A review of the successful eradication of feral cats from sub-Antarctic Marion Island, Southern Indian Ocean

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Received 15 July 2001. Accepted 12 March 2002

This paper reviews the history of the feral cat eradication programme on sub-Antarctic Marion Island based on unpublished minutes of meetings, reports, letters, theses and published scientific papers; and reflects on the outcome of the eradication campaign. The 19-year programme comprised seven phases, commencing with a description of the effect of the cats on the Marion Island ecosystem, the characteristics of the cat population and the formulation of a management policy (phase 1: 1974–1976). Methods for control were selected and preparations were made for the implementation of the primary control measure, biological control with the feline panleucopaenia virus (phase 2: 1976/77). The virus was released in 1977 (phase 3: 1977), followed by the determination of its effects (phase 4: 1977–1980). Monitoring of the effects of the virus continued, and the secondary control measure of hunting at night was tested (phase 5: 1981–1983). Full-scale implementation of hunting and continued monitoring of the effects of both the disease and hunting followed (phase 6: 1986–1989). The inclusion of intensive trapping and poisoning as tertiary control measures culminated in the final eradication of cats from Marion Island in 1991 (phase 7: 1989–1993).

Key words: feral cats, eradication campaign, overview, Marion Island.

INTRODUCTION

In June 1962, at the 13th Conference of the International Council for Bird Preservation, concern was voiced about the effects of man and domestic animals on the avifauna of sub-Antarctic islands. An appeal was made to governments to recommend measures to protect and conserve sub-Antarctic fauna and flora. As a result of this appeal Dr E.M. van Zinderen Bakker was asked at the first meeting of the South African Scientific Committee on Antarctic Research (SASCAR) to establish the effects of feral domestic cats (*Felis catus*) on the bird populations of Marion Island (Unpublished SASCAR minutes, June 1963).

Cats had been introduced to the island in early 1949 to control feral house mice (*Mus musculus*) in the area of the meteorological station (van Aarde 1977). These mice were thought to have been introduced before 1818 by the earliest sealers or from shipwrecks (Watkins & Cooper 1986). In 1965 van Zinderen Bakker reported that the feral cat population was not large enough to threaten bird populations, and that the cats were indeed contributing to the control of mice in the meteorological station (Unpublished SASCAR minutes, October 1965). However, ten years later, the cats were considered to be detrimentally affecting bird populations, and an assessment of the impact of the cat population was recommended (Condy 1974). With proposals from Anderson & Condy (1974) as guidelines, SASCAR approved a project on the cats, with the aim of eradicating the population and so enabling recovery of bird populations.

Marion Island (46°54′S; 37°45′E) is a volcanic sub-Antarctic island in the Southern Indian Ocean.

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The island has an area of 29 000 ha and comprises coastal (0–100 m a.s.l.), interior (100–500 m) and central montane regions (500–1230 m). The central mountains are covered by snow and ice fields, particularly in winter. Most cats were found below 500 m, an area of approximately 19 000 ha. The island is continuously subject to low temperatures (annual mean 5°C), strong westerly winds (gales on 107 days per year and gusting up to 160 km/hr) and high humidity. Mean annual precipitation in the form of rain, sleet and snow is 2576 mm. The island has a tundra biota, with habitat types comprising vegetated and bare black lavas, grey lavas, volcanic cones and coastal *Cotula* hummocks (van Aarde 1977).

The subsequent eradication programme can be divided into seven clearly defined phases spanning 19 years.

PHASE 1

Since an eradication programme would require detailed knowledge of the interaction between the cats and their environment, a study on distribution, density, habitat selection, feeding and reproduction in the cat population was carried out from December 1974 to April 1976 (van Aarde 1977, 1978, 1979, 1980, 1983, 1984). Originating from two groups of two and three cats respectively, the 1975 population was estimated to be 2139 ± 290 individuals, increasing at a rate of 26% per annum (van Aarde 1979). The population then consumed an estimated 450 000 burrowing petrels annually and posed a serious threat to the burrowing avifauna of the island (van Aarde 1980), with the common diving petrel (*Pelecanoides urinatrix*) apparently having been driven to local extinction as early as 1965 (van Aarde 1980; Watkins & Cooper 1986).

While this investigation was in progress, plans were already being formulated to eradicate the cats. At an *ad hoc* discussion in June 1976 it was recognized that a multi-faceted approach would be necessary for their eradication. Two methods were considered most likely to succeed, namely biological control and poisoning. However, as Marion Island was at the time considered to not lend itself structurally to an effective but lengthy hunting or poisoning campaign, biological control with its immediate impact was deemed most feasible. Therefore, the Department of Infectious Diseases in the Faculty of Veterinary Sciences, University of Pretoria, was approached to prepare a report as to what a biological control programme would entail. At a second *ad hoc* meeting in July 1976 a sub-committee of SASCAR was appointed to advise on biological control of the cat population.

PHASE 2

By March 1976 research on the feasibility of biological control was well under way and a proposal for a biological control programme using feline panleucopaenia virus was presented to the *ad hoc* Task Group on Extermination of Cats and Mice on Marion Island (Howell 1976). Through serological testing on a small sample collected in 1975, it was demonstrated that the cat population was fully susceptible to feline panleucopaenia virus (van Aarde 1977; Erasmus 1979; Howell 1984). The virus was deemed the most appropriate disease at the high cat densities present at that time, and it was decided that its introduction should be implemented. The feline panleucopaenia virus is host-specific, highly infectious, results in high mortality, is highly resistant to environmental factors and occurs worldwide (van Aarde & Skinner 1981). From July 1975, cats, which up to this point had been live trapped and then killed to obtain samples and measurements, were held captive in custom-made cages on the island to serve as future carriers for the establishment of the disease. This trapping was done throughout 1976 to March 1977 (Erasmus 1979). It was recommended that a justification for biological control using the virus be prepared for SASCAR to consider, and in July 1976 the final decision was taken to release the virus. However, because it had been recognized that the virus would not remove all of the cats and that an integrated control programme incorporating various methods would be necessary, the *ad hoc* Task Group on the Use of Poisons and Other Methods for the Control of Cats and Mice on Marion Island was already considering additional methods, some of which were to be tested for their feasibility for use on the island, while others were rejected as unsuitable.

PHASE 3

The feline panleucopaenia virus was introduced as a primary control measure in March 1977 when the cat population was estimated to be 3405 (van Aarde 1979). Ninety-six captive cats were each inoculated with 1000 $TCLD_{50}$ of the first passage of an isolated street virus, prepared in feline kidney monolayers. The carriers were released over a

period of three days at 93 locations around the island using dedicated helicopter support (Erasmus 1979; van Aarde & Skinner 1981; Howell 1984).

PHASE 4

From November 1976 to May 1978 research was undertaken to establish the effect of the release of the disease on the cat population. This revealed an estimated 53.6% reduction in population size after 18 months (Erasmus 1979).

Other control measures were also evaluated for possible incorporation into the programme. Trapping had previously been tested; cage traps (Condy, Anderson, Heijnen & Smit 1975) had been used between December 1974 and April 1976 to collect samples (van Aarde 1975a,b, 1976), and between April 1976 and March 1977 to catch carrier cats, but were ineffective (Bester 1976; Erasmus 1979). In fact, cage trapping was so unsuccessful that the carrier cats were eventually all caught by hand. Cage traps were again tested in November 1977 and April 1978, but were still ineffective with a low success rate of 702 hours per cat. Gin traps were also tested in 1978 but these proved equally ineffective. Two cats were caught in 31 trap-days (372 h per cat), a return considered unacceptable (Keith 1978; Scholtz 1978).

Cats are primarily predators and not scavengers, thus the main reason suggested for the low trapping success was the lack of a successful attractant bait (Erasmus 1979). Twenty different attractant baits were tested on the island, including baits used for caracal (*Felis caracal*) in South Africa (van Aarde 1975b), and others that had been specially formulated (van Aarde 1975b; Bester 1976; Keith 1978; Scholtz 1978). Limited success was obtained with natural prey of cats as well as raw liver. Catnip oil and jackrabbit distress calls were unsuccessful as attractants (Erasmus 1979). Coyote-getters were unsuccessful owing to lack of suitable attractant bait (Keith 1978; Scholtz 1978).

The use of poison also proved unsuccessful as a control agent. Sodium monofluoroacetate (compound 1080) was considered to be the most suitable poison as it posed little threat of pollution and, according to the available literature, birds had a higher tolerance than mammals. Toxicity trials were carried out on the island on likely non-target birds, but it was found that these all had similar lethal doses to cats, and it was recommended that experiments with 1080 be abandoned (Erasmus 1979). The massive campaign that would be necessary to lay poison baits, and the lack of suitable bait, also made poisoning impractical. However, it could perhaps be used under very specific circumstances (Keith 1978; Scholtz 1978; Erasmus 1979), such as to target particular cats while taking care to prevent non-target species from taking the bait.

Poison gas was considered unsuitable, due to the honeycomb nature of the terrain with innumerable crevices and burrows as well as the danger to burrowing birds. A sticky substance containing poison, applied to burrow entrances and ingested by cats while grooming, was considered too time-consuming, costly and impractical owing to the number of burrows that would need to be treated. Unless 1080 was used, the possibility of poison leaching into the environment, with unknown consequences, was also considered unacceptable.

Cadmium and lithium in bait were considered as sterilizing agents. However, at the 4th meeting of the Work Group for the Monitoring of Sea Pollution in July 1975 it had been strongly recommended that Marion Island not be disturbed in any way, so as to provide a reference point for monitoring pollution. Suitable control measures therefore had to be found with this recommendation in mind and the method was rejected. The lack of suitable bait would also make this method impractical (Unpublished SASCAR minutes, March 1976).

Because trapping had proved unsuccessful, both van Aarde (1977) and Erasmus (1979) had resorted to shooting to collect cats. Both used .410-gauge shotguns, hunting during the day, which removed a total of 190 cats at 2.64 hours per cat. They concluded that using only two hunters would not significantly reduce the population. Keith (1978) tested hunting using a .22 calibre rifle, both during the day and at night. He concluded that night hunting would be no more effective than day hunting because the headlamps did not 'hold' cats (*i.e.* spotlights were not used) and that hunting at night was too dangerous. Shotguns were, however, more effective than rifles.

The use of dogs to hunt cats was at first thought to be inappropriate due to the nature of the terrain and the possible impact of the dogs on birds. However, it was subsequently decided to test three Jack Russell terriers on the island. This resulted in three cats being killed at a rate of 6.67 hours per cat and this method was dismissed. However, the dogs had been trained in the hunting of rock hyrax (*Procavia capensis*), not cats, and were used on

only six days for a total of 20 hours of hunting (Linger 1978). Dogs were again tested on the island in August 1989. One German shepherd and one Labrador were used for three days of hunting, and although unsuccessful it was concluded that dogs would be a useful method for use in conjunction with any other methods (Bekker 1989). Bekker (1989) pointed out, however, that dogs would need to be specifically trained to hunt cats and that considerable logistical support for the dogs would be essential.

It must be emphasized, however, that much of the above-mentioned testing (other than trapping and hunting) was carried out over 6–24 days and was probably inadequate.

In February 1978 some doubt was expressed that the cats could ever be eradicated, but that they could be further controlled by a combination of mechanical methods (Unpublished SASCAR minutes, August 1978). Hunting was proposed as the method of choice, to be implemented as soon as possible. This would require a large hunting team, working for long periods, applying a great deal of effort, so as to remove as many animals as quickly as possible. Shotguns were considered the most effective weapons and hunting teams should use these (van Aarde & Erasmus 1978). It was also recognized that hunting, as with biological control, would only be partially effective, after which it would be necessary to incorporate still further methods.

In 1980, three years after the release of the virus, the newly-formed *ad hoc* Specialist Evaluation Group on Marion Island Cats recommended that further control, monitoring and research were essential (Unpublished SASCAR minutes, 1980).

PHASE 5

A third study was undertaken between April 1981 and May 1983 to determine what effect feline panleucopaenia virus had had on the cat population, social structure and space use by the remaining cats, their effect on bird populations and the cost-effectiveness of hunting as a secondary control measure (van Rensburg 1985; 1986a,b; van Rensburg, Skinner & van Aarde 1987; van Rensburg & Bester 1988a,b). It was concluded that the release of the virus had resulted in an epidemic with cat numbers decreasing by 26% annually to an estimated 615 ± 107 cats in 1982 (18% of the 1977 population). It was clear that the virus was responsible for the population decline. Postweaning litter size had decreased and age structures had changed between 1975 and 1982 owing to a decrease in subadult numbers, as subadults less than one year old were subject to highest mortality from feline panleucopaenia. The disease had spread successfully throughout the population as indicated by serum samples collected around the island. As the remaining cats apparently developed immunity to the disease, indicated by a shift from moderate to low antibody titres in sampled cats, the population began to stabilize. The decline in cat numbers of 26% per year over five years from 1977 to 1982 had stabilized to a non-significant decline of 8% between 1982 and 1983 (van Rensburg *et al.* 1987).

In the 18 months after the virus was released it was estimated that the cat population had decreased by 53.6%, but despite this the bird populations were still being severely affected (Schramm 1986; van Rensburg 1986b). Greatwinged petrels (*Pterodroma macroptera*), being the more abundant of only two winter-breeding petrels, were proving particularly vulnerable. Schramm (1983) reported zero breeding success in 1979 and 1980, while breeding success two years later was 53.5% inside cat-free exclosures as opposed to 8% outside (van Rensburg & Bester 1988a). White-chinned petrels (*P. aequinoctialis*) and Salvin's prions (*P. vittata*) also bred more successfully in cat-free exclosures, but van Rensburg & Bester (1988a) estimated that 76 000 prions still fell prey to cats in 1982. Kerguelen petrels (*P. brevirostris*) had disappeared from a specific study area by 1975 and had not reappeared (van Rensburg 1985; Newton & Fugler 1989). Therefore, despite much reduced cat predation, burrowing petrel populations were still threatened, but breeding success in the cat-free areas suggested that eradication of the cats could allow for recovery of bird populations.

At these reduced cat densities, hunting at night as a secondary control measure became feasible. In a specific area, sightings per hour, an index of density, had decreased linearly over a short period of intensive night hunting (van Rensburg & Bester 1988b), and as a result of these trials a full-scale hunting effort was initiated in the austral spring of 1986. As hunting was practicable throughout the island (van Rensburg 1986a), an intensive constant hunting effort was directed at controlling and possibly eradicating the remaining cats (van Rensburg & Bester 1988b). The delay of three years between the decision that hunting was indeed feasible and the start of the hunting

Table 1. Night hunting, trapping and poisoning effort and returns on Marion Island from 1986 to 1993.

Season[1]	Hours hunted	Cats seen[2]	Cats shot	Cats trapped	No. traps	No. baits	Total cats killed[3]
86/87	2 768	1 395	393	–	–	–	458
87/88	2 999	786	174	–	–	–	206
88/89	3 437	603	124	2	5	–	143
89/90	2 641	310	66	78	144	–	145
90/91	1 378	61	11	109	410	–	120
91/92	1 003	0	0	8	1 279	12 000	8
92/93	131	0	0	0	1 387	18 000	0
Total	14 357	3 155	768	197			1 080

[1]1986/87 to 1989/90 data from Bloomer & Bester (1992), 1990/91 to 1993/94 data from Bester *et al.* (2000).
[2]Includes resightings of some individuals.
[3]Includes cats shot during the day.

programme was due to the time taken for final reports to be processed and evaluated, proposals to be made and funding to be obtained.

PHASE 6

Initially scheduled to run over three extended summer seasons between August 1986 and May 1989, eight two-man teams using battery operated spotlights and 12-guage shotguns killed 458, 206 and 143 cats, respectively (Table 1). By the end of the third season progressive declines in hunting success and sighting rate of cats (Bloomer & Bester 1991) suggested that hunting alone was no longer reducing their numbers sufficiently. Although extremely effective, it was soon apparent that the aim of eliminating all the cats by the end of the three-year hunting programme would not be realized (Bloomer & Bester 1992). An extension to the programme was requested, with a view to also reassess methods that had been unsuccessful, inappropriate or impractical when the cat population was large, and to have hunting teams remain on the island during the winter of 1989 (Bester 1988, 1989). At the same time, in 1988 the Department of Environment Affairs solicited an independent evaluation of the eradication programme by the South African National Parks Board. Randall & De Vos (1989) concluded that there was indeed a need to eliminate the cats, that the chances of eradication were good, that continued sporadic control would be an unsatisfactory substitute for eradication, but that hunting was indeed dangerous and that the programme did also have some negative environmental impact. They also recommended that the programme be continued. They supported hunting during winter, that dogs and baits again be tested and that controlled gin trapping and poisoning be used. These methods had previously been tested, albeit inadequately, when cat density was high and would possibly prove more appropriate at the low cat density resulting from the hunting campaign.

The drastic decrease in density of cats led to a decline in pregnancy rates and in fecundity from 1.49 to 0.89 female offspring per female, possibly as a consequence of lower encounter rates between males and females (Bloomer & Bester 1991), which may have increased the likelihood of eradicating the cat population at low densities (Bloomer & Bester 1992). A return to pre-disease litter sizes also suggested that the disease was no longer effective. At a meeting called by the Department of Environment Affairs in June 1988, the cat programme was reviewed, and a task team appointed to evaluate and make recommendations on the cat programme on an ongoing basis with a view to exterminating the cats as soon as possible.

PHASE 7

Since increased hunting effort was financially and logistically impossible, a combination of hunting and trapping was expected to further reduce the population (Bloomer & Bester 1992). Experimental trapping in the winter of 1989 by four two-man teams with 48 traps, and then with increasing numbers of traps over the following two years (96 traps in 1989/90, 410 traps in 1990/91) by five two-man teams, proved a more effective technique than hunting alone, accounting for 54% and 91% of all cats removed in the respective seasons (Table 1; Bester & Skinner 1991; Bloomer & Bester 1992). During the final year of the eradication campaign, which ended in March 1993, up to 1387 gin traps were deployed (Bester, Bloomer, Bartlett, Muller, Van Rooyen & Büchner 2000). The use of lures

Table 2. Non-target species caught in gin traps from 1990 to 1993 on Marion Island.

Species	90/91	91/92	92/93	Total	Est. island population[1]
Salvin's prion, *Pachyptila salvini*	37	64	85	149	>100 000
Subantarctic skua, *Catharacta antarctica*	23	21	48	92	1 800
Lesser sheathbill, *Chionis minor*	31	13	34	78	1 960
Rockhopper penguin, *Eudyptes chrysocome*	1	8	10	19	137 600
White-chinned petrel, *Procellaria aequinoctialis*	3	3	6	12	10 000
Blue petrel, *Halobaena caerulea*	0	0	3	3	>10 000
Great-winged petrel, *Procellaria macroptera*	0	1	0	1	>10 000
Giant petrel, *Macronectes* spp.	0	0	1	1	3 200
Grey-headed albatross, *Diomedea chrysostoma*	1	0	0	1	5 000
Sooty albatross, *Phoebetria fusca*	0	0	1	1	2 000

[1]From Anon. (1996).

(Rocky Mountain Wildlife Products, La Porte, U.S.A.) to bait traps suggested that at least some worked well at attracting cats. Inevitably, birds such as subantarctic skuas (*Catharacta antarctica*) and lesser sheathbills (*Chionis minor*) were also trapped (Table 2), although care in setting traps kept incidental trapping to a minimum (Bloomer & Bester 1992).

In conjunction with increased trapping, a large-scale poisoning campaign, using sodium monofluoroacetate injected into the carcasses of 12 000 day-old chickens, commenced in May 1991 and was continued throughout the following winter and early spring. Poisoning was repeated over a similar period in 1992 (Bester *et al.* 2000) with 18 000 chicks. The exercise was governed by a very strict and detailed protocol for the use of the poison, documented by Bester & Naude (1991) and amended following van Rensburg (1991), to safeguard personnel and minimize detrimental effects on the biota and the environment.

The last cats were trapped by July 1991, and no further signs of cats were seen despite the continued efforts of two successive teams of ten and six hunters/trappers respectively in the following 20 months (1991–1993), (Table 1; Bester *et al.* 2000).

The number of non-target species caught in traps increased substantially, in particular the number of subantarctic skuas (Table 2; Bester *et al.* 2000). However, breeding success of great-winged petrels had improved from 0% in 1979 to 59.6% in 1990, and was up to 64.2% in 1991 (Cooper & Fourie 1991; Cooper, Marais, Bloomer & Bester 1995). Blue petrels had a breeding success of 64% in 1991/92, as opposed to 23.5% in 1982/83 (Fugler, Hunter, Newton & Steele 1987). Whitechinned petrel breeding success was lower in 1991/92 than in 1980/81 (21.8% as opposed to 36.2%; Cooper *et al.* 1995). But this was within the range of success for this species at cat-free South Georgia (Hall 1987). The improved breeding success of burrowing petrels after the eradication of cats suggested that the recovery of affected bird populations would ensue. No cats, or signs of cats, have been seen on Marion Island during the nine years since the last cats were trapped in July 1991 (Bester *et al*. 2000), and it is beyond doubt that feral cats have finally been eradicated from Marion Island.

CONCLUSIONS

Very little effort has been expended on the control and/or eradication of cats on sub-Antarctic islands, and attempts to eradicate cats from other islands have met with varied success. The few such programmes that have succeeded have all been on small continental islands with small cat populations and more hospitable conditions, including Herekopare Island (28 ha, 33 cats), Little Barrier Island (2817 ha, 151 cats, Fitzgerald & Veitch 1985; Veitch 1985) and Jarvis Island (400 ha, 120 cats, Rauzon 1985). On sub-Antarctic Macquarie Island (12 000 ha) cats were not eradicated after ten years of intermittent control (Brothers & Copson 1988).

The eradication campaign on Marion Island has been the largest and only successful one of its kind. With the benefit of hindsight, the campaign could arguably have been carried out more efficiently over a shorter period of time. Veitch (1985) suggested that the eradication of cats can only be achieved by the combined and persistent use of several methods. In order to make the operation as economical as possible, a quick initial

reduction is required, followed by a large and persistent effort, using a combination of methods to remove the remaining animals. However, on Marion Island, the desire to consult widely and to fully evaluate the possible effects of each method on the native fauna and flora resulted in a cautious approach. The considerable expense of mounting each phase also made several long interruptions to the programme unavoidable.

Several factors are considered to have been critical to the success of the programme on Marion Island. Perhaps the most important of these were the susceptibility of the population to feline panleucopaenia virus. The lack of high stands of vegetation, which would have rendered the hunting campaign impossible due to decreased sighting rates and hunting success. The recolonization of preferred habitats, cleared of cats, from neighbouring suboptimal areas served to continually concentrate surviving cats in smaller areas. Other factors contributing to the success of the programme were: the initial study to obtain detailed knowledge of the cat population; the absence of other terrestrial predators which would have interfered with the trapping and poisoning campaigns; the inclusion in each new team of experienced personnel from previous teams to continue the programme; and finally the resolve of the funding bodies to provide the necessary support. Several of the above-mentioned factors were peculiar to the Marion Island situation, and may not apply elsewhere. The success of the Marion Island programme may therefore not be repeatable in the same way on other islands, and this should be considered when planning control or eradication of feral cats on other islands.

ACKNOWLEDGEMENTS

We are indebted to the funding bodies, initially the South African Department of Transport and latterly the Department of Environment Affairs (now the Department of Environmental Affairs and Tourism), which acted on the advice of the South African Scientific Committee for Antarctic Research (SASCAR) and SACAR respectively. The Department of Environment Affairs had the resolve to fund, and provide the logistics, to the conclusion of the eradication campaign. In doing so it maintained the morale and commitment of all those involved, without which this programme could not have succeeded. The late C.A. du Toit played a crucial role in obtaining approval for biological control. We acknowledge the role played by the then Sub-directorate Antarctica and Island Management in sustaining the momentum, in particular the then logistics manager of the National Antarctic Programme, D.J. van Schalkwyk. The former Chief Director of the Department of Environment Affairs, H.F. Gaum, and the former Director General, W.V. Visagie, remained supportive throughout the logistically demanding and expensive phases 6 and 7 of the eradication programme; their judgement to do so vindicated by the success of the programme.

Our sincere gratitude goes to the 76 colleagues involved in the fieldwork over the 20 years between 1973 and 1993, many of whom returned to Marion Island for a second, and even a third time under extremely demanding circumstances; and to those expedition members from other disciplines that lent a helping hand in innumerable ways. Few would understand what it takes to be a successful hunter on Marion Island, and particularly what it required to prove the absence of cats over the last 22 months of the programme.

We thank you all, and may the continued absence of cats, and its conservation value to the Prince Edward Islands, stand eternally to your credit.

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