Ship rat (*Rattus rattus*) irruptions in South Island beech (*Nothofagus*) forest

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Abstract

A recent increase in ship rat numbers in beech forest around the South Island is cause for concern. High levels of ship rat predation on mohua nests have been recorded. Ship rats have previously been considered scarce in pure beech forest and above 1000 m, but recent records of rats in areas where they were previously absent, i.e. Craigieburn Forest Park and Mt Stokes, suggest a reassessment of their distribution is necessary. Ship rat abundance appears to be linked to food supply in beech forests, with increases in abundance recorded after seedfall. Minimum temperatures may be important in limiting ship rat distribution. Ship rat irruptions may be triggered in part by a mild winter coinciding with a beech mast. Research is needed to explore these theories.

1. Objectives

This report was commissioned by the Department of Conservation, Nelson/ Marlborough Conservancy, after a dramatic reduction in mohua *(Mohoua ochrocephala)* numbers on Mt Stokes (Marlborough Sounds) coincided with an apparent increase in ship rat *(Rattus rattus)* numbers on the mountain. This report reviews current literature and unpublished observations on ship rats to answer the following questions:

1. What information is known about the distribution and abundance of ship rats in South Island beech forest and how this is affected by temperature or food supply?

2. What information exists on the occasional irruption increases of ship rats, the timing of these irruptions and the subsequent presence of ship rat in areas where they are normally absent?

3. Can these events be predicted by food supply or climate?

2. Background

In 1985 a remnant population of mohua (yellowhead) was discovered in silver beech *(Nothofagus menziesii)* forest on Mt Stokes in the Marlborough Sounds. Over recent years, intensive pest control has been carried out on the mountain for possums, stoats, weasels, goats, and pigs. During this period, the Mt Stokes mohua population has increased rapidly, reaching a total of 90 birds at the end of the 1998/99 breeding season. However, over the winter of 1999, more than half of these birds went missing. Only 32 birds could be found in October 1999 when monitoring commenced for the breeding season. The to the cold. Stoats and ship rats were caught on Mt Stokes traplines in October 1999, indicating that both species were present over winter. Few ship rats had been caught in these traplines previously.

Research suggests that mohua are at greatest risk from predation during a stoat plague year and stoats are considered to be the greatest threat to mohua (Elliott 1996, O'Donnell et al. 1996). However, abnormally high ship rat numbers were recorded in many parts of the South Island last summer (1999/2000) and there was evidence of higher levels of ship rat predation on mohua nests (P. Dilks, pers. comm.) than had been previously recorded.

The fact that the Mt Stokes mohua population declined over winter prior to nesting challenges previous assumptions that mohua, as hole nesters, are only at risk from predation during nesting. Previous thinking was that only incubating females and nestlings were vulnerable to predation. However, last summer, male mohua were observed roosting in holes where they would have been easy targets for rats and stoats (P. Dilks, pers. comm.). Mohua may be more vulnerable to predation from stoats and rats than previously thought, if in fact mohua use holes throughout the year rather than just over the nesting period.

The threat of ship rats to mohua needs to be assessed. Finding answers to the proposed questions is part of this assessment.

3. Findings

3.1 DISTRIBUTION AND ABUNDANCE OF SHIP RATS IN SOUTH ISLAND BEECH FORESTS

Information on the distribution of ship rats throughout New Zealand is patchy, as a systematic survey has never been conducted. Ship rats are the most widespread of the three rat species in New Zealand. Ship rat distribution extends from the coast to the treeline in the South Island. However, ship rats have previously been considered scarce or absent in pure beech forest and above 1000 metres (Innes 1990). Data collected from rat trapping transects, run over several years at Mt Misery, Nelson Lakes National Park, showed the upper limit of ship rat distribution to be c. 1025 metres asl, which is also the upper limit of the red beech (*N. fusca*) forest. Despite considerable trapping effort in the silver and mountain beech (*N. solandri*) forest and alpine tussock at higher altitudes, no ship rats were caught (R.H.Taylor, unpubl. data).

3.2 EFFECT OF TEMPERATURE AND FOOD SUPPLY ON DISTRIBUTION AND ABUNDANCE OF SHIP RATS

The majority of published data on ship rats stems from research conducted in North Island lowland broadleaf/hodocarp forest where ship rats are most abundant (refer to Daniel 1978, Innes 1990, King et al. 1996). There are few published accounts of ship rat population biology from (high altitude) beech forest (refer to King and Moller 1997, King, 1983).

Temperature

There are few data on the lowest temperature tolerance of ship rats in New Zealand forests. R.H. Taylor (unpubl. data) found that in the Nelson Province, the ship rat's altitudinal limit away from human habitation seemed to coincide with approximate mean monthly temperatures (mean daily maximum + mean daily minimum / 2) of below 2.0°C during mid-winter months.

From the early 1960s through to the late 1980s, ship rats were living in the wild at many forest sites in the Nelson Lakes area where mean daily minimum temperatures in July were as low as -2.2°C, but where the daily maximum temperatures were over 8°C. However, despite extensive trapping, they were not found at three high-altitude forest sites (all >1300 m a.s.l.), Cupola Basin, Mt Robert, Mt Misery. At Cupola Basin, the mean daily minimum temperature for July was recorded as -2°C, but the mean daily maximum was only 3°C, giving an approximate mean monthly temperature of 0.5°C.

Lapse rates (in °F/1000 ft) of temperature change with altitude in winter of 4.2 for maxima and 1.7 for minima (Coulter 1967) were applied to different altitudes, with and without ship rats on Mt Robert and Mt Misery, using climate data collected at lake-level stations. The results indicated the 2.0°C approximate mean monthly temperature threshold. The data suggest that it may not be absolute cold, but the effect of prolonged cold on foraging for food, that is the limiting factor to ship rat distribution (R.H. Taylor pers. comet.).

This initial finding was supported by a later review of the world distribution of ship rats and site-specific climate records. The results indicate that ship rats do not exist outside of human settlement on islands, or in regions, where the approximate mean monthly temperature falls below 2°C in winter (R. H. Taylor, pers. comet.).

Ship rat breeding in New Zealand appears to be limited to some extent by temperature, with breeding generally occurring between September and April (Innes 1990). This creates a seasonal pattern of low numbers in spring, building up to a peak in autumn. However, it appears that the limiting effect of temperature on breeding may be reduced in years of increased food supply. Research in Pureora Forest Park (broadleaf/podocarp) between 1947 and 1970 (average monthly temperature was 10.3°C), found that ship rats bred over winter in years of heavy fruiting (Innes et al. unpubl.). Indications of winter breeding were also found in beech forest in the Hollyford valley after a good seeding year (King & Moller 1997).

Food supply

Ship rats are omnivorous generalists, but little information exists on the diet of ship rats in South Island beech forest. Ship rats in a South Island podocarp forest were reported to eat mainly plant material. The main animal foods eaten were wetas, beetles and moths (Best 1969). However, in studies throughout the country (Brown 1997, King et al. 1996, Moors 1983, Atkinson 1978, Bell 1978) ship rats have been identified as important predators of New Zealand forest birds. P. Dilks (pers. comm.) collected video evidence of rats predating mohua nests in the Eglinton Valley last summer (1999/2000). Female mohua were predated from 4 nests by ship rats and 2 more nests were found with similar predation sign.

Ship rat abundance has been linked to autumn seedfall in several studies. In an Orongorongo Valley study (podocarp/broadleaf forest), ship rat abundance over winter and spring was significantly correlated with the size of the autumn hinau seedfall. Winter breeding by female ship rats only occurred after heavy seedfalls of hinau and pigeonwood (Daniel 1978).

It appears that ship rat numbers fluctuate most dramatically in beech forest and that this could be linked to infrequent and irregular seedfalls (Alterio et al. 1999, King & Moller 1997). Increases in ship rat numbers were recorded in the Eglinton Valley in spring and summer 1995/96 following the 1995 beech mast. Increased numbers were recorded again this past summer (1999/2000) after seedfall in autumn 1999 (P. Dilks, pers. comm.). Ship rat numbers increased significantly after beech seedfall in red beech forest on Mt Misery (R.H.Taylor, unpubl. data). King & Moller (1997) found a correlation between 1976 beech seedfall and an increase in ship rat numbers in the Eglinton and Hollyford Valleys in the 1976/77 summer.

It is not clear whether ship rats eat beech seed or whether beech seeding is an indicator of other favourable environmental conditions. Fitzgerald et al. (1996) suggested that increases in mice populations after beech seedfall might have been linked to the large number of moth larvae emerging from the beech seed litter, rather than to the amount of seed available.

It is likely that seedfall is only one of the factors regulating ship rat numbers in beech forest. There are some examples where ship rat numbers do not increase after beech seedfall. A partial mast in the Dart and Caples Valleys last autumn (1999) did not result in high rat numbers in summer 1999/2000, although rats were present (B. Lawrence, pers. comm.). King (1983) recorded an increase in rat numbers in the Hollyford and Eglinton Valleys after seed fall in 1996 but found no increase after a beech mast in 1979.

Elliott (1990) observed that mohua have survived for over 100 years of rat and stoat predation in beech forest where rat abundance is generally low with only occasional peaks. However, the fast disappearance of mohua from diverse lowland forest on the South Island West Coast and on Stewart Island could have been attributable to the relatively high rat numbers which increase every summer in these forests after seedfall.

3.3 INFORMATION AVAILABLE ABOUT IRRUPTIONS OF SHIP RATS

The perception that large numbers of ship rats suddenly invade areas where they were previously absent is probably untrue. Ship rats tend to be very cryptic at low numbers (J. G. Innes pers. comm.) and may be present in an area for some time before they are noticed. With their fast breeding potential, ship rats can quickly take advantage of a favourable change in environmental conditions and with an increase in numbers they become suddenly more noticeable.

Nonetheless, it appears that ship rats are an intermittent predator in the Mt Stokes area. They were first recorded on Mt Stokes in 1998, despite intensive trapping during the previous seven years. In 1998, one was caught on a trapping line and another was seen in the Mt Stokes hut (Edmonds 1998). The trap lines, using covered Fenn traps, are set between 1000 and 1140 metres above sea level in pure silver beech forest. Previously, this high-altitude beech forest was thought to be unsuitable habitat for ship rats, so the traps were baited with hen eggs to target stoats. Last season (1999/2000) many ship rats were caught on traplines around the mountain. As there has been no targeted monitoring of rat numbers, it is unknown when ship rat numbers began to increase. Low numbers of stoats were caught on the mountain in 1997/98 (Edmonds 1998) and a beech mast seedfall occurred in autumn 1999. Reduced predation pressure and an increased food supply, coupled with a mild winter in 1999, may have contributed to increased ship rat numbers on the mountain. It is not known whether the rats bred over winter, but it appears likely that they survived the winter on the mountain and may have bred in early spring.

Craigieburn Forest Park is another area where rats have only recently been detected. Rodent trapping in the Park has been conducted over several years in mountain beech forest between 790 metres and 1340 metres asl (King & Moller 1997, King 1983). However, ship rats were trapped for the first time last summer (1999/2000) (E. Murphy, pers. comm.). This new record of ship rats in pure beech forest and above 1000 m, in addition to the records on Mt Stokes, necessitates a reassessment of ship rat distribution in the South Island.

From observations around the country, it appears there is significant annual variation in ship rat abundance. Flack and Lloyd (1978) found that rodent predation on robin nests at Kowhai Bush varied markedly from year to year between 1971 and 1976. During five and a half breeding seasons, rodents predated a total of only 9% of nests. However, during two of those seasons, rodents predated 49% of robin nests. Tracking tunnel surveys showed that ship rats were more abundant during these years of high predation. Flack and Lloyd (1978) suggested ship rats were the main rodent responsible for this increase in nest predation. Tracking tunnel rates of rat footprints collected over the last five years in the Eglinton also vary greatly (from >40% to <1% between 1995/96 and 1997/98) between years (P.Dilks, unpubl. data).

There are virtually no data indicating the mechanisms that control annual variation in ship rat abundance. It has been suggested that the most important factors controlling ship rat abundance in mainland forests are food supply and predation by cats and stoats (Daniel 1978, Murphy & Bradfield 1992). D. Choquenot (pers. comm.) suggested social factors might also play a part in controlling numbers by imposing an upper limit on rat numbers. This has been found to be the case in mice populations, where breeding is suppressed at high densities (Fitzgerald 1978). It seems likely that temperature may also be a factor regulating ship rat numbers. If so, it follows that especially in areas close to their threshold temperature, numbers will fluctuate with changes in the temperature.

Effect of predation on regulating rat numbers

Predation appears to play some role in affecting rat numbers (D. Choquenot, pers.comm., Innes 1990). Feral cats and stoats are known to eat ship rats (Daniel 1978, Innes 1990) and the presence of a higher predator level (stoats and cats) in an area may limit ship rat numbers (Innes 1990). On Stewart Island, rats are the staple food of cats (Karl & Best 1992) and in Mapara Reserve (podocarp/hardwood forest) ship rats were the main food item of stoats in 1989/90 (Murphy & Bradfield 1992). However, ship rats were not an important food for stoats in the Hollyford and Eglinton Valleys even in years of relatively high rat abundance (King & Moller 1997).

These studies highlight the need to carefully assess pest management objectives and to integrate pest control. The removal of one pest species from an ecosystem may alleviate limiting pressures on other pest species, causing an increase in numbers (meso-predator release) (Courchamp et al. 1999) or causing a prey switch (Murphy & Bradfield 1992).

In January 2000, P. Gaze (pers. comm.) found the abundance of mice on Mt Stokes to be thirty times greater in those areas subject to stoat control, indicating stoats were a major limiting factor on mouse numbers.

After a 1080 possum control operation in Mapara Reserve, ship rat density was reduced by over 90% and stoats responded to this change in rat abundance with a change in diet. For example, before the poison drop, the stoats' diet comprised 74.3% rats (by weight) and only 3.1% birds, whereas, after the poisoning, stoats switched to eating more birds (39.1%) and fewer rats (23.4%) (Murphy & Bradfield 1992). Consequently, it is not clear whether birds were safer while rat numbers were low.

Stoat trapping on Mt Stokes and at Craigieburn Forest Park has not lowered the threshold to ship rats on its own, because otherwise ship rats would have established in the area before now. However, in conjunction with other favourable factors, i.e. an increase in food supply, stoat trapping might have lowered the threshold significantly to allow rats to survive in areas of marginal habitat.

3.4 PREDICTION OF SHIP RAT IRRUPTIONS

Food supply appears to play a role in regulating ship rat abundance and distribution, especially in beech forests where the food supply is irregular and infrequent. Climate may also play an important part in ship rat abundance and distribution. If ship rats are limited to areas in New Zealand where the average monthly temperature is above 2°C (as is found in other parts of the world) this may explain the distribution and varying abundance of ship rats around the country. It may also explain the distribution of mohua and other bird species, which may be limited by ship rat predation. For example, mohua now persist only at relatively high altitudes and other locations where low temperatures are likely to be unsuitable for ship rats.

There are no temperature data available from any of the mohua study sites. The closest NIWA weather station to the Eglinton Valley is at Manapouri (200 metres asl). Temperature data recorded at Manapouri over the last 9 years show that the average monthly temperature in July is 3.83' C with a minimum of 2.4' C recorded in 1991. The Eglinton Valley is c. 200 metres higher in altitude than Manapouri and it is a steep-sided valley that sees little sun in winter. It is therefore reasonable to assume that average winter temperatures in the Eglinton valley would be lower than at Manapouri. If winter temperatures in some years drop below 2°C in the Eglinton Valley this could explain the varying annual abundance of ship rats. When the valley experiences a mild winter ship rat abundance could be expected to increase. If a mild winter coincided with a beech mast year it is likely that these two factors may contribute to abnormally high rat numbers. Beech mast years in red beech are known to occur every 5-6 years (Franklin 1974). Mild winters occur at a similar frequency, so the two events will coincide every 20 years or so. If, in addition to these factors, stoats are being controlled, the conditions will be even more favourable for ship rats, and numbers will expand accordingly.

It is not clear if results collected in the Dart Valley last summer (1999/200) fit this hypothesis. Conditions in the Dart Valley would have been similar to those in the Eglinton Valley over the last year (1999/2000) as both valleys experienced mild winters and had significant red beech seedfall, and both valleys were trapped for stoats. However, in the Eglinton Valley, where a full mast was recorded, rat numbers increased dramatically and in the Dart Valley where a partial mast was recorded, rat numbers remained low. Can these differences be explained by differences in the size of the seedfall? If not,there may be additional factors other than temperature, food supply and predation affecting the variation in ship rat abundance in South Island beech forests.

If rat irruptions cannot be predicted by external environmental conditions, monitoring rat numbers may be advisable in important areas. King and Moller (1997) suggest that research is necessary to determine if rat trapping in July and August would keep rat numbers low.

4. Conclusions

Gaps in current knowledge:

- Up-to-date information on ship rat distribution in New Zealand.
- The extent to which ship rats are limited by temperature in New Zealand.

- The benefits for mohua of stoat control in the presence of rats.
- The extent stoat control plays in allowing rats to establish in a new area.
- Options for integrated pest control.
- The effectiveness of winter rat control.

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