Item 1a

Powelliphanta augusta

Recovery Strategy

2021 – 2031

The southern form of *Powelliphanta augusta.* Image Kath Walker

P. augusta Recovery Working Group:

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Introduction

Powelliphanta augusta is a species of giant land snail endemic to the Stockton Plateau, approximately 24 km north-east of Westport on the West Coast of the South Island, New Zealand. It currently has the highest threat ranking of 'Threatened: Nationally Critical' and has been prioritised for management by the Department of Conservation (Department of Conservation 2017).

The snail was discovered in 1996 with a few shells collected near Mt Augustus on the western edge of the Stockton Plateau. However, it was not recognised as a separate taxonomic entity until 2003, and described as a unique species in 2008 (Trewick et al. 2008, Walker et al. 2008). The original range of *P. augusta* is unknown. In 2004, it occupied about 10 ha of habitat along the Mt Augustus ridgeline. Any former habitat to the east had already been destroyed by opencast coal mining.

Between 2006 and 2008, around 60% of the remaining habitat were also destroyed by opencast coal mining. The mining company Solid Energy NZ (SENZ) was granted Wildlife Act Permits by the Department of Conservation (DOC) to clear habitat under the condition that they collect live snails from the mining areas prior to clearance (WC-1903-FA, WC-20788-FA). The collected snails were taken into captivity, marking the start of an intensive species recovery programme.

P. augusta is a taonga species. Its (former) range on the Stockton Plateau is located within the rohe of Ngāti Waewae. The Department, therefore, works with Ngāti Waewae on the recovery of this taonga.

The recovery work has been guided by a technical advisory group, initially made up of internal and external experts: Kath Walker, Ian Stringer, Rod Hitchmough (all DOC), John McLennan, Ruth Bartlett (both consultants for SENZ) and Mike Hadfield (captive snail expert, University of Hawaii). Today the group consists only of DOC staff (the authors of this strategy). Other internal or external experts have been and are being called upon as required.

The day to day work on *P. augusta* has been guided by recovery strategy documents. These define goals and objectives, and the management actions required to achieve these (Gruner 2007a, Otley et al. 2015). The most recent strategy covered the work until mid-2020 (Otley et al. 2015). The present document updates this strategy taking the programme forward to 2031.

The document is longer and contains more detail than normally expected of a recovery plan. This is deliberate, as information about *P. augusta* is scattered across numerous published papers, unpublished reports and theses, and much of it is in people's heads. We have tried to pull this information together, summarising contents and providing references for those who want to find out more detail. By doing so, this document also provides in one place all the information required by decision makers to understand and approve the recovery strategy for *P. augusta* for the next 10 years.

The strategy begins in Part A with a summary of current knowledge and recovery actions to date. Part B presents the current state of *P. augusta* and assesses achievements against the goals of the 2015-2020 strategy. Parts A and B set the context for Part C, which defines the goals and recovery actions for the next ten years. This is the operational part of the recovery strategy, driving the annual workplan. Part D provides some of the rationale behind the goals and actions identified in Part C.

Part A – Current knowledge and recovery actions to date

Life history of *P. augusta*

Unless otherwise referenced, the following information on the life history of *P. augusta* is taken from Walker (2008), Allan (2010), Hamilton (2015) and experience gained during the captive management of the snails (L. Flanagan, R. Phillips, S. Martini, DOC, pers. comm.).

The life-history of captive snails is not necessarily comparable to that of wild snails, as captive snails are held under artificial conditions (plastic containers, constant 6-8°C temperature, beech forest litter and sphagnum moss substrate, light-dark cycle mimicking natural cycle, abundant compost worm food). However, for many aspects of the species' biology, the knowledge gained from captive snails is the best we have.

P. augusta is thought to normally be an out-crossing hermaphrodite. However, in captivity, two self-fertilised eggs have successfully hatched. In the wild, most eggs are thought to be laid in spring. In captivity, egg laying initially peaked around November, but now occurs throughout the year. Eggs are laid in clutches of 1-3 eggs with larger snails having larger clutch sizes. In the captive population, adult snails lay on average two eggs per month; one captive snail laid seven eggs in one month. Egg production generally decreases in larger snails (over 40 mm diameter). For unknown reasons, not all adult snails in captivity have laid eggs.

P. augusta eggs resemble miniature chicken eggs. They are pinkish-white in colour initially, which gradually turns to light brown, and they have a smooth calcareous shell. They are on average 8.02 mm long x 6.76 mm wide. In captivity, incubation takes on average 400 days when the eggs are held at a constant temperature of 6-8°C. Incubation time for wild snails is unknown.

Usually, one hatchling emerges from each egg, although twins and triplets have occasionally been observed in captivity. Single hatchlings have a maximum shell diameter of around 8.5 mm. After hatching, the little snail eats its eggshell, presumably for its calcium content. In the case of twins or triplets, hatchlings have been seen to also eat their siblings.

Growth rates in the wild have been estimated at an average of 2.6mm per year, with smaller snails growing faster than larger snails (20-25mm snails: 5.4mm/year, snails >35mm: 0.9mm/year). Based on these estimates, wild snails are likely to take around 8 years to reach sexual maturity (maximum shell diameter $\geq$ 32 mm). In captivity, snails reach this diameter after 6-7 years. The maximum size of a *P. augusta* snail is around 40 mm maximum shell diameter. Currently, the largest captive snail has a diameter of 42 mm.

It is unknown how long *P. augusta* live in the wild. The oldest individuals in captivity are at least 22 years old, as some of the adults captured in 2006 are still alive now.

In the wild, *P. augusta* are nocturnal. Activity seems mainly driven by local weather conditions and is highest on relatively warm and wet nights after a dry spell (Wildland Consultants 2009). Snails are most active in late spring and move least during the winter months. To avoid unfavourable conditions, they can bury themselves up to 5cm deep in litter or soil, in crevices between rocks or at the bases of plants, preferably gahnia or tussocks.

In captivity, the snails have changed their behaviour, potentially because conditions are always favourable. Sub-adults and adults born in captivity appear to lose their natural 'caution'. They emerge readily from their shells during the day and do not retract in response to signals that would normally be perceived as danger (e.g. being touched, strong vibrations). As this behaviour change has only been observed in subadults and adults, it seems to be learned behaviour rather than a genetic change.

The key food for *P. augusta* are earthworms they encounter in the leaf litter of their habitat (Boyer et al. 2011, Boyer et al. 2013). Feeding does not appear to be targeted to specific species of earthworms but seems opportunistic (Boyer et al. 2011, Boyer et al. 2013). It is unknown how much food a snail requires in the wild to sustain itself; smaller snails appear to eat smaller worms (Boyer et al. 2011). In captivity, the snails are fed the exotic earthworm *Eisenia andrei* and a supplement of cuttlefish bone. Worms are selected to match the size of the snail. Every 4-5 weeks, each snail receives six worms, which generally get eaten before the next feeding event.

The log of a snail's weight has been found to be linearly related to the log of its maximum shell diameter. This relationship has been used to define a body condition index (Allan 2010). This index varies in wild snails throughout the year, with the best condition observed during summer months. Captive management aims to maintain snails near this summer optimum. However, the body condition index of the captive population has not been assessed since 2010.

Natural habitat

Powelliphanta snails need habitat where they can maintain their life-sustaining water balance. This means they need moisture provided either through an accumulation of damp litter or a suitably damp microclimate. Another key factor in *Powelliphanta* distribution and abundance is the availability of their earthworm food, which in turn seems to depend largely on soil fertility (Climo et al. 1986, Parrish et al. 2005).

Intensive habitat studies were undertaken between 2004 and 2006, prior to habitat clearance, to understand the ecology of *P. augusta*. This was to aid selection of suitable translocation sites, inform habitat rehabilitation post-mining and to provide clues for successful captive management. A constraint was that, by the time habitat studies got underway, the majority of habitat had likely already been lost to mining activity further east. In 2004, the remaining range of *P. augusta* formed a narrow band along the Augustus ridgeline from the area around the north peak (northern limit: NZTM E1504473 N5386477) to just south of the former high point of Mt Augustus (southern limit: NZTM E1504930 N5385448) (Walker et al. 2008). The summit of Mt Augustus (1011 m asl) and its north-eastern faces, where the first shells of *P. augusta* had been found, had already been mined (Figure 1). The following habitat descriptions are based on information in Bartlett (2005), Walker et al. (2008) and Rate (2010) unless otherwise referenced.

Vegetation

P. augusta occurred in a range of vegetation types. The vegetation along the Augustus ridgeline included:

- stunted mountain beech (*Fuscospora cliffortioides*) forest with pink pine (*Halocarpus biformis*), southern rata (*Metrosideros umbellata*), inaka *(Dracophyllum longifolium)*, and leatherwood tupare (*Olearia colensoi*),
- scrub with variable dominance of manuka (*Leptospermum scoparium*), leatherwood, *Dracophyllum* spp., and mountain flax wharariki (*Phormium cookianum*),
- tussock communities with broadleaved snow tussock (*Chionochloa flavescens*), North Westland snow tussock (*Chionochloa juncea*), mountain gahnia (*Gahnia procera*) and bush flax kakaha (*Astelia fragrans*),
- fern-sedgeland dominated by tangle fern (*Gleichenia dicarpa)*, wire rush (*Empodisma minus*) and stunted manuka.

These vegetation types occurred in a densely interwoven mosaic with *P. augusta* present at highest densities in the ecotones, the zones where one vegetation type merged with another. In these ecotones, the vegetation was generally dense, knee to thigh high, with high plant diversity and abundant litter on the ground (Figure 2).

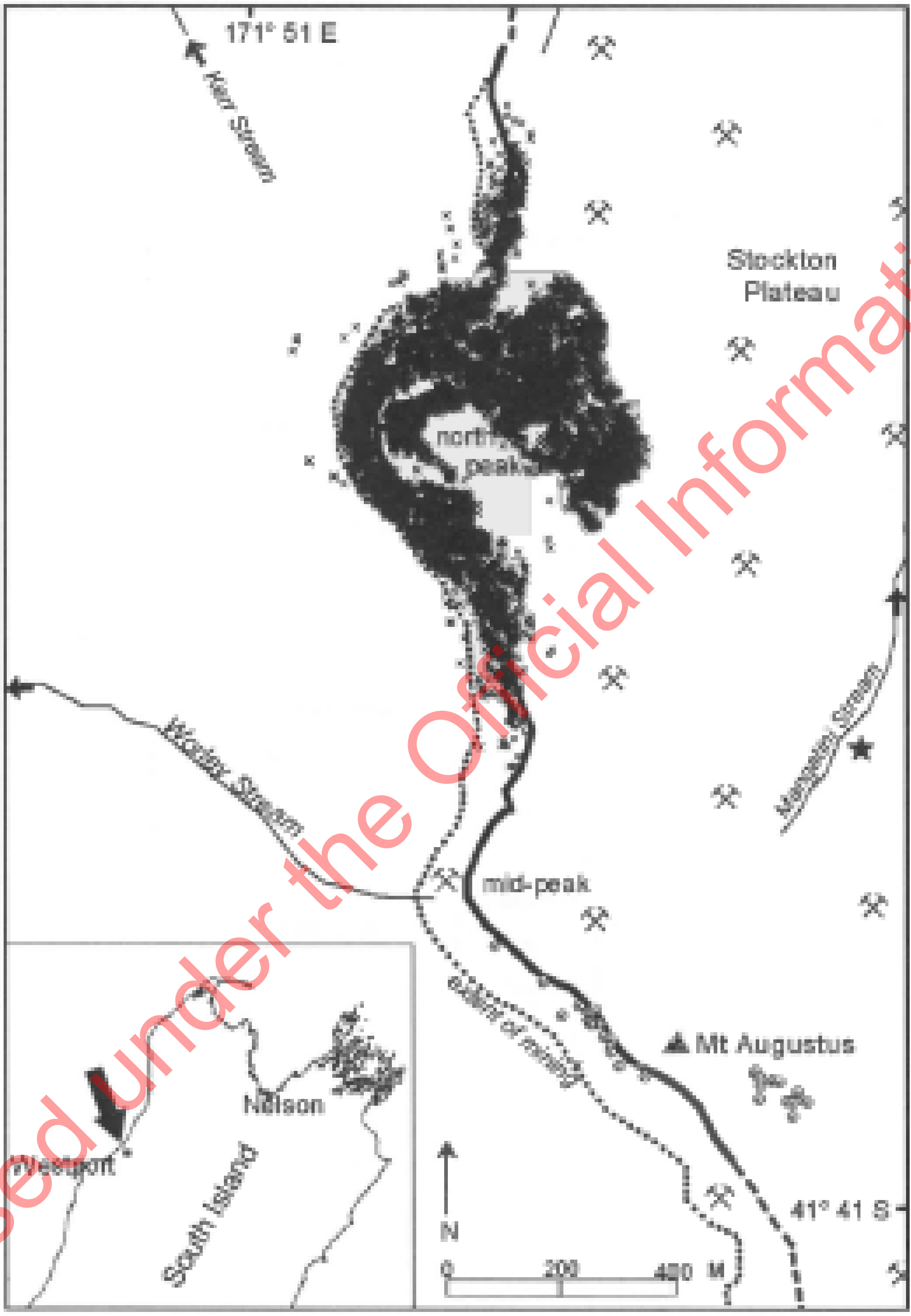


Figure 1. Known distribution of live Powelliphanta augusta 2004-2007. Crosses indicate locations of snails of the Northern and Central groups, dotted circles are locations of Southern snails. The black star near Mangatini Stream represents the site where six shells were collected in 1996. The western escarpment of the Stockton Plateau where high cliffs formed the Augustus massif is shown as a solid black line, dashed lines indicate the former ridgeline north and south of the massif. The sharp edges of the snail's distribution east of the ridgeline are not natural but the result of mining activity in these areas. By late 2007, coal mining had removed all snails and habitat east of the dotted line. Figure copied from Walker et al. (2008).

Figure 2. Ecotone between stunted mountain beech forest and scrub in snail search block 4c.

Altitude and climate

P. augusta occurred naturally above 850-900m asl. The climate in the area was cool and wet. Mean daily air temperatures were below 3°C in winter (Jun-Aug) and 11-13°C in summer (Jan-Mar). The average annual rainfall has been estimated at 6.7-7.3 metres with a strong gradient of decreasing rainfall with decreasing altitude. As the Augustus ridgeline formed a coastal range, the area was characterised by regular and persistent cloud formation shrouding the *P. augusta* habitat in fog on otherwise clear days, even during summer.

Soils

Soils in *P. augusta* habitat were acidic with a mean pH of 4.3. Their calcium content was accordingly low with a mean of 2.05 me/100g. Organic matter in the soils was subject to very slow decomposition as indicated by a C/N ratio of 25.4. The soils were generally characterised by poor drainage, making them permanently damp. The litter layer was not necessarily well developed throughout (mean depth 1.85 cm), suggesting that the waterlogged soils and damp climate played a critical role in the persistence of *P. augusta* in this area.

Worms

The acidic soils made the *P. augusta* area marginal habitat for earthworms. No New Zealand earthworm has been found in soils with a pH below 4.0 (Lee 1959). Soil sampling showed that despite this, earthworm numbers were relatively high with an average density of three worms/6.25 litres of soil or an estimated 47 worms/m^2 (Toft and Karl 2009).

Site clearance

For site clearance and mining purposes, the area occupied by *P. augusta* was divided into mining and snail search blocks (Maps 1 and 2 in Appendix). The northern part of the area was covered by mining blocks A10 and A14, the middle part by mining block A13 and the southern part by mining blocks A12 and A11. Snails, eggs and shells were recovered according to snail search blocks within the larger mining blocks, providing a detailed record of their geographic origin within the species' range.

Between April 2006 and June 2007, 6139 snails and 1173 eggs were collected and transferred to a snail husbandry facility with DOC in Hokitika. 8057 snail shells were collected and sent to *Powelliphanta* expert Dr Kath Walker, DOC Nelson. The large number of recovered live snails implies that *P. augusta* occurred with an average density of over 1000 snails/ha; the highest density of 1900 snails/ha was recorded for search block 4d[1].

An unknown number of snails and eggs were not recovered from the mine site and instead transferred with sods of vegetation to Vegetation Direct Transfer (VDT) sites. Most of this material was used to revegetate the R6 VDT area to the north. Some sods from an area east of Mt Augustus were moved to a site called "Downers Garden". Several empty shells were found there in 2007, but no live snails were found or are known to occur there now.

During mining, the Augustus ridgeline was lowered by 20-30 m. All snail habitat to the east was destroyed. Around 40% (4 ha) of the 2004 range of *P. augusta* were not mined, leaving a narrow strip of natural habitat along the western escarpment adjacent to mining blocks A10 and A14, known as 'Site A' (Map 1). Further south, adjacent to mining block A12, some low growing natural vegetation remains, but it is unclear whether it presents snail habitat ('A12 natural vegetation' on Map 1). An area known as NASA, at the northern end of Site A and adjacent to snail search area 4d, contains what is thought to be the best remaining habitat. The NASA area, originally a low saddle along the Augustus ridgeline, and the escarpment at the northern end of the A12 mining area are now high points along the modified ridgeline.

Revegetation

After conclusion of mining in the A10/A14 mining blocks, an artificial landform was created to the east of Site A using granite overburden gravels and 20-50 cm of top and sub-surface soil. Sods of vegetation from another, snail-free area on the Stockton Plateau were placed on the surface. A total of 4.1 ha were revegetated in this way between Jan 2012 and May 2016 (A10 VDT on Map 1). A small area of the remodelled landform was revegetated by hand-planting nursery-raised seedlings.

The area to the east of NASA was not included in this revegetation. Here, a steep drop towards the mine area leaves the edge of NASA exposed to ongoing erosion. The steep drop and adjacent gentler slopes to the north were sown with exotic grass seed instead of revegetating them with native plants.

Mining in the A13 block was completed in 2020 and some recontouring and revegetation was planned by the mining company. The extent and quality of this revegetation has not been assessed by DOC.

In the A12 mining block, some revegetation occurred by hand-planting nursery-raised seedlings on a re-contoured surface east of the ridgeline in 2008 (A12 planted). However, this revegetation area is separated from the remainder of natural vegetation west of the ridgeline by a strip of exposed coal floor. At its northern end, the A12 area drops steeply into the pit of the A13 mining block.

[1] Stated densities are calculated based on the number of recovered snails. As not all snails were recovered, actual snail densities were even higher than stated.

In 2015, the Department commissioned a rehabilitation plan for the ridgeline, covering the area from NASA south to the A12 mining block (Lloyd 2015). The purpose of this plan was to design rehabilitation that would prevent further degradation of the remaining areas of natural habitat and provide the potential for additional habitat and habitat connectivity. This plan was not implemented.

Morphological and genetic diversity

Since its discovery, *P. augusta* has been studied morphologically and genetically to establish its position within the genus *Powelliphanta*. These studies have shown that *P. augusta* is distinct from all other *Powelliphanta* warranting species status (Trewick 2005, Trewick et al. 2008, Walker et al. 2008, Buckley et al. 2014). Its closest relative is the lowland *P. lignaria*. Its closest geographical neighbour, *P. patrickensis*, which also occurs on the Stockton Plateau, is more distantly related (Trewick 2005, Trewick et al. 2008).

Genetic variability within the surviving *P. augusta* was found to be relatively low (Trewick et al. 2008). The species comprises three distinct groups (Part D-this report) that differ in their shell morphology and genetic makeup (Walker 2006, Trewick et al. 2008, Walker et al. 2008, Buckley et al. 2014, Buckley 2015). As the three groups also differ in their original geographic distributions, they have been labelled as Northern, Central and Southern *P. augusta* (Figure 3).

The Northern *P. augusta* were found in the northern parts of Site A and mining block A10, as far south as search block 6d (Map 2). The area south from there to search block 10a was occupied by snails of the Central group. Search blocks 2a-d seemed to form a gap in snail distribution. No live snails were found in these blocks, although one shell was found in 2d and one live snail in 1g. The Southern group occurred further south, in mining blocks A12 and A11b. However, in 1996, six shells of the Southern group were collected just east of what was to become mining block A15.

The Northern and Southern *P. augusta* are considered separate subspecies, because of their clear morphological, genetic and geographic separation (Walker in prep). The taxonomic status of the Central group remains uncertain. They are distinct from both the Northern and Southern *P. augusta*: morphologically they are more closely aligned to the Southern subspecies (Fig 3 and Walker in prep), however genetically they are more closely aligned to, though still distinct from, the Northern subspecies (Buckley 2015). Their range is geographically separate from both subspecies, with only a narrow overlap (< 100m) with the Northern snails. All these features suggest that the Central snails also have a unique evolutionary origin and trajectory.

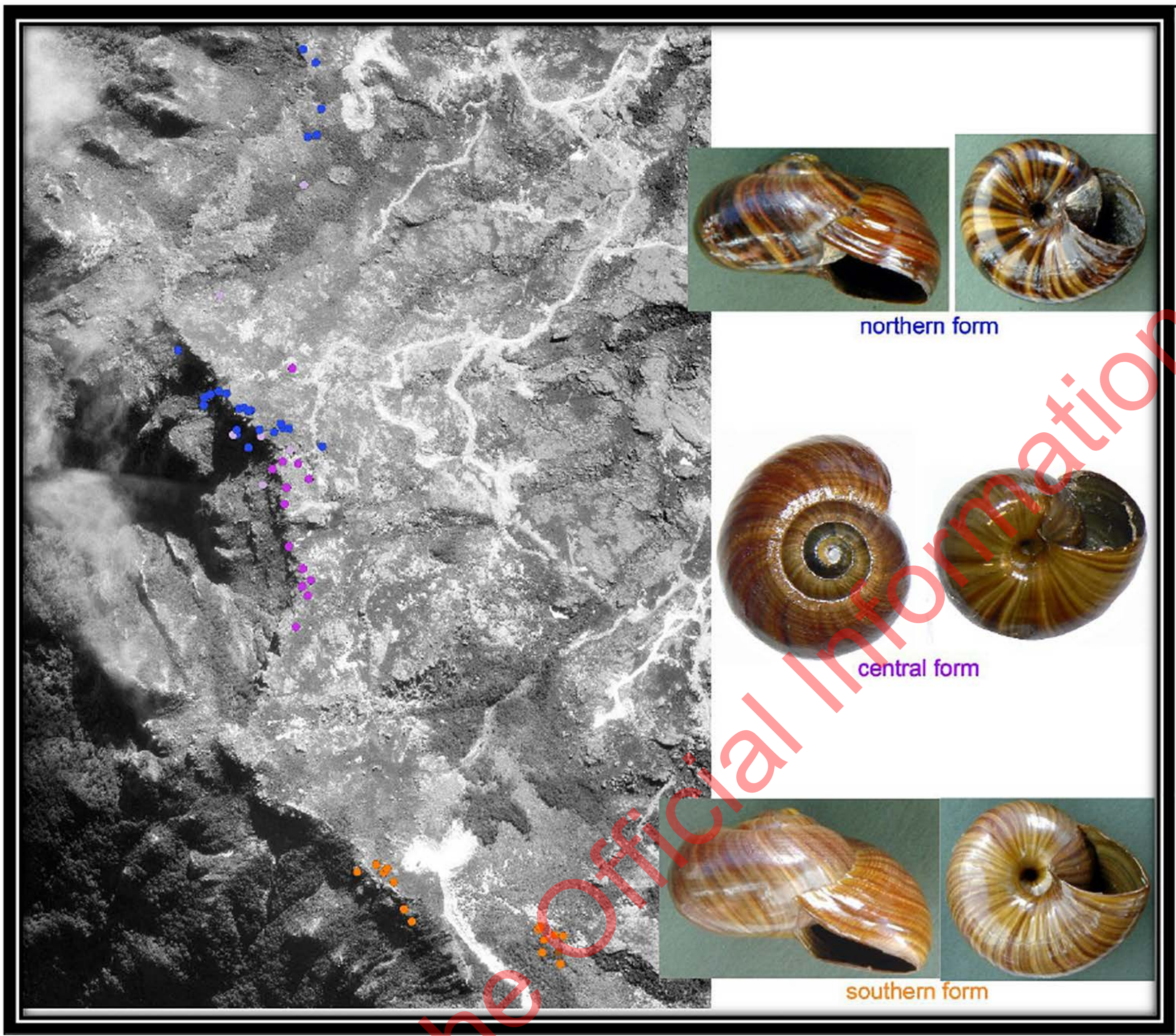


Figure 3. Geographic distribution of Northern (blue dots), Central (purple dots) and Southern (orange dots) P. augusta. The aerial photo was taken in 1988 before mining had begun in the area. Pale lilac dots show snails with both Northern and Central genetic cluster membership. The overlap zone between the Northern and Central forms is less than 100 m wide, just south of the boundary between the A10 and A14 mining blocks (see Map 1). Figure adapted from Walker (in prep)

Translocations and releases

Search for translocation sites

A thorough assessment of sites to which *P. augusta* could potentially be translocated was undertaken in 2007. This included sites on and away from the Buller Plateau (Bartlett and Knightbridge 2007, Eason et al. 2007, Knightbridge 2007). The *P. augusta* Technical Advisory Group developed a list of criteria for this assessment (Gruner 2006). It was decided that the most promising translocation sites were Extended Site B, located along the Stockton ridgeline to the north of the original habitat, and Mt Rochfort on the Denniston Plateau, about 15 km southwest of the original habitat.

Between December 2006 and September 2007, a total of 3913 snails and 1080 eggs were translocated to these sites (Table 1, Map 1). To provide the best chance for survival, the translocation sites were divided into smaller sub-areas, and the habitat quality within each sub-area was subjectively assessed and mapped. The number of snails released into each sub-area was then adjusted according to habitat quality to not exceed assumed carrying capacity (Maps 3 and 4a-c).

Only snails and eggs of the Northern subspecies were released in 2006/07, as they were the most numerous group in captivity. In Extended Site B, an attempt was made to replicate the original geographic distribution of snails by pairing source search blocks with specific translocation blocks.

Table 1. Translocation/release sites and the numbers of snails and eggs released into each.

Site	Group	Snails	Eggs	Year of release
Extended Site B	Northern	1609	516	2006/07
Rochfort Summit	Northern	1085	165	2007
Rochfort Basin	Northern	1219	399	2007
Site A and A10 VDT - North	Northern and Central	4584	4415	2013-2020

Since 2013, eggs and young snails produced by the captive population have repeatedly been released into the original range of *P. augusta*. These releases also tried to replicate the original distribution by releasing eggs and snails as near as possible to the snail search blocks in which their parents had been captured: Eggs and young snails with parents from search blocks 3, 4, 5, 8 and 9 (Northern *P. augusta*) were released into the northern portions of Site A and the A10 VDT, those with parents from search blocks6 and 10 (Central *P. augusta*) were released into the southern portions of both sites. The snails released into the A10 VDT were marked with water-proof paper tags to identify them as captive releases. Releases of Southern snails have not yet occurred, as their number in captivity is still considered too low.

Monitoring

Short-term survival

To assess the short-term survival and behaviour of translocated snails immediately after translocation, transponder monitoring was set up at six sites: search areas 8i and 8j, Site B snails (Central B), West 3, West 3 South, Mt Rochfort Summit and Mt Rochfort Basin (Maps 2, 3 and 4). At each site, a sample of snails was fitted with transponders and followed over time with the help of a harmonic radar device. Snails in mining blocks 8i and 8j were monitored from Nov 2006 until site clearance in February 2007. At the other sites, transponder monitoring began with the translocation of snails and continued until March 2009. The following summary of results is based on the analysis of the transponder monitoring data undertaken by Murray Efford for Wildland Consultants (Wildland Consultants 2009).

Mean annual survival of the translocated snails ranged from 55% to 79%, with snails at Mt Rochfort Summit (79%) and Central B (76%) having the highest survival rates. Mortality was related to habitat quality; most mortality occurred in low stature coal measure vegetation on low fertility, poorly drained peat or gravel substrates. Movement of snails was limited. The median net displacement of monitored snails was 19 m after 18 months. Most snails stayed within 50 m of their release site, although some moved almost 120 m. Snail movement was also related to habitat quality, with higher displacement in lower quality habitat.

Wildland Consultants (Wildland Consultants 2009) also developed a population model for the average annual survival rates required for long-term population persistence as a function of age to maturity and fecundity. Based on the knowledge at the time, the survival rates observed during transponder monitoring did not seem high enough to support the *P. augusta* populations long-term. However, current knowledge suggests that the survival rates at Central B and Mt Rochfort Summit may have been sufficient (based on 8 years to maturity and at least 2 eggs per annum, see Life history). A caveat here is that the model provides the average survival probability over all life stages (Wildland Consultants 2009). Hatchling and juvenile snails are likely to have lower survival rates than larger snails, which means adult survival, as monitored by the transponder monitoring, needs to be higher than estimated by the model to compensate for this.

Table 2. Minimum annual survival (%) needed for long-term population persistence as a function of age at maturity and fecundity (after Wildland Consultants 2009). Currently, P. augusta are thought to take 8 years to reach maturity and lay at least 2 eggs per year.

		Fecundity (eggs per year)											
		1	2	3	4	5	6	7	8	9	10	11	12
Age at maturity (years)	4	72.4	64.8	60.3	57.2	54.8	52.9	51.3	50.0	48.8	47.8	46.9	46.0
	5	75.5	68.9	65.1	62.3	60.3	58.6	57.2	56.0	54.9	54.0	53.2	52.4
	6	77.8	72.0	68.6	66.2	64.4	62.9	61.6	60.6	59.6	58.8	58.0	57.3
	7	79.7	74.5	71.5	69.3	67.6	66.3	65.1	64.2	63.3	62.5	61.9	61.2
	8	81.2	76.5	73.7	71.8	70.3	69.0	68.0	67.1	66.3	65.6	65.0	64.4
	9	82.4	78.2	75.7	73.9	72.5	71.3	70.4	69.5	68.8	68.2	67.6	67.1
	10	83.5	79.6	77.3	75.6	74.3	73.3	72.4	71.6	70.9	70.3	69.8	69.3
	11	84.4	80.8	78.6	77.1	75.9	74.9	74.1	73.4	72.8	72.2	71.7	71.2
	12	85.3	81.9	79.8	78.4	77.3	76.4	75.6	74.9	74.3	73.8	73.3	72.9

Long term population trends

Mark-recapture monitoring

Since 2009, mark-recapture techniques have been used to monitor population trends of the Northern subspecies in translocation sites and in the remnant original habitat (Site A). This monitoring provides information on the abundance and survival of snails >20 mm maximum diameter over time. The most recent measurement, done in summer 2019/20, included six monitoring sites along the Augustus ridgeline (Map 1). The populations translocated to Mt Rochfort were not assessed, as *P. augusta* cannot be reliably distinguished during the monitoring from *P. patrickensis*, which is also present at Mt Rochfort. The following is based on the latest report prepared by Darryl MacKenzie (MacKenzie 2020).

In 2019/2020, *P. augusta* was present at all monitoring sites. Trends in abundance over time could not be determined because of the relatively large uncertainty associated with estimates and the large variation between years at some sites (Figure 4). Furthermore, interpretation of trends for Site A High and Site A Low is made difficult, because the repeated releases of eggs and young snails from captivity into adjacent habitat from 2013 onwards may have boosted the populations within the monitoring sites. The steep increase in abundance at Site A Low in 2020 could possibly be attributed to this. However, this effect was not apparent at Site A High, where mean abundance has declined since 2013.

Snail abundance as presented in Figure 3 cannot be directly compared between sites, as the monitoring sites differ in size. We therefore calculated snail densities, i.e. estimated number of snails per ha (

Table 3). This showed that snail densities varied greatly between the sites. At translocation sites, snail densities are probably driven by the number of snails originally released at each site. For Site A High and Site A Low it is unknown whether the observed densities reflect healthy populations at the natural carrying capacity of the local habitat, or whether they represent populations in decline (boosted by releases). It is also unknown whether *P. augusta* populations require a minimum density to be able to persist long-term.

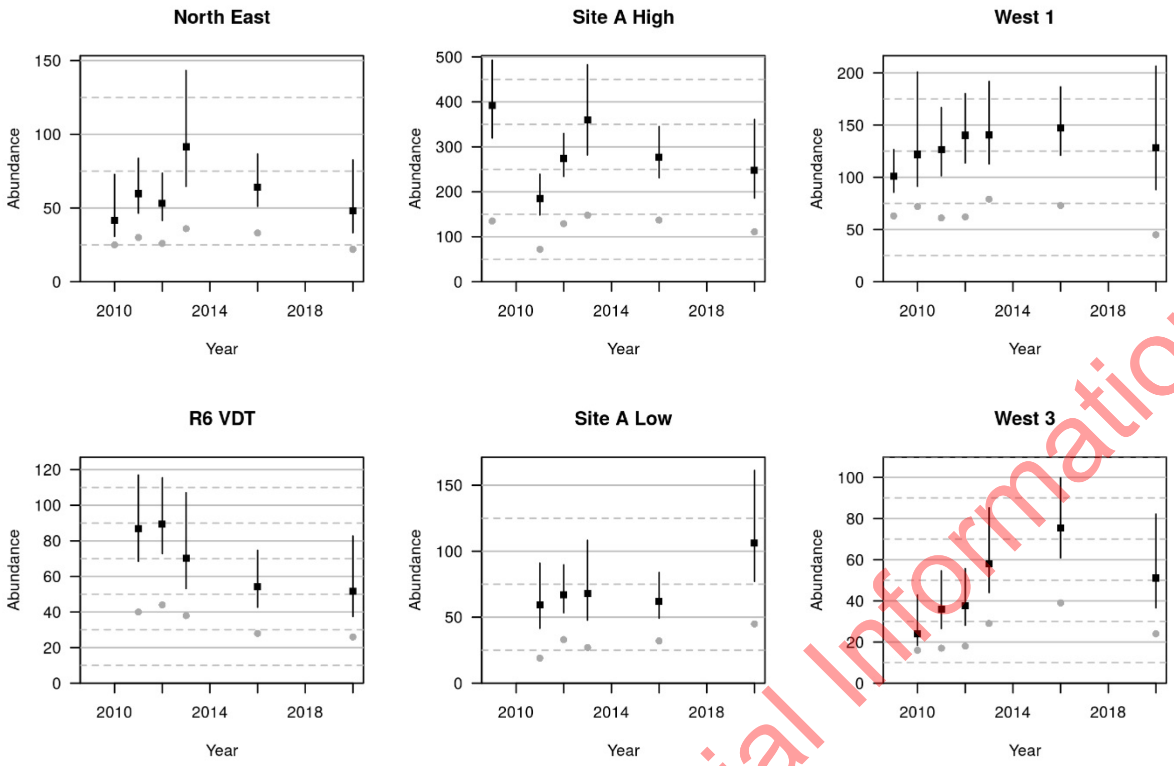


Figure 4. Estimated number of individuals (abundance) of P. augusta *with 95% confidence intervals in the six long-term monitoring sites on the Augustus ridgeline. The number of individual snails seen each year is also indicated.*

Table 3.Estimated P. augusta *densities in the six long-term monitoring sites along the Augustus ridgeline; 95% confidence interval in brackets. Densities are for snails >20 mm maximum diameter.*

Monitoring site	Area (ha)	Density (Snails/ha)
Site A High	0.38	653 (489-950)
West 1	0.25	516 (352-824)
Site A Low	0.32	331 (241-503)
West 3	0.19	268 (195-447)
North East	0.23	209 (143-361)
R6 VDT	0.38	137 (100-218)

Survival probabilities presented by MacKenzie (2020) need to be interpreted as 'the probability of surviving **and** staying within the monitoring site', as emigration of snails from the site in the years between monitoring occasions is likely (Table 4). True survival is therefore likely to be higher than the presented estimates. Survival over the monitoring period was highest in Site A High, Site A Low and West 1 (73-74%), lowest in R6 VDT (60%).

Table 4. Survival probability estimates ($\hat{S}$) for P. augusta *for the six long-term monitoring sites on the Augustus ridgeline, with standard error (in parentheses) and 95% confidence intervals (CI) (from (MacKenzie 2020)).*

Site	$\hat{S}$ (SE)	CI
North East	0.70 (0.03)	0.63 - 0.76
R6 VDT	0.60 (0.04)	0.52 - 0.68
Site A High	0.73 (0.02)	0.69 - 0.76
Site A Low	0.74 (0.04)	0.66 - 0.80
West 1	0.74 (0.02)	0.70 - 0.78
West 3	0.68 (0.04)	0.60 - 0.76

Using the population model developed by Wildland Consultants (Wildland Consultants 2009), the survival probability estimates suggest that Site A Low, West 1 and Site A High are possibly sustaining viable snail populations. The model suggests that a minimum survival rate of 73.6 % is required for population viability, assuming snails take 8 years to reach maturity and lay 3 fertile eggs per year.

An analysis of the size and weight data collected during the mark recapture monitoring (DOC-6369998) (Gruner 2020) shows that snails are in good condition at all sites. Changes in the size class structure in the various populations over time suggest that the populations at Site A High, West 3 and R6 VDT might be stable or recovering, while populations in West 1 and North East appear to be ageing (Figure 5).

Overall, the results from the mark-recapture monitoring are inconclusive. None of the monitoring sites provides consistent evidence that the local population is stable or increasing. Site A High appears to be the most promising site. This emphasises the importance of maintaining this remnant of high quality habitat (NASA) in good condition.

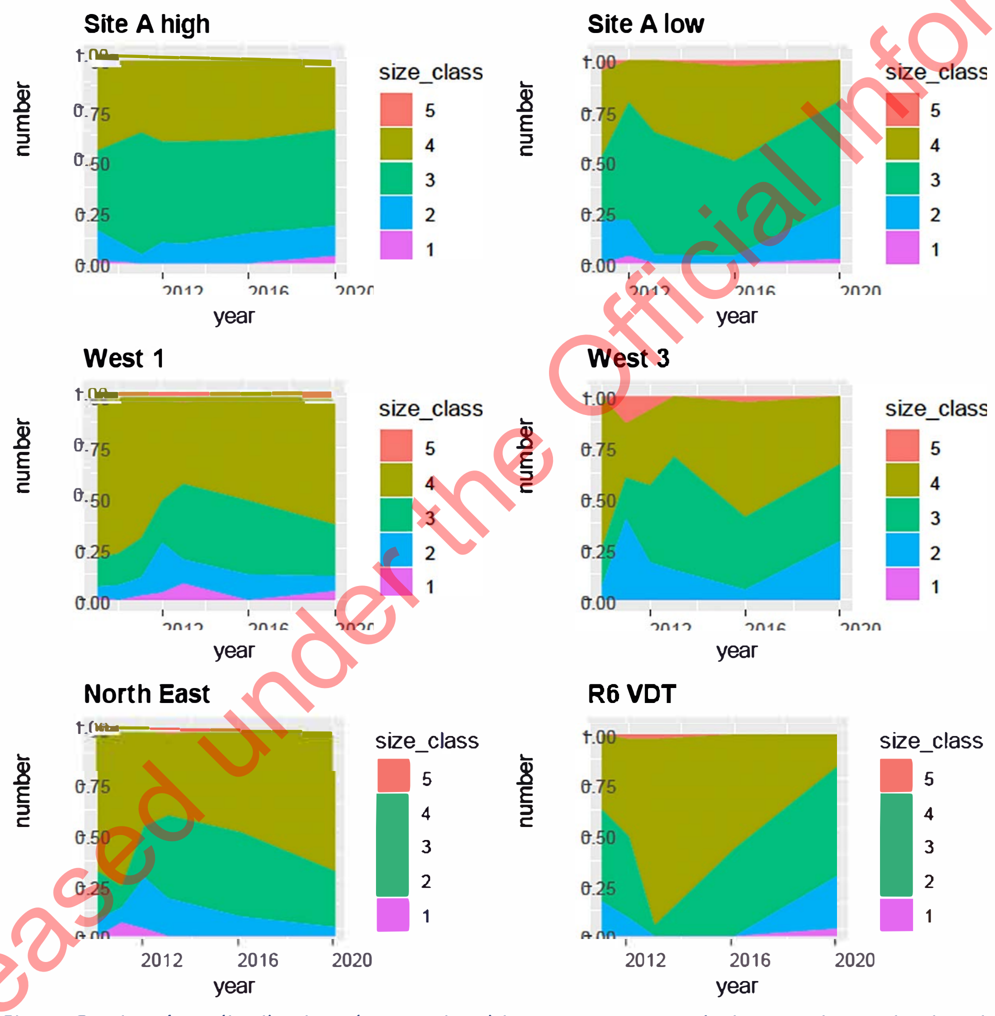


Figure 5. Size class distributions (proportions) in P. augusta populations at six monitoring sites over time. Size classes are: 5 - > 40 mm, 4 - 32 – 40 mm, 3 - 25 – 31.9 mm, 2 - 20 – 24.9 mm, 1 - < 20 mm max diameter.

10x10 m plots

A series of standard 10x10 m diurnal plots was set up between 2012 and 2014 to provide an alternative to the (more costly) mark-recapture monitoring (Map 1). The standard 10x10m method is described in DOC-6115162.

Six plots were located within the mark-recapture plots in Site A (4 in Site A high, 2 in Site A low). Eight plots were put into Extended Site B, both, inside and outside of the mark-recapture plots. Two plots were located within the R6 VDT mark-recapture plot. Ten plots were placed within the Mt Rochfort translocation areas (5 at Rochfort Summit and 5 at Rochfort Basin). As with the mark-recapture monitoring, this monitoring captured only snails of the Northern subspecies. After establishment in 2012-2014, the plots were re-measured in March-May 2015 and vegetation recces undertaken. Numbers of snails were very low, with on average one live snail and one shell per plot, making the use of 10x10 m plots as an alternative monitoring technique questionable.

Captive management

Initially, 2226 snails and 93 eggs collected from the mine site were retained in captivity. 1762 snails belonged to the Northern subspecies, 439 to the Central group, and 25 to the Southern subspecies.

Husbandry techniques changed with increasing experience and with the changing objectives of the captive management. In the beginning, the focus was on finding suitable husbandry techniques to ensure survival of the snails. Snails were housed in individual containers to provide optimal environmental conditions and prevent disease spread. When this technique resulted in high survival rates, the focus switched to gaining knowledge about the snails' breeding biology. This was required to ensure a self-sustaining population could be held in captivity until the wild populations were known to be secure. For the Southern subspecies, breeding was particularly important, as only 25 of these snails had been collected from the mine site. In November 2007, the captive population of the Southern subspecies was made up of 21 adults, 3 sub-adults, 1 juvenile and 48 eggs.

Snails were moved into groups to facilitate breeding. Cross-breeding was only allowed between snails of the same geographic origin, i.e. breeding groups were formed as much as possible according to snail search blocks. This meant that not only the Northern, Southern and Central snails were held separately, but also that finer-scale genetic variability within the species was maintained.

During the first few years, husbandry included intensive monitoring and research to monitor success, ensure any potential issues were detected early, and to gain a better understanding of *P. augusta*'s biology (e.g. Allan 2010, James et al. 2013). Over the last few years, husbandry has largely become routine, as the captive management methods proved successful, with high survival rates and successful reproduction.

According to the 2015-2020 strategy, the current objectives for the captive population are:

- for Northern and Central snails, to maximise survival, particularly for adults and subadults. Breeding is only facilitated to the extent necessary to maintain self-sustaining populations of the two groups. Despite this, annual releases of surplus eggs and hatchlings had to be undertaken to limit numbers in captivity.
- for the Southern subspecies, to maximise survival and breeding to increase their numbers to a level at which the captive population can be considered self-sustaining and secure.

Threats

Habitat loss from mining is responsible for the current 'nationally critical' threat status of *P. augusta* (Hitchmough et al. 2007). The current key threats to its persistence are:

- Small extent and fragmentation of remaining habitat,
- Low habitat quality in translocation and rehabilitation sites,
- Habitat degradation through weed invasion, sedimentation, erosion, fire, trampling and herbivore impacts,

- Predation by ship rats, weka, stoats, possums and song-thrushes,
- Trampling/crushing by people accessing habitat areas,
- Negative effects on individual fitness from small population size, e.g. mate limitation or lack of calcium from dead shells,
- Reduced moisture levels through loss of higher altitudes of former Augustus ridgeline,
- Climate change,
- Loss of genetic diversity limiting adaptability.

The first five threats listed above can be directly managed with targeted actions, e.g. high-quality rehabilitation, habitat enhancement, weed and predator control. The last four can only be addressed indirectly by aiming to increase population sizes, providing the best-possible habitat, and maintaining as much genetic diversity as possible to increase adaptability.

Part B – Current state

Wild populations

P. augusta is currently found in the wild in many more or less isolated subpopulations on the Stockton and Denniston Plateaux (Table 5, Maps 1 and 3). The Northern subspecies has 11 subpopulations along the Augustus ridgeline and three at Mt Rochfort. The Central snails have two wild subpopulations, one in the southern part of Site A and one in the adjacent A10 VDT. The Southern subspecies may occur in a sliver of natural vegetation west of the now lowered A12 ridgeline, but the vegetation in the area is not considered good snail habitat and only one shell has ever been found in this area despite intensive and repeated searches (Otley et al. 2014).

Table 5. P. augusta groups and the sites where they are currently found in the wild. Habitat quality is based on subjective assessments. Snail origin 'wild capture' refers to snails that were briefly held in captivity in 2006/07 before their release to translocation sites.

Groups	Site	Size (ha)	History	Habitat quality	Snail origin	Translocation year
Northern	Site A northern section		Natural snail habitat	High at NASA, else moderate	Natural and captive eggs/hatchlings	2013-2020
Northern	A10 VDT northern section		VDT in 2012-2016	Doubtful	Captive juvenile snails (tagged)	2013-2019
Northern	Extended Site B	7.6	Natural vegetation		Wild capture	2006/07
Northern	West 4		Natural vegetation	Moderate	Captive eggs and hatchlings	2013-2019
Northern	West 3		Natural vegetation	High - low	Wild capture	2006/07
Northern	West 2		Natural vegetation	Low	Wild capture	2006/07
Northern	West 1		Natural vegetation	High - low	Wild capture	2006/07
Northern	North West 2		Natural vegetation	High - low	Wild capture	2006/07
Northern	North West 1		Natural vegetation	Moderate - low	Wild capture	2006/07
Northern	Site B		Natural vegetation	Moderate - low	Wild capture	2006/07

Northern	R6 VDT	4.0	VDT in 2006/07	Doubtful	With VDT	2006/07
Northern	Mt Rochfort Summit, upper	3.5	Natural vegetation	High	Wild capture	2007
Northern	Mt Rochfort Summit, lower		Natural vegetation	Low	Wild capture	2007
Northern	Mt Rochfort Basin	4.8	Natural vegetation	Poor	Wild capture	2007
Central	Site A southern section		Natural snail habitat	Medium to low	Natural and captive eggs/hatchlings	2016 - 2019
Central	A10 VDT southern section		VDT in 2012-2016	Doubtful	Captive juvenile snails (tagged)	2016 - 2019
Southern	A12 natural vegetation		Natural vegetation	Low	natural? (1 shell found in 2014)	NA

With 4.27 ha, Site A represents the largest continuous habitat area, but its narrow linear shape is not conducive to maintaining a healthy population. Site A is a 30-80 m wide and 900m long strip of land on the western slopes below the escarpment. Habitat quality is variable and is negatively affected by silt run-off from the escarpment. The area of highest habitat quality (NASA) is threatened by erosion.

Captive population

Table 6 summarises the status of the captive population by group. The populations of the Northern and Central groups currently provide for short-term security from extinction with 187 and 84 adults, respectively. The population of the Southern subspecies has grown to a total size of 265 snails, but has only 16 adults, and can therefore not be considered secure. However, the large number of hatchlings and juveniles suggests that this population has a good potential for recovery within the next few years.

Table 6. Current status of the captive population of P. augusta in the Hokitika husbandry facility by group (total numbers as on 4 September 2020, but size class distribution from beginning of 2020).

Group	Adults	Subadults	Juveniles	Hatchlings	Eggs	**Total**
Northern	187	183	142	674		**1186 + eggs**
Central	84	96	224	284		**688 + eggs**
Southern	16	21	66	162	72	**265 + eggs**
Total	**287**	**300**	**432**	**1120**	**516**	**2139 + eggs**

The current survival rate in captivity is high, at around 95 % per annum for adults, and even higher for smaller size classes. Over 90% of all eggs hatch successfully.

140 of the currently 287 adults are still original wild-capture snails (5 of the Southern subspecies). Most of these snails were brought into captivity as adults, i.e. their estimated age is ≥ 22 years. As is to be expected, the survival rate for this ‘senior’ group is lower, at 80 % per annum.

While the captive management methods are successful, they have not been documented. This poses a substantial risk to the operation.

Achievements against the 2015-2020 strategy

An assessment of achievements against the 2015-2020 strategy (Otley et al. 2015) shows that the *P. augusta* recovery programme has made good progress. Four of six intermediate outcomes were achieved.

Long-term recovery goals 2015-2020	Status
1. To prevent the extinction of the species.	Achieved
2. To secure one self-sustaining population of the species in the wild, with allelic diversity not too dissimilar to what it might have been without the mining disturbance.	Not achieved
3. To ensure genetic diversity within the species is protected, with each distinctive genotype and phenotype represented in the wild population.	Partly achieved Northern and Central snails represented in wild population; no wild population of Southern snails

Intermediate outcomes 2015-2020	Status
The species has not become extinct.	Achieved
There is an insurance population of the northern morph and intermediate snails held in captivity and the populations are mixed age and self-sustaining. Only releases of surplus snails have occurred.	Achieved
There is an insurance population of the southern morph snail held in captivity and it has increased in size, is mixed age and is self-sustaining. No releases of the southern morph snails have occurred.	Achieved But population is not secure
Much of the area that snails occupied when the species was discovered in 2004 has been appropriately rehabilitated and is gradually returning to a condition able to support snails beyond 100 years.	Partly achieved A10 VDT (4.1ha)
The population of A10 snails in Site A is stable or increasing.	Possibly achieved Survival rate and size structure suggest stable population, but mean abundance at the best site (NASA) has declined since 2013 with the habitat there continuing to degrade
Monitoring has occurred and there has been a 10-year trend assessment of population abundance/density, size class distribution and recruitment in the wild populations.	Achieved.

Part C – Third strategic period: 2021 – 2031

Definitions 2021-2031

Populations in the wild

The following definitions apply to populations in the wild. They are based on those underpinning Intermediate Outcome Objectives 1.1 and 1.2, the work of Natural Heritage Specialist groups and the integrated species prioritisation project (Department of Conservation 2008, 2012, 2015, Bridgman 2018).

Security from extinction is achieved when available evidence indicates that there is one viable population that is stable and will allow future recovery, for which key agents of decline have been identified, and have been removed or mitigated.

A population is defined as viable when it is predicted to have a 95% probability of survival where:

(a) there is an intrinsic ability to increase given additional management because the population is large or because recruitment ≥ mortality, and

(b) there is resilience against low and moderate level stochastic events over a 50-year time frame.

The minimum level of population viability is the point at which the species has been secured from extinction (i.e. it is no longer in decline), key threats are understood and managed, and the population has the ability to recover given the addition of extra resources.

Long-term persistence is achieved when there is a 95% probability the species will persist in the wild for the next 50 years or three generations (whichever is longer), given that all human-induced threats likely to occur within 300 years are adequately mitigated.

Long-term persistence requires that populations are viable and buffered against the impacts of loss of genetic diversity and long-term environmental events such as climate change.

In the context of *P. augusta*, we need to apply a 50-year timeframe to assess long-term persistence. Based on current knowledge, one generation is around 14 years (see Life history):

c. 1 year from egg laying to hatching (based on data from captivity)
\+ 8 years to reach sexual maturity (based on data from wild snails)
\+ 5 years to reach the middle of adult life (based on data from captivity)
= c. 14 years for one generation.

Full recovery of populations is the restoration of the species to its maximum potential within healthy, functioning ecosystems.

Healthy, functioning ecosystems are defined as having high ecological integrity, which means most indigenous plants and animals typical of a place are present, together with the key ecosystem processes and features that sustain functional relationships between them (Lee et al. 2005). Healthy, functioning ecosystems are expected to be resilient to natural disruptions and to persist in the long term.

Captive populations

To provide guidance for the captive management of *P. augusta*, we define that a captive population is

- **secure from extinction in the short-term**, when the population has an effective population size ≥ 50,
- **secure from extinction in the long term**, when the population has an effective population size ≥ 500,

and, in both cases, the population can maintain this size through recruitment in captivity.

An effective population size of 50 individuals is thought to avoid inbreeding depression in the short-term, while an effective population size of at least 500 is required to maintain full genetic variability and evolutionary potential in the long-term (Franklin 1980, Soulé 1980, Franklin et al. 2014). These population sizes represent a well-established rule-of-thumb, often used in the absence of species-specific information. More recently, some geneticists have taken the view that effective population sizes need to be twice as large as suggested by the rule-of-thumb to achieve the stated aims (Franklin and Frankham 1998, Lynch and Lande 1998, Frankham et al. 2014).

The **effective population** size is defined as the size of an idealised population of breeders that would give rise to the same change in gene frequencies as observed in the actual population (Frankham 1995). It serves to quantify the magnitude of genetic drift and inbreeding in a real population. This means it is not the same as the number of individuals in a real population. The ratio of effective population size to the number of adults in a real (wild) population is generally thought to be about 0.1-0.14 (Frankham 1995, Jamieson and Allendorf 2012). A ratio of 0.5 has been calculated for the snail *Cepaea nemoralis* (Greenwood 1974 in Frankham 1995).

In captivity, *P. augusta* adults are likely to have a higher chance to contribute to reproduction than in the wild. The ratio of effective population size to the number of adults in the captive population is therefore likely to be higher. However, it is not equal to 1, as even in captivity not every adult is an effective breeder, e.g. not all captive adults of the Southern group have successfully laid eggs. To reflect this, we used a 'best guess' ratio of 0.8 in

Table 7.

Table 7. Minimum number of snails of different size classes required to provide short- and long-term security from extinction for captive P. augusta. Numbers assume 95% annual survival for all size classes, 90% successful hatching rate and that snails take on average 2 years to outgrow each size class.

	Short-term security	Long-term security
Adults	63	625
Sub-adults	12	70
Juveniles	14	78
Hatchlings	18	86
Total snails	**107**	**859**
Eggs	10	50

Long-term recovery goal

The long-term recovery goals put forward in the 2015-2020 strategy are still relevant, as they have not been fully achieved and the status of *P. augusta* has not substantially changed. However, we have reviewed these goals to align with the Department's outcomes model and other species recovery programmes. This is to ensure the *P. augusta* programme follows best practice and contributes to achieving the Department's intermediate outcomes and vision. This review has reduced the number of long-term recovery goals to one and changed the wording though not the basic intent.

Long-term recovery goal:

To ensure the long-term persistence of *P. augusta* by restoring the species and its morphological and genetic diversity within healthy, functioning ecosystems throughout its natural range as much as possible.

Recovery phases

The long-term recovery goal describes the ultimate desired outcome once full recovery has been achieved (Department of Conservation 2015). To get there, the Department has developed a model that identifies four phases of recovery actions (Department of Conservation 2003, 2008):

Phase 1 Research to establish scientific understanding of the species and key agents of decline. This is a fundamental first step, as status, distribution, threats and the means to recover the species need to be understood to achieve recovery.

Phase 2 Security from extinction. This might require urgent and adaptive management action ('salvage') and could initially mean management in captivity or at a safe site outside the species' natural range. Focus is on managing short-term, immediate causes of decline.

Providing for security from extinction in the wild means securing at least one viable population within the species' natural range. This leads into Phase 3.

Phase 3 Recovery. Priority recovery sites within the species natural range are managed to ensure at least one viable population is increasing in numbers. Recovery requires management of longer-term threats to buffer the population against longer term or catastrophic events. Genetic diversity is maintained wherever practical.

Phase 4 Maintenance. Full recovery has been achieved with the species becoming part of healthy, functioning ecosystems, ideally throughout its entire former range and with a level of genetic variation that buffers against longer term (200 year) stochastic, demographic and catastrophic events. The threat status of the species has improved and management intervention can be reduced to sustaining gains with ongoing appropriate monitoring and management. Ideally, the species is managed as a normal part of ecosystem management.

During the first two strategic periods of *P. augusta* recovery the focus was on Phases 1 and 2 (Gruner 2007a, Otley et al. 2015). Priorities were to increase our knowledge about the ecology of the species and to ensure its immediate security from extinction. The management and monitoring of wild populations moved the programme into Phase 3. The species is now secure in captivity. The focus for the next ten years needs to be on ensuring the viability and recovery of at least one wild population and on the maintenance of the genetic diversity within the species wherever practical.

Recovery goals for 2021 – 2031

The 2021-2031 goals are what we want to achieve within the timeframe of this strategy. They are milestones on the way to achieving the long-term recovery goal and move the programme through Phase 3 of species recovery.

1 High quality rehabilitation has been completed over as large an area as possible, and has developed into snail habitat or is well on its way to being suitable in

   a mining areas adjacent to NASA in the north, east and south;

   b mining blocks A14 and A13 adjacent to Site A;

   c mining blocks A12 and A11 adjacent to the remainder of natural vegetation

2 Enhancement of existing habitat through enrichment planting, hand-filling of gaps in VDT, and removal of silt fences and accumulated material has occurred wherever it is beneficial and feasible.

3 The threats posed by habitat degradation (incl. weeds), predation and trampling/crushing have been managed effectively.

4 The populations in the six mark-recapture monitoring sites have been monitored and trends in abundance/density, survival and size class distribution assessed at least twice by 2031.

5 At least one population of each, Northern, Southern and Central *P. augusta*, is known to be secure from extinction either in the wild or in captivity.

Management actions 2021-2031

This action plan is informed by an options and risk assessment looking at how best to manage each of the three distinct groups within *P. augusta* (DOC-6449065). Maintenance of the genetic diversity represented by the three groups has become the focus for *P. augusta* recovery in an attempt to maximise its adaptability to the new environmental conditions and protect its unique evolutionary history (see How do we manage genetic diversity within the species?).

Management actions are grouped into nine workstreams:

- Project management
- Rehabilitation and habitat enhancement
- Habitat management
- Predator control
- Survey and monitoring
- Management of captive populations
- Translocations/releases
- Advocacy and information sharing
- Research

The nine workstreams and key actions are briefly described below; more details can be found in Table 8 and the options and risk assessment (DOC-6449065).

Programme management

The Hokitika District Operations Manager is the accountable manager for the recovery programme. However, day-to-day operations need to be managed by a programme lead with overview over this complex programme to ensure timely implementation of the recovery strategy. The programme lead will be a part-time position, estimated at 0.4 FTE (2 days/week) initially, but likely to reduce over time.

The programme lead will prepare an annual workplan in accordance with this strategy, plan and lead the completion of management actions, manage contracts, consult with the Technical Advisory Group, manage the relationship with the mining company, Bathurst Talleys (BT), coordinate research, monitor progress and report back to the accountable manager. They will also lead the review of the current strategy in 2030/31.

Rehabilitation and habitat enhancement

Rehabilitation of mining areas within the original range of *P. augusta* and enhancement of disturbed areas within existing habitat and vegetation are key activities during 2021-2031.

Rehabilitation adjacent to remnants of natural vegetation and habitat is to protect these from further degradation, but the hope is of course to also create additional habitat areas. Because of this, rehabilitation needs to occur over as large an area as possible and use techniques that maximise the chance that these areas develop into suitable habitat within 10-15 years. Rehabilitation plans developed by Walker (Walker 2013) and Lloyd (Lloyd 2015) present a starting point.

Habitat enhancement in degraded areas within currently occupied habitat and remnants of natural vegetation is done through enrichment planting. All plants must be eco-sourced to ensure they are adapted to the harsh conditions of the Augustus ridgeline.

Close collaboration between DOC and BT is required to confirm plans and costs for rehabilitation and habitat enhancement, and to clarify the funding for this work.

There is a risk that rehabilitation areas, even if successful in the medium-term, will not support *P. augusta* long-term. Increased drainage and fertility on the recontoured surfaces may eventually lead to the establishment of forest, which is not thought to present good *P. augusta* habitat. However, even if this occurs, high-quality rehabilitation and habitat enhancement still provide the best chance for a viable population to persist, as the area of suitable habitat would be maximised and forest areas would provide a buffer towards entirely unsuitable areas.

Habitat management

Regular habitat monitoring needs to occur, triggering management interventions as required, in all habitat of wild populations and at all rehabilitation sites to maintain and improve habitat quality. The following factors have been identified as potential issues:

- Erosion: The lowering of the ridgeline and mining activities have led to erosion, silt run-off and rock fall into snail habitat on adjacent slopes. In some areas, these processes are continuing.
- People: People accessing snail habitat and rehabilitation sites can cause damage to vegetation, soils and snails through trampling. They may introduce weeds, rubbish and toilet waste.
- Herbivores: Herbivory can impact the quality of existing habitat and hinder the development of rehabilitated vegetation. Hare browse has been observed on the Augustus ridgeline, especially in the NASA area.
- Weeds: *Juncus squarrosus* and gorse are currently the most problematic weeds. They threaten to displace native plants and alter vegetation structure making it less suitable as snail habitat. Other weeds, e.g. some exotic grasses, may also become problematic.
- Fire: An extended period of dry weather could pose significant fire risk especially in the drier, revegetated areas.

Funding for any necessary management interventions and weed control should be sought from BT, as the need for this work is a direct legacy of mining[2].

Predator control

A ground-based predator monitoring and control programme targeting possums, rats and stoats throughout the range of the Northern and some Central *P. augusta* has been in place since 2007 (currently funded by BT). A review of the ongoing need for this control programme should be undertaken, considering predator capture and snail predation rates as well as trampling impacts. Aerial predator control, especially following beech mast events, needs to occur and can be achieved by including the Augustus ridgeline in aerial pest control operation undertaken in surrounding areas.

Survey and monitoring

The mark-recapture monitoring of wild populations of Northern snails needs to continue to assess their viability. Without this information progress and success of the recovery programme cannot be fully assessed. Nocturnal surveys to determine whether a wild population of Southern snails remains in the natural vegetation west of A12 could be done but is not essential to the recovery programme.

Management of captive population

Management of the captive population over the next 10 years needs to focus on

- Increasing the number of snails of the Southern subspecies,
- Providing for long-term security of Northern and Central snails,
- Documenting husbandry methods.

The three *P. augusta* groups should continue to be held separately to maintain genetic diversity within the species. In addition, the Northern snails should continue to be grouped by snail search block to maintain finer scale diversity. The risk of accidental loss will continue to be managed by spreading the

[2] The Stockton Coal Mining Licence (CML) requires BT to control noxious weeds within the CML.

three groups and their size classes across two cool-storage units. Survival rates, body condition and fecundity need to be monitored to ensure success of the programme.

Translocations/releases

During the term of this plan, releases will only occur for snails and eggs that are surplus to requirements in the captive populations. This will initially only affect Northern snails as their numbers are currently higher than required for long-term security in captivity, but over time surplus eggs and hatchlings of Central and Southern snails are likely to be produced. All these releases will occur into already occupied habitat, or, in the case of the Southern snails, into remnant natural vegetation at A12.

No snails or eggs will be translocated or released to additional sites outside of the original *P. augusta* range (see Translocation of *P. augusta* beyond the species' original range).

Recovery of *P. augusta* from Mt Rochfort and translocation to Extended Site B or into captivity could be done to reduce the impact of the *P. augusta* population on resident *P. patrickensis*, but as full recovery is impossible this action is of low priority.

Advocacy and information sharing

The recovery of *P. augusta* remains a high-profile programme that is periodically picked up by the media. Since DOC, as government department, is answerable to the public, it would be beneficial to be more pro-active about publicly reporting on our progress with the programme. The programme lead should prepare regular media releases and take other opportunities to raise the profile.

We should also publish some of the knowledge gained about the ecology of the species, its captive management and monitoring in the wild. This information would likely be useful for other conservation programmes dealing with molluscs or other elusive invertebrates. The more general aspects of the programme, i.e. management of a narrow-range endemic species in the conflict space between human land use and preservation, would likely also be of wider interests. Making our knowledge and experiences available to others would maximise the benefit derived from DOC's investment in this programme by contributing to the larger context of threatened species management worldwide.

Research

Further research could increase our understanding of the ecology of *P. augusta* and *Powelliphanta* in general, and help us to identify and successfully manage critical threats. This could determine the ultimate success of the recovery programme.

Table 8. Action plan for *P. augusta* recovery programme 2021-2031 detailing timing, priority and resources required for the required management actions. Resources/costs are estimates only and will require review as actions are planned.

Workstream	Action	Details	Timing	Priority	Resources	Group
Project management	Appoint programme lead	Part-time position to lead recovery programme.	21/22-30/31	High	$32,000/year (0.4 FTE); likely reducing	All
Rehabilitation and habitat enhancement	Rehabilitate mine areas adjacent to NASA	Details of works to be confirmed. Minimum is planting of existing slopes; optimum is back-filling, re-contouring and planting.	by 23/24	High	to be confirmed	Northern
Rehabilitation and habitat enhancement	Rehabilitate A12/A11 ridgeline	Details of work to be confirmed. Focus on area between existing revegetation and remnant natural vegetation on western slopes.	by 23/24	High	to be confirmed	Southern
Rehabilitation and habitat enhancement	Rehabilitate A13 and A14 mining areas	Details of work to be confirmed.	by 23/24	High	to be confirmed	Central
Rehabilitation and habitat enhancement	Enrichment planting in southern Site A	Plant eco-sourced natives into degraded areas in remaining natural habitat of Central snails.	by 23/24	High	$1,700 once (750 plants @ $1.50 each plus $600 for planting)	Central
Rehabilitation and habitat enhancement	Enrichment planting at A12	Plant eco-sourced natives into degraded areas in remnant natural vegetation at A12.	by 23/24	High	$18,000 once (8,000 plants @ $1.50 each plus $6,000 for planting)	Southern
Rehabilitation and habitat enhancement	Enrichment planting in A12 revegetation	Plant eco-sourced natives at high density into existing revegetation area at A12.	by 23/24	Medium	$36,000 once (17,000 plants @ $1.50 each plus $11,000 for planting)	Southern
Rehabilitation and habitat enhancement	Removal of silt fences	Remove silt fences and accumulated material, where feasible without causing damage to habitat below.	by 23/24	Low	to be confirmed	All
Habitat management	Habitat monitoring	Check all snail habitat and rehabilitation areas for damage from: erosion/sedimentation, people, herbivore browse.	annual	High	$1,000/year (3 days); covered by programme lead	All
Habitat management	Habitat management interventions	Undertake required remedial work, e.g. stop erosion or undertake herbivore control, as identified during the annual habitat monitoring.	as required	High	Variable, depending on work required	All
Habitat management	Weed detection and control	Control *Juncus squarrosus*, gorse and other problem weeds using best practice methods in all snail habitat and rehabilitation areas; use control visits for detection of new weed issues	twice annually	High	$4,000/year	All

Workstream	Action	Details	Timing	Priority	Resources	Group
Habitat management	Fire control plan	Develop a fire control plan for the Augustus ridgeline to minimise risk to snails	21/22	Medium	$1,000 once (3 days); covered by programme lead	All
Predator control	Predator control review	Review need for ongoing ground control	21/22	High	$1,000 once (3 days); covered by programme lead	All
Predator control	Aerial predator control	Ensure Augustus ridgeline is included in aerial predator control operations covering adjacent areas	following beech masts	High	$18,000 per operation ($18/ha), up to 3x during 2021-2031	All
Predator control	Predator ground control	Undertake monthly monitoring and ground control of possums, rats and stoats	monthly	Medium	$8,000/year, but may be stopped after review	All
Survey and monitoring	Mark-recapture monitoring, Northern *P. augusta*	Monitor existing 6 sites along Augustus ridgeline. Analyse trends in abundance, survival, size class distribution and body condition.	25/26 and 30/31	High	$90,000 per measure, 2x during 2021-2031	Northern
Survey and monitoring	Survey A12 natural vegetation for remnant population	Undertake nocturnal surveys to determine presence, extent and status of a remnant wild population of the Southern snails	21/22	Low	$8,000 once	Southern
Management of captive population	Maintain captive management facility	Maintain facility with min. 2 cool-storage units, lab space, worm farm and security system.	Ongoing	High	$11,000/year	All
Management of captive population	Increase number of Southern *P. augusta*	Aim is long-term security from extinction, i.e. 625 adult snails; also to provide healthy founder population for rehabilitated areas	Ongoing	High	$9,000 increasing to $30,000/year ($35/snail year)	Southern
Management of captive population	Increase number of Central *P. augusta*	Aim is long-term security from extinction, i.e. 625 adult snails; also to provide healthy founder population for rehabilitated areas	Ongoing	High	$21,000 increasing to $30,000/year ($35/snail year)	Central
Management of captive population	Reduce number of Northern *P. augusta*	Aim is long-term security from extinction, i.e. 625 adult snails; also to provide healthy founder population for rehabilitated areas	Ongoing	High	$30,000/year ($35/snail year)	Northern
Management of captive population	Monitor wellbeing of snails	Monitor survival, body condition and fecundity	Ongoing	High	$8,000/year (0.5 day/week); covered by programme lead	All

Workstream	Action	Details	Timing	Priority	Resources	Group
Management of captive population	Document husbandry methods	Document husbandry methods (incl. worm farm management) in protocol (DOCCM-499357) and potentially other media (e.g. instructional videos)	21/22	High	$6,400 once (20 days), minimal ongoing costs; covered by programme lead	All
Management of captive population	Improve husbandry methods	Conduct experiments as required, e.g. on environmental triggers for reproduction	Ongoing	Low	$8,000/year (0.5 day/week); covered by programme lead	All
Management of captive population	Share knowledge	Seek and take opportunities to share experience and knowledge gained to benefit other programmes	Ongoing	Low	minimal; covered by programme lead	All
Management of captive population	Investigate alternatives to DOC captive populations	Investigate options for other institutions to hold *P. augusta* captive populations	21/22 onwards	Low	minimal; covered by programme lead	All
Translocations / releases	Release snails and eggs surplus to captive requirements	Release snails and eggs surplus to requirements of captive populations into existing wild populations of the same group/geographic origin; for Southern snails, release into remnant natural vegetation at A12; avoid mark-recapture monitoring sites.	likely annual	High	$3,000 /year	All
Translocations / releases	Recovery of *P. augusta* from Mt Rochfort	Collect Northern P. augusta from Mt Rochfort sites to boost captive population or release into Extended B. Genetic testing necessary to prevent accidental transfer of *P. patrickensis*.	21/22 and 22/23	Low	$8,000 x2, plus genetic tests	Northern
Advocacy and information sharing	Media stories	Publish media stories (newspaper, radio, DOC blog/website)	At least once a year	Medium	$640/year (2 days); covered by programme lead	All
Advocacy and information sharing	Scientific papers	Publish two scientific papers on the recovery programme	Before 2030	Medium	$20,000 each; covered by TAG members	All
Research	Re-analyse growth data	Reanalyse growth data collected during mark-recapture monitoring to get better understanding of growth rates in the wild	25/26	Medium	$1,600 once (5 days); covered by programme lead	All
Research	Undertake new research	Identify and implement new research projects as questions and opportunities arise.	Ongoing	Low	to be determined	All

Summary of costs

Over the ten years of the strategy, the *P. augusta* recovery programme is estimated to cost a maximum of $1,681,700 plus the funding required for rehabilitation, removal of silt fences, habitat management interventions, genetic tests for Mt Rochfort snails and additional research (Table 9). This assumes that all actions identified in the action plan above are undertaken, irrespective of their relative priority. Focus on high priority actions only, would reduce total costs to $1,501,700 plus the costs for rehabilitation and habitat management interventions. Further efficiencies may be gained over time if, e.g. the hours for the programme lead can be reduced, predator ground control is no longer required, or part of the captive population are managed by a different institution.

Table 9. Summary of estimated maximum costs for the P. augusta recovery programme for 21/22 to 30/31.

Workstream	**21/22**	**22/23**	**23/24**	**24/25**	**25/26**	**26/27**	**27/28**	**28/29**	**29/30**	**30/31**	**Total**
Project management	$32,000	$32,000	$32,000	$32,000	$32,000	$32,000	$32,000	$32,000	$32,000	$32,000	$320,000
Rehabilitation and habitat enhancement	$19,700	$19,700	$19,700								$59,100
Habitat management	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$40,000
Predator control	$9,000	$26,000	$8,000	$8,000	$26,000	$8,000	$8,000	$26,000	$8,000	$8,000	$135,000
Survey and monitoring	$8,000				$90,000					$90,000	$188,000
Management of captive population	$71,000	$74,000	$77,000	$80,000	$83,000	$86,000	$90,000	$93,000	$97,000	$101,000	$852,000
Translocations/releases	$11,000	$11,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$46,000
Advocacy and information sharing						$20,000				$20,000	$40,000
Research	$1,600										$1,600
Total	**$156,300**	**$166,700**	**$143,700**	**$127,000**	**$238,000**	**$153,000**	**$137,000**	**$158,000**	**$144,000**	**$258,000**	**$1,681,700**
Plus costs for rehabilitation, removal of silt fences, habitat management interventions, genetic tests for Mt Rochfort snails and additional research											

Part D – Rationales

This section discusses two fundamental questions regarding the management of *P. augusta* during the 2021-2031 strategic period and beyond:

1. How do we best manage genetic diversity within the species?
2. Should snails be translocated to additional sites outside the species' original range?

How do we best manage genetic diversity within the species?

The strategy continues the previous approach of managing the three distinct groups – Northern, Central and Southern *P. augusta* – separately to ensure their persistence. Within-group diversity of Northern snails should also be maintained as much as feasible. This approach is recommended because it

- maximises the species adaptability to new environmental conditions, and thus, increases the probability of persistence of *P. augusta*;
- protects and enables continuation of the unique evolutionary history of *P. augusta*.

The genetic diversity of a species is the total number of genes present in all living individuals of that species. The larger the genetic diversity the more likely it is that a species will persist long-term, as it has a greater potential to survive diseases and environmental challenges, e.g. droughts, and to adapt to long-term environmental change. Because of this, it is critical to maintain as much genetic diversity as possible when managing threatened species (McNeely et al. 1990, Soulé and Mills 1998, Jamieson and Allendorf 2012, Department of Conservation 2017, Aotearoa New Zealand Government 2020).

The remaining wild populations of *P. augusta* live in either modified, formerly unoccupied or newly created (rehabilitated) habitat, making adaptability to new environmental conditions important for its persistence. While Trewick et al. (2008) found overall relatively low genetic diversity within *P. augusta*, we can distinguish three genetically and morphologically distinct groups. To maintain genetic diversity within *P. augusta* and maximise its adaptability to the new environmental conditions, we need to maintain these three groups. In addition, we should also try to maintain smaller scale genetic diversity, by using geographic distribution as a proxy for genetic diversity, i.e. by managing snails by their geographic provenance (snail search block).

Mixing of Central and Southern snails with Northern snails would likely lead to the loss of typical Central or Southern genes, as these two groups would be genetically overwhelmed by the much more numerous Northern snails. Northern snails number several thousand animals in the wild, occurring at densities of up to 650 snails/ha (see Mark-recapture monitoring), while fewer than 300 Southern snails are in existence. Numbers of Central snails in the wild populations are not known but are likely low because of low habitat quality. Only 700 Central snails are currently in captivity.

The description of Northern and Southern *P. augusta* as separate subspecies (Walker in prep) also calls for the maintenance of these two groups. While the Central group has not been distinguished at subspecies-level, it is distinct from Northern and Southern snails and of different evolutionary origin (Walker in prep). As such, the protection of all three groups is required to maintain and continue the evolutionary history of *P. augusta*.

In addition, the Central snails play a role as insurance for the continuation of at least some of the unique genetic makeup of the Southern snails should the recovery of the latter be unsuccessful. The Central snails are morphologically similar to the Southern snails. This morphology is presumably the expression of particular "Southern" genes, that would persist in Central snails should Southern snails become extinct.

The best management options for the recovery of the three distinct *P. augusta* groups are discussed in DOC-6449065.

Should snails be translocated to additional sites outside the species' original range?

The recommendation here is to undertake **no** further translocations outside of *P. augusta*'s original range. The option of translocating *P. augusta* to additional sites, including sites away from the Buller Plateau, has repeatedly been discussed. Extensive consultation with internal and external experts was undertaken (Barker and Overton 2007, Gruner 2007b, Armstrong 2014, Otley et al. 2014). Every time, the option was dismissed. The key reasons were:

Lack of suitable sites on the Buller Plateau

Additional sites on the Buller Plateau that would provide suitable habitat and be large enough to support a self-sustaining population of *P. augusta* are not available. All potential sites were thoroughly assessed (Bartlett and Knightbridge 2007, Gruner 2007b, Roxburgh and Hamilton 2012, Walker 2012, Otley et al. 2014). Of these, the chosen translocation sites (Extended Site B and Mt Rochfort) were deemed to be the best available options. If *P. augusta* is found to persist at one of these sites or within remnant natural habitat, the recovery goal will be achieved and no further sites are required. If the populations at the current sites fail, it is unlikely that translocations to other, lower quality sites would lead to a better outcome.

Conservation policy and guidance

Several policy, SOP and guidance documents stipulate that priority for conservation management is to maintain species within their natural ranges (New Zealand Government 2000, Department of Conservation 2010, 2012, IUCN/SSC 2013). Management of species outside their natural ranges should only be considered when persistence cannot be achieved within (Department of Conservation 2012). In accordance with this, the previous *P. augusta* recovery strategies specified that no additional translocation sites should be considered unless there was clear evidence that the current populations were failing (Gruner 2007a, Otley et al. 2015).

Impacts on the receiving ecosystem

Translocation of *P. augusta* to sites outside its original range would mean the introduction of an alien species into the receiving ecosystem. If successful, *P. augusta* would alter this ecosystem, e.g. through predation, competition or disease transmission. This presents a threat to the receiving ecosystem and its species, especially as the translocation would be irreversible. We cannot predict the effects of this, and therefore, cannot fully assess associated risks (Ricciardi and Simberloff 2009). Translocation should not be the preferred option under these circumstances, as conservation interests of other species and habitats should not be jeopardised (IUCN/SSC 2013).

Impacts on biogeographic patterns and processes

Current biogeographic patterns have developed over millions of years. They are the result of the earth's long geological and biological history. The study of biogeography helps us to understand this history. Because of this, biogeographic patterns in themselves warrant protection. A translocation of *P. augusta* to sites outside its original range disturbs natural biogeographic patterns and sets in train processes that would otherwise not have occurred. The impact is more severe the further away from the original range translocation sites are.

Impact on P. augusta

As a species, *P. augusta* is a natural spot endemic characterised by its occurrence on the Brunner coal measures of the Mt Augustus range (Walker et al. 2008). Translocating these snails to a new site, away from the Mt Augustus range or away from the Buller Plateau, would not ensure the persistence of the species. As conditions at the new site will be different, the species would be set onto a different evolutionary trajectory. It would present a *P. augusta* lineage, but over time, would transform into a different species that would naturally not have occurred.

Recommended approach for 2021-2030

Based on the recent long-term monitoring results, it seems appropriate to continue with the approach of the previous strategies: the existing populations have not shown any drastic declines; survival rates in Site A and West 1 may be sufficient for long-term persistence. At this point in time, translocation to additional sites outside the original range does not seem necessary and presents the added risk of creating further disjunct populations.

Moreover, we propose to take an even stronger stance against translocations outside *P. augusta*'s original range by considering such translocations inappropriate even if the current populations were to fail. This is for the following reasons:

The question whether to translocate *P. augusta* to sites outside its natural range is largely a value judgement: It needs to balance the potential benefits to the species against negative effects and risks arising from such a translocation. Where the balance is found depends on the value put on, for example, the integrity of the receiving ecosystem or natural biogeographic patterns versus the persistence of *P. augusta* (albeit on a different evolutionary trajectory). However, the risks of such a translocation cannot be fully assessed, and any successful translocation of *P. augusta* would be irreversible, even if unforeseen detrimental consequences became apparent later. The IUCN guidance on translocations suggests that if the risks of a translocation outside a species' natural range cannot be fully assessed, preference should be given to alternative solutions (IUCN/SSC 2013). In the case of *P. augusta*, these alternatives lie in the existing wild populations and intensive rehabilitation efforts within the species' original range.

In the international literature, translocation of species to areas outside their natural range is highly controversial (e.g. Ricciardi and Simberloff 2009, Minteer and Collins 2010, Seddon 2010, Lawler and Olden 2011, Sgrò et al. 2011). In New Zealand, such translocations have occurred for one of two rationales:

- The translocated species were highly threatened and taxonomically highly distinct (e.g. kakapo and tuatara, Lloyd and Powlesland 1994, Miller et al. 2012).
- The translocated species filled an ecological niche left vacant by the extinction of other native species. This means the translocations helped to restore ecological processes within the receiving ecosystems (e.g. petrels, Miskelly et al. 2009).

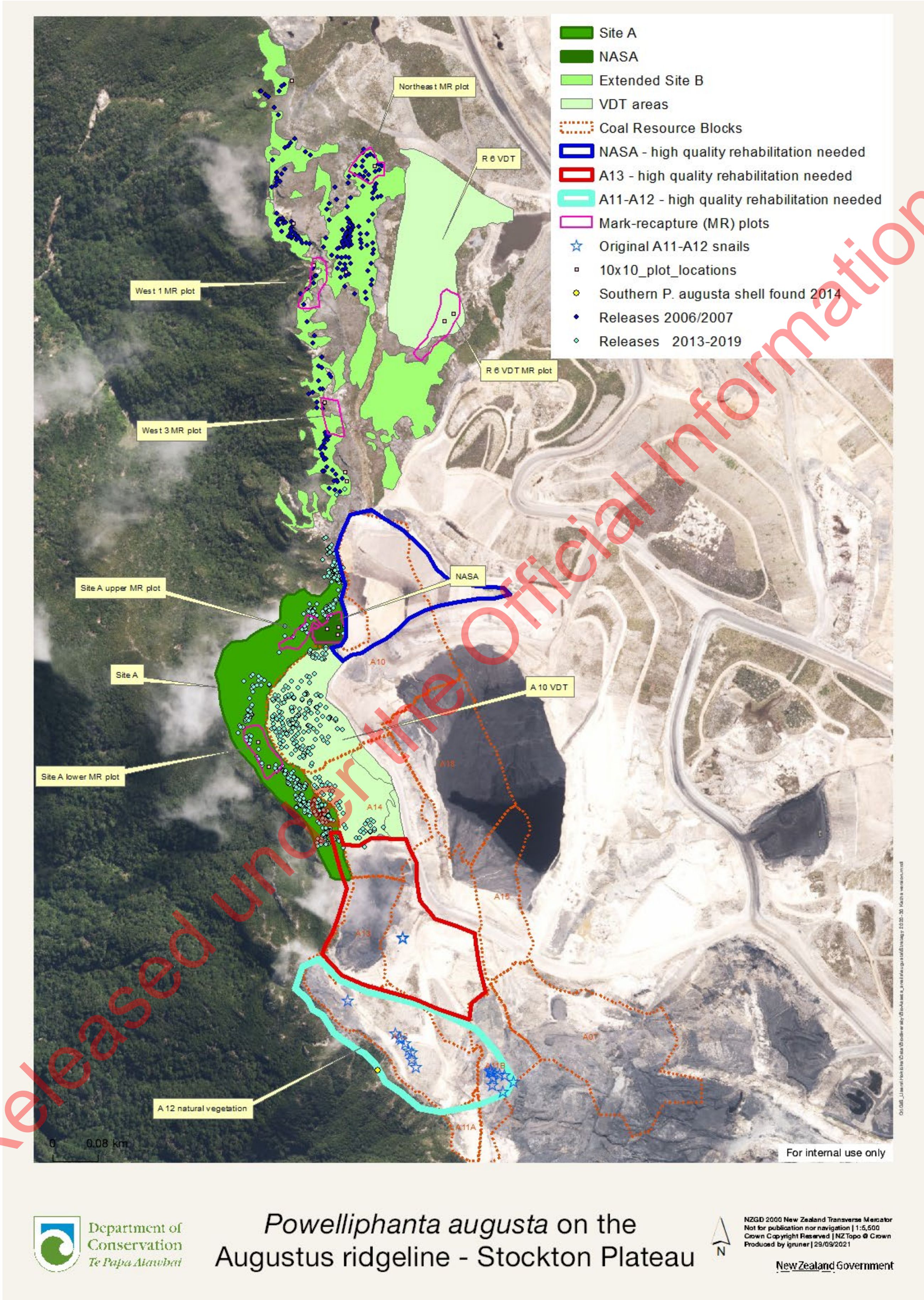
A third rationale seems appropriate and associated with relatively low risk:

- The species is threatened with extinction in its natural range due to unmanageable threats, and the secure translocation site is within the range to which natural dispersal seems possible in the long-term, i.e. the translocation can be regarded as accelerating natural dispersal.

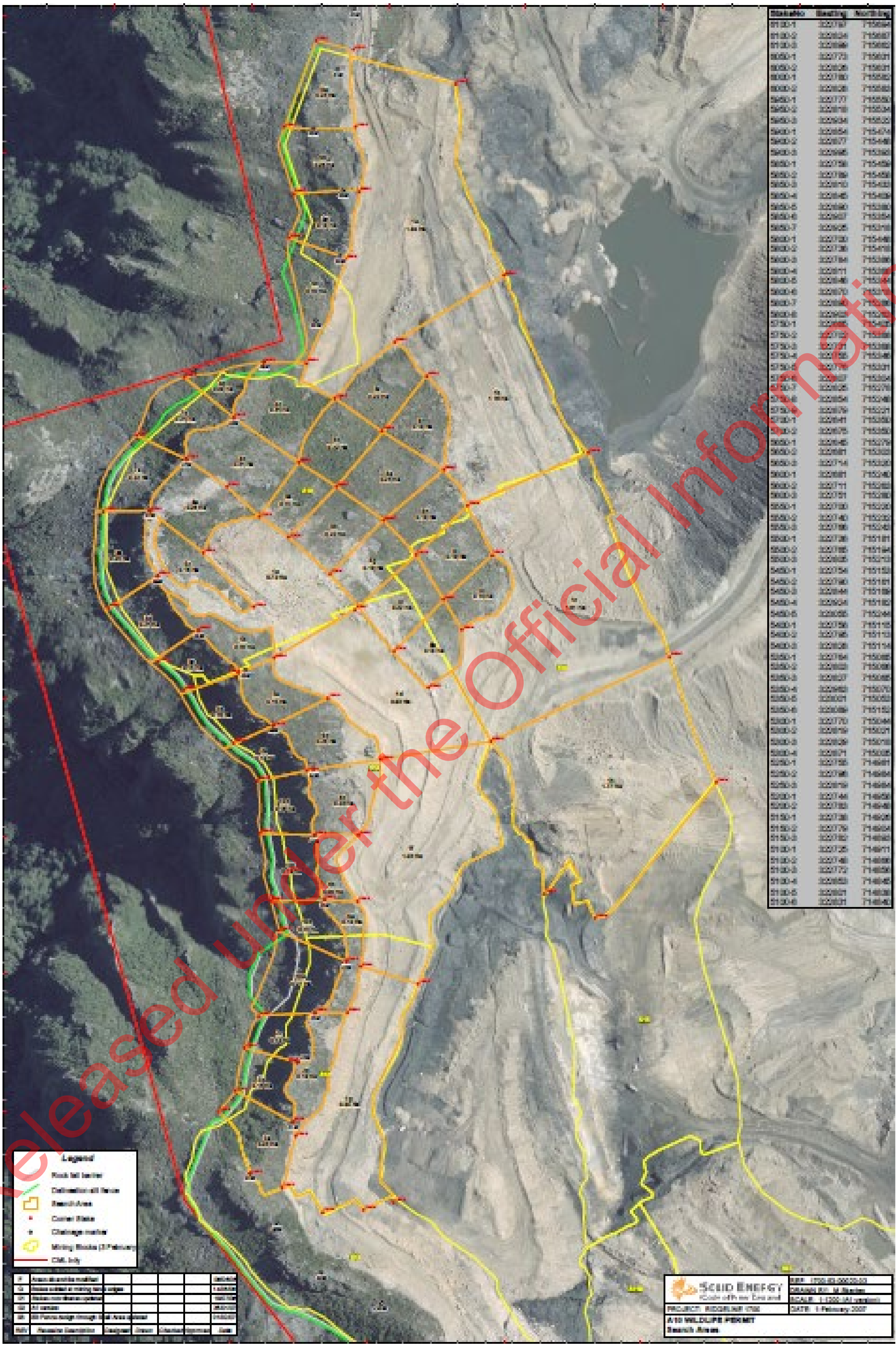
The translocation of *P. augusta* to sites in Extended Site B can be interpreted as meeting the third rationale. However, translocations to sites further afield fit neither of the above criteria. While *P. augusta* is a distinct species, there are 20 other species in the same genus, making it less taxonomically unique than, e.g. kakapo and tuatara. When released into habitat without *Powelliphanta*, it does not replace an extinct carnivourous land snail but represents an invader. Release into habitat already occupied by another *Powelliphanta* species is inappropriate, as it creates competition and carries the risk of hybridisation and disease transfer. In hindsight, the translocation of *P. augusta* to Mt Rochfort should not have occurred. At the time, reducing the immediate extinction risk for *P. augusta* was given priority over associated negative impacts and risks.

Maps

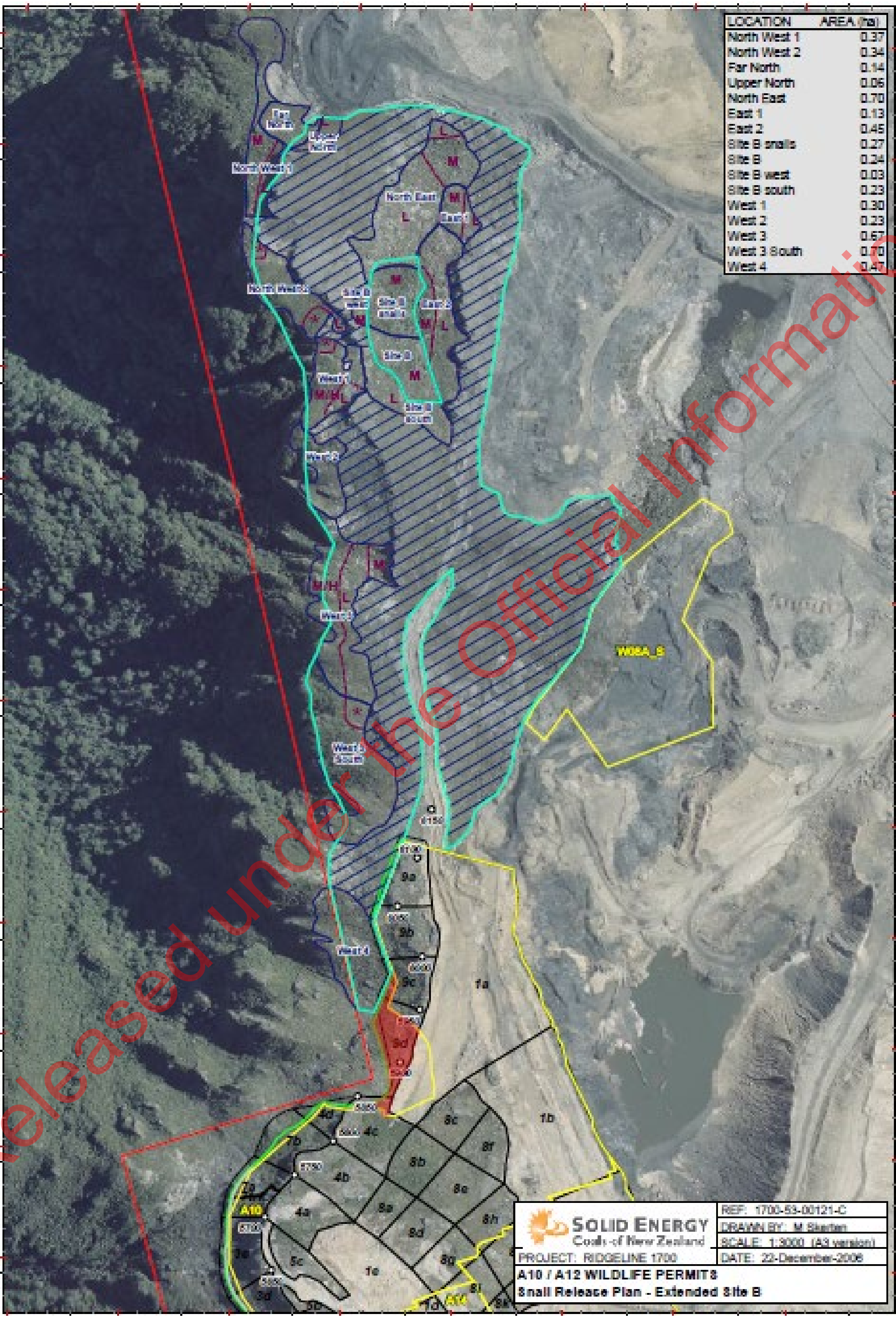
Map 1. Key locations relevant for management of *P. augusta* along the Augustus ridgeline



Map 2. Snail search blocks along the Augustus ridgeline (S:\3_Tech Support\Augustus\Capture data\Map of GPS coordinates of mine sub-areas).

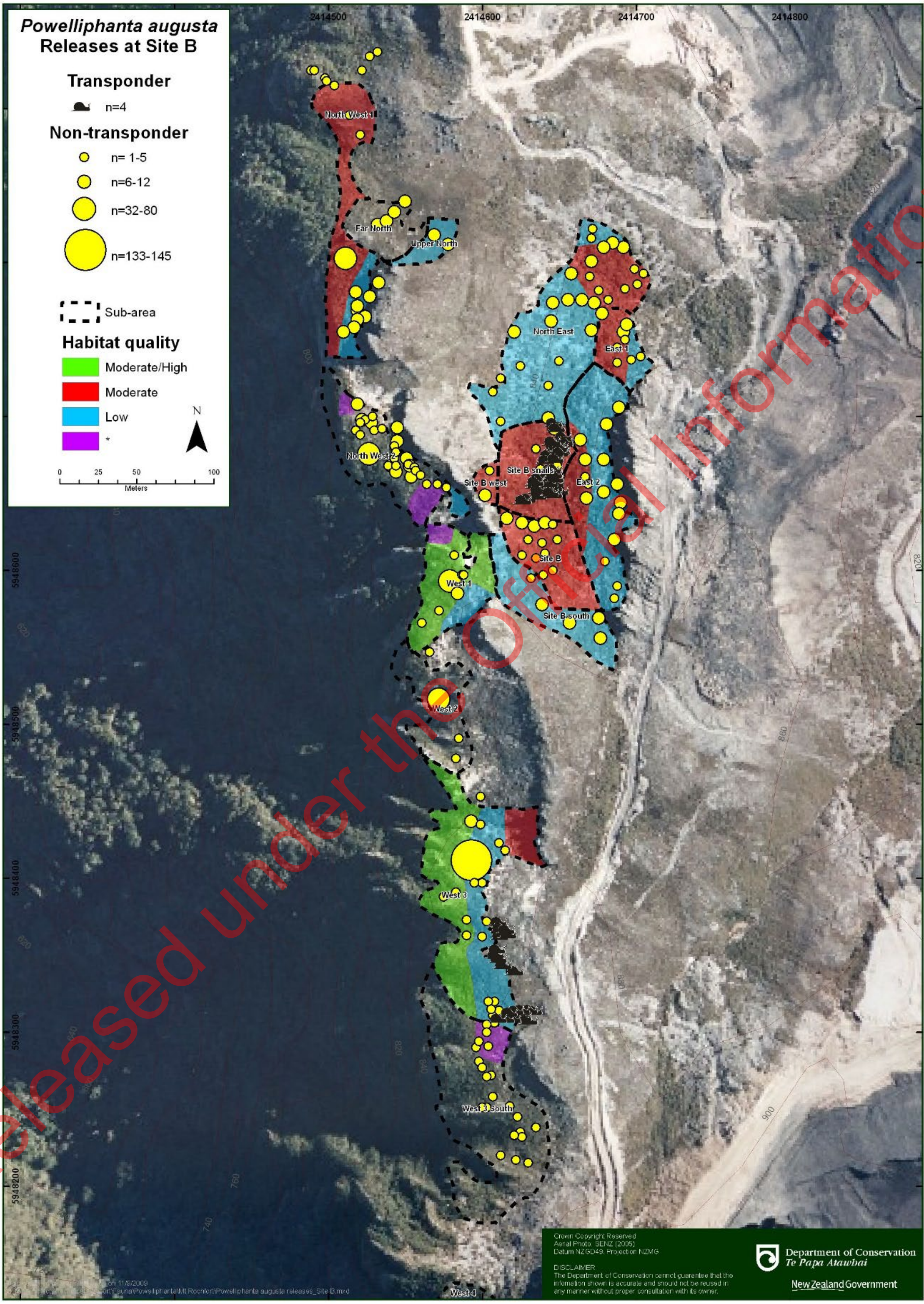


Map 3. Translocation sites at Extended Site B with subjectively assessed habitat quality. Asterisk – very high, H – high, M – moderate, L- low habitat quality, cross hatch – unsuitable habitat (S:\3_Tech Support\ Augustus\ Translocations 2006 & 2007\Extended Site B\ \Release Extended Site B_release areas_22 December 20061700-53-00121-C).

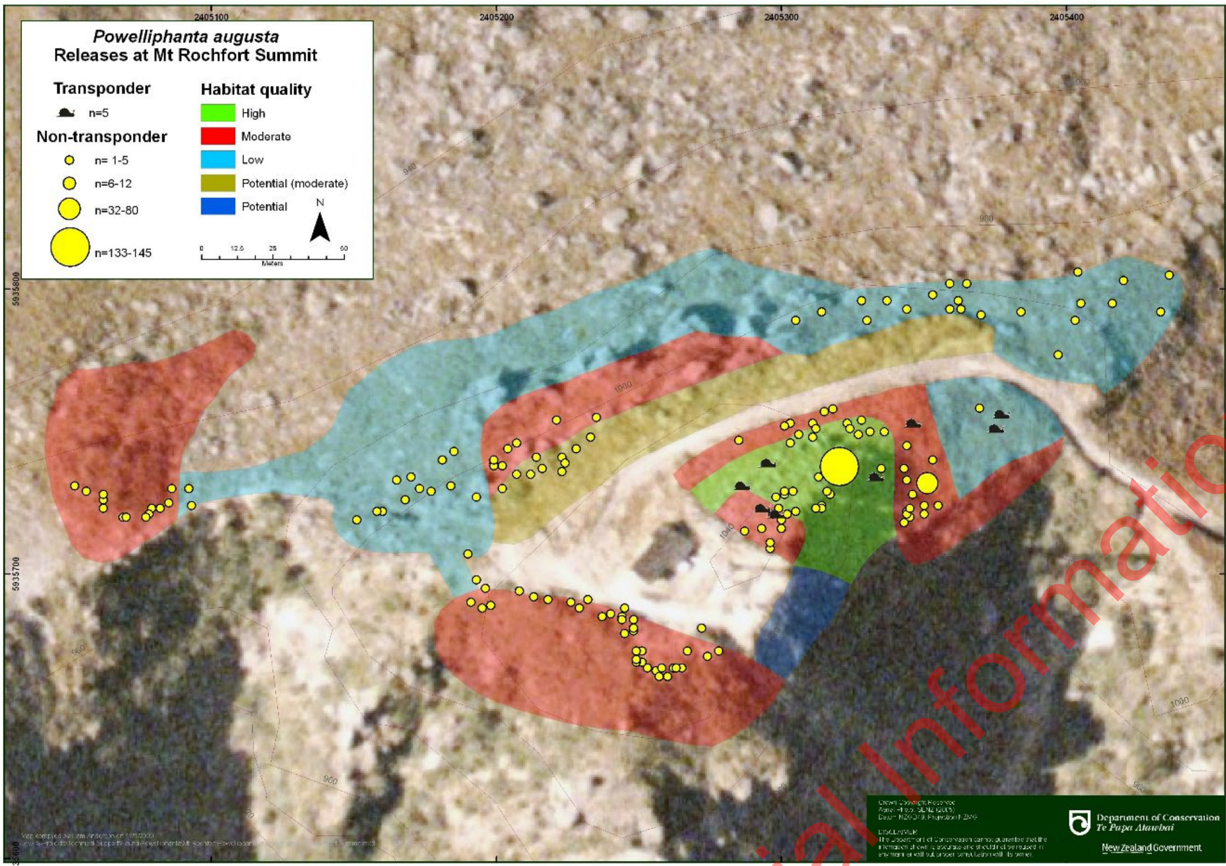


Maps 4a, b and c. 2006/07 translocations: Extended Site B, Mt Rochfort Summit and Mt Rochfort Basin. Each site was divided into sub-areas where habitat quality was subjectively assessed to adjust release densities. Some snails at each site were fitted with transponders to monitor short term survival (S:\3_Tech Support\Augustus\Translocations 2006 & 2007).

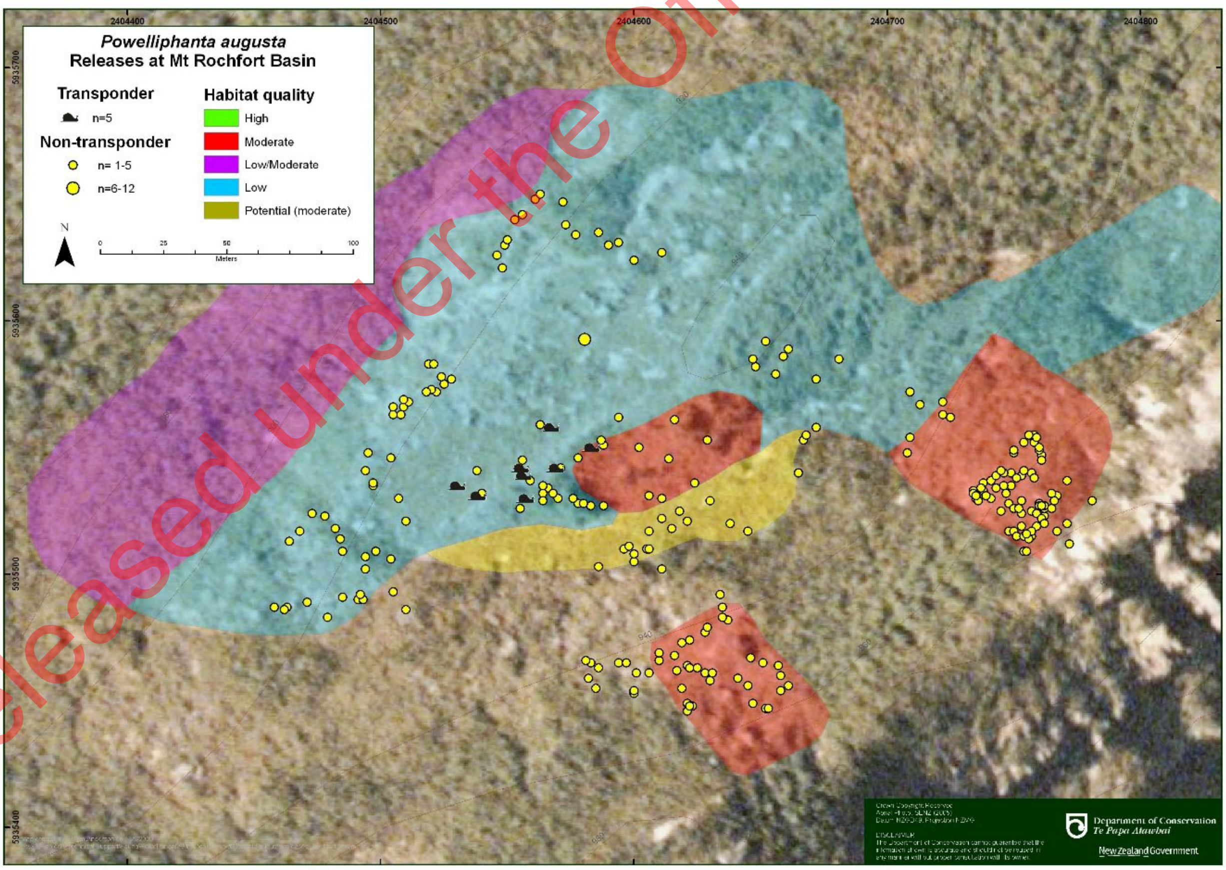
a



b


Powelliphanta augusta
Releases at Mt Rochfort Summit
Transponder
n=5
Non-transponder
n= 1-5
n=6-12
n=32-80
n=133-145
Habitat quality
High
Moderate
Low
Potential (moderate)
Potential
Department of Conservation
Te Papa Atawbai
New Zealand Government

c


Powelliphanta augusta
Releases at Mt Rochfort Basin
Transponder
n=5
Non-transponder
n= 1-5
n=6-12
Habitat quality
High
Moderate
Low/Moderate
Low
Potential (moderate)
Department of Conservation
Te Papa Atawbai
New Zealand Government

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P. augusta recovery strategy 2021-2031 – Management of genetic diversity

Options and risk assessment

Executive summary

This document explores options for the management of three genetically and morphologically distinct groups within the critically threatened land snail *Powelliphanta augusta*. The preferred options will inform the management of *P. augusta* under the 2021-2031 recovery strategy (DOC-6115162).

The persistence of the three *P. augusta* groups has become the focus for its conservation management to ensure its genetic diversity is maintained and, through this, the probability for its persistence maximised. The recommended approach for all three groups is to minimise extinction risk and aim for full recovery by re-establishing each group over as much of its original range as possible. Key management activities are habitat enhancement and revegetation to create better and more habitat. This is combined with captive management to secure populations while revegetation areas develop into habitat, and to provide founder populations for release into these new habitats.

The following table summarises the estimated 10-year costs of the recommended options (use the hyperlinks for quick access to details in the main text for each group and each preferred option).

Group	Option name	10-year costs (2021-2031)	Average annual cost
Southern	Option D – Full recovery	$301,000	$30,100
Central	Option C – Full recovery	$355,000	$35,500
Northern	Option C – Full recovery	$537,000	$53,700
Total		**$1,193,000**	**$119,300**

The costs include only high priority actions within each preferred option ('musts'), and do not include the salary for the essential position of an overall *P. augusta* programme lead. The success of the *P. augusta* recovery programme depends strongly on this programme lead to maintain overview, momentum and consistency. Most costs for rehabilitation and habitat enhancement/management are also excluded, as the extent, costs, and responsibility for these costs still need to be clarified.

Financial constraints are likely to be the main factor preventing full recovery of *P. augusta*. Currently, an annual budget of approximately $65,000 is available within the DOC Hokitika District. This funding is sourced from mining compensation funds which may not be available much longer. Twice the currently available amount, and likely more, will be needed to fully implement the preferred options. High-level discussions between DOC and Bathurst Talleys, as the responsible mining company, are needed to determine who is financially responsible for which parts of the recovery programme.

Context

Successful maintenance of genetic diversity is seen as key to ensuring the long-term persistence of threatened species (McNeely et al. 1990, Soulé and Mills 1998, Jamieson and Allendorf 2012, Department of Conservation 2017, Aotearoa New Zealand Government 2020). High genetic diversity within a species increases its adaptability to environmental changes and, therefore, increases the probability for its long-term persistence.

The current wild populations of the critically threatened land snail *Powelliphanta augusta* live in either modified, formerly unoccupied or newly created (rehabilitated) habitat, making adaptability to new environmental conditions paramount for its persistence. Morphological and genetic research have led to the distinction of three groups within *P. augusta*, labelled Northern, Southern and Central in reference to their respective geographical distributions. The Northern and Southern *P. augusta* are distinct at subspecies-level; the Central group presents a distinct lineage with currently uncertain taxonomic status (Walker in prep). The maintenance of the three genetically and morphologically distinct groups within *P. augusta* has become the focus for the management of genetic diversity within the species to increase its probability for long-term persistence. In addition, maintenance of the three groups protects and enables the continuation of the unique evolutionary history of *P. augusta*. Mixing of the three groups would most likely lead to the loss of genetic diversity because of a gross imbalance in numbers: the much more numerous Northern snails would genetically overwhelm the rarer Central and Southern snails.

To date, the management of *P. augusta* has been guided by successive recovery strategies. The latest strategy expired in 2020. A new strategy, spanning 2021-2031, is currently in preparation. This options and risk assessment supports the completion of the new strategy by exploring options for the management of the three *P. augusta* groups. The preferred options will inform the planning of management actions for 2021-2031.

Presentation of options – Read me first

Readers need to be familiar with the background information presented in the first sections of the *P. augusta* recovery strategy 2021-2031 (DOC-6115162, pp. 1-21). An overview map of key localities along the Augustus ridgeline can be found in the Appendix.

The current status and resulting management needs of the Northern, Southern and Central *P. augusta* differ drastically. We therefore discuss options for their management separately, starting with the Southern subspecies as the most threatened group. Options are compared with regard to key actions, timeframes, estimated costs, underlying assumptions and risks. We present the management options for each group summarised in a table first, before describing them in more detail in the text.

Timeframes of options state when one-off management activities and those with defined end-points are likely to be completed. After their completion, recovery moves into a 'maintenance and monitoring' phase in which some ongoing management activities still need to occur. The following activities are required in these 'maintenance and monitoring' phases for all three *P. augusta* groups, irrespective of which management options are chosen. The costs for these activities will be shared across the three groups.

- **Habitat monitoring and management**: All current and potential (i.e. rehabilitated) habitat needs to be regularly monitored and any impacts mitigated to prevent degradation, e.g. erosion or severe browse damage. Habitat monitoring is estimated to cost $1,000/year for the entire Augusta ridgeline. Funding of any necessary management interventions needs to be discussed with the mining company, Bathurst Talleys (BT), as impacts are likely to be a direct legacy of mining.
- **Weed detection and control**: Several invasive weeds (e.g. *Juncus squarrosus*, gorse) occur along the Augustus ridgeline and need to be detected and controlled to enable establishment and persistence of healthy native vegetation. This work is estimated to cost $4,000/year across the entire Augustus ridgeline. Funding for this should be covered by BT, as weeds are a direct legacy of mining.
- **Predator control**: BT currently fund regular monitoring and ground control of possums, rats and stoats across the range of the Northern and some Central *P. augusta*. This may need to continue and be extended to include all wild snail populations. The estimated cost for this ground control is $8,000/year. However, a review of the ground control operation may show that the use of periodic aerial predator control would be sufficient. This could be achieved by including the Augustus ridgeline in large-scale aerial predator control operations undertaken in adjacent areas.

Southern P. augusta

Table 1: Options for the management of Southern P. augusta, 2021-2031 (raw table in DOC-6413237).
√ - essential action ('must'), (√) – optional action ('should or could').

Action	**Option A - Immediate release - north**	**Option B - Immediate release - south**	**Option C - Release after monitoring**	**Option D - Full recovery**	**Estimated costs**
Survey A12 natural vegetation for remnant population	(√) No population found or not viable	√ Population found	√ Population found	(√)	$3,000 once
Release captive snails into southern Site A and A10 VDT	√				$3,000 once
Release captive snails into A12 natural vegetation in Year 1 or 2		√			$3,000 once
Monitor wild population in A12 natural vegetation		√	√		$15,000 x3 during 2021-2031
Grow captive population to provide short-term security			√		$11,000/year for facility (shared with Northern and Central snails) + $4,000/year for husbandry
Release captive snails into A12 natural habitat once population is confirmed viable (10+ years)			√ if remnant population not viable move to Option A or D		$5,000 once (post-2031)
Grow captive population to provide long-term security				√	$11,000/year for facility (shared with Northern and Central snails) + $9,000/year increasing to $30,000/year for husbandry
Release surplus captive eggs and young snails into A12 natural habitat			√	√	$3,000 per release, x3 during 2021-2031 (shared with Northern and Central snails)
Enrichment planting in A12 natural habitat		(√)	(√)	√	$18,000 (8,000 plants @ $1.50 each plus $6,000 for planting; paid by BT?)
Maximise extent and quality of revegetation in A11/12 mining area		(√)	(√)	√	to be confirmed (paid by BT?)
Release and monitor snails in rehabilitation areas once considered suitable (post-2031)				√	to be confirmed (post-2031)
Habitat monitoring and management	√ covered by Central snails	√	√	√	$1,000/year (shared with Northern and Central snails) + management costs (to be confirmed, paid by BT?)
Weed detection and control	√ covered by Central snails	√	√	√	$4,000/year (shared with Northern and Central snails; paid by BT?)
Predator control	√ covered by Central snails	√	√	√	ground control $8,000/year, aerial $18,000/operation (shared with Northern and Central snails; paid by BT?)
Timeframe (years to 'maintenance and monitoring' phase)	1	1-2	10+	10+	
Total costs over 10 years, 2021-2031 (maximum estimates and 'musts' only)	$3,000	$112,000 (+ habitat management; paid by BT?)	$189,000 (+ habitat management; paid by BT?)	$319,000 (+ habitat management, enrichment planting and rehabilitation; paid by BT?)	
Assumptions/Approach	assumes persistence of separate population of Southern snails impossible	assumes viability of remnant population in A12 natural habitat	precautionary - confirm viability of existing wild population before release	most precautionary - strives to achieve long-term recovery	
Risk of extinction	extreme	high	low	lowest	

The Southern *P. augusta* snails have no known wild population. Very little, if any, of their original habitat remains. The narrow strip of tussock-shrubland left on the western slopes below the A12 mining area is not considered good snail habitat (Figure 1). In addition, this area has been damaged by silt run-off, rockfall and silt fence construction (Figure 2). Intensive daytime searches between 2006 and 2013 did not find any sign of *P. augusta* in the area, but one recently dead, empty shell was found in 2014 (Otley et al. 2015).

Only 25 Southern *P. augusta* were recovered during site clearance and the current captive population is still too small to provide for even short-term security.

Figure 1. Looking northwards to the A12 ridgeline in 1994 (top) and in 2007 (bottom), with the arrow marking a distinctive hillock. Southern snails were found in tussock-shrubland adjacent to mountain beech forest on both, the western slope of the A12 ridge and the uphill side of the forest on the eastern slope (top). The remaining narrow strip of tussock-shrubland on the lowered ridgeline is not considered good habitat (bottom).

Figure 2. Vegetation on the western slopes below the A12 mining block has been severely damaged by silt run-off and rockfall. The area would benefit from enrichment planting with appropriate native species.

We have identified four options for the future management of the Southern snails (Table 1).

Option A: Immediate release to northern sites

Assumptions/Approach: This option assumes that the persistence of a population of the Southern snails in the A12 area is impossible. This may be for ecological or operational reasons, e.g. a survey of the remaining tussock-shrubland below the A12 ridgeline may fail to find a wild population, and rehabilitation of the adjacent A12 mining block may be considered impossible.

Actions: All captive Southern snails would be released into the southern end of Site A and the A10 VDT, i.e. Southern snails would be mixed with existing populations of Central and potentially Northern snails. Because of this mixing, monitoring of the released population would be impossible.

Timeframe: This option carries the shortest timeframe, as all captive Southern snails would be released in Year 1.

Costs: This option carries the lowest cost, as only about $3,000 would be required for snail release. 'Monitoring and maintenance' costs would be covered by the Central and Northern groups.

Risks: This option would lead to the extinction of the Southern *P. augusta* subspecies as a distinct taxonomic unit, as the released snails would be become part of a mixed population. The unique genetic makeup of the Southern snails would be subsumed into the resident population and likely disappear over time, as Central and Northern snails are much more numerous. The extinction of a subspecies poses a high reputational risk for DOC.

Option B: Immediate release to A12 natural habitat

Assumptions/Approach: This option can only be pursued if a survey of the remaining vegetation west of the A12 mining block results in the discovery of a remnant population of Southern *P. augusta*. It is then assumed that this population is viable.

Actions: Following a successful survey of the remaining strip of natural vegetation west of the A12 ridgeline, all captive Southern snails would be released into this area. Monitoring would be established to understand population trends over time. This could be done using mark-recapture monitoring, or a new technique may be developed. This monitoring would then become part of the 'maintenance and monitoring' activities for the term of the 2021-2031 strategy and beyond.

Planting of appropriate native plants to improve habitat quality in the remaining habitat area could be included in this option, as could be the revegetation of adjacent mining areas to increase habitat area in the long-term and, thus, the probability of long-term success.

Timeframe: Survey of the area and release of captive snails could occur in Years 1 and 2. Monitoring would need to be established immediately after the release to collect baseline data. Recovery would then enter the 'maintenance and monitoring' phase.

Enrichment planting and additional revegetation, if included, could occur at any time, but would best be done early on, as it will take at least 10 years before these areas may be suitable as snail habitat.

Costs: Costs for this option amount to $112,000 over 10 years plus possible additional costs for habitat management. Costs for enrichment planting and revegetation, if included, would also be additional. Some of these costs would likely be carried by BT, as issues are a direct legacy of mining.

Risks: The risk of extinction for the Southern snails in this option would be high, as the viability of the remnant wild population cannot be assumed. *P. augusta* snails are long-lived and any live snails still present in the vegetation west of the A12 escarpment might be the remainder of an ageing, declining population. Monitoring would not be able to provide reliable information on population trends in the short-term, because of the likely low snail numbers. If monitoring confirmed a decline in the long-term, an emergency recovery could not recover a large enough number of snails to ensure persistence. Because of the high extinction risk, the option carries a high reputational risk for DOC.

Option C: Release after monitoring

Assumptions/Approach: This option takes a more precautionary approach by first seeking to confirm that any remnant wild population is viable before captive snails are released. As Option B, this option can only be pursued, if a survey of the remaining vegetation west of the A12 ridgeline results in the discovery of a population of Southern *P. augusta*.

Actions: The remnant population of Southern *P. augusta* would be monitored until its viability has been confirmed. In the interim, the captive population would be allowed to grow to a level that provides short-term security from extinction. If the captive population produces surplus eggs and young snails, these would be released into the remaining vegetation at A12. Once the monitoring data confirm population viability, all captive snails would be released. If the monitoring shows that the remnant population is not viable, a decision would need to be made to move to either Option A or D.

As for Option B, enrichment planting and additional revegetation could be included in this option.

Timeframe: The timeframe of this option would reach beyond the term of the 2021-2031 strategy, as it is unlikely that the status and trend of a remnant wild population would be sufficiently understood within 10 years.

Costs: The costs for this option would be higher than for Option B, because of the maintenance of a captive population. However, costs for the captive facility would be shared with the Central and Northern *P. augusta* and, potentially, other threatened *Powelliphanta* species.

Risks: This option carries a relatively low risk of extinction for the Southern group, as captive snails would only be released once any newly discovered wild population is confirmed to be viable. However, the option carries a relatively high risk of 'technical failure': Monitoring may not be able to ascertain populations trends with sufficient certainty, as the population is likely to be sparse and releases of surplus eggs and snails from captivity could confound results. In this case, a decision would need to be made to move to either Option A or D.

Option D: Full recovery

Assumptions/Approach: This option is the most precautionary. It aims for persistence of the Southern *P. augusta* subspecies by attempting to create habitat and growing the captive population to a secure size before release. This option could be chosen regardless of whether a population remains in the strip of natural vegetation below the A12 escarpment.

Actions: Habitat enrichment in the remnant natural vegetation and high-quality rehabilitation of adjacent mining areas, including enrichment planting in an existing revegetation area, are key activities (Figure 3 and Figure 4). The captive population would be grown to provide long-term security from extinction and a healthy founder population for the new habitat areas. Once rehabilitated areas are considered suitable, snails would be released and monitored.

Timeframe: The timeframe of this option reaches beyond the term of the 2021-2031 strategy. While habitat enrichment and rehabilitation could be completed within the first two years, it would take at least 10 years before a release of snails could occur. The captive population is estimated to reach a size of around 625 adults, as required for long-term security, by 2031.

Costs: The costs for this option would be higher than for the other options, because of the larger size of the captive population, and habitat enrichment and rehabilitation works. A part of the costs would potentially be covered by BT, as the existing habitat degradation and the need for rehabilitation are a direct legacy of mining. Costs for the captive facility would be shared with the Northern and Central snails, and, potentially, other threatened *Powelliphanta*.

Risks: The risk of extinction for the Southern subspecies is minimised by this option, as it maintains a secure population in captivity and aims to maximise habitat extent to sustain a viable population in the wild. It is important to note that, while this option minimises extinction risk, the risk is still high, as rehabilitation may not be successful in the long-term. High quality rehabilitation may create snail habitat in the medium-term, but areas may develop into less suitable forest in the long-term because of the increased drainage and fertility of the re-contoured surfaces. The hope is that a mosaic of vegetation types would remain and that this together with increased habitat connectivity would allow the Southern *P. augusta* to persist.

Figure 3. The coal floor on the now highest part of the A12 ridgeline. This area needs to be covered with granite and topsoil, and then densely planted with species that promote formation of snail habitat (e.g. Chionochloa flavescens). The access road also needs to be revegetated to connect the area with the already revegetated eastern slopes (visible in the middle distance). These areas need enrichment planting with snail-preferred species to accelerate habitat development. Protective sleeves should be used around plants to prevent hare browse, increase growth rates and allow effective weed control.

Figure 4. The road along the A12 ridgeline presents a barrier to snails. It needs to be retired and densely planted (once revegetation on the high point of the ridge is complete). Existing plantings on the road verges and to the east need high-density enrichment planting with appropriate native species.

Recommendations – Southern P. augusta

Option D should be the starting point for the management of the Southern *P. augusta*. This option poses the least extinction risk for the subspecies and the best chance for recovery and persistence. Option C also carries low extinction risk, but this option has an equally long timeframe with a high risk of failure, because population monitoring may be unsuccessful. It seems more expedient to use the 10+ years to revegetate habitat areas and grow the captive population of Southern snails to a safer size, i.e. pursue Option D.

The success of Option D relies heavily on a strong programme lead exploring and negotiating options and funding to maximise the extent and quality of rehabilitation in the A12/A11 mining blocks.

Central P. augusta

Table 2: Options for the management of Central P. augusta, 2021-2031 (raw table in DOC-6413237).
√ - essential action ('must'), (√) – optional action ('should or could').

Action	Option A - Immediate release	Option B - Release after habitat enhancement	Option C - Full recovery	Estimated costs
Release all captive snails into southern end of Site A and A10 VDT in Year 1	√			$5,000 once
Maintain captive population (short-term security)		√		$11,000/year for facility (shared with Northern and Southern snails) + $4,000/year for husbandry
Release all captive snails into southern end of Site A and A10 VDT after habitat enhancement and fence removal (Year 3)		√		$5,000 once
Grow captive population (long-term security)			√	$11,000/year for facility (shared with Northern and Southern snails) + $21,000/year increasing to $30,000/year for husbandry
Release surplus captive eggs and young snails into southern end of Site A and A10 VDT			√	$3,000 per release, x5 during 2021-2031 (shared with Northern and Southern snails)
Rehabilitate adjacent A13/14 mining area			√	to be confirmed (paid by BT?)
Enrichment planting in southern end of Site A	(√)	√	√	$1,700 (750 plants @ $1.50 each plus $600 for planting; paid by BT?)
Remove silt fences	(√)	√	√	to be confirmed (paid by BT?)
Habitat monitoring and management	√	√	√	$1,000/year (shared with Northern and Southern snails) + management costs (to be confirmed, paid by BT?)
Weed detection and control	√	√	√	$4,000/year (shared with Northern and Southern snails; paid by BT?)
Predator control	√	√	√	ground control $8,000/year, aerial $18,000/operation (shared with Northern and Central snails; paid by BT?)
Release and monitor snails in rehabilitation areas once considered suitable (post-2031)			√	to be confirmed (post-2031)
Timeframe (years to 'maintenance and monitoring' phase)	1	2	10+	
Total costs over 10 years, 2021-2031 (maximum estimates and 'musts' only)	$66,000 (+ habitat management; paid by BT?)	$84,000 (+ habitat management, enrichment planting and silt fence removal; paid by BT?)	$355,000 (+ habitat management, enrichment planting and silt fence removal; paid by BT?)	
Assumptions/Approach	assumes existing wild population is viable	assumes wild population is viable within current area	strives to achieve long-term recovery	
Risk of extinction	high	high	low	

The current range of Central *P. augusta* in the wild is very limited, as almost all their original habitat was destroyed. Snails in this group currently occur in a small area at the southern end of Site A and in the adjacent A10 VDT. The remnant of natural habitat in Site A has been badly damaged by erosion, silt run-off, rockfall and the construction of silt and rockfall fences during mining (Figure 5 and 6). The vegetation in the VDT area is still in the 'dying-off phase' following sod placement a few years ago. Trends in the populations of Central snails have not been monitored.

Figure 5. The remaining unmined natural habitat of Central snails has been badly damaged by erosion, silt run-off, rockfall and the construction of silt and rockfall fences. Material caught behind the rockfall fence in the bottom picture needs to be removed to prevent impact on habitat below as the rockfall fence degrades. The A13 coal floor and the A12 ridgeline are visible in the top left of the bottom picture.

Figure 6. Remaining natural habitat of Central snails in Site A (right foreground) damaged by erosion, silt run-off and rockfall. Overhanging it, held up by a tattered remnant of silt fencing, are coal-fines and silt threatening to cause further damage to the habitat below. The edges of VDT sods in the A10 VDT area are visible to the left. In the background is the open A13 coal pit. This was capped in October 2020 and planted (at low density) in November 2020. A highwall remain,s separating this area from the A12 ridgeline, visible on the skyline behind.

We have identified three options for the future management of the Central snails (Table 2).

Option A: Immediate release

Assumptions/Approach: This option assumes that the current wild population of the Central group will persist long-term, even though the habitat area is small and of low quality, and the population has not been monitored.

Actions: All captive snails would be released into the southern end of Site A and the adjacent A10 VDT in Year 1. Habitat and weed monitoring/management and predator control would be ongoing 'maintenance and monitoring' activities.

Habitat enhancement through enrichment planting in the remainder of natural habitat and the careful removal of silt fences and accumulated material may be included in this option to improve habitat quality and connectivity.

Timeframe: The release of captive snails, and enrichment planting and silt fence removal, if included, could be completed in Year 1, bringing the recovery of Central snails into the 'maintenance and monitoring' phase from Year 2.

Costs: Costs associated with this option would be relatively low. Only $5,000 would be required for the snail release in Year 1. Costs for 'maintenance and monitoring' activities would be shared with Northern and Southern snails. Any required habitat management (e.g. erosion control) would likely completed by BT, as issues would be a direct legacy of mining.

Risks: The risk of extinction for the Central snails under this option is high, as the remaining habitat area is small and of low quality. Effective monitoring of the Central snails is impossible because of the small area, the steep terrain, and because snails are likely to mix with Northern snails from adjacent habitat to the north. Furthermore, because of this mixing, the distinct genetic make-up of the Central group is likely to be lost over time, as the much more numerous Northern snails are likely to genetically overwhelm the small population of Central snails. Loss of this diversity within *P. augusta* increases the risk to *P. augusta* as a whole.

Option B: Release after habitat enhancement

Assumptions/Approach: This option aims to increase the area and quality of available habitat before captive snails are released. However, the option still assumes that the population will persist in a relatively small area adjacent to Northern snails, without monitoring data to support this.

Actions: Enrichment planting in Site A and the careful removal of silt fences and accumulated material are key actions in this option. A small captive population would be held to provide short-term security from extinction, but captive snails would be released as soon as the habitat enhancement is complete. As in Option A, habitat and weed monitoring/management and predator control present ongoing activities.

Timeframe: Habitat enhancement and removal of silt fences could be completed within 2 years. This means the recovery of Central snails would enter the 'maintenance and monitoring' phase in Year 3.

Costs: The costs for this option would be higher than for Option A, because of the maintenance of a small captive population until Year 3 and the costs for enrichment plantings and silt fence removal. However, costs for the captive facility would be shared with the Northern and Southern snails, and, potentially, other threatened *Powelliphanta*. Enrichment planting and silt fence removal costs may, at least partly, be covered by BT, as the need for these measures is a direct legacy of mining.

Risks: The risk of extinction for the Central snails under this option is still high. The gain in habitat quality and extent from enhancement and fence removal would be minimal. As for Option A, effective monitoring would be impossible and genetic swamping by the adjacent Northern snails likely.

Option C: Full recovery

Assumptions/Approach: This option aims to establish a population of the Central snails that is likely to be large enough to persist and effectively contribute to the genetic diversity within *P. augusta* long-term.

Actions: Key activities under this option would be to maximise the extent and quality of rehabilitation in the A13/14 mining blocks and enrichment planting in the currently occupied areas. Silt fences and the accumulated material within them should be removed wherever this is feasible without causing damage to the habitat below. To provide for long-term security from extinction and a healthy founder population for new habitat areas, the captive population would be increased in size. Captive snails would be released once the rehabilitated areas are considered suitable. Habitat and weed monitoring/management and predator control would be ongoing activities as for the other options.

Timeframe: The timeframe for this option goes beyond the term of the 2021-2031 strategy. Rehabilitation in the A13/14 area could be undertaken in Year 1, as mining in the area has ceased. However, it would take at least 10 years before snails could be released into these areas.

Costs: Additional costs would arise from the maintenance of the captive population and rehabilitation in the A13/14 mining block. The latter would have to be negotiated with BT, as they have responsibility for these works. Costs for the captive facility would be shared with Southern and Northern snails, and, potentially, other threatened *Powelliphanta*.

Risks: This option has a low risk of loss for the Central snails as habitat extent and quality would be maximised, and the captive population would be large enough to populate new habitat areas. The threat of genetic swamping would be reduced, although may not be completely removed, depending on the long-term success of rehabilitation.

Recommendations – Central P. augusta

Option C should be the starting point for the future management of the Central *P. augusta*. This option poses the least risk of loss for the group and the best chance that the Central snails can effectively contribute to the genetic diversity within *P. augusta*, supporting its adaptability to the new environmental conditions.

Option C relies heavily on a strong programme lead exploring and negotiating options to maximise the extent and quality of rehabilitation, and source the necessary funding. Depending on what can be achieved, Central *P. augusta* may be restored to wider parts of their original range or the population will remain largely restricted to its current extent.

Northern P. augusta

Table 1: Options for the management of Northern P. augusta (raw table in DOC-6413237).
√ - essential action ('must'), (√) – optional action ('should or could').

	Option A - Immediate release	Option B - Deferred release	Option C - Full recovery	Estimated costs
Actions				
Release all captive snails into selected habitat in Extended Site B in Year 1	√			$5,000 once
Maintain captive population (short-term security)		√		$11,000/year for facility (shared with Central and Southern snails) + $4,000/year for husbandry
Release captive snails into selected habitats once monitoring confirms viability of existing population		√		$5,000 once
Prevent further erosion at NASA	√	√		to be confirmed (paid by BT?)
Rehabilitate mine area adjacent to NASA	(√)	(√)	√	to be confirmed (paid by BT?)
Remove silt fences	(√)	(√)	√	to be confirmed (paid by BT?)
Grow captive population to provide for long-term security			√	$11,000/year for facility (shared with Central and Southern snails) + $21,000/year increasing to $30,000/year for husbandry
Release surplus captive eggs and hatchlings into existing wild populations		√	√	$3,000 per release (shared with Southern and Central snails)
Monitor long-term trends in existing wild populations	√ if existing populations not viable, emergency recovery and move to Option C	√ if existing populations not viable, move to Option C	√	$15,000 per site and measurement, total $90,000 x 2 during 2021-2031
Habitat monitoring and management	√	√	√	$1,000/year (shared with Southern and Central snails) + management costs (to be confirmed, paid by BT?)
Weed detection and control	√	√	√	$4,000/year (shared with Southern and Central snails; paid by BT?)
Predator control	√	√	√	ground control $8,000/year, aerial $18,000/operation (shared with Northern and Central snails; paid by BT?)
Release and monitor snails in rehabilitation areas within original range once considered suitable (post-2031)			√	to be determined (post-2031)
Transfer snails from Mt Rochfort sites to Extended Site B	(√)	(√)		$3,000 /search
Transfer snails from Mt Rochfort sites to captive population			(√)	$3,000 /search
Timeframe (years to 'maintenance and monitoring' phase)	2	5-10	10+	
Total costs over 10 years, 2021-2031 (maximum estimates and 'musts' only)	$246,000 (+ NASA stabilisation and habitat management; paid by BT?)	$289,000 - $332,000 (depending on timing of release; + NASA stabilisation and habitat management; paid by BT?)	$537,000 (+ NASA and other rehabiliation, removal of silt fences and habitat management; paid by BT?)	
Assumptions/Approach	assumes at least one existing wild populations is viable	precautionary - confirm viability of existing wild population before release	most precautionary - strives to achieve long-term recovery	
Risk of extinction	high	low	lowest	

The Northern *P. augusta* are currently the most numerous group in the wild. However, translocations have created a severely fragmented population, with the Mt Rochfort sites being the most extreme outliers. Monitoring results to date are inconclusive on whether any of the isolated sub-populations are viable. The area of natural habitat of Northern *P. augusta* has been greatly reduced to a narrow, long strip along the escarpment. The shape of this remaining natural habitat is not conducive to the maintenance of a viable population. The highest quality patch of habitat within this area, the NASA area, is threatened by ongoing erosion towards the mining area (Figure 7 and Figure 8).

Figure 7. The steep, eroding eastern side of NASA after coal extraction. The slope was left over-steepened, leading to erosion of the best remaining natural habitat of P. augusta on the adjacent DOC land to the west.

Figure 8. The eastern slopes of NASA about 2015. Instead of being densely planted in native shrubland species which might have created snail habitat, the area was sprayed with exotic grass seed. Ideally this slope would be backfilled, re-contoured and revegetated with appropriate native species to stop erosion and provide additional snail habitat (Option C).

We have identified three options for the management of the Northern *P. augusta* (Table 3). All three options include the need for ongoing mark-recapture monitoring in the existing wild populations in Site A and Extended Site B. This is done at c. 5-yearly intervals to understand population status and trends. This monitoring costs around $15,000 per site per measurement, i.e. $90,000 every 5 years for the current six long-term monitoring sites.

Option A: Immediate release to Extended Site B

Assumptions/Approach: This option assumes that at least one of the existing sub-populations of the Northern snails in Site A or Extended Site B is viable long-term, despite the current monitoring results being inconclusive.

Actions: All captive Northern snails would be released into selected habitat patches within Extended Site B (outside of the mark-recapture plots), maintaining their original grouping by geographic provenance as much as possible. As the NASA area is the site where population persistence is most likely, intervention is required to prevent further erosion of this high-quality habitat (Figure 7 and Figure 8). As a minimum this would be achieved with establishment of native shrubs capable of stabilising the current steep slope, but a solution that would reduce the gradient would be preferable. Removal of silt fences, where possible, could also be included to increase habitat connectivity (Figure 11).

Timeframe: The release of captive snails could be undertaken in Year 1. The eroding face of the NASA area could probably be stabilised within 2 years. After this, the programme would move into the 'maintenance and monitoring' phase with habitat and monitoring/management, predator control and 5-yearly mark-recapture monitoring.

Costs: Costs for this option are relatively low. Around $5,000 would be required for snail releases in Year 1. The costs of stabilising and planting the NASA area need to be determined in discussion with BT, and may be covered by them, as the current erosion problem is a direct legacy of mining. The costs for 'maintenance and monitoring' activities including the 5-yearly mark-recapture monitoring amount to $241,000 over 10 years, with the mark-recapture monitoring being the largest cost item.

Risks: The risk of extinction for the Northern *P. augusta* would be relatively high. The current mark-recapture results are inconclusive regarding the viability of the existing wild populations. The small, relatively linear and fragmented layout of Sites A and Extended B are not conducive to sustaining a population long-term. Releasing all captive Northern snails into existing populations without increasing habitat area risks reducing the survival of both, released and resident snails, as the carrying capacity of the existing sites is unknown. Should the ongoing population monitoring show serious decline, an emergency recovery of snails would unlikely recover a sufficient number of snails to ensure long-term persistence. The option carries a relatively high reputational risk for DOC.

Option B: Deferred release with short-term captive security

Assumptions/Approach: This option takes a more precautionary approach by seeking to confirm the viability of the existing wild populations first, before all captive Northern snails are released.

Actions: A small captive population providing short-term security from extinction would be maintained until monitoring provides clearer results on population trends in the wild. Work to prevent further erosion at the NASA site would occur as in Option A, preferably including the rehabilitation of this area. The removal of silt fences may also be included. When at least one wild population is confirmed to be viable, the remaining captive snails would be released to the most appropriate sites. If the monitoring results suggest that none of the populations is viable, management would move to Option C.

Timeframe: It is expected that monitoring results would provide clearer results during the term of this strategy, either in Year 5 or Year 10. More frequent monitoring could be considered to shorten the timeframe.

Costs: The costs for this option would be higher than for Option A because of the maintenance of a small captive population until at least 2026. However, costs for the captive facility would be shared with the Southern and Central *P. augusta*, and potentially other threatened *Powelliphanta* snails.

Risks: The risk of extinction for the Northern subspecies would be low with this option, as it provides security in captivity until population viability in the wild is confirmed. Option B presents a continuation of the current approach, except that the size of the captive population would be reduced to provide only short-term security.

Option C: Full recovery

Assumptions/Approach: This is the most precautionary option. It aims to connect the remnant of original habitat west of the ridgeline (Site A) to re-created snail habitat in the east, including the lower flanks of NASA, to provide a large, rounded and connected habitat area more conducive to long-term persistence of the snail population than the current narrow, linear and fragmented habitat area.

Actions: Under this option, the exposed eastern side of the NASA area would not only be stabilised but an attempt would be made to re-create snail habitat. Ideally, the area would be backfilled, re-contoured and then planted at high-density with appropriate native species (Figure 9). High-quality revegetation would also occur on the north-eastern slopes of NASA (Figure 10) previously sprayed with biosolids, to join Site A to the A10 VDT. The careful removal of silt fences and accumulated material within them, wherever this is feasible without causing damage to the habitat below, would also be included (Figure 12).

To provide security from extinction and a healthy founder population for rehabilitated habitat areas, the captive population would be grown. Once rehabilitated areas are considered suitable, snails would be released.

Timeframe: The timeframe for this option goes beyond the term of the 2021-2031 strategy. While rehabilitation works could be completed within the first 2-3 years, it would take at least 10 years before snails could be released into these areas.

Costs: Additional costs for this option would mainly arise from the maintenance of a larger captive population and rehabilitation works around the NASA area. Costs for the latter need to be determined in discussion with BT, and may be covered by them, as the need for these works is a direct legacy of mining.

Risk: This option has the lowest risk of extinction for the Northern snails, as habitat extent and quality would be maximised. If rehabilitation is successful, the improved size and shape of the habitat area around NASA would substantially increase the probability of persistence for *P. augusta*. It is important to note that, even if successful in the medium-term, there is a risk that the rehabilitation areas will not support *P. augusta* in the long-term. Increased drainage and fertility on the recontoured surfaces may eventually lead to the establishment of forest, which is not thought to present good *P. augusta* habitat. However, even if this occurs, high-quality rehabilitation and habitat enhancement still provide the best chance for a viable population to persist, as the area of suitable habitat would be maximised and forest areas would provide a buffer towards entirely unsuitable areas.

Figure 9. The eastern slopes of NASA in 2005, just before the area was mined, with a dense shrubland of snow tussock, mountain flax and inaka. These species prefer more well-drained and fertile sites, and if carefully planted at high density could stabilise and rehabilitate the currently bare and eroding eastern slopes of NASA.

Figure 10. Former snail habitat on the northern foot-slopes of NASA which have been sprayed with exotic grasses and biosolids. Under Option C, this area would be revegetated with native species to provide additional snail habitat. Extended Site B is visible in the background.

Figure 11. Silt and coal fines held by a decaying silt fence above Site A. This material needs to be dug out by hand and fences carefully removed to avoid run-off into the snail habitat below. Recovered material might have to be helicoptered out to prevent further impacts to vulnerable snail habitat.

Management of subpopulations at Mt Rochfort

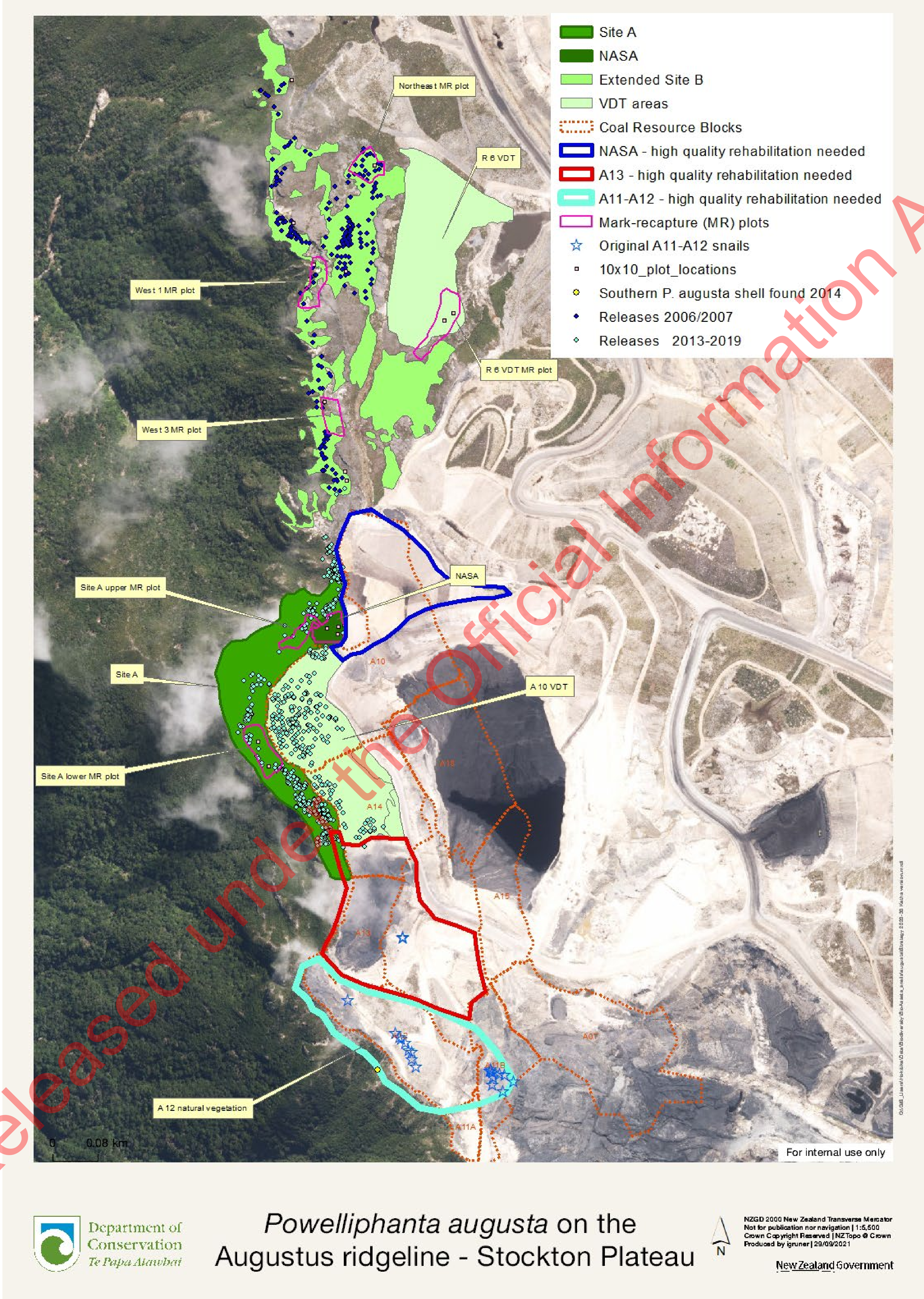
The Mt Rochfort sites are no longer considered part of the recovery for the Northern subspecies. If a translocated population persists at Mt Rochfort, it will be on a different evolutionary trajectory from the populations on the Augustus ridgeline, because of the different environmental conditions and the potential hybridisation with *P. patrickensis*. This will eventually result in a distinct taxonomic unit, i.e. the Mt Rochfort population will not actually preserve the Northern subspecies of *P. augusta*, but a novel genetic lineage. Because of this, it would be preferable to reverse the translocation, or at least minimise its impact by removing as many *P. augusta* as possible from these sites. It is unlikely that all *P. augusta* would be recovered, i.e. a residual impact would remain. In Options A and B, recovered snails could be added to the wild populations in Extended Site B or A10 VDT. In Option C, the recovered snails could play a role in increasing the genetic diversity of the captive population. For all options, genetic testing of the recovered snails would be essential to ensure no *P. patrickensis* are accidentally transferred. Other management activities at the Mt Rochfort sites, e.g. monitoring and threats management, can be discontinued.

Recommendations – Northern P. augusta

Option C should be the starting point for the future management of the Northern *P. augusta*. It is the only option that aims for full recovery and thus, represents conservation best practice. It relies heavily on a strong programme lead exploring and negotiating options to maximise the extent and quality of rehabilitation in mining areas adjacent to Site A, especially adjacent to NASA, and sourcing the necessary funding.

Appendix

P. augusta recovery strategy 2021-2031. Options and risk assessment – Overview map



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