Department of Sustainability and Environment

Background and Implementation Information for the Smoky Mouse *Pseudomys fumeus* National Recovery Plan

Peter Menkhorst and Linda Broome

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Victoria
The Place To Be

Prepared by Peter Menkhorst (Department of Sustainability and Environment, Victoria) and Linda Broome (Department of Environment and Climate Change, New South Wales)

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This publication contains detailed background information and implementation detail for the 'National Recovery Plan for the Smoky Mouse *Pseudomys fumeus*' (Menkhorst and Broome 2006a), and should be read in conjunction with that document (available at www.dse.vic.gov.au).

This document has been developed with the involvement and cooperation of a range of stakeholders, but individual stakeholders have not necessarily committed to undertaking specific actions. The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved. Proposed actions may be subject to modification over the life of the plan due to changes in knowledge.

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Summary

The Smoky Mouse *Pseudomys fumeus* is a small native rodent endemic to mainland south-eastern Australia, where it occurs in Victoria, New South Wales and the Australian Capital Territory. The species has a relatively wide but disjunct distribution, populations are small and fragmented, and there appear to have been local extinctions in several areas. The Smoky Mouse is lsted as Endangered under the Australian Government *Environment Protection and Biodiversity Conservation Act 1999*. Major threats to the species include predation by introduced carnivores, habitat changes due to altered fire regimes, dieback caused by the Cinnamon Fungus *Phytophthora cinnamomi*, and loss, modification and fragmentation of habitat due to road construction and intensive timber harvesting. This national Recovery Plan for the Smoky Mouse is the first recovery plan prepared for the species. The plan details the species' distribution, habitat, conservation status, threats, and recovery objectives and actions necessary to ensure the long-term survival of the Smoky Mouse. It is intended to be the national Recovery Plan, so that local plans and actions for recovery conform with the national plan.

Species Information

Conservation Status

The Smoky Mouse is Listed as Endangered under the Australian Government *Environment Protection and Biodiversity Conservation Act 1999*. In Victoria it is listed as Threatened under the *Flora and Fauna Guarantee Act 1988*, and is considered Endangered (DSE 2003). In New South Wales the Smoky Mouse is lsted as Endangered under the *Threatened Species Conservation Act 1995*, and in the Australian Capital Teritory it is listed as Endangered under the *Nature Conservation Act 1980*. Under the IUCN Red List threat categories and criteria (IUCN 2001), the Smoky Mouse qualifies as Endangered (B2ab(ii,iv); C2a(i).

Downlisting the Smoky Mouse from Endangered to Vulnerable would require a reversal of the population declines indicated by the results of recent surveys (Ford 1998a, Kambouris 1999, authors unpublished). It is possible that further survey will locate new populations and therefore trigger a downgrade in conservation status, but recent targeted surveys in ACT, Victoria and NSW have not achieved this.

Classification and Taxonomy

Pseudomys is the largest genus of Australian rodents, and has a fossil history dating to the early Pliocene (~4.5 Mya), along with a suite of endemic Australian genera informally termed the conilurine rodents. McKenzie and Burbidge (2002) recognised 26 species in the genus, although several of these are probably synonymous with earlier described forms. Much variation exists within *Pseudomys*, and it may represent more than a single genus, but affinities are not clear (Watts *et al.* 1992). Recent DNA sequencing and morphological studies have highlighted divisions within the genus that will probably be proposed as full genera (F. Ford pers. comm., Ford 2006). The Smoky Mouse has no clear sib-relationship with any *Pseudomys* species (Watts & Aslin 1981), but is probably allied with the Silky Mouse *Pseudomys apodemoides* and the Ash-grey Mouse *Pseudomys albocinereus* (Watts *et al.* 1992; F. Ford pers comm., Ford 2006).

The Smoky Mouse was described by Brazenor (1934) from animals collected in tall wet forest at Turtons Pass in the Otway Range of southern Victoria. There appears to be a degree of morphometric variation between Smoky Mouse populations in the eastern and western parts of its range (Menkhorst and Knight 2004; Menkhorst and Seebeck unpublished data), although the significance of this variation is uncertain. Clarification of the morphological and genetic variation within the Smoky Mouse, and its implications for taxonomy, is proposed as an action in this Recovery Plan.

Distribution

Until 1985 the Smoky Mouse was known as a living animal only from Victoria, where it occurred in widespread but disjunct populations in The Grampians, Otway Range, Eastern Highlands and coastal East Gippsland (Menkhorst & Seebeck 1981; Menkhorst 1995). In 1985 and 1987, single animals were trapped at two sites in the Brindabella Range, ACT (Osborne & Preece 1987; Mayo 1987). In January 1993, Smoky Mouse hair was identified from a hair sampling tube near Mt Poole in Nungatta State Forest, south-east New South Wales. In 1994 a Smoky Mouse hair was identified from a bird nest collected from Mt Namadgi (ACT), and another possible Smoky Mouse hair was identified in the vicinity from a hair sampling tube. In September 1994, the first live animals from NSW were captured in Nullica State Forest, north-west of Eden (Jurskis *et al.* 1997). It has subsequently been recorded at several sites in south-eastern NSW, mainly from a small area of Nullica State Forest and the adjoining South East Forests National Park (14 sites, DECC, FNSW unpublished). There are also three records in Kosciuszko National Park (Ford 1998a), plus records from Ingebyra State Forest adjacent to the park (one hair record, SF) and Buccleugh State Forest (one capture site, S. Banks, pers. comm. June 2001). Sub-fossil remains of Smoky Mice have been found in several cave deposits in far western Victoria, eastern Victoria and south-eastern NSW, north to the Jenolan Caves, indicating that the species formerly had a wider distribution than current records suggest (Menkhorst & Seebeck 1981).

The distribution of Smoky Mouse records is shown in Figure 1. The records can be divided into five biogeographic regions: The Grampians, Otway Range, South Eastern Highlands, and coastal East Gippsland-Eden Hinterland. It is not certain that the species persists in all of these regions, as recent targeted surveys in coastal East Gippsland and the Otway Range have failed to detect any animals (Menkhorst & Homan unpublished). There have been no definite records of live animals from the ACT since the original animals were captured in 1985 and 1986, despite targeted surveys (Lawrence 1986; Lintermans 1988) (Table 1). However, more recent records from NSW at Buccleugh State Forest and Yarrangobilly Caves in Kosciuszko National Park are located 17 km and 33 km respectively from the ACT border.

The potential bioclimatic distribution of Smoky Mouse was modelled using the program BIOCLIM (Nix 1986) using all available capture, definite hair tube and hair-in-predator-scat records of the Smoky Mouse. A predicted distribution based on 19 temperature and precipitation variables is shown in Figure 1. This suggests that, given there is suitable habitat, the species could be expected to occur more widely in southern Victoria, especially in the South Eastern Highlands, ranges to the north-west of Melbourne and sub-coastal East Gippsland. In NSW this model includes areas around the fossil sites at Marble Arch, London Bridge, Wombeyan and Jenolan Caves (site records that were not included in the analysis).

A second, more conservative model that includes moisture index and radiation variables (an additional 16 variables) restricts the prediction in NSW to only the Eden Hinterland and Snowy Mountains. In Victoria the predicted area using the second model is very similar, although a little more restrictive, to that shown in Fig. 1.

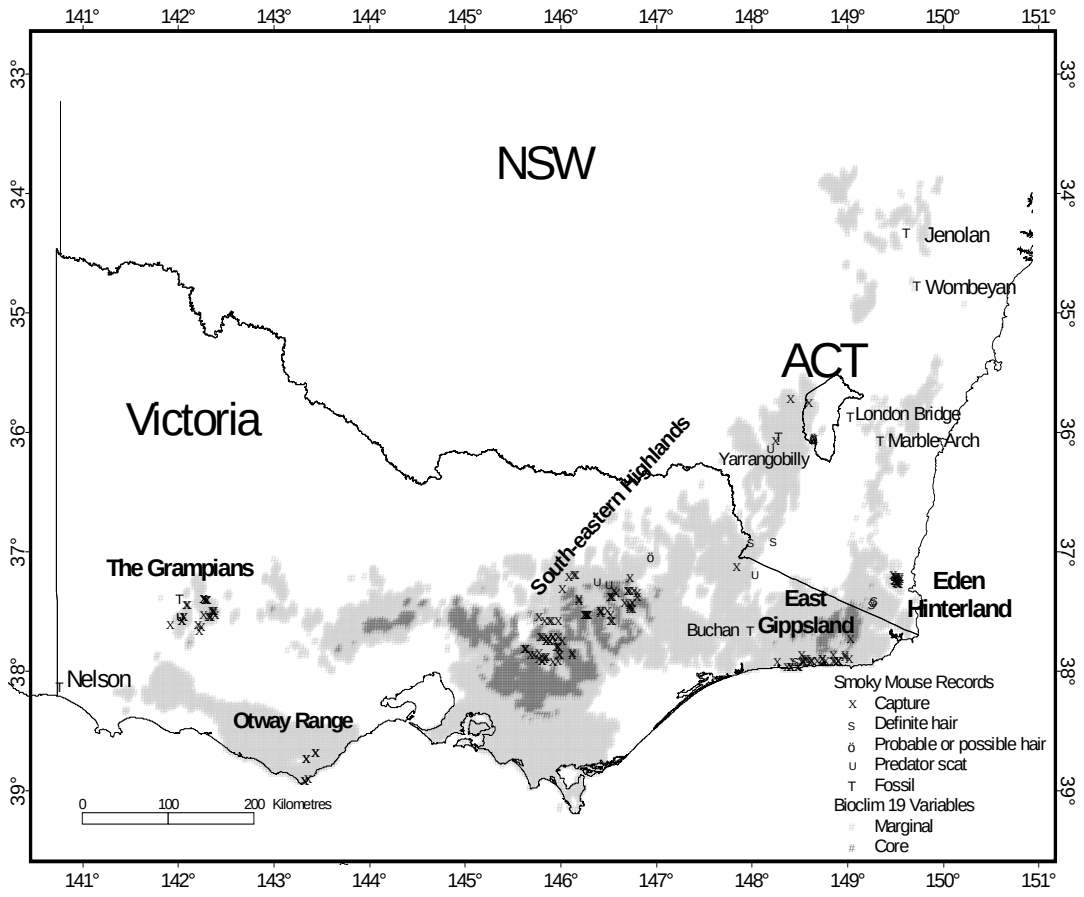

Figure 1. Distribution of the Smoky Mouse *Pseudomys fumeus*. The map shows all records (data from Atlas of Victorian Wildlife and NSW Wildlife Atlas) as well as a predicted distribution using the BIOCLIM climatic model. The Bioclim analysis is modelled on 19 temperature and precipitation variables, with core bioclimatic domain based on the 10-90% levels in the bioclimatic envelope; the marginal bioclimatic domain is the remainder (see Lindenmayer *et al.* 1996 for explanations).

Table 1. Year of most recent record of the Smoky Mouse from each biogeographic region, and the tenure of land from which the species has been recorded.

Region	Land tenure	Year of most recent record
The Grampians	Crown conservation reserve, Vic	2005
Otway Range	Crown conservation reserve, Vic	1985 (2 confirmed records since 1937)
South Eastern Highlands	Crown conservation reserve, State forest, Vic, NSW, ACT	2007 (in ACT no captures since 1987, hair record from 1994)
East Gippsland coast	Crown conservation reserve, Vic	1990 (1 record since 1979)
Eden Hinterland	Crown Conservation reserve, State forest, NSW	2004

Habitat

The precise habitat requirements of the Smoky Mouse are not clear. A wide range of vegetation communities are occupied, from damp coastal heath in East Gippsland, to sub-alpine heath. However, most records are from ridgeline dry heathy open-forest in the South Eastern Highlands, The Grampians and Eden Hinterland (Menkhorst and Seebeck 1981, Ford *et al.* 2003). Smoky Mice have also been trapped in wet forest communities; indeed, the type locality at Turtons Pass is surrounded by some of the wettest forest communities in Victoria and vegetation mapping shows only wet forest or temperate rainforest vegetation classes for many km in all directions (DSE BioMap database). There is evidence that some of the records from forest gullies may represent dispersing animals rather than locally-resident populations. However, in The Grampians, resident colonies are known from damp gully communities in two different locations (Silverband Falls and Victoria Range Road). The Victoria Range Road site has been trapped on two occasions, 27 years apart, in September 1974 and April 2002. Smoky Mice were captured in good numbers on both occasions. The Silverband Falls site produced captures, including breeding females, between October 1962 and June 1971 but no captures were recorded in 2002 (Atlas of Victorian Wildlife unpublished data).

A characteristic of Smoky Mouse localities, except those in wet gullies, is a floristically diverse shrub layer with members of the plant families Epacridaceae, Fabaceae and Mimosaceae well represented (Menkhorst & Seebeck 1981; Cockburn 1981a; Jurskis *et al*. 1997; Ford 1998a, b; Ford *et al.* 2003; DEC, FNSW unpublished). Ground cover is also likely to be critical and can be in the form of dense low vegetation, such as occurs in heaths, or grass tussocks, rocks and logs in more open habitats. Soil conditions also need to be conducive to burrowing and growth of hypogeal fungi, a major component of the diet.

Life History

Life cycle and social organisation

Life history studies have been conducted at two sites; one in sub-alpine heath on Mt William in The Grampians (Vic) (Cockburn 1975, 1979, 1981a, 1981b), and another in heathy dry forest at Nullica in the Eden Hinterland (NSW) (Ford 1998b; Ford *et al.* 2003). Although the NSW study spanned only one breeding season, a number of commonalities occur in the findings of the two studies.

Smoky Mice occurred in small discrete colonies based around patches of dense heath. They sheltered in small groups, sometimes comprising a male and up to five breeding females, in a large, complex burrow system that can be up to 10 m^2 and more than 25m in length, with multiple nesting chambers (Ford *et al.* 2003; Woods & Ford 2000; Ford in prep.). Breeding occurred from September–April, and 1–2 litters, each of 3–4 young, were produced. Males developed scrotal testes by late August, and began to secrete an oily, strongly musk-odoured substance that covered much of their body fur. This musky scent was present on males until the end of October, and was generally very pungent on resident males, less so on transient individuals (Ford 1998b). Regression of testes occurred around April. The female-biased sex ratios found in high quality habitat may result from dominance relationships between males and the group nesting of females. At Nullica, all females were perforate by mid to late September, and by the end of September nearly all were pregnant. Some births occurred in September, although it appears that neither the offspring from these births nor the females giving birth survived. It was not until November that a lactating female was recorded. In the Victorian studies, lactation was observed from October–December, depending on the year. Only those females occupying the best quality habitat survived to breed in a second year. Numbers declined rapidly in autumn, principally from loss of young recruits, especially males, in sub-optimal habitat, as food resources dwindled. Only those that remained in, or found, high quality habitat were expected to survive the winter.

The two studies that have followed populations through a breeding season have both shown a marked population reduction in spring. In The Grampians this decline mostly involved males, and was attributed to a nutritional crisis due to the decline in available fungi in sub-optimal habitat, mostly occupied by males, during late spring. Fluctuations in the number of females were not so large because of female-biased sex ratios in habitat where fungi persisted, and flowers and seed provided sufficient nutrients for breeding (Cockburn 1981b). At Nullica, after initial female-biased sex ratios in spring 1997, female numbers also declined. No adults were trapped by February 1998 and no animals have been captured since August 1998 (DECC unpublished data). Ford *et al.* (2003) suggested that the decline may have been partly due to the onset of breeding at a time when preferred food resources were scarce, due to low rainfall in previous months, but suggested predation may have also been implicated in the population decline.

Recruitment

Litter size is usually 3-4, after a gestation period of about 30 days. There is some evidence of a post-partum oestrus and females in the wild have been observed to produce one or two litters in a season and one captive pair produced three litters (Cockburn 1981b, Woods & Ford 2000). However, the little available data suggest that survivorship of juveniles and adults, except those in the best quality habitat, can be low (Cockburn 1981b, Ford 1998b). On Mt William all females occupying the best quality habitat survived to breed in a second year (Cockburn 1981b).

Population size and dynamics

Almost nothing is known about the population number and dynamics of the Smoky Mouse. Trapping rates are usually low, typically 3–4% or less (Menkhorst & Seebeck 1981, Ford 1998a, Mills & Broome unpublished). However, rates can be quite high in quality habitat when conditions are good. For example, on the summit of Mt William in The Grampians during the mid–late 1970s, trapping rates were 12% (24 captures

from 196 trapnights) (Menkhorst & Seebeck 1981) and 7.3% over 9,600 trapnights (Cockburn 1981a). In the Victoria Range in The Grampians in 2002, rates were 19% (15 captures from 80 trapnights) (Menkhorst & Homan unpublished). Trapping rates at the original Nullica site were 12–15% in September 1994 and September 1997 (Jurskis *et al.* 1997; Ford 1998b).

A characteristic of Smoky Mouse colonies is their ephemeral nature, both spatially and temporally. There are numerous examples of unsuccessful attempts to locate the species at sites where it had been found only a few months previously (eg. Lawrence 1986; Lintermans 1988; Ford *et al.* 2003; DECC, FNSW unpublished data). This may be due to shifts in home range following fluctuations in resource availability due to climatic fluctuations, or to differences in trappability, or, in the longer-term, to vegetation succession. An apparent decline at Mt William over the last decade (no individuals were trapped in April 1996 (Cockburn pers. comm. 2001) and only one in March 2002 (Menkhorst & Homan unpublished)) was not, at first glance, associated with visible vegetation change, or with the disappearance or decline of any vascular plant species (Cockburn pers. comm. 2001). This may suggest some effects on the ecology of the hypogeous fungi that form such an important part of the species' diet (Cockburn pers. comm. June 2002). Such fluctuations in numbers and patchiness in distribution within apparently suitable habitat are characteristic of many species of *Pseudomys* (Watts & Aslin 1981), and make population monitoring and conservation planning particularly problematic.

Population fluctuations may not be wholly due to changes in resource availability. It has been suggested that excessive predation by foxes and cats can control population increases and suppress recovery of low-density small mammal populations in the arid zone (Newsome & Corbett 1975; Watts & Aslin 1981; Dickman *et al.* 1999). Predation may also contribute to patchiness in distribution of the Hastings River Mouse *Pseudomys oralis* in northern NSW, particularly near areas of vegetation clearing (Smith *et al.* 1996). Where there is a sufficient extent of habitat to support natural population dynamics, *Pseudomys* species generally show population pulses in response to changes in resource availability. Between these pulses they persist at low population densities, except where resource-rich habitat patches allow higher densities (Watts & Aslin 1981; Brandle & Moseby 1999; Townley 2000; NPWS 2002). This pattern of distribution appears to be shown by the Smoky Mouse, but site persistence appears to be extremely low. Menkhorst and Seebeck (1981) noted only two sites at which more than ten individual Smoky Mice had been captured in Victoria. In the Eden Hinterland, 15 females and 13 males were trapped in an area of habitat exceeding 5 ha at the original capture site (Ford 1998b). Between one and three females and mainly single males have been located at another 10 smaller patches of understorey heath that occur on the dissected ridge system within a 10 x 6 km area surrounding this site. Females have been trapped at only three of these sites in more than one year, and some apparently suitable habitat is generally unoccupied (Ford 1998a; DECC, Forests NSW unpublished data). This distribution, and the identification of transient males that may represent individuals moving between sub-populations in search of mates (Ford 1998b), suggests that Smoky Mice exist in the area as a metapopulation. Long-term survival of the population would therefore be contingent on recruitment and immigration between habitat patches, and the regional dynamics of resource availability (Harrison 1994). It is likely that this is also the situation with populations of Smoky Mice in other areas.

The Smoky Mouse is not likely to be an invasive species, unlike the smaller New Holland and Silky Mice (Cockburn pers. comm. 2002). Rather, it seems to have a relatively low reproductive potential and appears to be most abundant in relatively stable habitats, with access to well-developed, diverse, heathy understoreys. Although the magnitude of changes in resource availability, particularly of hypogeal fungi, are unknown, the low species abundances in apparently suitable habitat (Kambouris 1999; DECC, FNSW unpublished data), and extremely ephemeral nature of most known Smoky Mouse populations, in environments that would appear to be relatively stable compared to desert environments, is of considerable concern.

Foraging behaviour and diet

The Smoky Mouse is primarily herbivorous but also consumes invertebrates, with diet varying seasonally according to food availability and energetic demands. At the summit of Mt William, Cockburn (1981a) found that the fruiting bodies of underground fungi predominated in the diet in winter and early spring, with a small proportion of seeds and soil invertebrates. There was a sudden switch to flowers, seeds and Bogong Moths *Agrostis infusa* in late spring–early summer, while seeds predominated through summer and autumn. A similar pattern was found at Nullica (Ford 1998b; Ford *et al.* 2003), but without the invertebrate component. The Smoky Mouse may be more dependant on the fruiting bodies of hypogeal fungi than are other *Pseudomys* species, and leaf material may be less important than in other large species of *Pseudomys* (Ford *et al.* 2003).

Recovery Information

Existing Conservation Measures

Population Studies

Only two studies of Smoky Mouse population dynamics, habitat requirements and diet have been undertaken – a PhD study by Cockburn (1979, 1981a, b) and a BSc (Hons) study by Ford (1998b; Ford *et al.* 2003). Jurskis *et al.* (1997) briefly investigated habitat usage at the original Nullica State Forest site and this work was expanded by Ford (1998a).

Surveys

Baseline surveys for the Smoky Mouse in Victoria were summarised by Menkhorst and Seebeck (1981). Subsequently, surveys were undertaken by Kambouris (1999) and Menkhorst and Homan (unpublished). These have been complemented in New South Wales and the ACT by studies undertaken by Lawrence (1986), Lintermans (1988), Jurskis *et al.* (1997), Ford (1998a), Broome *et al.* (DECC, unpublished) and Slade *et al*. (FNSW unpublished).

Habitat Reservation

Writing in 1982, Cockburn (1983) correctly stated that none of the known Smoky Mouse localities were protected in conservation reserves. That situation has changed substantially. All Smoky Mouse localities in The Grampians, the Otway Range and the ACT are now within conservation reserves, as are most localities in coastal East Gippsland and the Victorian portion of the South Eastern Highlands (Table 2. In NSW half the known localities in the Nullica area are within the Nullica section of South East Forests National Park, while others occur within the Kosciuszko National Park.

Table 2. Conservation reserves in which the Smoky Mouse has been recorded.

Region	Conservation reserve with Smoky Mouse record	Year of last record
The Grampians	Grampians NP	2004
Otway Range	Great Otway NP	1985
South Eastern Highlands	Alpine NP	2007
	Baw Baw NP	1978
	Lake Eildon NP	1989
	Yarra Ranges NP	1988
	Mt Terrible NFSR	1989
	Kosciuszko NP	1998
	Namadgi NP	1986
East Gippsland	Cape Conran CP	1979
	Croajingalong NP	1979
Eden Hinterland	South East Forests NP	2004

CP – coastal park, NFSR – natural features scenic reserve, NP – national park.

Management Planning

There has been little management planning specifically for the Smoky Mouse (Lee 1995). In Victoria, management plans for relevant National Parks list the Smoky Mouse as a threatened species that occurs within the park but include no specific management actions. The species was listed under the Victorian *Flora and Fauna Guarantee Act 1988* in December 2000, but an FFG Action Statement has not yet been produced. In the Australian Capital Territory, an Action Plan has been produced under the *Nature Conservation Act 1980* (ACT Government 1999). In New South Wales a Threatened Species Priorities Action Statement, under the *Threatened Species Legislation Amendment Act 2004* (amendments to the *Threatened Species Conservation Act 1995)* has been written. Half of the 23 known sites in NSW are within timber production forests. Protection measures within State Forests have been identified under the Eden and Tumut IFOA (Integrated Forestry Operations Approval Package, State of NSW and Commonwealth of Australia 1999, 2002). However, there have been concerns that these protection measures (3–4 nights trapping for pre-logging surveys and reservation of habitat only around identified capture sites) are insufficient to identify Smoky Mouse presence and to retain sufficient suitable habitat to sustain metapopulations within areas of intensive (integrated) logging. An alternative protection strategy and management plan for the population in Nullica State Forest, that retains a network of high quality, known and potential habitat across the area, has therefore been developed and implemented.

Strategy for Recovery

The strategy for recovery of the Smoky Mouse will be to secure the habitat and stabilise population numbers of the Smoky Mouse in a majority of known populations in each of the five Smoky Mouse biogeographic regions (Table 1). This will be achieved through the designation of Smoky Mouse Protection Zones around areas of

high quality known and potential habitat, followed by targeted predator control, the construction of trial small-mammal refuges, and the instigation of a valid population monitoring protocol. A captive breeding colony will be established for nutritional studies and potential re-introduction. Further research into the floristic composition (including hypogeal fungi) and habitat use of Smoky Mouse habitat in each region will allow the development of ecological burning regimes and management strategies in timber production forests aimed at providing continuity in availability of patches of high quality habitat.

Recovery Objectives

The **Long-term Objective** of recovery is to achieve a down-isting of the Smoky Mouse to the Vulnerable category through reduction of threats to populations in The Grampians, South Eastern Highlands and Eden Hinterland. This will be achieved by increasing regional population sizes to at least 150 adult individuals, and by appropriate management of fire, logging regimes and predators.

Within the life span of this Recovery Plan, the **Specific Objectives** of recovery are to:

1. Designate protection zones around known populations.
2. Refine knowledge of distribution and abundance.
3. Examine population partitioning.
4. Minimise predation by the Red Fox, feral cat and wild dog.
5. Establish small-mammal refuges at key sites.
6. Develop and test burning regimes to maintain and enhance habitat quality.
7. Study habitat preference, diet and the effects of disturbance on population survival and connectivity.
8. Establish a captive breeding colony of Smoky Mice.
9. Assess and minimise the risk of habitat loss through *Phytophthora cinnamomi* infection.
10. Increase community awareness and involvement.

Objective 1. Designate protection zones around known populations

Recovery Criterion:

Two or more Smoky Mouse Protection Zones established in each of The Grampians, South Eastern Highlands and Eden Hinterland.

Action 1.1 Designate Protection Zones around key Smoky Mouse populations.

At present there is little information available on the processes that drive Smoky Mouse population dynamics and the levels of habitat disturbance and predation that populations can tolerate. As a first step in the Recovery Program, the Recovery Team will identify likely key areas of known Smoky Mouse populations that will receive a high level of protection. Protection Zones that are likely to encompass functional metapopulations will be designated around two or more areas of Smoky Mouse habitat

in each region where Smoky Mouse is known to be extant. These areas should be large enough to include clusters of known sites and sufficient high quality, potential habitat, with interconnecting corridors, to reasonably allow normal metapopulation processes to operate into the foreseeable future. Where there is uncertainty about the area required and any continuing, acceptable level of disturbance, estimates should be precautionary. These areas will be targeted for predator control and burning regime trials and will receive the maximum amount of protection from wildfire. Under the current Eden and Tumut IFOA (Integrated Forestry Operations Approval Package, State of NSW and Commonwealth of Australia 1999, 2002), timber harvesting exclusion zones of 100 ha minimum are required to be established around records of the Smoky Mouse within SF tenure. These conditions are being revised under new agreements, which include the protection of high quality habitat and the establishment of Smoky Mouse reserves in the Eden area. The level of protection needed may need to be refined following survey, habitat modelling and research.

Responsibility: Recovery Team and relevant land management agencies

Action 1.2 Review current protection zones in the Eden Hinterland.

To conserve Smoky Mouse in timber production forests, it is essential that logging plans and prescriptions allow adequate habitat patches to remain unaltered to provide a source of animals to recolonise logged areas if suitable habitat returns. Retained patches must be in a suitable conformation to sustain metapopulation dynamics in the area. Consideration will be given to whether current exclusion zones in Nullica State Forest are adequate to protect the Smoky Mouse metapopulation in the area. Mapping of all areas of high quality heathy understorey will be conducted as a prelude to this review.

Responsibility: FNSW, DECC, Recovery Team

Action 1.3 Review current IFOA conditions for Smoky Mouse in NSW.

Given the difficulties in encountering the Smoky Mouse using traditional survey techniques, there were concerns that the current protocols (3-4 nights trapping and reservation of habitat only around identified capture sites) are inadequate to identify Smoky Mouse presence and to retain sufficient suitable habitat to sustain metapopulations within timber production forests in NSW. These conditions are under review and alternative exclusion zones that incorporate high quality habitat will be nominated as Smoky Mouse reserves under the revised agreement due in 2008, to provide a high level of protection to Smoky Mouse populations in the Nullica area.

Responsibility: FNSW, DECC, Recovery Team

Objective 2. Refine knowledge of distribution and abundance

Recovery Criterion:

Increases in knowledge of population numbers and distribution in all regions.

Action 2.1 Develop targeted survey techniques and monitoring protocols.

Recent primary surveys have covered substantial areas of the likely range of the Smoky Mouse in Victoria and NSW, but there are still areas of potential habitat to be searched in both States and the ACT. An improved understanding of distribution, population numbers and density is essential to accurately assess the likely impact of future timber harvesting, for reserve acquisition, for planning overlays, to assist with EPBC Act referrals, and for knowing when recovery program goals have been achieved. Current trapping and survey data will be reviewed and trials of new trapping and survey techniques will be undertaken. Predator control should be undertaken prior to and in conjunction with any long-term trapping studies that may disturb patches of dense vegetation. Frequency of trapping for monitoring studies and repeated capture of pregnant or lactating females should be kept to a minimum.

Responsibility: Recovery Team, Project Officer

Action 2.2 Develop habitat suitability index.

Reliable identification of potential habitat requires a clear method for quantified, repeatable assessment of habitat suitability. This project aims to assimilate current knowledge of the habitat requirements of the Smoky Mouse and develop criteria that can be used to score the suitability of any site at the local site level. The results of each survey can be used to progressively refine the index.

Responsibility: Recovery Team, consultant

Action 2.3 Undertake field surveys and mapping in the ACT.

Smoky Mouse distribution and relative abundance in ACT will be defined and areas of known and potential habitat mapped.

Responsibility: ACT PCL

Action 2.4 Undertake field surveys and mapping in NSW.

Smoky Mouse distribution and relative abundance in the Eden Hinterland, in Kosciuszko NP and elsewhere in the South Eastern Highlands region of New South Wales will be defined and areas of known and potential habitat mapped.

Responsibility: DECC

Action 2.5 Undertake field surveys and further mapping in Victoria

Smoky Mouse distribution and relative abundance in the Otway Range and coastal East Gippsland will be defined and areas of known and potential habitat mapped.

Responsibility: DSE and PV

Objective 3. Examine population partitioning

Recovery Criterion:

Study of population partitioning completed and the results incorporated into future versions of this plan. Levels of genetic diversity and meta-population structure determined within sub-populations in The Grampians, South East Highlands and Eden Hinterland regions.

Action 3.1 Estimate levels of genetic partitioning between the regions.

The Smoky Mouse is currently known to occur in five separate biogeographical regions separated by large tracts of inhospitable country (Figure 1). Although BIOCLIM analysis suggests some of these regions may have previously been connected by potential habitat (Figure 1) there is now little likelihood of genetic interchange between those regions due to vegetation clearance. An exception may be between East Gippsland and the Eden Hinterland. There is morphological evidence that suggests a degree of divergence between populations in the western and eastern parts of the range but the numbers of museum specimens are inadequate to allow a robust statistical comparison of morphometrics. A better understanding of levels of genetic partitioning between the regions, and of the levels of heterozygosity within them, will help establish population management strategies. Hair or tissue samples from 10-20 individuals in each region will be collected and analysed using appropriate molecular techniques to determine past and present levels of gene flow between the regions.

Responsibility: Recovery Team and contractor

Action 3.2 Measure levels of heterozygosity within and between biogeographical regions.

Using the samples collected for Action 3.1, micro-satellite analyses to test for evidence of low genetic variability within populations will be undertaken.

Responsibility: Recovery Team and contractor

Objective 4. Minimise predation by the Red Fox, feral Cat and wild Dog

Recovery Criterion:

A high level of predator control is carried out in designated protection zones.

Action 4.1 Develop predator control strategies.

Trials of a range of predator control strategies, and monitoring of the response of the Smoky Mouse populations, are required to test the significance of predation by red foxes, cats and dogs. The Southern Ark project in East Gippsland has provided a model of how landscape-scale fox control programs can be successfully organised and carried out, to the benefit of small and medium-sized mammals. Parks Victoria have also conducted a study of fox control in The Grampians NP. Increasing evidence suggests that concurrent cat control measures may be needed because of increased cat abundance due to meso-predator release following control of dogs and foxes. In consultation with predator control agencies in each range state, a series of predator control strategies will be developed for the three critical Smoky Mouse regions - The

Grampians, South Eastern Highlands and Eden Hinterland, building on work already undertaken in the East Gippsland Coast region under Southern Ark.

Responsibility: Recovery team, DECC, FNSW, PV, ACT PCL

Action 4.2 Implement predator control strategies.

Predator control strategies for The Grampians, South Eastern Highlands and Eden Hinterland will be progressively implemented, including monitoring of predator and Smoky Mouse population response.

Responsibility: PV, DECC, FNSW, ACT PCL

Objective 5. Establish small-mammal refuges at key sites

Recovery Criterion:

Small mammal refuges developed and tested at two sites.

Action 5.1 Establish small-mammal refuges in The Grampians and Eden Hinterland.

One method of ensuring the persistence of a population would be to utilise small-mammal refuges (Smith & Quin 1996). These are predator-proof enclosures that encompass the home ranges of 10–20 breeding females. The mesh size allows the passage of dispersing rodents while preventing the ingress of foxes, cats, quolls and goannas. They should be located in areas with good surrounding cover and links to other nearby patches of potential habitat.

Responsibility: PV, DECC, FNSW

Objective 6 Develop and test burning regimes to maintain and enhance habitat quality

Recovery Criterion:

Areas to be treated by ecological burning are defined and mapped, and burned when appropriate.

Action 6.1 Review data on floristic composition and fire response life history attributes.

Fire regimes are a key ecological process that strongly influence habitat quality for the Smoky Mouse. Current knowledge is inadequate to accurately specify an ideal burning regime for any of the key populations. Improved knowledge is most likely to be gained by using an adaptive experimental management approach involving ecological burning of habitat patches close to known Smoky Mouse colonies and monitoring of Smoky Mouse occupation of the regenerating habitat. The timing and intensity of the burn will be determined on the basis of the best available knowledge of the responses to fire of known Smoky Mouse food plants including fungi. Data on floristic composition and structure of Smoky Mouse habitat in The Grampians, South

Eastern Highlands and Eden Hinterland will be reviewed and recommended burning regimes defined to maintain floristics and structure of those habitats.

Responsibility: Project Officer in conjunction with Recovery Team.

Action 6.2 Select sites and undertake trial ecological burns.

At least one appropriate site adjacent to a known Smoky Mouse colony in each of The Grampians, South Eastern Highlands and Eden Hinterland will be selected for implementation of the suggested ecological burning regime. After burning, vegetation (including fungi) and Smoky Mouse response will be monitored at yearly increasing to three-yearly intervals over at least a 15-year period.

Responsibility: Project Officer in conjunction with Recovery Team.

Action 6.3 Monitor vegetation and small mammal response to ecological burns.

At the sites selected for trial ecological burns, pre- and post-fire monitoring of vegetation floristics and structure, and Smoky Mouse population responses will take place. Initially monitoring will occur at yearly intervals then increase to three-yearly intervals over at least a fifteen year period.

Responsibility: Project Officer in conjunction with Recovery Team.

Objective 7 Study habitat preference, diet and the effects of disturbance on population survival and connectivity

Recovery Criterion:

Information on diet and habitat use in a range of habitat types and disturbance regimes obtained and used for conservation management.

Action 7.1 Investigate utilisation of habitat and diet in undisturbed, burnt and logged sites.

Smoky Mouse habitat use has mostly been inferred from trapping, which can often be misleading and provides no detailed information on movements, foraging preferences or nesting locations within various microhabitats. Smoky Mice have been trapped in recently disturbed sites but there is no information available on the extent to which they rely on adjacent undisturbed areas and no data to indicate whether logging, frequent burning or absence of burning will have long-term deleterious effects on Smoky Mouse habitat. It is important to establish this in regions of Smoky Mouse habitat that are in timber production forests, such as the Eden Hinterland, South Eastern Highlands and East Gippsland, to assist long-term management planning and protection strategies. Radiotracking of Smoky Mice and dietary studies will be conducted in areas of disturbed and undisturbed habitat.

Responsibility: DECC, FNSW, Project Officer in conjunction with Recovery Team

Action 7.2 Establish the nutritional importance of food resources and their relationship to habitat quality.

The issue of whether Smoky Mice are restricted to specific habitats because of dietary requirements will be assessed by measuring physiological responses of a captive colony (see Objective 8) to a range of foods available to them in the wild. This study will help to determine whether low numbers of Smoky Mice are due to nutrition or are a result of other factors such as predation.

Responsibility: DECC in collaboration with universities, Project Officer

Action 7.3 Monitor vegetation succession and Smoky Mouse populations in disturbed and undisturbed sites.

Vegetation change (including fungi) will be monitored at 1–3 year intervals in areas of potential habitat in the Eden Hinterland and The Grampians that were logged and/or burnt recently, and at undisturbed known sites (determine fire history), to establish regeneration and senescence history. Small mammal trapping in these sites will be conducted in conjunction with the vegetation assessment.

Responsibility: DECC, FNSW

Action 7.4 Review data and survey floristic composition and small mammals at regenerating logged sites.

Surveys of floristic composition and small mammal abundance will be conducted at forest sites of various ages after logging that were likely to have supported suitable Smoky Mouse habitat before logging.

Responsibility: Project Officer or student in conjunction with Recovery Team.

Objective 8. Establish a captive breeding colony of Smoky Mice

Recovery Criterion:

Captive breeding colony of Smoky Mice successfully established, breeding and recruiting young.

Action 8.1 Establish a captive breeding colony of Smoky Mice.

A captive colony of Smoky Mice is required for the study of nutritional requirements (Action 7.2) and as insurance against the demise of the wild population. A captive colony has previously been successfully held at Melbourne Zoo, but no captive populations currently exist. It is proposed to establish a captive colony at an appropriate facility, to be chosen after consultation.

Responsibility: DECC, Project Officer in conjunction with Recovery Team

Objective 9. Assess and minimise the risk of habitat loss through *Phytophthora cinnamomi* infection

Recovery Criterion:

Presence and risk of *Phytophthora cinnamomi* infection in each Smoky Mouse region identified and strategies developed to protect susceptible key areas.

Action 9.1 Assess risk to Smoky Mouse from Cinnamon Fungus

The extent of infestation and degree of threat posed by Cinnamon Fungus to Smoky Mouse habitat requires identification in each region. Strategies to minimise spread and possible quarantine measures in susceptible areas will be developed, in conjunction with national and state threat abatement plans. Trials of spraying affected areas with phosphonate as a means of controlling spread of Cinnamon Fungus are currently being conducted in areas of Smoky Mouse habitat in South East Forests National Park (K. McDougall, pers. comm. September 2006). If successful this method will will be extended to affected key habitats.

Responsibility: Project Officer in conjunction with Recovery Team.

Objective 10. Increase community awareness and involvement in the recovery process

Recovery Criterion:

Community support for and participation in Smoky Mouse conservation is increased.

Action 10.1 Involve the community in the Recovery Program.

The Smoky Mouse, like most native rodents, has a very low profile amongst the general public. It is an attractive small mammal with great potential to act as a flagship species for Australia's diverse and unique rodent fauna. Survey and monitoring are activities in which volunteers can actively participate. There are several mammal survey groups that have expertise and equipment that could be utilised in primary surveys and in population monitoring, and their involvement will be sought. University student groups are also available to assist as part of their course and practical experience requirements.

Responsibility: Recovery Team, Project Officer

Action 10.2 Provide information about the Recovery Program.

Information on the Smoky Mouse and the Recovery Program will be provided to agencies, participants and the general public, through preparation of an annual review of the Smoky Mouse Recovery Program, providing an annual summary of results, and media information on 'one-off' events such as successful population increases.

Responsibility: Recovery Team, Project Officer

Affected Interests

The Smoky Mouse occurs on land with a variety of managers and management tenures. Consequently, management is the responsibility of a range of agencies and organisations, and several community groups also have an interest in Smoky Mouse recovery. These are listed below:

Department of Sustainability and Environment, Victoria

Parks Victoria
Glenelg Hopkins Catchment Management Authority (CMA)
Field Naturalists Club of Victoria
Corrangamite CMA
Port Phillip and Western Port CMA
Goulburn Broken CMA
West Gippsland CMA
East Gippsland CMA
Murrumbidgee CMA
Murray CMA
Southern Rivers CMA
Department of Environment and Climate Change, NSW
ACT Department of Municipal Services
Forests NSW

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Appendix 1 Smoky Mouse Recovery Team Membership and Abbreviations

Recovery team Membership

ACT Parks Conservation and Lands

Department of Environment and Climate Change, South Branch

Forests New South Wales, Southern and Tumut Regions

Department of Sustainability and Environment, Biodiversity and Natural Resources Division

Department of Sustainability and Environment, Gippsland Region

Department of Sustainability and Environment, South West Region

Department of Sustainability and Environment, North East Region

Parks Victoria

A small mammal ecologist

A representative of the Threatened Species Network

Abbreviations

ACT PCL Australian Capital Territory, Territory and Municipal Services, Parks Conservation and Lands

ANU Australian National University, Canberra

CSIRO Commonwealth Scientific and Industrial Research Organisation

DECC Department of Environment and Climate Change, New South Wales

DEWHA Department of Environment, Water, Heritage and the Arts(Commonwealth)

DSE Department of Sustainability and Environment, Victoria

FNSW Forests New South Wales

FS Forests Service, Department of Sustainability and Environment, Victoria

PV Parks Victoria

TSN Threatened Species Network

Appendix 2. Recovery Plan Costs ($ x 1000)

Action	Description	Priority	Source	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
1.1	Designate Protection Zones	High	Agencies	12					12
			Other						0
1.2	Review Protection Zones	High	Agencies	10					10
			Other						0
1.3	IFOA Survey Conditions	High	Agencies	8					8
			Other						0
2.1	Survey Techniques	High	Agencies	8	4				12
			Other	18	14				32
2.2	Habitat index	Medium	Agencies	8					8
			Other	18	6				24
2.3	Surveys ACT	High	Agencies		5	5			10
			Other		15	10			25
2.4	Surveys NSW	High	Agencies	9	9	9	9		36
			Other	10	30	31	32	10	113
2.5	Surveys Vic	High	Agencies		5	5	5		15
			Other	10	30	31	32	10	113
3.1	Genetic partitioning	Medium	Agencies		4	4	4	2	14
			Other					16	16
3.2	Heterozygosity	Medium	Agencies		2	2	2	2	8
			Other					21	21
4.1	Predator Strategy	High	Agencies		10				10
			Other		8				8
4.2	Predator Control	High	Agencies	40	40	40	40	40	200
			Other	35	35	35	35	35	175
5.1	Refuges	Medium	Agencies		20	10	15	17	62
			Other		10				10
6.1	Floristics and fire	Medium	Agencies	6					6
			Other	5					5
6.2	Ecological Burns	Medium	Agencies		20				20
			Other		30				30
6.3	Monitor response	Medium	Agencies		6	6	6	6	24
			Other						0
7.1	Habitat and diet study	High	Agencies	5	10	10	10	10	45
			Other			12	21		33
7.2	Nutrition and habitat	High	Agencies	5	5	5	5	5	25
			Other		10	10	10		30
7.3	Monitor succession	High	Agencies	25	25	25	25	25	125
			Other	5	5	5	5	5	25
7.4	Survey logged sites	Medium	Agencies		5	5			10
			Other		5	5			10
8.1	Captive breeding colony	High	Agencies	10	5	5	5	5	30
			Other	30	20	20	20	20	110
9.1	Phytophthora	High	Agencies	6	6	6	3	3	24
			Other	5	5	5	2	2	19
11.1	Community involvement	Medium	Agencies	7	7	7	7	7	35
			Other						0
11.2	Program information	Medium	Agencies	3	3	4	4	5	19
			Other						0
	TOTAL		Agencies	162	191	148	140	127	768
			Other	136	223	164	157	119	799
			Total cost	298	414	312	297	246	1567

Appendix 3 Locality information for all Smoky Mouse records

Record type:

1 – trapped

2 – identified from hair collected in a hair tube

3 – probable record identified by hair analysis

4 – possible record identified by hair analysis

5 – Identified from hair or bones in predator scat

6 – subfossil record.

Only records of types 1, 2 and 5 were used in the Bioclim analysis.

Record number	Reference Number	Latitude	Longitude	Altitude m ASL	Record type
1.	GR15	-37.3339	142.2847	780	1
2.	GR16	-37.2333	142.3167	560	1
3.	GR17	-37.2333	142.3333	520	1
4.	GR18	-37.4167	142.4500	440	1
5.	GR20	-37.4667	142.4500	480	1
6.	GR21	-37.3167	142.5000	440	1
7.	GR38	-37.1833	142.5167	370	1
8.	GR45	-37.1833	142.5333	400	1
9.	GR47	-37.3333	142.5500	1060	1
10.	GR48	-37.3333	142.5667	1000	1
11.	GR57	-37.2833	142.6000	1120	1
12.	GR59	-37.3167	142.6167	440	1
13.	OT1	-38.8333	143.5500	60	1
14.	OT2	-38.6333	143.5667	560	1
15.	OT4	-38.8167	143.5833	5	1
16.	OT5	-38.5833	143.6667	560	1
17.	CH1	-37.6333	145.8500	360	1
18.	CH2	-37.6500	145.8000	570	1
19.	CH3	-37.6333	145.8667	580	1
20.	CH4	-37.6833	145.9167	400	1
21.	CH6	-37.6833	145.9500	640	1
22.	CH8	-37.3333	146.0000	600	1
23.	CH9	-37.6667	146.0000	800	1
24.	CH13	-37.7167	146.0000	620	1
25.	CH16	-37.5167	146.0167	700	1
26.	CH17	-37.5167	146.0333	700	1
27.	CH21	-37.7333	146.0333	620	1
28.	CH22	-37.5333	146.0500	880	1
29.	CH23	-37.3833	146.0667	620	1
30.	CH24	-37.7000	146.0667	720	1
31.	CH25	-37.7167	146.0667	700	1
32.	CH28	-37.5500	146.0833	760	1
33.	CH29	-37.7000	146.0833	1060	1
34.	CH30	-37.5333	146.1000	880	1
35.	CH33	-37.3833	146.1167	1020	1
36.	CH39	-37.3833	146.1333	1260	1
37.	CH45	-37.5167	146.1500	1100	1
38.	CH46	-37.7500	146.1500	1000	1
39.	CH47	-37.5500	146.1667	1200	1

40.	CH48	-37.6167	146.1833	840	1
41.	CH49	-37.3833	146.2000	440	1
42.	CH55	-37.5167	146.2000	1160	1
43.	CH59	-37.6167	146.2000	900	1
44.	CH60	-37.7333	146.2000	1140	1
45.	CH62	-37.6833	146.2167	600	1
46.	CH63	-37.0833	146.2500	600	1
47.	CH64	-37.5500	146.2500	1010	1
48.	CH66	-36.9667	146.3167	900	1
49.	CH67	-37.6667	146.3500	800	1
50.	CH68	-37.6833	146.3500	1060	1
51.	CH69	-36.9500	146.3667	540	1
52.	CH70	-37.1667	146.4167	1200	1
53.	CH71	-37.2000	146.4167	600	1
54.	CH74	-37.3167	146.4833	1020	1
55.	CH77	-37.3167	146.5000	960	1
56.	CH83	-37.3167	146.5167	1040	1
57.	CH88	-37.0167	146.6167	850	5
58.	CH91	-37.2833	146.6500	1180	1
59.	CH93	-37.3000	146.6500	1000	1
60.	CH95	-37.2833	146.7167	1545	1
61.	CH96	-37.0500	146.7333	800	5
62.	CH97	-37.1500	146.7500	580	1
63.	CH99	-37.3167	146.7500	1605	5
64.	CH100	-37.3667	146.7500	1540	1
65.	CH101	-37.1500	146.7667	720	1
66.	CH102	-37.3667	146.7667	1540	1
67.	CH103	-37.1000	146.7833	1100	1
68.	CH104	-37.1167	146.8167	1000	1
69.	CH106	-37.2167	146.9000	500	1
70.	CH113	-37.1000	146.9333	1200	1
71.	CH114	-36.9833	146.9500	580	1
72.	CH115	-37.1000	146.9500	1300	1
73.	CH116	-37.2333	146.9500	900	1
74.	CH118	-37.2500	146.9500	1000	1
75.	CH119	-37.2667	146.9500	1080	1
76.	CH122	-37.2167	146.9833	550	1
77.	CH123	-37.2667	146.9833	1200	1
78.	CH124	-37.1000	147.0000	1200	1
79.	CH125	-37.1167	147.0333	1160	1
80.	CH126	-37.1500	147.0333	880	1
81.	CO1	-36.8833	148.0667	1280	1
82.	CO2	-36.9500	148.2670	800	5
83.	EG1	-37.8000	148.6000	40	1
84.	EG3	-37.8000	148.6167	20	1
85.	EG4	-37.8000	148.6333	40	1
86.	EG9	-37.7333	148.7000	90	1
87.	EG10	-37.8000	148.7167	20	1
88.	EG12	-37.8167	148.7333	20	1
89.	EG13	-37.6833	148.7500	140	1
90.	EG14	-37.7500	148.7500	60	1
91.	EG16	-37.7167	148.7667	80	1
92.	EG18	-37.7333	148.7667	80	1
93.	EG21	-37.7500	148.7667	40	1
94.	EG27	-37.7167	148.8000	40	1
95.	EG28	-37.7500	148.8333	40	1

96.	EG31	-37.7333	148.8500	20	1
97.	EG34	-37.7167	148.9667	60	1
98.	EG35	-37.7167	148.9667	40	1
99.	EG37	-37.7333	149.0000	40	1
100.	EG40	-37.6833	149.0833	40	1
101.	EG42	-37.7333	149.0833	40	1
102.	EG43	-37.7333	149.1000	40	1
103.	EG44	-37.7333	149.1333	40	1
104.	EG54	-37.6833	149.2000	100	1
105.	EG55	-37.7000	149.2000	160	1
106.	EG57	-37.7167	149.2500	40	1
107.	EG58	-37.5333	149.2667	200	1
108.	CH127	-36.7810	147.1760	XX	4
109.	BR1	-35.3856	148.8313	1020	1
110.	BR2	-35.7162	148.8761	1820	1
111.	BR3	-35.6846	148.8764	1620	3
112.	BR4	-35.6960	148.8890	1710	4
113.	KN1	-36.6569	148.2275	1220	2
114.	KN2	-35.8030	148.4260	890	5
115.	KN3	-35.7280	148.4830	880	1
116.	KN4	-35.3500	148.6389	1100	1
117.	KN5	-36.6405	148.4640	1270	2
118.	SE1	-37.2198	149.4894	348	2
119.	SE2	-37.1982	149.5090	665	2
120.	SE3	-37.2012	149.5132	730	2
121.	SE4	-37.1801	149.5184	695	2
122.	SE5	-37.0025	149.7264	500	2
123.	SE6	-37.0040	149.7312	445	2
124.	SE7	-37.0060	149.7590	380	2
125.	SE8	-37.0030	149.7300	462	1
126.	SE9	-37.0160	149.7250	570	1
127.	SE10	-37.0320	149.7410	570	1
128.	SE11	-37.0332	149.7470	530	1
129.	SE12	-37.0366	149.7687	284	1
130.	SE13	-37.0156	149.7703	412	1
131.	SE14	-36.9533	149.7086	540	1
132.	SE15	-37.0347	149.7475	550	1
133.	SE16	-37.0400	149.7497	405	1
134.	SE17	-36.9725	149.7336	330	1
135.	SE18	-36.9711	149.7275	380	1
136.	SE19	-36.9814	149.7761	440	1
137.	SE20	-36.9683	149.7525	435	1
138.	SE21	-36.9969	149.7794	305	1
139.	SE22	-36.9978	149.7436	360	1
140.	FO1	-35.7290	149.5760	XX	6
141.	FO2	-35.5140	149.2640	XX	6
142.	FO3	-35.7300	148.4820	XX	6
143.	FO4	-37.4630	148.2160	XX	6
144.	FO5	-34.3190	149.9610	XX	6
145.	FO6	-33.8260	149.8530	XX	6
146.	FO7	-37.9830	141.0000	XX	6
147.	FO8	-37.1670	142.2500	XX	6