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*Survival of femur fractures in wild stoats (*Mustela erminea*)*

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Abstract

*Stoats (*Mustela erminea*) are active hunters and, therefore, one might predict that any broken bones or other injuries impeding active movement would incur a serious risk of starvation. Dead stoats (n = 560) were collected from trappers operating predator control lines in three conservation areas of New Zealand from 1972–1978. Femurs were cleaned and examined for healed injuries and deformities. Five femurs from four stoats (one with both femurs injured) showed traumatic distortions following healing of complete breaks incurred during life. A further case recorded during post-eradication monitoring in 2010 on Rangitoto, an offshore island, is added. These data provide evidence that wild stoats have a remarkable capacity to tolerate catastrophic femur fractures. They can survive long enough, despite the implied limitation to their energetic hunting style, to permit full healing even though the result is a gross distortion of the femoral shaft.*

Keywords: *animal welfare, fractures,* Mustela erminea*, stoat, vehicle impacts, wildlife injuries*

Introduction

Stoats (*Mustela erminea*) are very active small predators. They move rapidly, running, jumping, climbing and swimming long distances. To supply the massive energy they need, they have huge appetites. Captive stoats eat between one-quarter and one-third of their bodyweights each day (Müller 1970), and more active wild ones probably eat more. They are tied to a life of frequent small meals, and cannot endure going without food for long, which is one of the difficulties of live-trapping them (King & Powell 2007).

Stoats do not form pair-bonds or social groups, so immobilised individuals are unlikely to be fed by others unless they are young enough to still be part of a family group. For independent adults, survival without treatment of debilitating wounds is therefore expected to be rare. If documented, however, they would be of potential interest to anyone concerned about animal welfare.

The first survey of injuries to trapped stoats was conducted in 1972–1976. It was a nationwide study of 1,599 dead stoats from 14 study areas around New Zealand (King & Moody 1982). During routine processing of the carcases, the frequency of recent and old (well-healed) external injuries was documented (King 1981). Possible internal damage was suspected but not analysed at the time.

This paper describes a sub-sample of material from the first survey, comprising clean leg bones of 560 stoats collected in three of the best-documented study areas in which collections were extended to 1978 (King 1983). An additional case from 2010 was added from an independent source. The objective of this study is to document the remarkable evidence that some wild stoats are capable of surviving debilitating injuries.

Study areas

The Hollyford Valley, in Fiordland National Park on the western side of the Main Divide of the Southern Alps (45°25′S, 167°43′E), supports extensive stands of rich mixed forest, accessible by a one-lane gravel track. No stoat control was carried out there until February 1975, when a systematic survey began using Fenn traps. These traps, the most humane available at the time (King & Edgar 1977), were set for two weeks a month and inspected daily until April 1978.

The Eglinton valley, in Fiordland National Park on the eastern side of the Main Divide (45°25′S, 167°43′E), is traversed by a two-lane tourist road through untouched beech forest to Milford Sound. This road carries substantial traffic, including fast-moving tourist buses. The local New Zealand Wildlife Service ranger established permanent Fenn traps along this road in late 1972, and inspected them intermittently (King 1980). They were replaced by systematically positioned Fenn traps set for two weeks a month, inspected daily, from early June 1973 to April 1978.

Craigieburn Forest Park (43°15’S, 171°73’E) is a high-elevation remnant of pure mountain beech forest on the

Figure 1

Female from the Hollyford Valley, Fiordland National Park, born October 1972, killed 4 December 1975, aged 38 months.

Figure 2

Male, from the Eglinton Valley, born October 1968, killed 17 July 1973, aged 57 months.

eastern foothills of the Southern Alps in Canterbury. The Fenn trapping programme was established along a steep single lane gravel access track in early 1973 and ran until August 1978. Further details of these areas and programmes are given elsewhere (King 1983).

Rangitoto Island (36° 47' S, 174° 51' E), in the Hauraki Gulf, northern New Zealand, is one of many important conservation islands around the coast that are steadily being cleared of all species of invasive mammals (King & Forsyth 2021). It was the site of a successful eradication of stoats (and other pests) in June 2009, but is within stoats' swimming distance of the mainland (Veale 2013; King *et al* 2014). A stoat swam to the island within 13 months of the end of the eradication programme, and in July 2010 was caught in a DoC (Department of Conservation) 200 trap set for routine island distribution and post-eradication surveillance. Genetic analyses showed that this stoat had come from East Auckland (Veale *et al* 2012). This case is not part of a systematic survey but was considered remarkable enough to add to the other descriptions.

Material examined

The 560 carcases available from the 1970s included 189 from the Hollyford Valley,184 from the Eglinton Valley, and 187 from Craigieburn Forest Park. External injuries to the front limbs had been recorded during processing of the whole carcases. Only the hind-leg bones were cleaned, because they were needed for a parallel study on methods of age determination (King 1991). Flesh was removed by gentle autoclaving, and measured to 0.01 mm with a Vernier caliper, using the neck of the femur or the tibio-femoral suture as reference points. The ages of all specimens in year classes were estimated as described by Powell and King (1997). The Rangitoto specimen was supplied already cleaned by cold water maceration (AJ Veale, personal communication 2021).

Abnormalities in the femurs were defined as any variation to the normal form and structure compared with the same bone in the other leg. The shaft of the femur is normally composed of a tube of compact osseous tissue covered by a layer of periosteum. Healed breaks in a substantial bone such as the femur of an adult, especially if covered by periosteum, imply extended survival (of the order of weeks to months) after a previous injury. In young stoats, the proximal and distal ends of the femur are the growth points, constructed of cancellous bone, a vascularised, spongy, porous tissue adjacent to the articulating surfaces. The fusion of the shaft with the joint is marked by a clearly visible suture.

Results

Among the 561 sets of femurs examined (560 collected during the 1970s, one in 2010), there were five cases of femurs grossly deformed by having been broken but healed during life. In four cases, only one femur had been broken; in the fifth, both.

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Case 1

The right femur (26.2 mm in length) has fractured half-way along the shaft between the base of the femoral neck and the tibio-femoral joint. The femur re-healed 10° out of line. Remodelling was complete, because smooth fibrous periosteum covered the entire damaged area. In addition, a spike-like outgrowth of new bone (3.4 × 4.3 mm; length × width), was developing near the tibio-femoral joint (Figure 1).

Case 2

The left femur (length 36.6 mm) had been completely severed, but bone regrowth had rejoined the halves even though the original tube of compact osseous tissue has not reconnected. No periosteum coated the re-joining tissue, which resembled new bone originating from the periosteum of the two halves. The extent of the bone regrowth prevented identification of the site of the break. Total remodelling and completion of the healing process appeared incomplete. The width of the femur in the area of the break had increased from 3.0 to 12.6 mm (Figure 2).

Case 3

This stoat was not yet full grown, as is evident from the open sutures visible at the tibio-femoral joint. The position of the break of the right femur (35.9 mm in length) is not clear, but tissue regrowth extends proximally for 20.6 mm from the tibio-femoral joint, and increases the femoral width from 2.3 to 7.7 mm.

Stoat families in New Zealand break up in January or February (King 1982), when the young are about 3–4 months old (King & Powell 2007). The extent of regrowth here suggests that this recently independent youngster was probably injured up to 6–8 weeks previously, whilst still learning to hunt with his mother and siblings. If so, he could perhaps have been fed by them until he recovered full mobility (Figure 3).

Case 4

In this male, almost two years old, both femurs had been broken part way down the shaft from the femoral head. On the right femur, tissue repair occupied half the length of the femur, which divided into two at around 24 mm from the base of the femoral neck, 6.8 mm from the fork. The other branch extends sideways for 6.2 mm (Figure 4).

On the left femur, extensive tissue regrowth began 6.9 mm from the tibio-femoral joint and extended all the way to the base of the femoral neck, greatly expanding the width of the femur. A small knob of tissue, 3.0 × 2.2 mm, has developed 4.4 mm from the femoral head.

This individual survived two femoral fractures at different times. The right femur was broken first, close to the growth plate, a physical impact which can stimulate regrowth of a new femoral head. The knob of new tissue near the femoral head of the left femur could have formed a similar new structure in time. The right femur in Figure 1 also showed a growing spike of new tissue, although in that case the growth seems to have stopped and is covered by a smooth fibrous periosteum.

Figure 3

Male, from Craigieburn Forest Park, born October 1977, killed 15 February 1978, aged 4 months.

Case 5

The right femur was broken (Figure 5) approximately 29 mm from the base of the femoral neck. The callus growth and the probable spiral/oblique fracture mean that both fragments have become longer than they had been before the break. The distal end of the femur has been angled 53° laterally and 18° distally, with a lateral rotation of 25°. It probably would have taken 3–4 months to heal to this stage, because the bones were over-ridden and mobile (Professor B Gartrell, Wildbase Research Centre, personal communication 2021).

Discussion

Healed fractures of the long bones of fur-bearing animals are not unusual in countries where use of leg-hold traps for winter harvest of fur-bearers is long established, or in samples collected as road kills (Argyros & Roth 2016). Which of these common hazards are most likely to account for the injuries described here?

Gin (leg-hold) traps

In and around our study areas, Australian brush-tail possums (*Trichosurus vulpecula*), an introduced fur-bearer, were common. Gin traps were not used on our standard lines, but

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Figure 4

Male (left and right) from Hollyford Valley, Fiordland National Park, born October 1971, killed 14 August 1973, aged 22 months.

fur-trappers often accidentally caught stoats in gin traps set for possums. In the survey previously described (King 1981), 41% of 336 stoats caught in gin traps sustained gross external injuries at the time of capture, and 32% were still alive when collected. Six had well-healed injuries suggesting a successful escape from a previous trap, in which three had lost an entire severed front leg, two had lost part of their tails and one had lost four toes from one front foot.

Among those that became part of this collection by failing to escape a second time were many with broken teeth and crushed or severed toes. Stoat fur or part or all of a foot (or both) was found in the stomachs of 21 of the 317 stoats collected from gin traps whose guts were analysed. If that individual had the same part missing, it was classed as having chewed off and swallowed part of its own front foot during its attempts to escape (King 1981).

Gin traps are the most likely cause of injuries to the front limbs and toes of captured stoats, because the front foot is the first to strike the trigger plate. All these cases came from areas where gin traps were often used for possum hunting. The evidence that front leg injury can usually be attributable to escape from a gin trap is not conclusive but telling.

On the other hand, a stoat caught by the hind leg could hardly wriggle out of a gin trap unless the mechanism were defective. For example, trappers who regularly sprung and reset their lines knew that traps left permanently set could be weakened by metal fatigue. This is a possible but less likely explanation for some of the injuries described here. Standards of acceptable trap technology in New Zealand are much tighter now (Warburton *et al* 2008; Littin 2010).

Vehicle impacts

Stoats are often seen crossing roads, but they move very fast, and are seldom hit. Three standardised, one-day surveys over 1,660 km in the North Island recorded one stoat carcase in 1984, none in 1994 and two in 2005 among 1,466 corpses counted (Brockie *et al* 2009). Another survey conducted over two years from November 1976 solicited sightings of stoats from visitors to all the then ten National Parks of New Zealand. From half to two-thirds of the total of 1,747 sightings reported from the ten locations were of stoats running across the road. Animals noticed dead on the road included 50 lagomorphs, 46 possums and 37 stoats, of which several were recorded as lying alongside carrion (King 1982).

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Figure 5

Male, born October 2009, killed July 2010, aged 9 months (Rangitoto Island).

Carrion from road-killed possums or provided by trappers as skinned carcases left in roadside vegetation, is an attractive but dangerous source of food for stoats in hard times. Stoats feeding on carrion on or near a road spend time in the path of danger and could well be hit on the hind legs when fleeing oncoming traffic. Vehicle impacts could well explain several of the cases described here.

Neither gin traps nor vehicles can account for the fifth case described above. Rangitoto Island is an important conservation reserve 3 km offshore from the large, traffic-heavy conurbation of Auckland. This stoat was (Veale *et al* 2012) unlikely to have arrived in full health, and then suffered such a serious injury on an island with no traffic or old traps. In addition, the healing process would have taken 3–4 months, during which time gathering enough energy to survive would have been nearly impossible for a disabled stoat on an island recently cleared of all its main food resources (Veale *et al* 2012). The alternative explanation is that this stoat was injured on the mainland, months before swimming the 3 km to the island. The injury must have greatly reduced its hind-leg function, but that would not have prevented the stoat from swimming, since most swimming power is provided by the forelimbs (King *et al* 2014). Swimming with forelimbs only for 2–3 h at a steady 1 km h^{-1} is well within a stoat's capabilities (King *et al* 2014).

Whatever the causes of the injuries described here, the ability of stoats to survive such serious physical trauma confirms many other observations of wild stoats as disproportionately tough for their size (King & Powell 2007).

Animal welfare implications

Taken together, previous observations of external injuries on whole carcases and the present analyses of clean bones show that, although stoats with broken or missing legs or damaged front claws must have been affected in their hunting capability, at least some of them could continue to survive for long enough to allow disabling injuries to heal. These data demonstrate an extraordinary resilience in injured stoats.

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