Heavy beech seedfall events ('masts') lead to population irruptions of rats and particularly mice (*Mus musculus*), which are stoats' primary prey in this system, supporting five-fold increases in stoat abundance and leading in turn to similar increases in predation pressure on ground- and hole-nesting native birds (King 2002).

The smallest New Zealand mustelid, the weasel (*M. nivalis vulgaris*), is less common and its distribution is much patchier than its two larger relatives. It is generally confined to areas of heavy ground cover, particularly in forests, and only on the two main islands of New Zealand (King 2005). Although weasels are likely to have a similar prey spectrum to stoats, King (2005) notes that accurate assessment of their impacts on native species is virtually impossible because they are much less common than stoats, albeit easily confused with them. They are therefore likely to have lesser impacts except where they co-occur with native prey of an appropriate size, such as a localised population of small lizards. Control of all three mustelid species is predominantly by trapping although, like cats, they are susceptible to secondary poisoning.

There are four species of murid rodents in New Zealand. The first to arrive was the kiore, or Polynesian rat (*Rattus exulans*), which arrived with Māori over 700 years ago and, accordingly, has traditional value to some northern iwi, both as a food item and an indicator of environmental conditions (Haami 1994). Kiore are often regarded as the least damaging of the three introduced rat species, partially by virtue of their being the smallest, but there is evidence that they have negative impacts on indigenous plants (Campbell & Atkinson 1999), insects (Green et al. 2011), reptiles (McCallum 1986), and smaller seabirds (Pierce 2002; Imber et al. 2003). Although once widespread across New Zealand, kiore are now confined to a few offshore islands and small localised areas of the South Island (Atkinson & Towns 2005).

Two rat species arrived with European colonists, the larger of which, the Norway rat (*R. norvegicus*) was initially the more common before its range contracted, possibly due to predation by stoats or competition from ship rats (*R. rattus*). Norway rats are now widely, but patchily, distributed and are primarily commensal with non-commensal populations preferring habitats associated with water bodies. They are mainly terrestrial foragers and therefore represent a risk to ground- and burrow-nesting birds and other small terrestrial species including endemic invertebrates. Ship rats are widespread in a wide range of habitat types on the three largest islands, but are most abundant in lowland native forest (Innes 2005). They are excellent climbers and can forage readily both terrestrially and in trees. They can thus prey on a wide range of native species and have been recorded preying on the eggs and chicks of kōkako (*Callaeas wilsoni*), kererū (*Hemiphaga novaeseelandiae*),

mohua, and other small forest birds. During the 1960s, ship rats were responsible for the decline or extirpation of populations of nine native birds, one native bat and a number of large invertebrates on Big South Cape Island (Bell 1978).

House mice, like the larger rat species, arrived accidentally on the ships of European colonists in the early-mid 19th century. They are now widespread on the main and many offshore islands around New Zealand and are found in most drier habitats where there is good ground cover (Ruscoe & Murphy 2005). Mice have both direct and indirect impact on biodiversity values. As predators, they consume native invertebrates, often in large numbers (Bull 1967) and both direct and indirect evidence has shown that they can have significant impacts on indigenous lizards (Newman 1994; Norbury et al. 2014). As noted above, heavy seed masts, particularly in beech forests, but also in podocarp forests and tussock grasslands, can lead to short-term rapid increases in mouse numbers, which in turn support increases in stoat numbers and subsequently higher predation pressure on native fauna when mouse numbers eventually decline.

All four rodent species are controlled primarily by the application of toxic baits, either by hand, in bait stations or sown aerially where difficult terrain precludes the use of ground-based methods or where large areas must be treated rapidly in response to a mast event.

4 Agencies

4.1 OSPRI

A large component of agency-led predator control in New Zealand is aimed at managing the wildlife vectors of bovine tuberculosis (TB), primarily brushtail possums and, to a lesser extent, feral ferrets. Since July 2013 this has been managed by OSPRI New Zealand Limited, an amalgamation of the Animal Health Board (AHB) and National Animal Identification and Tracing Limited (NAIT). OSPRI is funded from Crown revenue (via Vote Primary Industries and Food Safety), stock slaughter levies, and the dairy and meat industries. Pest vector control is carried out under the TBFree programme that was established under the AHB and combines in-herd disease management and control of stock movement from high TB risk areas with control of wildlife disease vectors under the Bovine TB National Pest Management Plan.

Possums are the main focus of TBFree pest management efforts, which aim to reduce possum densities to very low levels consistently across the landscape and maintain them there for at least 2 years so that TB drops out of the local population. This is achieved mainly through the use of ground-laid toxins (Feratox®, brodifacoum, 1080, and cholecalciferol), wide-scale use of leg-hold traps, and occasional use of kill-traps. Where ground control is impractical or not cost-effective, helicopter-delivered aerial application of sodium fluoroacetate (1080) baits is used.

Although feral ferrets are not primary control targets, they, along with pigs, are culled because of their utility as ‘sentinels’ of TB persistence in an area. Ferrets are culled by using

live- and kill-traps and the carcasses tested for signs of TB infection with the findings used to indicate where more widespread possum control might be required.

4.2 The New Zealand Department of Conservation

The Department of Conservation (DOC) is the national government agency responsible for the management of natural and historic assets on approximately 8.6 million hectares of Crown land. Pest control by DOC contributes primarily to its intermediate outcome: "The diversity of our natural heritage is maintained and restored." This incorporates the 10-year 'stretch goal': "50% of New Zealand's natural ecosystems are benefitting from pest management" (Department of Conservation 2015a). These benefits are intended to accrue to nationally threatened and iconic species and ecosystems, many of which suffer the impacts of introduced mammalian predators. Pest management by DOC varies from small, intensive management of reserves and key species to more widespread control of possums and rats in large tracts of native forest. This means that control is carried out over large areas of New Zealand; for example, in 2009, approximately 1.3 million hectares received some form of predator control (Parliamentary Commissioner for the Environment 2011) while in 2014/15, possums were controlled over a similar area (Department of Conservation 2015b).

Control of mustelids and feral cats by DOC is achieved using a variety of kill-traps, while rodents and possums are targeted using ground-set (in bait stations) and aerially sown toxins. These operations can represent ongoing management or can occur in response to changing ecological conditions. For example, during 2014/15, 27 targeted aerial 1080 operations were carried out, covering more than 600,000 hectares, in response to unusually heavy seeding ('masting') of native trees, which would have led to irruptions of seed-eating rodents and possums and subsequent increases in stoats due to the greater availability of their rodent prey. DOC also contributes pest control on Crown lands where they are adjacent to land under regional council pest management plans in response to the 'good neighbour' obligations implemented in the 2012 revision of the Biosecurity Act (1993). These were designed to address the external effects of pests spilling over onto adjacent properties and causing unreasonable costs to the occupier of that land.

4.3 Ngā Whenua Rāhui

Ngā Whenua Rāhui is a contestable Ministerial fund aimed at protecting indigenous biodiversity on Māori land. The fund is administered by a committee who act as kaumātua for projects that are developed and run in association with DOC. As the focus is on private land, landowners (iwi or hapū groups) are involved in developing the project from the start, and objectives are set based on spiritual and cultural values as well as biodiversity outcomes. An annual plan is developed for each project that outlines the expected benefits from the activities, an assessment of benefits relative to costs, and how the proposed management will be integrated with the landowners' other activities. Ongoing pest control, monitoring and management are fundamental to many Ngā Whenua Rāhui conservation projects. Plans for pest control set targets in terms of both outcomes and outputs (post-treatment pest levels) and all pest management work is undertaken in accordance with

national standards established by DOC. The DOC Annual Report 2014/15 (Department of Conservation 2015b) noted that, as of June 2015, over 230 sites covering over 170,000 hectares across New Zealand were protected under the scheme.

4.4 Regional and unitary authorities

New Zealand has 11 regional councils and a further six unitary authorities, all of which develop regional pest management plans (formerly 'strategies') in which declared pests of significance to the region or district are listed. Plans are adopted after public consultation and conform to directions in the Biosecurity Act (1993; amended 2012) and the National Policy Direction for Pest Management (2015). Plans also have to be approved by the Minister and meet one or more of the following goals:

- exclusion (preventing the establishment of a pest in an area)
- eradication (reducing the infestation level of a pest to zero levels in an area in the short or medium term)
- progressive containment (reducing or containing the distribution of the pest to an area over time)
- sustained control (ongoing control of the pest to reduce its impact and its spread)
- protecting any other values in place (e.g. cultural or biodiversity).

Pests are generally classified according to the relevant management goal, which is, in turn, based on impact, distribution and control feasibility for each species. Pest classification within a plan reflects the species' status within that region, so a species may occur in some regional plans, but not in others and may have different classifications between plans. The council is required to prepare an operational plan within 3 months of the strategy being adopted. It is then required to make a report on the plan after each financial year. Authorities vary in terms of the amount of mammalian pest management that they undertake themselves: this can range from none or supporting community groups and landowners, acting only as contractors to national agencies (e.g. OSPRI), region-wide control or intensive multi-species management at sites of high value. Not all listed pests are actively managed; for example, in 2005/2008 only 52% of listed animal pest species were targeted for control by council operations, of which possums were the most frequently controlled (Clayton & Cowan 2009). The majority of active mammalian pest control carried out by councils is ground-based, although aerial 1080 application may be used if conditions dictate.

5 Methods

5.1 Survey

In developing this work, we were aware that the agencies with whom we were engaging were highly likely to collect, record, and manage costing data differently. We therefore developed a common survey template in a Microsoft Excel spreadsheet to guide and standardise data collection. The template was reviewed both internally and externally to achieve a balance between collecting sufficient detail and ensuring compliance before being distributed to agencies. The survey was distributed to all mainland regional councils and unitary authorities with current pest management strategies, to Ngā Whenua Rāhui managers and to the DOC Outcomes Management Office. We asked for details of pest programmes, most importantly:

- programme name
- reason for control
- year (was this a 'mast' year?)
- whether the programme was landscape- or site-based
- area over which control was applied
- target taxa (cat, possum, mustelid, rat, mouse)
- method (ground – traps; ground – toxin; aerial)
- monitoring type (contractor performance; output; outcome).

We also asked whether agencies could supply detailed cost breakdowns for component costs of each programme, such as those associated with contractor fees, staff time, transport, monitoring and other operational expenditures. The survey included detailed instructions for entering data and requested cost information for the 2010/11 to 2014/15 financial years.

Our initial enquiries to OSPRI revealed that programme cost data had already been collated internally. We requested, and were granted access to, these data minus any information that might be considered commercially sensitive.

5.2 Data management and analysis

Not all councils incur costs from controlling predators: the Chatham Islands, Tasman-Nelson, and West Coast regions do not carry out mammalian predator control, and the Otago Regional Council controls possums only as a contractor to OSPRI, with associated costs included in the OSPRI data. We received data from the remaining 12 regional and unitary authorities that carry out direct control of introduced mammalian predators. The level of detail in the information provided by those agencies varied considerably from a single aggregate figure for a programme within a financial year to detailed cost breakdowns for a large number of programmes within each year. As a minimum, all agencies indicated the

targeted pests within each programme and the general methods used and provided an estimate of the area of control. In follow-up communications with council staff, the reasons for low levels of detail in some data sets were primarily that much of the information was not readily available or had not been recorded. Staff turnover and the associated loss of institutional knowledge was also a factor.

DOC staff used the Department's planning system to extract planned budgets from approved work programmes for the last 5 years. The underlying data structure changed over the time period of interest as DOC moved from a functional (i.e. output-based) approach to pest management to an integrated site management approach. Data represented programme budgets as DOC does not record actual expenditure at the pest-specific level. The budgeting approach used is based on general ledger accounting codes that were consistent over the period of interest; however, as the underlying management model (functional approach vs. key sites) changed over the period, the queries to extract budget data for the pests identified varied between years. In short, the type and format of data varied between years.

For all years before 2014/15, DOC data on targeted pests and control area were merged from separate spreadsheets. The 2014/15 data did not require this step, as area was already included alongside the pest information. DOC programmes are described in terms of a 'prescription' based in part on a combination of codes to identify the programme and site and a general 'activity' such as pest control, weed control, monitoring or fire management. A separate 'method' classification provides more detail on what was done at a site. We used these classifications to extract budget data from those programmes where activities involved vertebrate pest control and associated operational planning and where methods included kill-trapping, aerial bait application or the use of relevant vertebrate pest toxins using ground-based methods. Each worksheet then had columns added to indicate the occurrence or presence/absence of the type of pest control (pesticide – aerial, pesticide – ground, ground traps), monitoring (outcome, output), and for each of the pest species of interest (cat, possum, ferret, stoat, weasel, rat, mouse). We used a binary coding system to identify when programmes included an activity and/or pest of interest. Pivot tables were then used to summarise the data from each year and bring all the information associated with a programme on to one line summarising the operation, methods used, monitoring undertaken, pests targeted, and costs so that DOC data were in a format that was consistent with other agencies' data. The data were then filtered to remove operations that did not involve the pests of interest, and these data formed the inputs for the subsequent analysis. Data from Ngā Whenua Rāhui programmes, although administered by DOC, were received separately and corresponded to the format in our template so did not require the same manipulation.

OSPRI cost data included information on all general cost categories associated with programmes. From these cost categories, we extracted only those associated with direct control of mammalian predators.

Because the quality and quantity of information supplied to us varied across the agencies surveyed we needed to identify the highest common level of resolution at which we could aggregate and summarise all data to conform to the scope required by PFNZ. This required us to apply a series of filters and assumptions:

(i) Costs are assumed to be the direct costs of controlling the focal taxa plus any specified costs associated with operational planning. Other overheads are not included.

(ii) As the focus of the review was on the costs of direct control, outcome monitoring costs were excluded. This was a straightforward process for DOC and OSPRI data, but, although most councils indicated whether outcome monitoring was carried out in association with predator control, few gave details of the costs. Where costs were specified, they made up a small proportion of total programme costs (c. 5%) and were often shared with community groups. We therefore excluded specified outcome monitoring costs from council data where we could, but acknowledge that some programme cost estimates may be subject to a small positive bias.

(iii) Co-funding from outside an agency was excluded from all control costs to avoid double reporting, except where this was an explicit co-funding relationship between a regional authority and a local authority within that region. Co-funding of predator control via engagement with community groups is the subject of a separate survey.

(iv) Many programmes targeted multiple pest species, but costs describe the programme as a whole. To estimate costs of controlling each taxon we made the simplifying assumption that the cost per taxon within a programme was the total cost divided by the number of taxa named as targets. In defining categories of taxa, we aggregated ferrets, stoats, and weasels where any were identified as programme targets, into a single 'mustelid' category. This is because the same kill-trapping methods are used against all mustelid species.

(v) Where ground-based control methods are used, data were insufficient to discriminate between trapping costs and those associated with the use of toxic baits. We suggest this is because a programme budget is set and field operations attempt to achieve the best combination of control and coverage within that pre-set budget. We therefore summarise method costs as either aerial or ground-based.

(vi) Estimates of the area of control are assumed to represent a minimum in each category. This is because data were not available for all programmes. For DOC data, despite the department's planning and reporting business rules, area of management data were not recorded for all animal pest pressure/activity/methods. In some offices this work was treated as a low priority and the data set is incomplete. This means that approximately 36% of departmental programme costs had no data on the area managed in 2010/11; this has since improved to an approximately 14% under-reporting rate in 2014/15. Conversely, in some cases the entire area office/conservancy boundary was selected to represent the programme's extent, which may have over-inflated the estimated area of control. To estimate areas of control under DOC programmes, we used only those area values from programmes where there was an associated cost of controlling predators, as outlined above, in any financial year. Similarly, a number of RUAs noted that control areas were estimates rather than precise values. Control may also not be distributed evenly within a designated area because of habitat variation within that area. This will also vary depending on the reporting agency; DOC control will be based, generally, on areas of pest-specific habitat, whereas RUAs and OSPRI conduct much of their control on developed land so

10,000 hectares of control might only contain 2000 hectares of possum habitat scattered through the block.

(vii) Where the reported area of control includes more than one targeted taxon, the same area is applied to each taxon equally and independently. We aggregate and summarise areas of control by taxon, but estimates for different taxa could not be summed as this would over-inflate the total estimated area of control. We also report areas over which predators were subject to ground or aerial control. In programmes where both methods were used, we were able to obtain estimates of the areas to which each method was applied from managing agencies. These are assumed to be separate and not to overlap significantly.

6 Costs of predator control

For the first 4 years of our survey period (2010/11 to 2013/14) the total annual expenditure on controlling possums, cats, mustelids and rodents by the major national control agencies in New Zealand was fairly consistent (coefficient of variation, CV, = 3.25%), ranging from NZ$ 54.3 million to 58.4 million (Fig. 1). In 2014/15, the total cost increased to just over NZ$ 66 million, with the increase driven primarily by DOC's investment of an extra NZ$ 10.2 million in the Battle for our Birds (BFOB) programme, which aimed to mitigate the effects of a mast year on rat and possum populations in native forests.

Across all years surveyed, OSPRI's TB-free programme aimed at reducing and maintaining low densities of the wildlife vectors of the disease made up most national predator control expenditure. In 2010/11 to 2013/14, this typically accounted for 64–68% of the national total with both DOC and RUA expenditures representing 15–20% during that period. The investment in BFOB meant that DOC's relative contribution rose to 31% of the national total spend in 2014/15. Ngā Whenua Rāhui costs were relatively small compared with the other agencies surveyed, contributing c. 1% of the total national expenditure across all years.

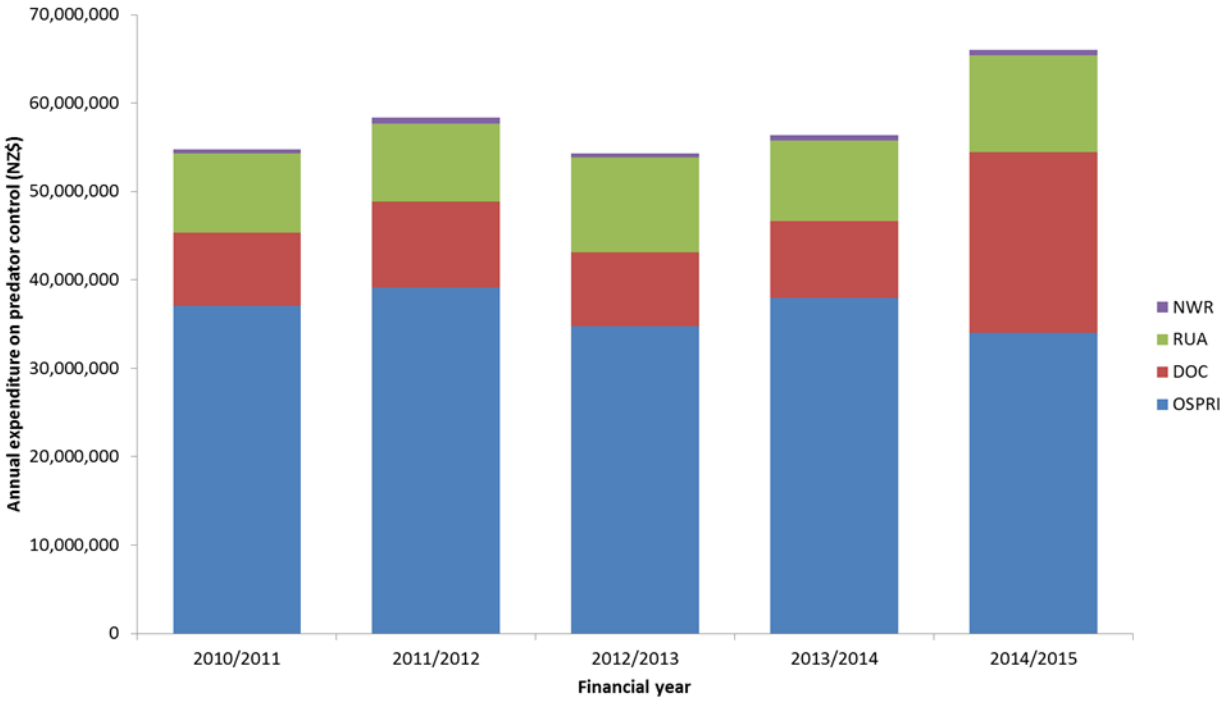

Figure 1. Total estimated annual expenditure on control of feral cats, possums, mustelids, and rodents in New Zealand, 2010/11 to 2014/15 showing contributions of national agencies OSPRI, the Department of Conservation (DOC), regional and unitary authorities (RUA), and Ngā Whenua Rāhui (NWR).

Breaking costs down by taxon shows that possum control accounted for 80% or more of the national total expenditure across all years surveyed (Fig. 2). Mustelid and rat control costs were similar, each making up approximately 5–7% of annual expenditure, except for 2014/15, when BFOB's focus on rat control led to targeted costs of c. 19% of the national total.

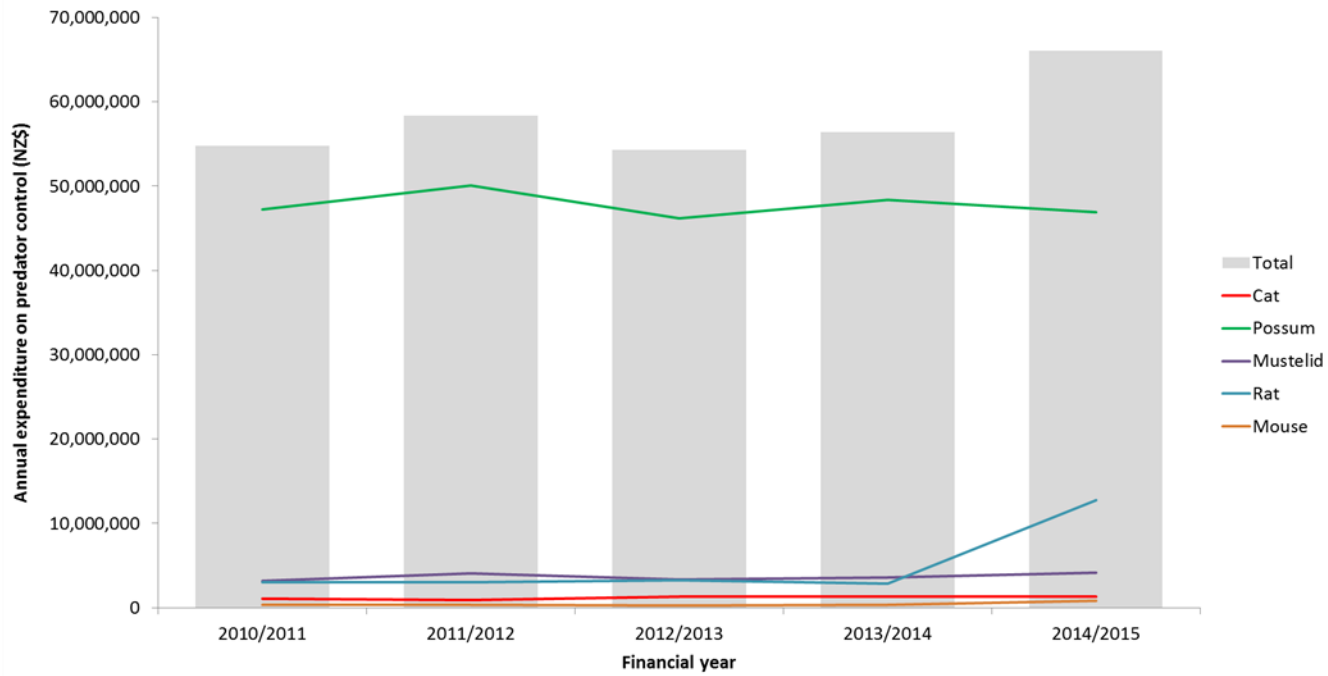

Figure 2. Total estimated annual taxon-specific expenditure on control of feral cats, possums, mustelids, and rodents by national agencies in New Zealand, 2010/11 to 2014/15.

Ground-based control (using traps and toxic baits) accounted for between 70% and 84% of total predator control expenditure during the 5 years surveyed (Fig. 3). The greatest investment in aerial control was in 2014/15 when just over NZ$ 20 million (c. 30%) was spent. This represented the sustained OSPRI control plus the additional aerial component of BFOB.

Even allowing for incomplete and potentially biased or inaccurate data in the provided estimates of the areas over which predators were controlled, possum control represents by far the greatest spatial component (c. 85%) of national predator control efforts (Fig. 4). Much of this made up of OSPRI (5–7 million ha/yr.) and combined RUA (1.5–2.2 million ha/yr.) programmes. The spatial extent of control of other predator taxa was consistently an order of magnitude lower than that of possum control reflecting the more site-focussed efforts against many of the other taxa.

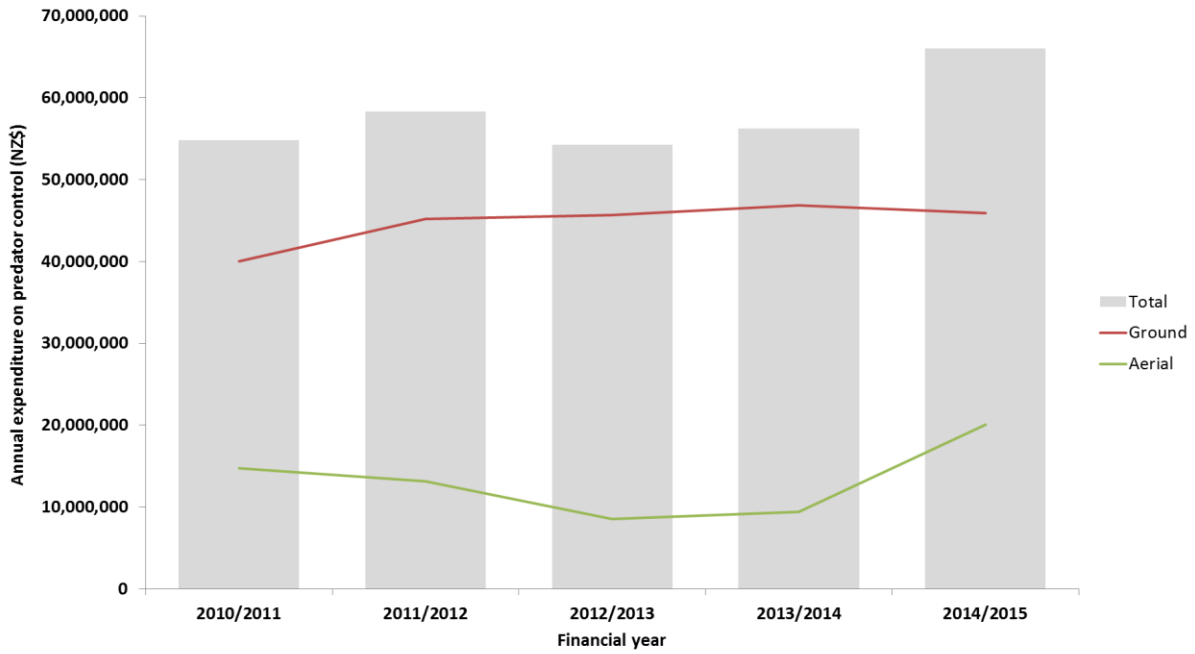

Figure 3. Total estimated annual expenditure on control of mammalian predators by national agencies in New Zealand, 2010/11 to 2014/15 showing contributions of ground-based vs. aerial control methods.

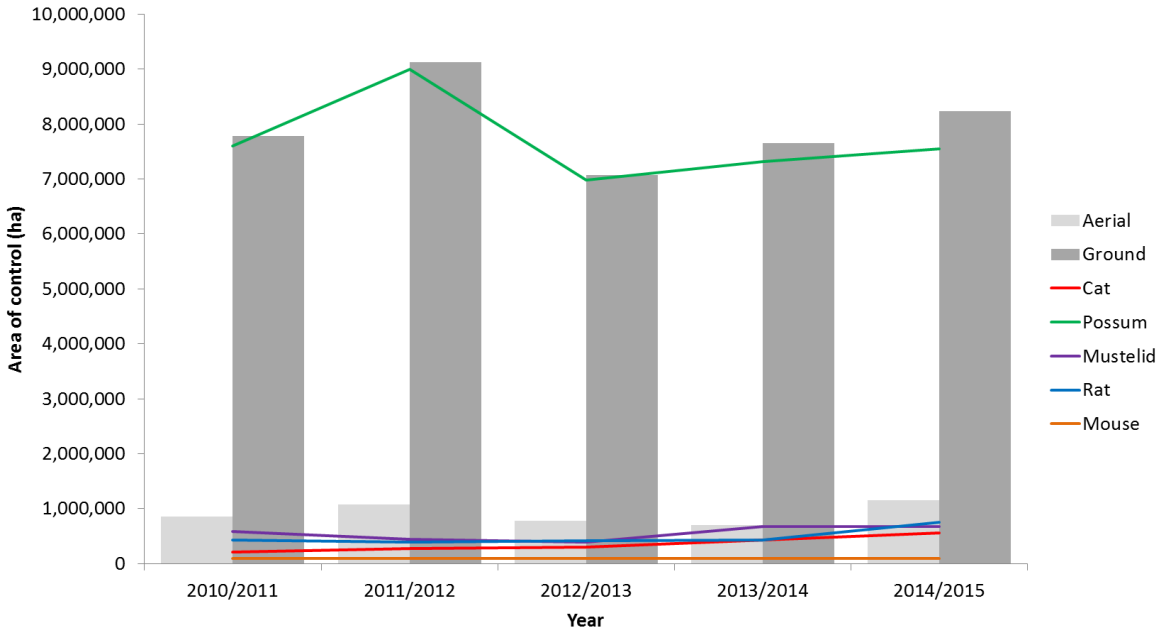

Figure 4. Estimated total national extent of control of mammalian predators by national agencies in New Zealand, 2010/11 to 2014/15 by method and taxon. Note: source data were incomplete and may be subject to a range of biases, so interpretation and subsequent inference should take this into account.

There are few contemporary or historic estimates of the funds expended on controlling mammalian predators in New Zealand with which to compare our findings. A number of reports have estimated the total costs of pest, or pest and weed, control based on gross expenditure by agencies, but none have focussed solely on the taxa targeted in this report. For example, Giera and Bell's (2009) review of the economic costs of pests to New Zealand

used Bertram's (1999) classification of 'defensive expenditure' to include the costs of quarantine and border control, surveillance, research, control and eradication of weeds and pests. The authors estimated some component costs within that wider definition. By surveying RUAs, they estimated that the cost of controlling all animal pests on council-managed land was approximately NZ$ 20.4 million in 2008. Similarly, they note that the cost to control all weeds and pests on Crown conservation estate was NZ$ 76 million. There is no further breakdown of costs by taxon. New Zealand is not alone in this regard; similar estimates of the costs of controlling vertebrate predators in Australia are rare and vary both in the level of detail and in what costs are included. For example, Reddiex et al. (2006) estimated national annual expenditure on animal pest control from interviews with representatives of primary pest control agencies, but only included labour costs and not operational expenditure.

We therefore have few comparisons with which to validate our estimates. Data collection and accounting processes varied across all the agencies surveyed in this work, so there will clearly be some inconsistencies in estimation of costs and in definition or classification of programmes. As noted above, some data simply were not available and where estimates were provided the level of detail varied considerably. Even within DOC the underlying management model evolved during the period of interest and therefore the structure and quantity/quality of data made available to us varied. We draw some consolation in noting that our estimate of the costs of controlling mammalian predators by DOC tracks the budget allocation for 'management of natural heritage' within Vote Conservation at a constant 5–6% for the first 4 years of our survey, only increasing to c. 13% of that allocation during the BFOB year of 2014/15 (http://www.treasury.govt.nz/budget/votehistory/conser/ accessed 22 July 2016).

Our estimates of the costs of controlling mammalian predators should be viewed as baseline minimum values against which subsequent estimates can be compared. They are not the total costs to New Zealand of controlling these taxa as much predator control is carried out by sanctuaries, community groups and by local and city councils across the country. The costs of this control were outside the scope of this report. The estimates will also be subject to bias and some unknown degree of inaccuracy. In simple terms, the surveyed agencies' function, in this context, is to control pests to the best of their abilities under clear budgetary constraints. They did not collect and store data with the intent of contributing to a survey such as this. It may be useful, therefore, to think carefully about likely data needs should there be a need to repeat this work at regular intervals in the future and to work with the agencies involved to ensure that data collected are of a consistent standard and resolution.

7 Acknowledgements

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Appendix 1 – Details of control cost and area.

All costs are in NZ$. Acronyms for agencies: DOC = Department of Conservation; RUA = regional and unitary authorities; NWR = Ngā Whenua Rāhui

Total annual costs broken down by agency ($)					
Year	OSPRI	DOC	RUA	NWR	Total
2010/2011	37,096,789	8,219,102	9,024,323	468,471	54,808,685
2011/2012	39,166,562	9,745,980	8,739,501	714,179	58,366,222
2012/2013	34,760,402	8,345,712	10,745,624	481,851	54,333,589
2013/2014	37,987,919	8,641,806	9,177,145	575,725	56,382,595
2014/2015	34,000,995	20,502,624	10,898,468	652,461	66,054,548

Total annual costs by taxon ($)					
Year	OSPRI	DOC	RUA	NWR	Total
Cats					
2010/2011	0	706,978	339,338	0	1,046,316
2011/2012	0	523,922	365,450	0	889,372
2012/2013	0	813,065	479,560	0	1,292,625
2013/2014	0	852,960	428,922	0	1,281,882
2014/2015	0	850,664	489,045	0	1,339,709
Possums					
2010/2011	36,568,694	3,890,658	6,686,744	117,118	47,263,214
2011/2012	39,040,651	3,977,611	6,762,366	293,108	50,073,736
2012/2013	34,760,402	3,374,633	7,805,700	228,595	46,169,330
2013/2014	37,959,919	3,106,569	7,046,528	260,241	48,373,257
2014/2015	33,907,478	4,209,618	8,372,010	404,900	46,894,005
Mustelids					
2010/2011	528,095	2,095,895	421,005	117,118	3,162,112
2011/2012	125,911	3,351,518	456,373	140,357	4,074,159
2012/2013	0	2,666,898	572,315	84,419	3,323,632
2013/2014	28,000	2,932,826	510,708	105,161	3,576,695
2014/2015	93,517	3,400,170	598,128	82,521	4,174,336

Total annual costs by taxon ($) (*cont.*)					
Year	OSPRI	DOC	RUA	NWR	Total
Rats					
2010/2011	0	1,430,659	1,482,917	117,118	3,030,693
2011/2012	0	1,819,711	1,057,825	140,357	3,017,893
2012/2013	0	1,426,936	1,788,515	84,419	3,299,869
2013/2014	0	1,658,524	1,074,188	105,161	2,837,873
2014/2015	0	11,400,616	1,307,086	82,521	12,790,223
Mice					
2010/2011	0	94,912	94,320	117,118	306,349
2011/2012	0	73,219	97,486	140,357	311,062
2012/2013	0	64,180	99,534	84,419	248,132
2013/2014	0	90,928	116,798	105,161	312,887
2014/2015	0	641,555	132,199	82,521	856,274

Annual costs by method ($)

Year	RUA		DOC		OSPRI		NWR		Total	
	Ground	Aerial	Ground	Aerial	Ground	Aerial	Ground	Aerial	Ground	Aerial
2010/2011	8,849,177	175,146	6,306,813	1,912,289	24,422,543	12,674,246	468,471	0	40,047,003	14,761,681
2011/2012	8,619,012	120,489	6,987,062	2,758,918	28,904,160	10,262,402	714,179	0	45,224,414	13,141,809
2012/2013	10,398,445	296,071	6,447,368	1,898,345	28,376,716	6,383,685	481,851	0	45,704,380	8,578,101
2013/2014	8,765,675	325,511	7,116,295	1,525,511	30,413,275	7,574,644	575,725	0	46,870,970	9,425,666
2014/2015	10,622,824	275,644	6,716,562	13,786,062	27,952,947	6,048,047	652,461	0	45,944,795	20,109,753

Area of control by taxon (ha)					
Cats					
Year	OSPRI	DOC	RUA	NWR	Total
2010/2011	0	64,775	139,763	0	204,538
2011/2012	0	136,300	131,383	0	267,683
2012/2013	0	146,812	150,079	0	296,891
2013/2014	0	259,012	166,025	0	425,037
2014/2015	0	397,175	155,746	0	552,921
Possums					
2010/2011	5,754,028	295,492	1,540,872	2,979	7,593,371
2011/2012	6,947,860	412,103	1,630,716	10,535	9,001,215
2012/2013	4,876,794	256,292	1,829,285	10,764	6,973,135
2013/2014	4,906,809	384,674	2,023,205	6,608	7,321,296
2014/2015	5,035,741	257,570	2,234,964	18,474	7,546,749
Mustelids					
2010/2011	172,599	261,361	146,063	2,979	583,002
2011/2012	107,147	194,244	138,015	2,979	442,385
2012/2013	26,128	207,214	156,915	3,208	393,466
2013/2014	21,437	480,498	172,751	2,979	677,665
2014/2015	35,591	468,057	162,810	2,929	669,387
Rats					
2010/2011	0	147,545	275,526	2,979	426,049
2011/2012	0	212,874	173,803	2,979	389,655
2012/2013	0	160,428	251,320	3,208	414,956
2013/2014	0	196,535	223,493	2,979	423,006
2014/2015	0	528,167	218,268	2,929	749,364
Mice					
2010/2011	0	2,540	84,071	2,979	89,590
2011/2012	0	1,848	84,514	2,979	89,341
2012/2013	0	8,359	85,437	3,208	97,004
2013/2014	0	5,385	84,180	2,979	92,543
2014/2015	0	2,727	86,646	2,929	92,302

Area of control by method (ha)					
Year	OSPRI	DOC	RUA	NWR	Total
Ground					
2010/2011	5,926,627	320,830	1,535,608	2,979	7,786,043
2011/2012	7,055,008	454,047	1,601,874	10,535	9,121,464
2012/2013	4,902,922	344,922	1,817,334	10,764	7,075,942
2013/2014	4,928,245	701,302	2,012,369	6,608	7,648,525
2014/2015	5,071,332	915,632	2,221,675	18,474	8,227,113
Aerial					
2010/2011	677,530	169,208	5,831	0	852,569
2011/2012	842,920	231,419	4,595	0	1,078,933
2012/2013	588,943	178,174	13,533	0	780,651
2013/2014	522,544	154,624	17,491	0	694,659
2014/2015	563,511	568,173	14,643	0	1,146,327