

Pandora's box down-under: origins and numbers of mustelids transported to New Zealand for biological control of rabbits

Carolyn M. King 

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Abstract This paper describes one of the world's first large-scale experiments in biological control of a major vertebrate pest of agriculture, which was tried in New Zealand during the second half of the nineteenth century. Starting from the late 1860s, pasture damage in Southland and Otago by European rabbits was causing serious reductions in productivity of sheep (wool clip and lambing percentages) associated with malnutrition of the breeding ewes, and a consequent decline in the value of pastoral land. In response, and despite repeated local and international warnings, ferrets, stoats and weasels (*Mustela furo*, *M. erminea* and *M. nivalis*) were liberated on the worst of the rabbit-infested pastures. They were perceived as the 'natural enemies of the rabbit' but (unlike foxes) too small to threaten lambs. Over the 50 years after 1870, upwards of 75,000 ferrets, most imported from Australia or locally bred, were released in the South Island. Over the decade 1883–1892, at least 7838 stoats and weasels arrived from Britain. At least 25 shipments are known, with an average of only 10% mortality per shipment. Of the 3585 animals listed by species, 73% were weasels. The total cost of the ferret programme cannot now be estimated; that of stoats and weasels alone was at

least £5441, probably twice that, or >\$NZ 1–2 million in today's money. Mustelids (and cats) killed many young rabbits, which was helpful because rates of change in rabbit populations are sensitive to variations in juvenile mortality, but in the most rabbit-prone semi-arid lands, mustelids could not remove enough rabbits to prevent the continuing damage to sheep pastures. The era of deliberate introductions of mustelids to control rabbits in New Zealand was short, expensive, and unsuccessful.

Keywords Invasive species · Biological control · New Zealand history · *Oryctolagus cuniculus* · *Mustela furo* · *Mustela erminea* · *Mustela nivalis*

Introduction

New Zealand was the last major archipelago to be colonised by Europeans during the nineteenth century (Dunlap 1999). The Maori people who had occupied the islands since c. 1300 AD had modified the environment by burning forests and hunting native birds, but the only native land mammals were bats. Until the first European explorers gifted pigs and goats to the Maori for food in the late eighteenth century, the country was completely devoid of any animals useful for European-style farming or sport hunting (King 2005).

C. M. King (✉)
Environmental Research Institute, School of Science,
University of Waikato, Hamilton, New Zealand
e-mail: carolyn.king@waikato.ac.nz

As soon as the Treaty of Waitangi (signed in 1840) permitted, an increasing tide of European settlers imported thousands of domestic livestock (sheep, cattle, goats, horses), and adapted familiar farming methods to suit their new environment. From the 1850s onwards, the first and largest leasehold pastoral enterprises spread rapidly across the extensive fire-induced grasslands of the eastern South Island (Fig. 1), converting them into huge privately-run sheep runs (Peden 2011). By 1882, more than a thousand runs were established, of which all but 26 were in the South Island (Registrar-General's Office 1882, p. 214).

Wild European rabbits spread rapidly from their early liberation sites in Southland, Marlborough and Hawke's Bay (King in press-a). Their numbers escalated to legendary proportions (Norbury and Reddix 2005), inducing massive pasture damage with drastic consequences for the economics of pastoral farming (King in press-a). Some idea of the extraordinary increase in numbers of rabbits after the mid 1870s can be gleaned from the annual Government export statistics (Fig. 2). The number of rabbits exported as skins or meat is not a measure of the national population of rabbits, but is surely correlated with it. Furthermore, official export data have the advantage of being accurately monitored, which the numbers of live rabbits were not. On a more local scale, detailed farm records clearly illustrate the dramatic impact of rabbits on wool production on individual properties (Holland and Figgins 2015).

Of course, rabbits did not have the same effect everywhere, and other environmental changes (especially periodic droughts and rampant weeds) contributed to the declining fortunes of the southern South Island pastoral industry (Holland 2013), but rabbits were the most obvious problem. In May 1876, a Parliamentary report (Richardson and Pearson 1876) found that pasture damage and malnutrition of ewes following the spread of rabbits had caused the reduction of the Southland wool clip by 700–800 fewer bales over 12 months, and losses of lambs averaging up to 20% across the province per season. It identified the absence of the rabbit's natural enemy as the reason for the unexpected irruption, and recommended the importation of ferrets, stoats and weasels. The New Zealand House of Representatives set up a Rabbit Nuisance Committee, which in August 1876 came to the same conclusion (Hodgkinson 1876).

The dominant run-holders persuaded the Colonial Government to agree to these recommendations, on the twin assumptions that ferrets, stoats and weasels really were capable of keeping down rabbit numbers, but too small to pose a serious threat to lambs. Attempts to make the proposed imports illegal failed (Wells 2006). In 1881, the Government strengthened earlier and less effective anti-rabbit legislation, and appointed a new Superintending Inspector, Mr Benjamin P. Bayly. The new legislation provided for legal protection for all enemies of the rabbit, including fines of up to £10 for killing a ferret or weasel, and up to £20 for failing to control rabbits. The average agricultural worker of the time earned about £1 a week (<http://logicgmt.com/1876/living/occupations.htm>).

Thence began an unprecedented, ambitious and uncontrolled experiment in state-sponsored biological control. The result has been the establishment of the largest invasive populations of these three species in the world, causing serious conservation damage to native fauna continuing to the present day. A strategy that seemed at the time to be merely logical turned New Zealand into a textbook example of the perils of misguided nineteenth-century acclimatisation (Gibb and Williams 1994).

Ferrets, stoats and weasels

The ferret *Mustela furo* is a domesticated version of, probably, the European polecat (*M. putorius*) (Davison et al. 1999). Ferrets were the first specialist rabbit predators to be imported, because they were easy to obtain and handle, and already present in Australia. Ferrets can be easily bred in large numbers given good housing and protection from disease, so many ferret stud farms were established from imported stock to supply animals for release on pastoral runs. Their long history of domestication and the confusing numbers of introductions around the world make any genetic analysis unhelpful for identifying origins, so this enquiry is concerned only with the numbers of domestic ferrets brought to and bred for release in New Zealand over at least 50 years from 1870.

By contrast, stoats and weasels (*Mustela erminea*, *M. nivalis*) are specialist predators of small rodents and rabbits native to the cooler parts of the northern hemisphere (King and Powell 2007; McDonald et al. 2000). Over a short period of 10 years 1883–1892, multiple private and official shipments of wild stoats

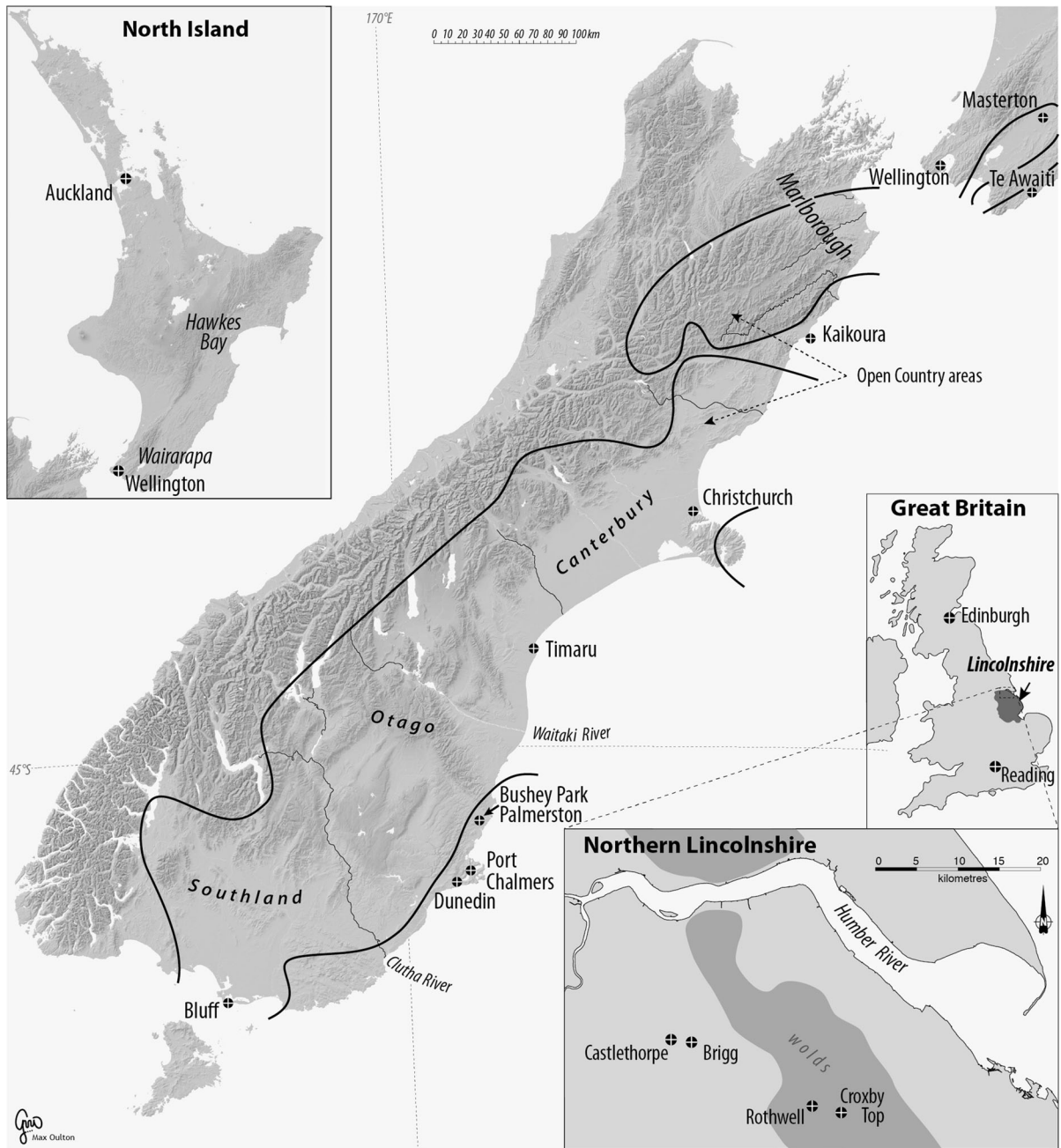


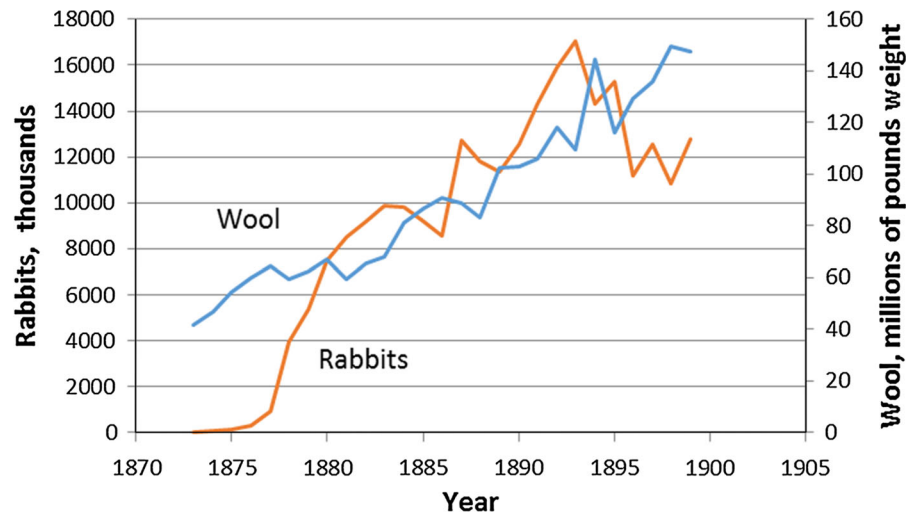
Fig. 1 Locations of places mentioned in the text. *Dark lines enclose* the extent of open country, as defined by Holland and Figgins (2015), i.e., the main area covered by pastoral runs and the favoured habitat for rabbits. For names, numbers and further descriptions of runs in Otago and Southland, see Pinney (1981)

and Sinclair (2003). *Inset, above left:* New Zealand North Island. *Inset, lower right:* locations of places in UK, with an enlargement for northern Lincolnshire, the centre of the former rabbit fur industry and of the mustelid collecting operations of Henry and Walter Allbones of Brigg

and weasels arrived from Britain, and the imported animals were immediately released in the most severely rabbit-infested areas.

The numbers of stoats removed from Britain were inconsequential to the remaining stoat population, but have since had an unexpected potential benefit for

Fig. 2 Exports of wool (in millions of pounds weight) and numbers of rabbits (in skins alone until 1893, then in frozen carcasses with skins on 1884–1899) (Glasgow 1901), from New Zealand in 1873–1899 (Registrar-General's Office 1870–1899)



their descendants. A recent analysis found five mitochondrial haplotypes in New Zealand stoats, only one of which survives in Britain (Veale et al. 2015).

This surprising result seems to be because the extensive sampling and transportation of British stoats to New Zealand in the 1880s has preserved much of the genetic diversity among stoats then living in Britain. Since then, British stoats barely survived a catastrophic population decline that followed the removal of their main food supply by the rabbit disease myxomatosis in 1953–1955 (Sumption and Flowerdew 1985); contrariwise, weasels and voles benefited from the removal of competition (King and Powell 2007).

Comparison of the genetic signatures of invasive species with those of their presumed ancestors can uncover information about the history of the invasion invisible to other forms of analysis, subject to certain assumptions. The critical data required for modelling of any invasion include informed estimates of the sizes and origins of the invading propagules, which strongly affect their chances of establishment (Blackburn et al. 2015).

The aim of this paper is to summarise what is known of the numbers of all three species imported, plus, for stoats and weasels though not for ferrets, where the wild animals were collected, and when they arrived.

Methods

Primary data detailing how the shipments were organised are preserved in archives and research

libraries in New Zealand and in England. Digitised versions of official reports of the New Zealand Parliamentary debates, and the Appendices to the Journal of the House of Representatives (AJHR), are the most reliable online sources. Deposits of unpublished official documents (handwritten letters, and unpublished files) are held in Archives NZ, most freely accessible to readers on site, and locatable in their catalogue <https://www.archway.archives.govt.nz/> from the Record Number given here. I have personally searched all of the main depositories held by Archives New Zealand, Statistics New Zealand and the Alexander Turnbull Library (all in Wellington); the Hocken Library (Dunedin); the Auckland Institute and Museum; the city libraries of Auckland and Dunedin; the Maritime Museums of Auckland, Port Chalmers and Bluff; the UK National Archives at Kew, the Caird Library of the National Maritime Museum, in Greenwich; the Bodleian Library (Oxford) and the Cambridge University Library; and the Museum of English Rural Life (Reading). Some smaller local depositories in New Zealand were searched by their archivists on my behalf. Dates of ship departures from England and arrivals in New Zealand are taken from Comber's Index, which ends in December 1889: <http://freepages.genealogy.rootsweb.ancestry.com/~nzbound/comber.htm>.

Online newspaper databases (<https://paperspast.natlib.govt.nz/> and <http://www.britishnewspaperarchive.co.uk/search>) are valuable and easily accessible. Stoats and weasels are similar in appearance and often confused, because the distinguishing black-tipped tail of the stoat is

not always noticed, then or now. Most of the primary sources cited here refer to both together, often under the general term 'weasels'; variant spellings ('weasle', 'weazel') are given here as in the original sources, to facilitate follow-up. Ferrets (*M. furo*) and polecats (*M. putorius*) are quite different, in appearance, biology and origin, but the generic label 'mustelids' includes all four species.

The very large body of information uncovered by these searches has been subdivided for publication as follows. (1) The present summary of the origins and numbers of all three mustelid species landed, with the minimum of historical details needed to appreciate the story. (2) A description of the locations where the imported stoats and weasels were released, and the pattern and timing of their subsequent spread across the South and North Islands (King in press-b). (3) A pair of companion reviews exploring the political and socio-economic conditions behind the decisions to import first, rabbits and ferrets, and second, stoats and weasels, with full historical details of the complex transport arrangements, the personalities of the main actors and the assumptions under which they operated, which need explaining because they were very different from ours (King in press-a, submitted). (4) The consequences of ferret predation for the native weka, a flightless predatory rail (*Gallirallus australis hectori*) of the southeastern South Island (King 2017). (5) New Zealand's narrow escape from importations of other alien predators of rabbits which arrived but failed to establish (mongoose *Herpestes* sp.) or for which serious proposals were made but never activated (Patagonian fox, pine marten, Scottish wild cat and others) (King in prep.).

Ethics statement: this project did not require the use of any human or vertebrate animal subjects or tissues. No permits were required.

Results

Ferrets, 1870s–1920s

At the time that British agents were collecting ferrets for transport to New Zealand and Australia, Britain's wild native polecat was almost extinct, largely due to historic persecution by gamekeepers (Langley and Yalden 1977). So there is little chance that any true polecats, which might have been more likely to

survive independently, were included among the shipments. Nevertheless, domesticated ferrets with dark polecat-like pelage were often believed to be crossbreeds.

Despite strong objections, importing alien predators remained legal (Wells 2009). A firm of stock agents in Melbourne asking for an import permit from the Colonial Secretary in Wellington was reassured that 'There is no law against it, and ferrets are not mentioned in S 2d of Protection of Animals Act 1873' (Bishop 1878). Table 1 lists the only official data found so far on the numbers of ferrets imported, which are probably a gross underestimate.

However, ferrets turned out to be over-sensitive travellers, and very susceptible to canine distemper. Several shipments were entirely destroyed by disease or bad handling en route; one runholder reported getting only two live ferrets out of a total of 1300 shipped (Randall Johnson 1884). From 25 consignments paid for by the Government between March 1882 and June 1883, only 178 of 1217 shipped from England landed alive, plus 198 of 241 from Melbourne (Bayly 1883). In 1884, the Government abandoned imports and shifted to a policy of purchasing ferrets bred in local stud farms (Bayly 1884).

The number of ferrets bred for deliberate release soon reached astonishing levels: e.g., 7539 in 1884–1886 alone (Anon 1886). Over 18 months in 1887–1888, contracts for supply of ferrets for district rabbit inspectors totalled 21,760 (Stock Department 1888). Clark (1949, p. 266) cites an unpublished estimate by R. M. Burdon that overall a total of 'upward of 75,000' ferrets were bred and released on the South Island. But right from the beginning it was observed that the mortality of the ferrets released into mountain country was often very high, especially over winter. Stoats and weasels, already adapted to colder conditions, were seen as a more hardy alternative (Anon 1881).

Stoats and weasels, 1883–1892

The idea of exporting weasels to New Zealand provoked strong objections from leading ornithologists concerned with the threat to New Zealand's endemic flightless native birds (Buller 1877), and despair among New Zealand landowners who had been investing heavily in acclimatising game birds for sport (Thomson 1922). Ignoring them, a few attempts

Table 1 Records of the numbers of live animals other than domestic stock imported into New Zealand, 1870–1886 (Registrar-General's Office 1870–1899); many more came in unrecorded

Year	Import category	Numbers of animals				Total
		NSW	Victoria	Tasmania	UK	
1870	Livestock: other kinds		1		342	343
1871	Livestock: other kinds	3	10		670	683
1872	No records					0
1873	Livestock: other kinds					0
1874	Livestock: other kinds	51				51
1875	Livestock: other kinds	310				310
1876	Livestock: other kinds	8	421		9	438
1877	Livestock: other kinds	4	17		6	27
1878	Livestock: other kinds	13	23		29	65
1879	Livestock: other kinds	4	20	1	12	37
1880	Animals: other kinds	4	12	2		18
1881	No records					0
1882	Animals: ferrets		204	28	10	242
1883	Animals: ferrets and weasels		66	20	(15)	101
1884	Animals: ferrets and weasels			25	(6)	31
1885	Animals: ferrets and weasels		23	41	(152)	216
1886	Animals: ferrets stoats and weasels				(284)	284
	Total	397	797	117	1535	2846

Most of the 1972 unspecified arrivals of 1870–1880 would have been private shipments of ferrets, especially those from Australia. In 1882, ferrets were given their own import category until ferret imports ended in 1886, and 590 arrivals are recorded before locally bred stock became more economic. Imports from UK in 1883–1886 (in parentheses) were probably mostly stoats and weasels. See Table 2

were made to import small numbers of weasels or stoats privately during the 1870s, but none was successful (King submitted). No-one at that time knew how to care for such active, highly-strung and aggressive animals for long enough to bring them safely round the world (Hodgkinson 1876), and land them alive in numbers sufficient to establish a population. The rabbits continued to ravage the South Island runs.

In early nineteenth-century England, rabbit-warrening and fur-dressing were important rural industries, especially in northern Lincolnshire (Beastall 1978; Bygott 1952; Thompson and King 1994, pp. 64–67). Wild rabbits were protected by networks of traps set to remove the stoats and weasels (native carnivores but regarded as vermin) that reduced the farmers' harvest of rabbitskins. Trappers were also employed on sporting estates to protect game birds (McDonald and Murphy 2000).

One English gentleman farmer, Samuel Grant, had a farm at Castlethorpe (Fig. 1), where he employed local professional vermin destroyers, including Walter Allbones (1863–1948) from the nearby town of Brigg. On an 1880 tour of New Zealand's South Island (Grant and Foster 1880), Grant had probably met Francis Dyer Rich, owner of Bushey Park, near Palmerston (Fig. 1). In 1882, Rich commissioned Grant to supply a trial shipment of mustelids for his estate, with an experienced man to accompany them on the journey from England (Grant 1883). Grant recommended Walter Allbones for the job. Over the next 10 years, Walter undertook at least five more deliveries to New Zealand, and his father Henry at least seven. Other and un-named couriers brought the total number of known shipments to 25 (Table 2).

The great majority of the animals shipped to New Zealand in the early-mid 1880s were collected from farms around Allbones' home base in northern

Table 2 Minimum number of known shipments of British stoats and weasels to New Zealand, 1883–1892, with estimated losses *en route*, and gross costs in pounds sterling

Year	Ship	Date arrived NZ	Reported shipments				Import records	Annual totals	Cost, £
			Sent	Landed per ship	Landed per year	References			
1883	Waitangi	March 26	25	10	10	(Grant 1883)	–	10	
1884	Doric	June 28	101	90	90	(Bayly 1885; Colonial Secretary 1884)	–	90	505
1885	Ionic	January 20	161	148	919	(Bayly 1885)	–	919	475
	Rimutaka	July 12	236	222		(Colonial Secretary 1885)			803
	Ionic	October 28	285	249		(Colonial Secretary 1885)			837
	Rimutaka	November 6	330	300		Riddiford contract 14 July 1885 (in private hands)			659
1886	Doric	January 19	330 (101 boxes)	303	303	<i>NZ Herald</i> , 23 January 1886	–	303	
1887	Rimutaka	October 9	231	223	223	<i>NZ Herald</i> , 20 Oct 1887	433	433	
1888	Tongariro	January 5	313	285	1453	<i>Marlborough Express</i> , 4 Jan 1888	1409	1453	
	Kaikoura	April 23	351	319	(Bayly 1888)				
	Doric	May 9	150	137	<i>Temuka Leader</i> , 19 May 1888				
	Ionic	July 3	312	295	(Chief Inspector of Stock in Sydney 1890)				
	Ruapehu	August 12	336	312	(Chief Inspector of Stock in Sydney 1890)				
	Ionic	November 21	110 (35 boxes)	105	<i>Press</i> , 30 Nov 1888				
1889	Kaikoura	June 18	300	270	497	<i>Marlborough Express</i> , 5 June 1889	1238	1238	
	Aorangi	August 13	254	227		<i>Marlborough Express</i> , 16 Aug 1889			607
1890	Tongariro	May 9	500	450	720	<i>Star</i> , 23 April 1890	2292	2292	
	Ruapehu	August 6	Unknown	Unknown		<i>NZ Herald</i> , 6 Aug 1890			
	Rangatira	October 3	300 (100 boxes)	270		<i>Western Mail</i> , 3 Oct 1890			
1891	Tongariro	30 January	374	42	954	<i>Wairarapa Daily Times</i> , 30 January 1891	1100	1100	
	Aorangi	February 26	121	13		<i>North Otago Times</i> , 26 Feb 1891			
	Rimutaka	February	356	321		<i>Wairarapa News</i> , 12 Feb 1891			
	Ruapehu	April 21	345	250		<i>Wairarapa Daily Times</i> , 14 May 1891			
	Kaikoura	May	532	'Extraordinary mortality'		<i>Wairarapa Daily Times</i> , 14 May 1891			
	Aorangi	July 16	349	328		<i>Wairarapa Daily Times</i> , 13 Aug 1891			

Table 2 continued

Year	Ship	Date arrived NZ	Reported shipments				Import records	Annual totals	Cost, £
			Sent	Landed per ship	Landed per year	References			
1892	Unknown	Unknown	838	838		(Ritchie 1892)	0	0	
		Totals	7540	5169	5169		7310	7838	5428

Names of ships and dates of arrival at the first port of call in New Zealand taken from the on-line Comber Index until it ends in 1889. Under “Reported shipments”, round numbers given in the first two columns are from informal sources e.g., press reports, which do not always agree with each other, but provide the only detailed data available for 1883–86 inclusive. “Import records” give the official figures recorded in the annual Statistics of the Colony of New Zealand (Registrar-General’s Office 1870–1899) for the year cited, which list stoats and weasels as a separate category only from 1887 to 1891. “Annual totals” use data from reported shipments until 1886, then from import records until these end in 1892. In every year except 1888, the number reported arriving was less than the official import record. Where the records give only the number shipped, the number landed is reduced by 10%, or vice versa. If only the number of boxes is given, the number of animals is counted at the standard rate of 3 per box (Grant 1883). The average mortality rate during a typical 6–7 week voyage was about 10%, except during three disastrous voyages in early 1891

England. A much later review of his work (Lincolnshire Times 1976) states that Walter got many of them from a farm at Croxby Top (Fig. 1, inset), near Rothwell in the Lincolnshire wolds, which is still a working arable farm quilted with hedges and copses, the classic gamekeepers’ trapping sites.

While Walter was away, Henry Allbones collected animals for the next consignment at his property in Brigg. He received offers of animals from all over the country but, at least in mid-1885, was still finding it cheaper to collect them himself in Lincolnshire (Auckland Star 1885). As the demand grew, Henry advertised in other county newspapers in northern England and lowland Scotland, and in a national sporting journal (The Field 1884). Throughout his operation he still continued advertising in Lincolnshire, offering to supply traps at 3s 6d and instructions if needed.

Other collectors worked in Hampshire, Devonshire and in Edinburgh. Henry was at one point offered ‘a full supply from Ireland’ (Nelson Evening Mail 1885), but no New Zealand stoats sampled so far have showed any genetic connections with Ireland, or from continental Europe (Veale et al. 2015). So far as it goes, the documentary evidence confirms that most stoats and weasels brought to New Zealand came from northern England, plus perhaps some from other parts of Britain. The Allbones dropped out of the trade in mid 1890, and all imports ceased in 1892.

Table 2 compiles annual estimates of stoat and weasel arrivals from published and unpublished sources. The total of 7838 could not have been carried

in only 25 shipments, averaging about 270 animals per consignment, which confirms my suspicions that some unknown number of shipments were never reported. Many more weasels than stoats (2622–963) were listed in the 16 records distinguishing the two species (King in press-b).

The first trial consignment of 25 stoats and weasels plus 8–10 ferrets was loaded onto the sailing vessel *Waitangi*, but when the ship hit a storm in the English Channel, all but ten mustelids were lost overboard. The ship recovered, and eventually arrived at Port Chalmers on 26 March 1883 (Otago Daily Times 1883). The surviving animals were delivered to Rich at Bushey Park. At Bayly’s urging (Bayly 1883), the Colonial Secretary in Wellington commissioned the New Zealand Agent General in London to begin an official programme of sending cargoes of weasels and stoats to New Zealand in the care of Walter Allbones (Colonial Secretary 1883). The first official consignment arrived on the steamer *Doric* 6 months later.

Between June 1884 and January 1886, six shipments totalling 1312 stoats and weasels arrived in New Zealand (Table 2). Four lots were commissioned by the Government for turning out on Crown lands, mainly in the South Island. Bayly’s plan was to populate the inland mountains with mustelids, so that the grey horde moving steadily north through Southland into Otago would be met by ‘industrious foes’ on reaching the Canterbury boundary (Mataura Ensign 1884). Another two shipments were private orders for properties in the lower North Island.

In January 1886 the Shaw, Savill and Albion Co., who chartered the *Ionic* and the *Doric* (Table 2) for the New Zealand trade (Waters 1961, p. 76), suddenly refused to convey stoats and weasels to New Zealand because of passenger complaints (Agent-General 1886). Bayly spent 18 fruitless months searching for alternative ships willing to accept official bookings, while fears among the run-holders continued to escalate. If rabbits did indeed overrun the whole high country, as seemed inevitable, the predicted cost to the Government would be £10,000 a year in lost revenue, plus the loss to wool producers of £35–40,000 a year (Baker 1887). Eventually, the shipping stalemate was resolved by a new agreement arranged by Henry Allbones in May 1887 with Shaw Savill's rivals, the New Zealand Shipping Company, with immediate effect—the next shipment arrived in October (Table 2).

From 1887, the annual import records distinguished stoats and weasels as a separate category (Registrar-General's Office 1870–1899). These figures provide independent estimates of the numbers of animals arriving each calendar year (Table 2), although without any further details. From 1887 to 1891 inclusive, these import categories recorded the arrival of 6516 animals—an astonishing total, but likely to be more accurate than the 3847 animals mentioned in press reports for the same years. The large numbers of stoats and weasels brought in during that period reflect the desperation of the run-holders and the pressure they were putting on the Government.

Continuing objections against Bayly's policies eventually precipitated an important change in Government policy in 1889. Bayly was demoted (Anon 1889), and official support for his programme was withdrawn. Local communities had to organise themselves, encouraged by a new official policy from October 1889 which stated that, where the settlers established a Rabbit Board formed under the rabbit nuisance legislation, it would be entitled to a pound for pound subsidy. If they did not constitute themselves into a Rabbit Board, they would be entitled to a bonus of £1 per stoat and 10 s per weasel imported by them into the Colony (Otago and East Coast Rabbit Association 1889). The Awatere Rabbit Board of Marlborough ordered 1000 stoats and weasels (NZ Herald 1888), which arrived in five lots from January 1888 and August 1889. The same Board then placed another

similar order. In 1890 alone, a total of 2292 stoats and weasels arrived, followed by 1100 in 1891 (Table 2).

Disagreements on rabbit control policy within nineteenth-century official circles are well illustrated by the report of the Joint Committee on Livestock and Rabbits in 1890. Long after Bayly's departure, the Committee repeated its trenchant 1889 criticism of the change in policy. They strongly recommended that the Government 'should... continue the introduction of stoats and weasels in large and continuous numbers' (Randall Johnson 1890). Nothing changed: the Rabbit Nuisance Committee's report for 1891 does not mention natural enemies at all (Lawry 1891).

Rabbit Boards continued to order shipments for another year, but after three of the six consignments sent in 1891 to the Wairarapa Rabbit Board suffered high mortality in transit (leaving the Board to pay for the loss), it decided to cease importing stoats and weasels. Rising protests against the introductions, and wider supplies of cheaper, locally-bred ferrets, helped to hasten the decision. Other Boards must have agreed, because from 1892 onwards, the 'Stoats and weasels' import category disappeared from the annual statistical report.

Discussion

Total numbers and costs of imports

It is obvious that the known records do not tell the complete story. Private agencies could and did release as many ferrets as they could obtain, and locally bred ferrets were easy to come by. Burdon's estimated total of 75,000 ferrets released is barely more than a guess, supported but not proven by multiple overlapping references in the literature mentioning liberations by the thousands. New Zealand now has the largest population of feral ferrets in the world (Clapperton and Byrom 2005).

For stoats and weasels, the list of consignments arriving up to January 1886 is probably reliable, because every shipment was of intense public interest, widely observed, officially reported and frequently commented on in the press and in Parliamentary documents. After 1887, Government switched to subsidising private importations, and press reports became increasingly vague, if existing at all (King

submitted). Most published records of shipping movements do not mention the animals, and no detailed cargo lists for the relevant voyages have turned up. Published passenger lists do not always name the people travelling in steerage class, as both the Allbones and other stock managers always did. Private consignments accompanied by un-named agents would be nearly impossible to find. Some at least could have arrived in response to the Government's promise of 'liberal support' for private importers (Poverty Bay Herald 1883).

Even so, Table 2 shows that the bare minimum number of stoats and weasels known to have been landed must have been at least 7838 individuals, of which about 5169 were reported in the press. The difference of 2669 animals could explain, at an average of 270 per shipment, some of the gaps in Table 2 plus perhaps other consignments in addition to the 25 known. The total cost of the programme was well over £5000, or (allowing for the number of gaps in the data, more likely twice that by the end of 1892), more than \$NZ 1–2 million in today's money (<http://www.rbnz.govt.nz/monetary-policy/inflation-calculator>).

Was the benefit worth the cost?

Experimental work in Australia by Pech et al. (1992) has demonstrated that the relationship between rabbits and foxes can alternate between two complementary states. The same two states can be identified in the history of rabbit predators in New Zealand.

In the first state A, rabbits at very high density are unaffected by predation, as is illustrated by conditions in the most rabbit-prone parts of the South Island high country and arid lands. The rabbit breeding season is short (September to January), and the seasonal absence of young rabbits reduces the numbers of overwintering mustelids and cats until late spring (November). In isolated areas, e.g., the peninsula on Lake Wanaka, where the first weasels were released in the winter of 1884 (Bayly 1886), rabbit numbers were at first reported to be declining, but this benefit could not be proven or extended to the surrounding huge, unfenced areas of high country where rabbit control was most needed. Hence, at the height of the nineteenth century crisis, the simple liberation of predators onto very large unfenced pastoral land could not add to, rather than merely replace, other forms of

rabbit mortality, so had very little effect on rabbit numbers.

In the second state B, rabbits already at low density can be kept down by predation. This state is illustrated in much of the North Island, where good rainfall, mild winters and close pasture management create habitat conditions in which rabbits at low density can breed almost year-round, maintaining the numbers of mustelids and cats over winter. Predation falls most heavily on young rabbits, and if high numbers of these predators are already present early in spring, when young rabbits first appear, they can have a substantial effect on a rabbit population (Gibb et al. 1978; Norbury and Jones 2015). Mustelids are especially good at this because they can enter the burrows and find the nestlings before they emerge. For example, 5 years after the first stoats and weasels were liberated on E J Riddiford's Te Awaiti station on the east coast of the Wairarapa in July 1885 (Winser 1885, 1886), his manager reported seeing few lactating doe rabbits and very few young rabbits. Organised management of rabbit populations in state B is rarely necessary (Parkes 1995), as was experimentally demonstrated in the North Island by Gibb et al. (1969).

Could predators help defeat the problem of unmanageable state A rabbit numbers by inducing a switch into state B? Foxes in Australia can achieve this effect after a drought, but in nineteenth century New Zealand the imported mustelids were usually liberated where rabbits were already hugely abundant, in numbers too small to achieve this effect. There were rare and local exceptions (King in press-a), but in most places ferrets had little effect on the numbers of rabbits. The same is true now, because ferret numbers are determined by rabbit numbers rather than vice versa (Norbury et al. 2002). Likewise, stoat numbers are closely linked to the abundance of rodents in spring (King and Powell 2011), and stoats have no compensatory benefit to New Zealand by controlling the numbers of introduced rats and mice (Jones et al. 2011; Ruscoe et al. 2011). So the answer, regrettably, is that the cost of Bayly's programme, in money and in conservation damage, was and remains beyond counting, while the benefit was roughly zero.

Conclusion

Faced with the unsustainable damage and losses caused by over-abundant rabbit populations, land

managers in nineteenth-century New Zealand searched for more effective and economically feasible means of killing rabbits. At first they hoped to cover the ruinous expenses of employing men to trap and poison rabbits over huge areas of high country by making the rabbits contribute to the costs of their own destruction. Hence the growth of ancilliary industries trading in rabbit skins and later, canned and frozen rabbit meat, but of course those so engaged would always leave a breeding stock for next year (Ritchie 1892). The problem with any policy of controlling a pest by using men paid for their work in products of the pest is that it guaranteed a workforce with a vested interest in doing profitable work that was ineffective in controlling rabbits. Only a de-commercialisation policy could overcome that unhelpful feedback, and that was not done until 1947 (Gibb and Williams 1994).

The theoretical attraction of employing natural enemies was the assumption that they would do the same work as paid labour, but cost-free. Unfortunately, the very same sentence as above could be re-stated: the problem with the policy of controlling rabbits using mustelids paid for their work in meals is that it guaranteed a workforce of animals with a vested interest in doing profitable work that was ineffective in controlling rabbits.

Nineteenth-century observers both in New Zealand and in Britain pointed out the certainty, even before the first mustelids arrived, that Bayly's policy would introduce a supposed remedy that would turn out to be worse than the disease. Their most urgent question was: how can we find more and better ways of killing rabbits to save our wool industry? In the twenty-first century we face a similar question: how can we find more and better ways of killing mustelids to save our native fauna? We can sympathise with the traumatic rabbit dilemma of 130 years ago, and should be careful to understand the issues at stake as the people of those times did. There are some interesting parallels with the pest management challenges of our own times (King in press-a).

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