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RESEARCH

The eradication of cattle from Enderby Island and subsequent ecological response

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Abstract: Cattle (*Bos taurus*) were liberated on 695 ha Enderby Island, the northernmost of the Auckland Island group, in 1894–96, after a previous liberation had died out. After reaching a peak population of c. 100 animals, they established a relatively stable population of 35–60 animals for the latter half of the 20th century. Eradication was mandated in the 1987 Auckland Islands Management Plan, but proposals for eradication were not universally supported due to the interesting traits of this long-isolated population and its adaptation to the subantarctic environment of the island. Therefore, retrieval of genetic material was permitted before the planned operation. Eradication of the cattle occurred between 1991 and 1993, with at least 47 animals shot in 3 weeks in February 1991, a further two in March–April 1991, and two in December 1991–January 1992. The only two surviving animals were removed alive in February 1993 for captive breeding. The ecological response is considered significant but unable to be completely differentiated from the effects of subsequent eradication of rabbits and mice. Attempts to preserve genetic material via ova, sperm, and live animals met with limited initial success but a small captive population has been established on mainland New Zealand.

Keywords: Auckland Islands, cattle, Enderby Island, eradication

Introduction

Enderby Island (695 ha; 50.50°S, 166.29°E) is a Nature Reserve and part of the Auckland Islands National Reserve and New Zealand's subantarctic islands UNESCO World Heritage Site. It is the northern-most of the islands within the archipelago, 465 km south of the South Island of New Zealand. The island group holds a range of endemic flora and fauna, many of which are considered threatened. Enderby Island holds significant populations of several Auckland Island endemic taxa, including the Auckland Island teal (*Anas aucklandica*), Auckland Island dotterel (*Charadrius bicinctus exilis*), Auckland Island snipe (*Coenocorypha aucklandica*) and the Auckland Island shag (*Leucocarbo colensoi*), and is also an important breeding ground for the New Zealand sealion (*Phocarctos hookeri*) (French et al. 2020).

An introduction of cattle to Enderby Island was made in 1850 as part of the Hardwicke settlement attempt of 1849 to 1852 (Trotter & Willis 2002). By 1865, these cattle were no longer present (Norman & Musgrave 1866). Rabbits (*Oryctolagus cuniculus*) were released in 1865 and successfully established on the island (Norman & Musgrave 1866), and mice (*Mus musculus*) prior to 1840 (Russell et al. 2020).

Cattle were re-introduced to Enderby Island sometime between 1894–96 (Trotter & Willis 2022), as part of a new farming venture on the island. An unspecified number of cattle were reportedly landed by the government steamer 'Hinemoa' in 1894 (Cockayne 1904), and three in 1895 (Bollons 1925) though there is some question over veracity or date of these releases (Trotter & Willis 2022). In 1896, nine cattle were established for Mr. W.J. Moffett of Woodlands, Invercargill, who had obtained a pastoral lease for Enderby Island and the neighbouring 80 ha Rose Island in a short-lived farming attempt. They had unclear origins, reputedly being of a stocky, short-legged, thick-necked pedigree shorthorn stock (Chamberlain 1991), with Taylor (1990) suggesting they may also have had Ayrshire and Friesian blood, but Trotter and Willis (2022) suggesting they most closely resemble the Shetland Island breed. At least two different releases support the possibility of a resulting mixed breed, as opposed to pure bloodlines. The cattle were predominantly black, or black and white, though a few were red and white. Many of the cows and a few bulls were polled.

By 1903, there were about 10 cattle on Enderby Island and another 15 on Rose Island (Cockayne 1904). The cattle were hunted for food by survivors of the 'Dundonald' shipwreck in 1907 (Otago Daily Times 1907). By 1910, several reports indicated up to 100 cattle present (Trotter & Willis 2022) and by 1916 it was reported the cattle on both islands were in poor condition and many were dying of starvation due to lack of food and competition with rabbits (Otago Daily Times 1916). By 1925 the cattle on Rose Island had died out, and only about 20 remained on Enderby Island (Bollons 1925). Coast-watchers present on the Auckland Islands during WWII shot some Enderby Island cattle for fresh meat supplies (Press 1945).

In the absence of human interference, the herd on Enderby

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Table 1. Recorded counts of cattle on Enderby Island.

Date	Cattle Numbers	Reference
1903	c. 10	Taylor 1976
1910	100	Waikato Independent 1910, Southland Times 1910
1925	c. 20	Taylor 1976
1954	29 (incomplete count)	
1963	50–60 (7 bulls were shot)	
1966	48 (16 adult bulls, 19 cows, 4 yearlings, 9 calves)	
1971	40	Taylor 1976
1972/73	39 (23 bulls, 10 cows, 6 calves)	Taylor 1975, 1976
1980	36 (27 male, 9 female)	Cunningham 1986
1981	45–50	Cawthorn 1982
1982	45–50	
1983	39 (incl. 6 calves, 2 yearlings, 2 heifers)	Cawthorn 1983
1985/86	40–50 (6 calves)	Cawthorn 1986
1988	At least 48	Taylor 1988
1991	52–54 animals (51–52 shot: 47 or 48 in February (25 cows, 22 bulls), 2 in March–April, 2 in Dec–Jan 1992). One adult cow and calf removed alive 1993.	Trotter & Willis 2022 Brown 2002

Island fluctuated between c. 35–60 animals in the period 1963–1983, with an average density of about six animals per 100 ha (Taylor 1990). Recorded counts are listed in Table 1. The cattle were most commonly observed above the northern cliffs near Derry Castle Reef and on the *Oreobolus pectinatus* moor, but were also regularly seen in the Sandy Bay catchment (Taylor 1988). The feral cattle on Enderby Island preferred to graze the taller herbs and grasses of the open sward, but were also regularly observed eating kelp (*Durvillaea antarctica*) washed up on the shore. Browsing sign was also observed on southern rātā (*Metrosideros umbellata*), *Myrsine divaricata*, *Bulbinella rossii*, *Poa litorosa*, rushes, sedges and ferns (Taylor 1990). In 1991, it was estimated that 30% of the diet was made up of kelp (Chamberlain 1991).

The normal social groupings appeared to be family groups with a dominant bull and a number of cows and their offspring. Five groups in 1966 ranged from four to 11 animals, each with only one mature bull (Taylor 1971). Other mature bulls existed as lone individuals or in small bachelor groups. Most observations recorded a notable bias towards males in the population. Calves were born from early October to early January, and reproductive rates noted were 47% in 1965/66 and 67% in 1972/73. Some mortality is suggested to have occurred from accidental deaths (such as falling over cliffs while attempting to reach food items), but most deaths were from no obvious cause. Skeletons were found showing that cattle sometimes got stuck in bogs or died during calving (Taylor 1990).

After the ill-fated farming attempts, Enderby Island became a Reserve for the Preservation of Flora and Fauna in 1934, which changed to a Nature Reserve status in 1977, with a subsequent over-lying classification in 1986 as a National Reserve, the highest protective land status in New Zealand. Apart from very brief occupations by farming staff and shipwreck survivors in the late 1800s–early 1900s, the island has remained uninhabited apart from periodic seasonal presence of scientific or conservation personnel.

Cockayne noted that by the time of his visit in 1903, a 'clearing' had been made all along the southern coast of Enderby Island (Cockayne 1904). By 1907, Enderby Island cattle had cut up the bush, but their effects were most noticeable on the tussock grass *Poa litorosa*, which was at risk of extermination in the grazed area (Aston 1912). The destruction must have been rapid, as by 1912, Davies (1919) recorded that after passing through the bush they came to the top which was covered in short grass. While cattle were not entirely responsible for all the damage (deliberate fires and the presence of rabbits were undoubtedly contributing factors) the grazing of cattle prevented regeneration, resulting in the original flora being replaced by short sward, composed of species previously confined to exposed coastal situations (Taylor 1971).

The impact of cattle alone could be gauged in 1966 by comparison with nearby Rose Island. This island still had rabbits present, but cattle had died out c. 40 years previously. Taylor (1971) identified that since 1954, major changes were apparent in the vegetation on Rose Island, compared to Enderby where the plant cover appeared unchanged for at least the previous 25 years. The response to cattle dying out on Rose Island was most noticeably a recovery of the *Poa litorosa* tussock and its recolonisation of areas of the induced short sward. In contrast, on Enderby Island, the cattle had altered the composition of the southern rata forest undergrowth and also encouraged the spread of *Bulbinella rossii* while preventing the regeneration of *Poa litorosa* and other subantarctic endemic herbs (Taylor 1971).

In 1840 the British Antarctic Expedition collected the South Georgian diving petrel (*Pelecanoides georgicus*) from Enderby Island, but it has not been recorded since. The disappearance of the diving petrels was considered to be linked with habitat changes due to its nests being in shallow burrows in sandy soils, areas on Enderby Island that were cleared of tussock, burrowed by rabbits and trampled by cattle (Taylor 1971). Taylor also suggests similar effects made both Enderby and Rose Islands less suitable for storm petrels and other small petrels and would have reduced the populations breeding there. The effect of cattle probably also resulted in the loss of habitat for nesting yellow-eyed penguin (*Megadyptes antipodes*), and damage or disturbance to southern royal albatross (*Diomedea epomophora*) nests.

The Enderby Island cattle were of interest to the Rare Breeds Conservation Society (RBCS) for a variety of reasons (Trotter & Willis 2022). The herd had remained unaffected by human selection for nearly 100 years, and it had adapted to harsh local conditions and survived without any active management (such as medication or food additives). By 1990, the shorthorn was listed as a rare breed, and the herd establishment on Enderby Island pre-dated the separation of the breed into separate beef and dairy shorthorn bloodlines. Taylor (1971) advocated that the cattle and other wildlife were now in an interacting relationship that was not obviously detrimental to the various species or the vegetation, and had a scientific interest and positive conservation value. He considered that control of cattle and rabbits seemed undesirable. The uniqueness of the situation, the isolation of the herd for over 100 years, and the adaptations of the cattle to survive in the inhospitable environment were listed as justifications to maintain the population in situ. For example, one advocate for the retention of cattle stated that he did not believe a return to the original ecological state was possible and that while it is relatively easy to eradicate the cattle, it would be nearly impossible to eradicate the rabbits or mice (Chamberlain 1991). In contrast to this view, both rabbits and mice were eradicated in 1993, just 2 years later.

Despite the scientific and genetic interest in the feral cattle, the Department of Lands and Survey's inaugural 1987 Auckland Island Management Plan (Department of Lands and Survey 1987) was clear in its objective to remove all non-indigenous species, with a policy to plan for the removal or eradication of the cattle from Enderby Island as soon as logistically possible. The justification for the policy was the implication that cattle may have led to the demise of the South Georgian diving petrel through damage to burrows, that they were suppressing vegetation recovery, and their presence was incompatible with the principles of the reserve. Later public objections to the proposed cull were met with the response that the Management Plan was widely advertised for public submission with the opportunity to provide comment on the policy (unpubl. data, letters on Auckland Island files, Lands and Survey/DOC, Invercargill). The eradication was planned to occur in 1990 when the Department of Conservation (DOC) – established in 1987 and replacing the Department of Lands and Survey as the department managing the Auckland Islands – had goat hunters on the main Auckland Island (Brown et al. 2022). Although capacity appeared available, implementation was deferred for a year to allow RBCS to prepare for collection of animals or genetic material (Trotter & Willis 2022).

Methods

Eradication

Individual animals or groups were stalked and shot by experienced DOC hunters over 3 weeks from 5−25 February 1991. The process was slow, as RBCS personnel (either doing the shooting or accompanying the shooters) required that specimens be very fresh to collect the necessary sperm and ova samples. Culling could not continue until these samples were obtained and stored. Inspections for remaining cattle, and their subsequent destruction, were to occur as a pre-tasked secondary objective of subsequent conservation management trips to the Auckland Islands. Experienced hunters (DOC staff or contractors) were assigned to this task. The 1991 culling team included Nick Torr, Brent Glentworth, Pete Willemse, Mark Mawhinney, Jim Catt, Lyall Miller, and Craig Fergussen. For live capture, a helicopter with a net-gun was used (full details in Trotter & Willis 2022).

The logistics and resources required to conduct an operation to remove live cattle off island, in sufficient numbers to constitute a viable genetic pool, was deemed impracticable by RBCS (Trotter & Willis 2022). Therefore, it was decided to concentrate on the removal of eggs and sperm from cattle as they were culled and later implanted as fertile embryos into surrogate cows present on the mainland of New Zealand.

Ecological response

Vegetation monitoring was instigated in 1989, 2 years before cattle eradication began, to measure responses to removal of grazing mammals. It has been repeated in 1993, 1998, 2003 and 2010 with plans for further re-measures. Results may be formally recorded at a later date (B. Rance pers. comm.). Eleven spot-sampling transects, each of 50 m, covered most vegetation communities on the island, including induced grasslands, forest, tussock, moor, *Bulbinella rossii* meadows, coastal turf, and megaforb communities.

Results

Eradication

The bulk of the cattle were killed in the 3-week operation in 1991. Figures vary between sources but it appears that most probably 47 cattle (or perhaps 48) were killed, but that at the scheduled conclusion of the trip approximately five to six cattle remained unseen and unknown to the hunters in the extremely dense forest and scrub vegetation (A. Roberts pers. comm.). Technical problems with the storage system meant that the eggs taken from culled females by the RBCS were later discovered as not viable. However, semen samples were successfully taken from culled bulls (Trotter & Willis 2022).

During a later trip in 1991, it was discovered that several cattle had escaped the main cull. DOC, unaware of the RBCS's problems with artificial insemination, continued the cull as and when possible. RBCS were unaware of the fact live animals remained on the island (M. Willis pers. comm.). Two bulls were shot in March/April 1991 (A. Roberts pers. comm.), and at that stage at least three further cattle were observed, with the possible sign of more. In October 1991 a helicopter pilot reported three or four cattle on Enderby Island (Main 1991). Two further cattle were shot in Dec 1991/Jan 1992 (A. Roberts pers. comm.).

By the time RBCS learned of the remnant population (in

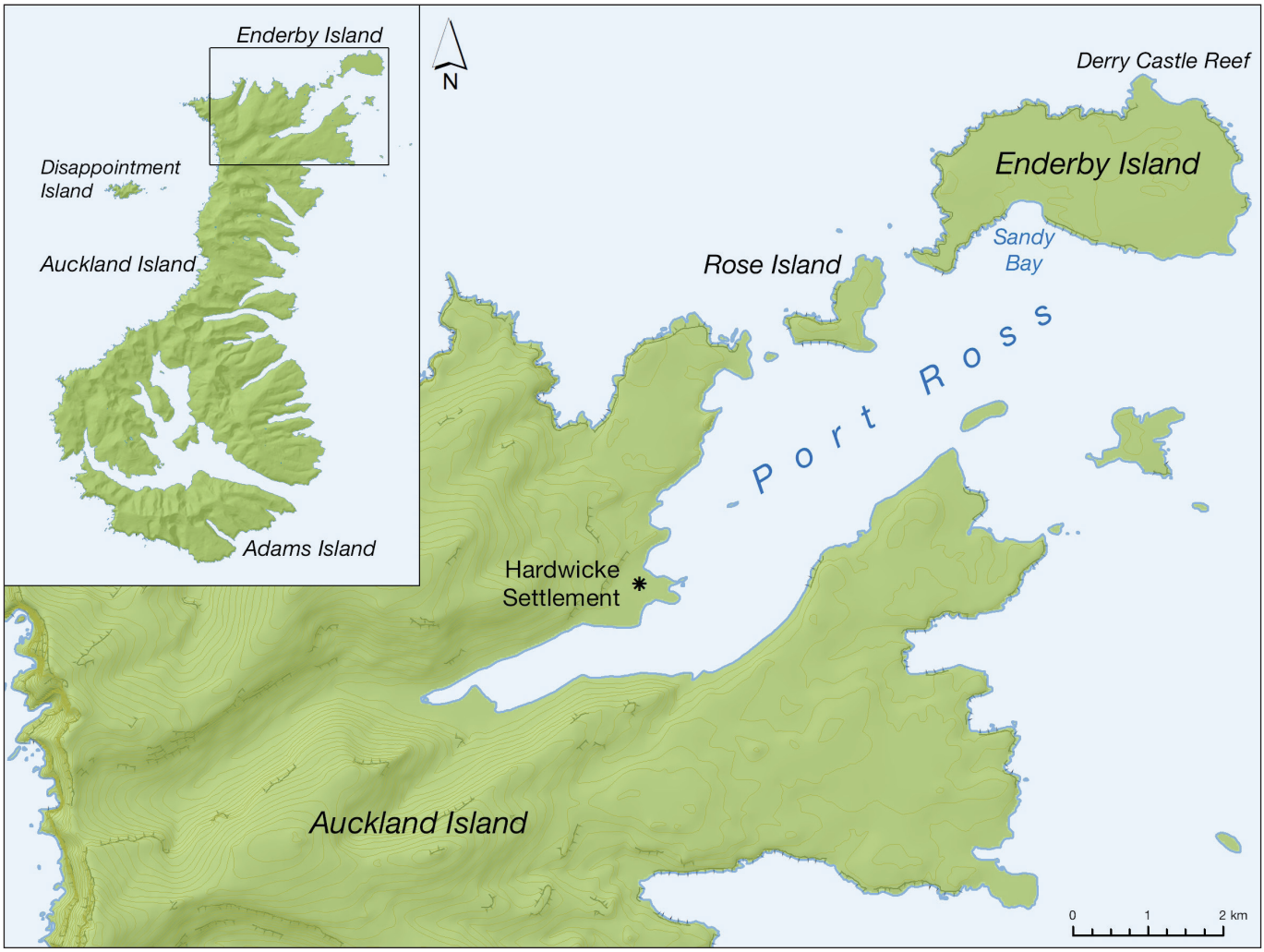

Figure 1. Map of Enderby Island, Rose Island and northern Auckland Island, including the Hardwicke settlement location.

September 1992), only two (a cow with a calf probably born after the main cull) survived. These animals were discovered while preliminary work (including collection of a number of live rabbits) was being undertaken for a proposed rabbit eradication, planned for the summer of 1992/93 (Torr 2002). The facilities associated with that trip were made available to the RBCS to capture these two animals and transport them to the mainland. The cow and female yearling captured were removed from Enderby Island in February 1993, but the yearling died in captivity shortly afterwards. Thus, a total of at least 51 cattle were shot between 1991 and 1992, and two live cattle were removed a year later.

The Enderby Island cattle operation was estimated in 1993 to cost NZ$19 400 plus an additional 150 hours of DOC staff time, with approximately half the cost associated with supporting RBCS genetic work (A. Roberts pers. comm.).

Ecological response

The response of vegetation may have been significantly inhibited until the subsequent removal of rabbits (and mice) in 1993 (Torr 2002). Less than 10 years after eradication, Torr reported that many palatable plants showed spectacular signs of recovery, and the formerly predominant tussock *Poa litorosa,* which had been severely restricted in distribution on Enderby Island, was quickly recolonizing herbaceous swards. The megaforbs *Azorella polaris* and *Anisotome latifolia* previously restricted to cliff areas could be found more widely over the island, and a few plants of *Pleurophyllum criniferum* (not recorded on Enderby Island for many years) were detected. Although some vegetation recovery may have occurred as a result of eradicating cattle alone (as evidenced by the changes on Rose Island where cattle died out before rabbits were removed), it took the removal of both cattle and rabbits to facilitate full vegetative recovery.

Current evidence has noted some clear responses. This includes 'closure' of *Poa litorosa* meadows, with tussock coverage and height increase being the major change in turf/sward areas in the north of the island. The highly palatable *Poa foliosa* has also increased. Low (<5 cm) herb and bryophyte turf/sward communities at Sandy Bay have been replaced by 50% cover of >15 cm sward dominated by exotic grass species, which, along with New Zealand sealion activity, may be slowing recovery of native communities there. There has been significant re-establishment or increase in some megaforbs. Unrecorded in early monitoring, *Azorella polaris* recovery is pronounced, becoming locally common and its re-establishment as a forest understorey species has been striking. In one herbfield monitoring site initiated in 1998, *Anisotome latifolia* has increased from 14% initial cover to 45% by 2010. The recovery of *Pleurophyllum* spp. has been

notably slower and they are still considered 'rare' on the island, possibly due to a combination of lack of local seed source and limited suitable habitat on Enderby Island. A similar situation may apply to the large tussock *Chionochloa antarctica* which remains uncommon on the island. Moor vegetation on the exposed summit of the island appears to have superficially changed the least, though comb sedge *Oreobolus pectinatus* has increased from 26% in 1993 to 45% coverage in 2010, at the expense of bryophytes. Recovery of shrubs such as *Veronica elliptica*, *Myrsine divaricata* and *Ozothamnus vauvilliersii* has also been noted, both in terms of coverage and height of existing shrublands, and of establishment of shrubs or seedlings elsewhere. The noticeable establishment of seedlings, shrubs and ferns in and adjacent to previously forested areas may be an indication of the primary stages of regeneration of the forest, though recovery of forest to its former extent is considered a longer-term prospect. Another long-term change anticipated is a recovery of *Bulbinella rossii* fields through invasion by other megaforb species (B. Rance pers. comm.).

The response of the avifauna to mammal eradications has also been documented (French et al. 2020), with notable recovery of Auckland Island snipe and New Zealand falcon (*Falco novaeseelandiae*) being reported, along with significant increase in tūī (*Prosthemadera novaeseelandiae*) and silvereye (*Zosterops lateralis*). Giant petrel (*Macronectes halli*) nesting appears to have increased, due to recovery of tall tussock nesting habitat, while white-fronted terns (*Sterna striata*) may have decreased for the same reason. Anecdotally, an increase in numbers of red-crowned parakeets (*Cyanoramphus novaezelandiae*) was noted in 2002 (B. Rance pers. comm.), presumably through an increased food resource in the form of seeding plants, but this was not corroborated by French et al. (2020).

Discussion

During the main operation in February 1991, the primary aim of eradicating cattle from Enderby Island was almost certainly compromised by a secondary task of obtaining genetic material, which appreciably slowed the hunting effort, and also affected potential hunting strategies. There may have been an expectation that hunting such a large quarry on a relatively small island would be a straightforward task, and to some extent it was, but ideally, far more time should have been factored into the programme. Realistically the logistical constraints with work in such an isolated and irregularly visited location meant such additional time was not practical. Had more hunting effort and monitoring/detection time been available, it is likely the five to six surviving cattle would have been detected and shot in the main operation. In one respect this was fortuitous, in that it allowed later recovery of two live cattle, but from an eradication perspective it extended the project duration. However, with subsequent trips planned and hunters tasked there was little possibility of the eradication failing from an operational perspective. There may also have been an underestimation (in terms of time allocated and hunting strategy) of the wariness of some of the Enderby Island cattle. It may have been chance that several cattle were undetected within the dense forest, but it is quite possible they were intentionally avoiding human presence.

The cattle population appeared to be constrained by food resources on Enderby Island. Cattle, through pressure for foraging may have opened up forest and shrubland areas, thus enabling rabbits to gain better access to such areas. Through eating of small seedlings, rabbits then acted in combination with the cattle to prevent forest regeneration (B. Rance pers. comm.). Upon autopsy, some shot cattle appeared to have virtually no fat reserves at all, with just the barest quantity of kidney fat (D. Barker pers. comm.). This may help explain the sex bias on Enderby Island towards bulls, which may have dominated competition for prime grazing. Alternatively, or correspondingly, cows may have had higher mortality due to lack of adequate food resources needed for successful pregnancy and calf-rearing. By contrast, the Campbell Island feral cattle sex-ratio was always biased towards cows (Brown & Cox 2022). There, the geology of the small limestone area of the island they occupied (and its potentially important mineral content) appeared more important than overall food resources. Dominant bulls protecting their group of cows may have driven other bulls out into poorer non-limestone habitats where, on the basis of historical evidence, survival was poor.

The Enderby Island cattle were considered in some quarters (e.g. Robinson 1997; Burke 1998) to be unique for their kelp-eating habits. However, this adaptation has also been shown to exist in the Chatham Islands (Anon 1997; J. Cooper, CEO Paua Industry Council, pers. comm.), King Island in Australia (Viney & Walls 1998) and is widespread in the Falkland Islands (DAB pers. obs.). The kelp-eating likely resulted from either an attraction to the salt or other minerals in the kelp and/or the result of severe grazing pressure leaving few other foods available.

The endeavours of the RBCS to preserve the gene-pool of the Enderby Island cattle were fraught with bad luck. What should have been a relatively straightforward captive breeding programme suffered numerous setbacks. Nevertheless, as of 2021, approximately 30 Enderby cattle survive in three herds in New Zealand (Trotter & Willis 2022).

In hindsight, and in contrast to the actual implementation, DOC was – in terms of planning – fully focused on the primary task of eradicating an introduced mammal. There were shortfalls in accommodating alternate viewpoints and desired actions, though these were to some degree eventually worked through to acceptable solutions. In a response to one of the objectors, DOC's Andy Roberts explained that DOC went to considerable extra expense and time delay to ensure that the project of the RBCS to collect semen, eggs and live cattle actually went ahead. It was estimated the cost of the project doubled to accommodate the RBCS requirements.

The considerable media interest in the Enderby Island cattle story reinforced the need for clear and effective lines of communication, and greater efforts to accommodate the differing views of other parties wherever possible. Whitaker and Rudge (1976) noted that after a history of focusing on eradications, embarking on a preservation policy required new thinking and cooperation between departments. As a result of the Enderby Island cattle work, DOC appeared to be better able to accommodate alternative views in later feral animal eradication projects. Thankfully, similar RBCS efforts to retrieve live specimens of Enderby Island rabbits and Auckland Island pigs (*Sus scrofa*) were organised and implemented in a far more acceptable fashion for both parties, and populations of these breeds have been secured in captivity (Trotter & Willis 2022).

Author contributions

DAB compiled historical records and wrote the manuscript with input from FSC.

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