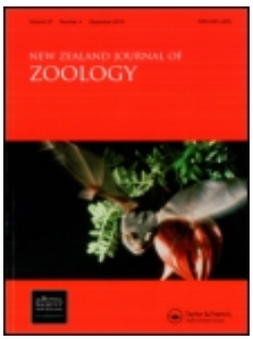

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Status, conservation, and management of the land snails of the genus *Powelliphanta* (Mollusca: Pulmonata)

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Abstract The distribution and the condition of the habitat of each of the land snails in the genus *Powelliphanta* are presented and the predation on each is reported. Distribution was assessed from field surveys and the literature, habitat from the condition of the vegetation, and predation from collections of empty shells showing diagnostic patterns of damage by rats, pigs, wekas, either kakas or keas or both, and either European blackbirds or song thrushes or both. The current status of each member of the genus is thereby assessed, and all are ranked in order of conservation priority.

All members of the genus have suffered to some extent from habitat loss, habitat modification by browsing ungulates, and predation by introduced predators since European settlement of New Zealand. A few members of the genus are close to extinction. Management recommendations are made for all vulnerable members of the genus.

Keywords Mollusca; Pulmonata; *Powelliphanta*; status; conservation; predators; forest modification; habitat destruction; New Zealand; land snail

CONTENTS

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INTRODUCTION

New Zealand has 3 genera of large, conspicuous land snails. The members of 2 genera (*Powelliphanta* and *Paryphanta*), are carnivorous; all are commonly called "Paryphantas"; the third genus, *Placostylus*, contains the vegetarian 'flax snails'. The numbers of species and distribution of all 3 genera have diminished since the arrival of European man in New Zealand. This paper considers the present status of *Powelliphanta*, the genus which includes the largest and most conspicuously marked of New Zealand's land snails.

The genus *Powelliphanta* was, until recently, considered to be a subgenus of *Paryphanta*, but Climo (1976) considered it different enough to warrant full generic status and he placed *Powelliphanta* and *Paryphanta* in the family Rhytididae (previously Paryphantidae). The family has an extensive range, from South Africa to New Guinea, some of the high islands of the south-western Pacific, Australia, and New Zealand (Powell 1979). *Powelliphanta* is, however, endemic to New Zealand. Most local forms are found in the southern North Island and the northern South Island but the genus ranges from Mt Egmont and Lake Waikaremoana in the north to Resolution Island, Lake Monowai, and the Mataura Range in the south.

Dell (1955) lists subfossil *Powelliphanta* from Ruakokopatuna, lower Wairarapa; Patoka and Waewaepa, Hawkes Bay; upper Waitotara River, Taranaki; Te Kuiti; Mangaroa Valley, Wellington; and Punipaua, western Nelson.

Powelliphanta has radiated into a variety of habitats, from lowland forest to alpine grassland, and this — with geographical isolation — has led to the evolution of many different forms. Powell (1979) assigned these to 10 species, including 34 subspecies and 4 forms. Climo (1978) recognised 2 species and 5 subspecies, while Parkinson (1979) recognised 5 or 6 species and 28 or 29 subspecies. The systematics and nomenclature of *Powelliphanta* are still controversial.

We follow Powell's (1979) classification of *Powelliphanta*, as it provides a finely divided nomenclature of local and geographical isolates, but we do not imply support or otherwise for any one classification.

Little is known of the biology of *Powelliphanta*. According to Powell (1947) there are at least 15 years between generations. Five specimens of *P. hochstetteri obscura* held in captivity by MJM (collected as "adult" in 1977) were measured and marked with a scratch at the beginning of summer (December) in 3 successive years. The length of the peripheral whorl increased by an average of 5 mm per year, which, expressed as an increase in shell diameter, is about 30% (1.5 mm) of the peripheral growth. The annual growth rings (Fig. 2d) show more clearly than do the intermediate rings on these shells, and similar growth rings are impressed in many shells of all the larger species of *Powelliphanta*. From ring counts, or the increase in shell diameter from hatching (10 mm) to the larger shells of the species (60–70 mm), it seems that individuals live 40 years or more.

Powelliphanta are cross-fertilising hermaphrodites. They lay their relatively large eggs (*P. h. hochstetteri*, 12×10 mm; *P. g. gilliesi*, 9×8 mm; *P. s. superba*, 14×12 mm) in leaf litter in late October, November, and December (O'Connor 1945).

Powelliphanta usually live in the deep, moist, non-acidic leaf mould that accumulates under some types of forest and scrub. As in most land snails, *Powelliphanta* have no operculum, nor can they conserve moisture by sealing the shell with an epiphragm. Because they are prone to dehydration and cannot survive in dry conditions, they are most active at night and in wet weather, and are more common in moist high-altitude forest than in drier forests at lower altitudes.

Their staple food is earthworms, but they also eat slugs, other snails (Powell 1979), and millipedes (K. Brown, in litt.).

The influence of calcium on land snails has long been recognised (e.g., Pfeiffer 1861) and most *Powelliphanta* are closely associated with calcium-rich soils.

As early as 1930, Powell (1930) noted that snails were eaten by wekas (*Gallirallus australis*), rats (*Rattus* spp.) and thrushes (*Turdus philomelos*), and that their forest habitat was deteriorating because of browsing by deer (*Cervus* spp.). He also noted that snails did not fare well where the forest was cleared. Later he wrote (Powell 1946) that *P. gilliesi aurea* and *P. g. brunnea* were restricted to small areas and that their survival was uncertain; he noted that the chances of survival of the Tararua form of *P. traversi traversi* at its type locality, and of *P. t. otakia* were slender. He also noted that *P. t. traversi* at Waiopehu Reserve had been almost exterminated by hedgehogs (*Erinaceus europaeus*), rats, and collectors, and that 3 specimens of the Koputaroa form of *P. t. traversi* collected in 1945 were probably the last of the colony.

We believe that many populations of *Powelliphanta* are still declining, though fortunately each subspecies and form that Powell (1946) expressed concern for still survives in at least 1 colony. Two other important predators of snails have been recognised: feral pigs (*Sus scrofa*) and large parrots — kakas (*Nestor meridionalis*) or keas (*N. notabilis*), or both.

With this background, Meads & Moller (1978) studied the population of *P. hochstetteri obscura* on Maud Island in the Marlborough Sounds, and

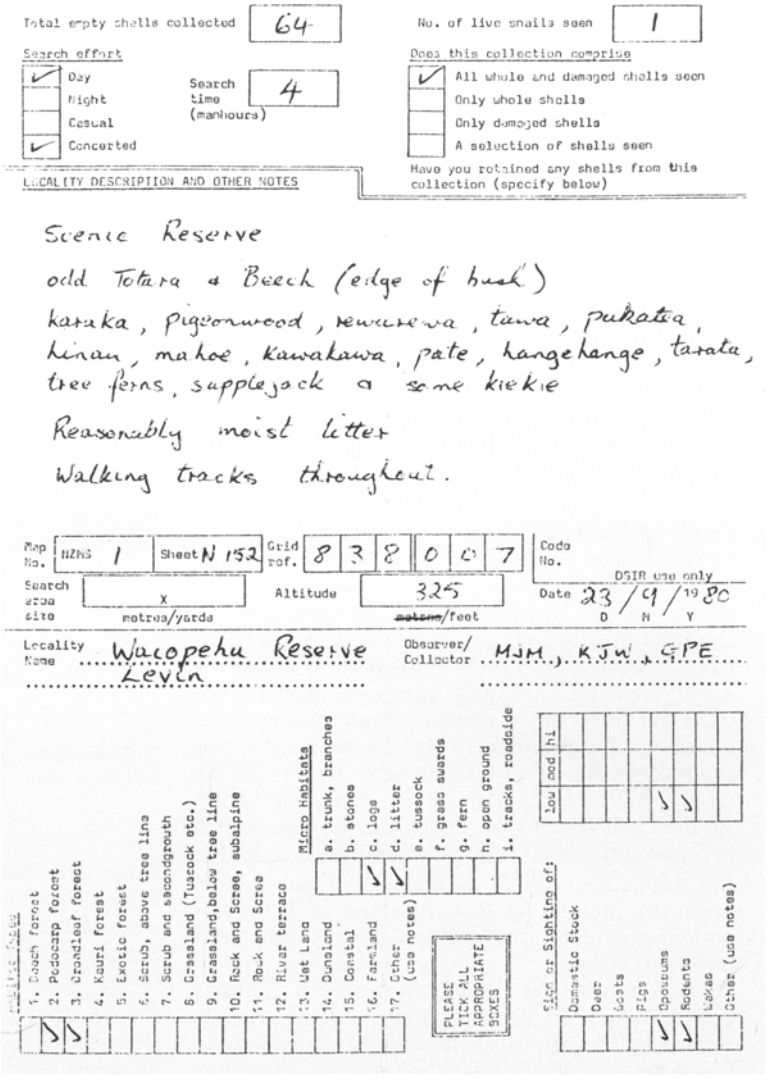


Fig. 1 The standard form used to record details of each collection.

Buckingham & Elliott (1979) studied the same subspecies on D'Urville Island. The apparently precarious state of both these populations, especially that on Maud Island, prompted this paper.

Our aims were to assess the status of all forms of *Powelliphanta*, to determine causes for declines in range and population density, and to suggest how to manage declining populations.

METHODS

Between December 1978 and April 1981 we visited at least 1 population of most of the subspecies of *Powelliphanta*. At each place, we recorded the vegetation and the presence of browsing ungulates and possible predators on standard forms (Fig. 1), and collected empty shells. At some places we also made more extensive surveys to determine the range of the snail population. Collections of shells were examined later to determine the causes of death.

Additional information was gathered from distribution records in the literature, and from the New Zealand Wildlife Service, the National Museum of New Zealand, and private collectors.

Collection

At each locality, after a quick, extensive search to confirm the presence of a *Powelliphanta* colony, (1

shell was sufficient), we searched the litter carefully while walking for a timed period, and collected every shell or shell fragment found. We occasionally found live snails on top of the litter, especially in wet weather, but usually they were hidden under litter, logs, or stones. Live snails were measured as for empty shells, weighed, and released. The average rate was 50 shells (man h)$^{-1}$.

Analysis

In the laboratory, each shell was washed in warm soapy water and dried at room temperature. Three measurements were taken from shells which were sufficiently intact (Fig. 2).

Any damage was then recorded, using the categories: undamaged, indeterminate, or damaged by wekas, parrots, pigs, rats, song thrush or European blackbird, or trampled by ungulates. The criteria for allocating a shell to a given category were:

Undamaged. Shells which have merely decayed are fairly easy to recognise. The apex and the peristome (mouth edge) are the weakest points in the shell and usually collapse first. *Powelliphanta* shells have 2 distinct layers: the thick inner ostracum is mostly calcium carbonate and some protein; the outer periostracum, a proteinaceous coating, gives a smooth glossy finish to the ostracum. When a snail dies, the periostracum soon wears off the empty shell, which then appears matt and faded. As the chalky ostracum flakes off, the whole shell becomes softer and can look 'crumpled' as it decays.

Indeterminate. When natural decay had broken down the shell so far that the cause of death was no longer evident, or if the damage was difficult to interpret.

Damaged by wekas. Shells from which the apex and the smallest internal spiral has been cleanly removed (Fig. 3d). All shells with this damage were found in areas where wekas are present. According to Powell (1930), "The weka always attacks the top of the shells, pecking out the spire and early whorls". We found that wekas also attack the base of a shell, making a hole through the centre where the concave underside stops the weka's beak from glancing off. In our collections, it is usually the smaller, high-spired forms such as *P. gilliesi subfusca* which show this form of damage.

Damaged by parrots. Shells with a hole — usually 15–30 mm across — gouged through the outer whorl nearest the aperture and through all the successively decreasing inner whorls. On some of the larger, thicker shells there were pairs of vertical scratches around the side of the shell, presumably where several attempts were made to penetrate the shell. The chisel action of the bird's lower mandible is clearly impressed in some shells (Fig. 3d).

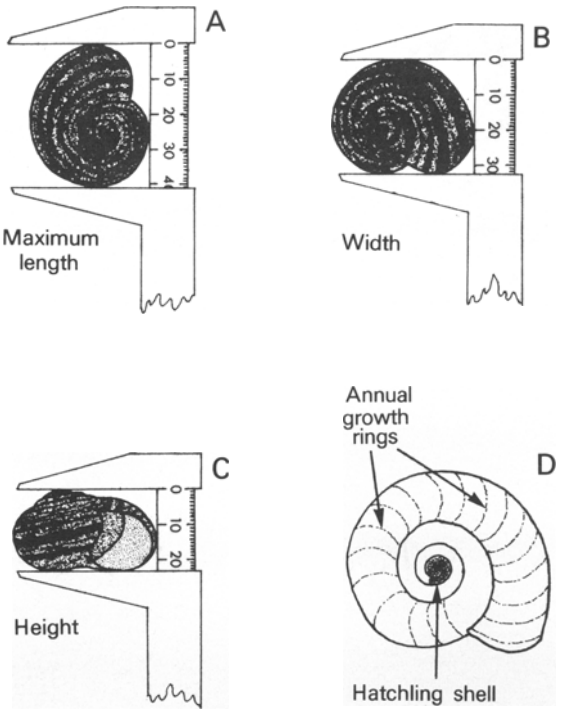


Fig. 2 A–C, Measurements taken of *Powelliphanta* shells; D, *Powelliphanta* shell showing annual growth rings and hatchling shell.

Shells damaged in this way were found only where kakas or keas are known to be present; in the northwestern Ruahines, and in parts of the Marlborough Sounds there are only kakas, but both are present in the Nelson region.

Damaged by pigs. Shells which were split around the periphery and flattened were classed as pig damaged because this damage has only been observed where feral pigs are present. The damage is very obvious, as the flattened halves of the shells often buckle and become convex in the sun. Teeth marks are often impressed as shatter points on the chalky inner surface (Fig. 3b). Pigs also take small snails and eggs whole, leaving only fragments of shell in their faeces.

Damaged by rats. This category included those shells which had holes in the side, or the top half of the shell removed, and with all of the cut edges being finely serrated. Marks made by incisor teeth were clearly visible on rat-gnawed shells, except on small shells (which are thin and brittle because the ostracum has not yet been laid down), and on specimens of the thin-shelled *rossiana*. The 3 species of rat in New Zealand have different average widths across the incisors (measured across the upper pair)

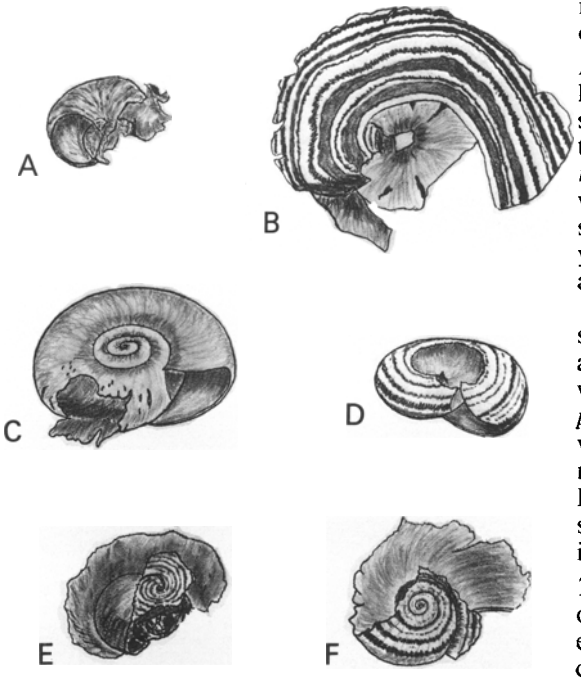


Fig. 3 Typical patterns of damage to *Powelliphanta* shells caused by 'natural' and introduced predators: A, damaged by blackbird or thrush; B, crushed by pig; C, damaged by kaka or kea; D, pecked by weka; E,F, gnawed by rat.

— *Rattus norvegicus*, 2.83 mm; *R. rattus*, 2.27 mm; and *R. exulans* 1.83 mm (B. W. Thomas pers. comm.). Although there is considerable overlap of measurements for the 3 species (and young rats also take snails), measurement of the incisor marks on a snail shell can indicate the species probably responsible for killing the snail.

The method of attack can also indicate the rat involved, but this is not conclusive, as all species can damage shells in other than the characteristic manner. Ship rats (*R. rattus*) usually gnaw through the side of the shell and inner whorls. Norway rats (*R. norvegicus)* normally begin at the lip and gnaw round all the shell spirals, leaving the shell shaped like a corkscrew (Fig. 3e); they attack snails of all sizes. Kiore (*R. exulans*) attack smaller snails (< 40 mm in diameter), usually gnawing around the aperture. Kiore is the only rat present in the habitat of *P. h. obscura* on D'Urville Island.

Some snails had recovered from rat attack. In these, the lip of the aperture had been gnawed, but the rat had not gained access to the snail and new shell had grown from under the gnawed edge.

Rats sometimes cache snails. In areas where Norway rats are present (e.g., Horowhenua Plains), it was not uncommon to find large accumulations of shells in burrow chambers.

Damaged by song thrush or blackbird. Shatter holes, usually through the outer whorl on the opposite side to the aperture were attributed to song thrushes (*Turdus philomelos*) or blackbirds (*T. merula*). The hole often extended through the inner whorls to the centre, and the shattered edges of the shell curled outwards when dry (Fig. 3a). Only young or small snails, whose shells are light, thin, and easily broken, were damaged in this way.

The thrush's habit of using anvils for smashing snails is widely known (e.g., Oliver 1930, Falla et al. 1970). Although blackbirds do not use anvils, we have observed them carrying small *Powelliphanta* to a previously-used open area in the forest, where the birds used their bills to alternately hammer and prise until the snail could be removed. Despite the different methods of extracting snails, shells damaged by thrushes and blackbirds are indistinguishable.

Trampled by ungulates. Occasionally, hoof-marks of wild ungulates or stock were impressed clearly enough on shells to identify this as the cause of death.

RESULTS

Results from all the collections are summarised in Tables 1–6. In the following, the forms are treated geographically, from north to south. Scientific names of plants are given in Appendix 1, and abbreviations for collectors and repositories of collections are given in Appendix 2.

Powelliphanta marchanti

P. marchanti is probably the most widely distributed form of *Powelliphanta.* It is found from the upper reaches of the Pohangina Valley to the Otupae Range in the Ruahine Ranges, with most records from near the Reporoa Bog; north of the Ruahines it has been reported from the Kaimanawa Range, the Maungaharuru Range, from near Lake Waikaremoana, and in the Urewera National Park. It is also recorded from Mt Egmont (Fig. 4).

P. marchanti is found only above about 900 m, in tussock grassland, scrubland, or high-altitude forest (often in stands dominated by mountain cedar). The only collections of *P. marchanti* we have seen came from near Reporoa Bog in the summer of 1976–77 (1)*. Of 103 determinable shells, 55%

*see Appendix 2.

Table 1 Summary of collections of *Powelliphanta marchanti* and *Powelliphanta traversi* (–, not recorded).

			Shells		Cause of damage						
Taxon	Locality	Date	No. examined	No. damaged	Pig	Rat	Weka	Kaka/ kea	Thrush/ blackbird	Trampling/ other	Collection rate (shells h^{-1})
P. marchanti	NW Ruahine Range	1977	103	55				17	36	2 stoat	–
P. t. traversi	Lake Papaitonga	1979/80	157	108		108					19
fa. 'koputaroa'	Koputaroa	1979	43	32		29			2	1	6
fa. 'florida'	Florida Road Reserve	1980	69	27		24			3		26
fa. 'latizona'	Greenaways Bush	1979	55	18		9			9		35
fa. 'tararuaensis'	Kaihinu	1973	20	15		15					–
	Kaihinu	1980	37	4						4	12
P. t. otakia	Rahui Road	1979	54	53		53					11

Table 2 Summary of collections of *Powelliphanta gilliesi* (–, not recorded).

			Shells		Cause of damage						
Taxon	Locality	Date	No. examined	No. damaged	Pig	Rat	Weka	Kaka/ kea	Thrush/ blackbird	Trampling	Collection rate (shells h^{-1})
P. g. gilliesi	Mt Burnett	1972	62	7	3	4					–
	Mt Burnett	1979/80	97	56	39	8	8			1	33
P. g. subfusca	Kaihoka	1979/80	222	66		37	22		7		66
P. g. kahurangica	Kahurangi Point	1980	98	72	56	14			2		75
P. g. brunnea	Paturau	1979/80	171	111		96				15	38
P. g. aurea	Mangarakau	1979	64	35	23	12					30
P. g. fallax	Onekaka, Parapara	1975/76	66	54		30	24				–
	Onekaka, Parapara	1979/80	38	27		27					9
	Parapara Peak	1979	30	14			14				–
P. g. compta	"The Castles"	1979/80	94	86		70	8	8			49*
P. g. montana	Bock Peak	1979	335	298			13	285			34
P. g. jamesoni	Slate Range	1980	68	46		7		39			

*Rat cache.

Table 3 Summary of collections of *Powelliphanta annectens* and *Powelliphanta superba* (–, not recorded).

			Shells		Cause of damage						
Taxon	Locality	Date	No. examined	No. damaged	Pig	Rat	Weka	Kaka/ kea	Thrush/ blackbird	Trampling	Collection rate (shells h^{-1})
P. annectens	Oparara	1974	59	54		5	6	41	2		–
	Gunner Downs/ Oparara	1982	401	267		46	1	169	51		39
P. s. superba	Cedar Creek	1978	36	36		3		33			–
	Bock Peak	1979	358	334		1	39	295			30
	Bock Peak	1981	63	56				56			31
P. s. prouseorum	Kahurangi	1964	35	1				1			–
	Kahurangi	1980	80	59				59			–
P. s. richardsoni	Gouland Range	1972	26	22				22			–
	Gouland Range	1980	48	45				27	18		–
P. s. harveyi	MacKay Hut	1980	134	90		1	11	78			159
P. s. mouatae	Saxon River	1980	93	57		1	2	15	39		86

Table 4 Summary of collections of *Powelliphanta hochstetteri* (–, not recorded).

			Shells		Cause of damage						
Taxon	Locality	Date	No. examined	No. damaged	Pig	Rat	Weka	Kaka/ kea	Thrush/ blackbird	Trampling	Collection rate (shells h^{-1})
P. h. hochstetteri	Takaka Hill	1972	78	35		17	18				–
	Takaka Hill, Canaan, Cobb	1979/80	325	172	54	18	100				48
P. h. anatokiensis	Anatoki Forks	1979/81	149	96		6	22	68			54
P. h. obscura	Maud I.	1976/77	25	12			6			6	1
	D'Urville I.	1978/80	178	144	50	7	69	18			12
	Mt Shewell	1979	63	56	35		16			5	36
	Tennyson Inlet	1980	422	371		4	6	361			82
P. h. bicolor	Blumine I.	1981	424	106			93	7	6		164
	Arapawa I.	1979	76	71	68	3					4
	Mt Stokes	1979	127	111	84		27				22
P. h. consobrina	Richmond Range	1979	188	145	36	2	81	26			18
	Bryant Range	1979/80	148	141	51	48	14	28			37

Table 5 Summary of collections of *Powelliphanta lignaria* (–, not recorded).

			Shells		Cause of damage						
Taxon	Locality	Date	No. examined	No. damaged	Pig	Rat	Weka	Kaka/ kea	Thrush/ blackbird	Trampling	Collection rate (shells h^{-1})
P. l. lignaria	Gentle Annie Point	1972	19	1			1				–
	Gentle Annie Point	1979	59	14		11	3				24
P. l. lusca	Glasseye Creek	1972	50	35		10	23	2			–
	Glasseye Creek	1979	133	46		37	1		8		62
P. l. unicolorata	Mohikinui River	1971	42	8		1	6		1		–
		1979	253	138		118	1		32		26
P. l. johnstoni	Ngakawau River	1977	54	9			8		1		–
	Ngakawau River	1979	85	16		5	8		3		180
	Charming Creek	1981	108	20			11	9			612
P. l. rotella	St Andrews Stream	1981	79	74		1	4	69			–
P. l. oconnori	Slippery Creek	1973	71	43		37	6				–
	Virgin Creek	1973	34	29		27	2				–
	Slippery Creek	1980	34	31		1	1		29		39
	Lower Crow River	1981	55	21		14		4	3		89

Table 6 Summary of collections of *Powelliphanta rossiana*, *Powelliphanta spedeni*, and *Powelliphanta fiordlandica* (–, not recorded).

			Shells		Cause of damage						
Taxon	Locality	Date	No. examined	No. damaged	Pig	Rat	Weka	Kaka/ kea	Thrush/ blackbird	Trampling	Collection rate (shells h^{-1})
P. r. rossiana	Ross	1967/73	108	97		97					–
	Mt Bonar, Harihari	1980	27	23		23					27
	South Westland	1968/73	126	7					7		–
P. r. patrickensis	Denniston Plateau	1972	125	113		113					–
P. r. gagei	Brunner Range	1976	26	3					2	1	–
P. r. fletcheri	Mt Tuhua	1969	18							1	–
P. s. spedeni	Mataura Range	No collections									
P. s. lateumbilicata	Mt Hindley	1968	23								–
P. fiordlandica	Resolution I.	No collections									

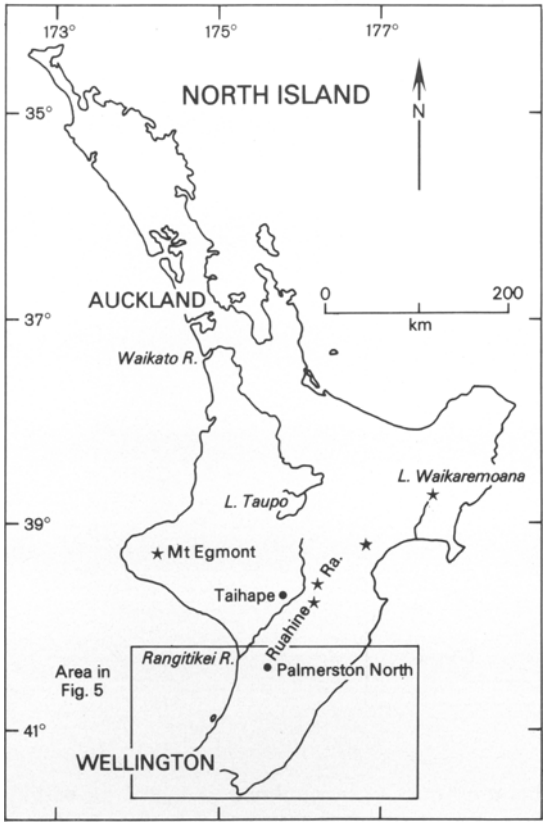


Fig. 4 Distribution of *Powelliphanta marchanti*, ★.

had been killed by predators; 35% by birds (probably thrushes or blackbirds), 2% by stoats (see 'Discussion'), and 17% probably by kakas. In the northwestern Ruahines, *P. marchanti* appears to be suffering moderate predation. Outside the Ruahines, however, records are few and scattered, and the state of the populations is unknown.

Powelliphanta traversi

Powelliphanta traversi, with 5 forms ('traversi', 'florida', 'koputaroa', 'latizona', and 'tararuaensis') of the nominate subspecies, and the subspecies *P. t. otakia*, is confined to small remnants of forest on the Horowhenua coastal plains and the foothills of the Tararua Ranges (Fig. 5). Up to 1965 it was known from 22 isolated localities, but is now confined to fewer than half of these. Because of their precarious situations, each form will be discussed separately.

P. traversi traversi The nominate subspecies is now confined to several small forest remnants near Levin. Vegetation of these remnants is dominated by tawa, pukatea, titoki, karaka, kahikatea, and rewarewa. Ground cover is sparse, with ferns and patches of *Tradescantia*. The remnants are fenced from stock, but suffer from heavy public use. Collectors have amassed large collections of snails from these areas over the past 50 years and many hundreds of live snails were moved elsewhere (Powell 1946, 1947).

During 1979/80, we collected 157 determinable shells, of which 69% had been damaged by rats, from these forest remnants. We found several accumulations of up to 40 shells in rat burrows. The average collection rate of 19 shells h^{-1} (as against the overall mean of 50 shells h^{-1}) indicates the low density of these populations.

P. t. traversi fa. 'koputaroa' This form once occupied the northern part of the Horowhenua coastal plain, from just north of Levin to the Manawatu River (Powell 1979). At the time of our survey, only 2 small colonies were found at Koputaroa, about 1 km apart, in a 5 ha remnant of secondary broadleaf forest of tawa and mahoe fringed by pines, and on a swampy flat (0.5 ha) dominated by raupo, a few regenerating kahikateas, and *Gahnia*. In November 1979 we collected 43 shells, of which 74% were damaged, mainly by rats (67%) (Table 1). The small size and poor condition of these 2 habitats, the large amount of rat damage to shells, and low collection rate (6 shells h^{-1}) give this population high priority for conservation (Table 7).

P. t. traversi fa. 'florida' This darker form of the typical subspecies is restricted to a few forest remnants near Levin: Kimberley Scenic Reserve, Florida Road Reserve, and the western end of Lake Papaitonga. In 1980 at the Kimberley Scenic Reserve we collected 69 shells of which 27 (39%) had been preyed on, mainly by rats (35%) but also by thrushes or blackbirds (4%). The collection rate of 26 shells h^{-1} is below average, but is relatively good compared with others in the *P. traversi* series on the Horowhenua Plains.

P. t. traversi fa. 'latizona' This form was described from Greenaways Bush in 1949; the colony still exists, despite fears of its extinction and attempts by Powell to move specimens to 2 other localities. Greenaways Bush is a forest remnant surrounded by pasture and pines on the Arapaepae Range, east of Levin (Fig. 5). It comprises mainly tawa, kamahi, putaputaweta, and rangiora. The tree fern *Dicksonia squarrosa* dominates the margins and subcanopy. The deep moist litter layer under the decaying fern fronds provides good habitat for *Powelliphanta* and many live snails were found.

In 1979 we collected 55 determinable shells, of which 33% were damaged (16% by rats, 16% by thrushes or blackbirds). Eighteen live snails were

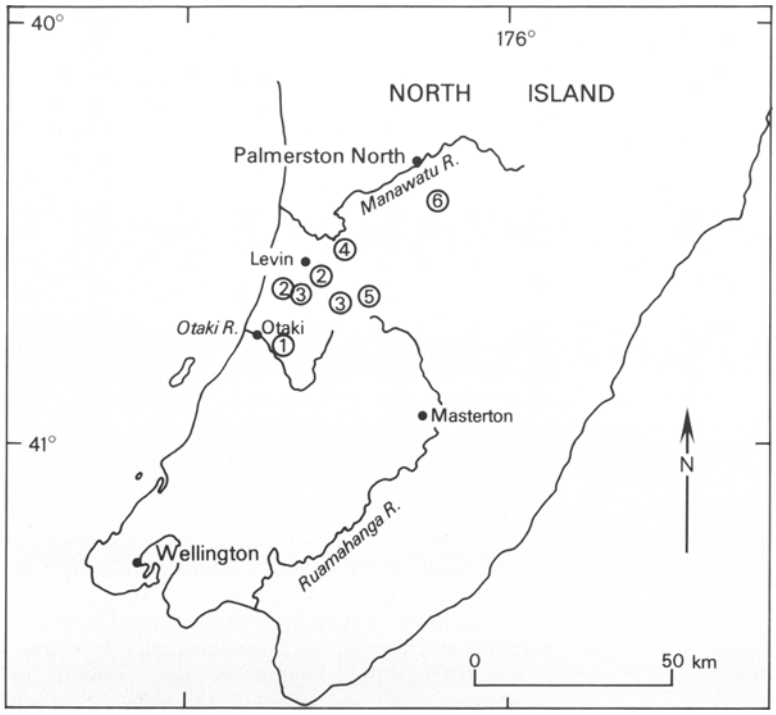


Fig. 5 Distribution of *Powelliphanta traversi*:(1) *P. t. otakia*; (2) *P. t. traversi*; (3) *P. t. traversi* fa. 'florida'; (4) *P. t. traversi* fa. 'koputaroa'; (5) *P. t. traversi* fa. 'latizona'; (6) *P. t. traversi* fa. 'tararuaensis'.

also found and these, together with the low damage rate, gives *latizona* low conservation priority compared to others of the *P. traversi* series. However as this form is confined to a small remnant of forest, formal protection of the habitat is required.

P. t. traversi fa. 'tararuaensis' This form is found only in the northern Tararua Range (Fig. 5) near Kaihinu (the type locality). Much of its podocarp/broadleaf forest habitat has been cut over. The fringes of the forest have been burned recently before planting the surrounding pasture in pine trees. Pigs are present, and stock has access to the bush.

The only complete collection was made in 1980, at 500–600 m on Kaihinu. We collected 53 shells in 4.5 h — a slow rate of 12 h^{-1}. Of the 37 determinable shells, 89% were whole, and 11% trampled by stock. Three incomplete collections made in 1973 in forest remnants in the same area indicated significant rat predation.

A survey to determine the complete distribution of this form is needed, and its status should be reassessed regularly. Formal protection of the habitat is desirable.

P. traversi otakia This subspecies, the most southern in the North Island, was known from several forest remnants in the Otaki and Te Horo districts; only the type locality still has snails. *P. t. otakia* appears to be confined to 1 or 2 ha within this remnant, which is surrounded by farmland and divided by a public road. The secondary forest comprises mainly mixed broadleaf species, with tangled kiekie and supplejack.

In November 1979 we collected 54 shells (11 shells h^{-1}) of which 98% had been killed by rats. A search in the same locality in August 1980 produced only 5 shells which were found at 0.7 shells h^{-1}, the lowest collection rate of the entire survey.

During August 1980, 14 boxes baited with rat poison were placed in the area of highest density of snails by officers of the Wildlife Service, Department of Internal Affairs, to stem the rapid decline of this last remaining colony of *P. t. otakia*.

Powelliphanta gilliesi

Shells of the *gilliesi* series are relatively small (maximum diameter 48.5 mm). They are found over a wide range of altitudes in the Golden Bay area of north-western Nelson (Fig. 6). Five of the subspecies are lowland forms, 2 are montane, and 1 (*P. g. fallax*) is found from sea level to 1300 m.

P. gilliesi gilliesi This subspecies seems to be restricted to the immediate vicinity of the marble and dolomite formation of Mt Burnett at the northern end of the Wakamarama Range in Golden

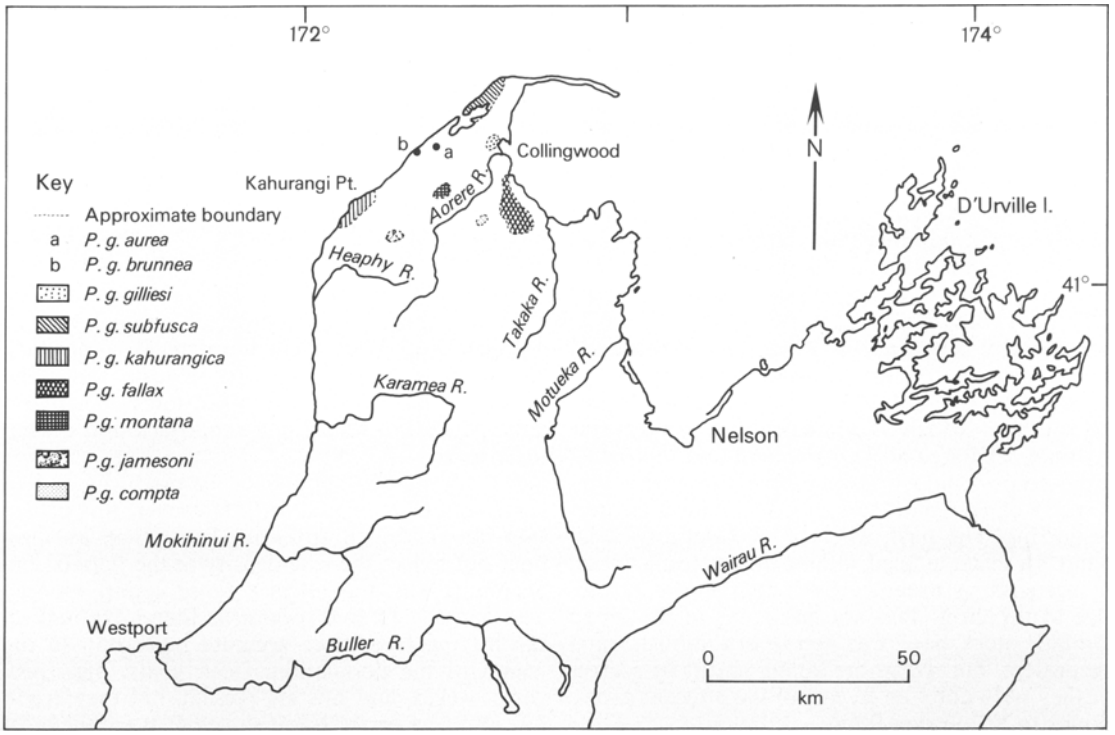


Fig. 6 Distribution of *Powelliphanta gilliesi*. For Fig. 6–9 (inclusive), see key to taxa on each figure; location of mapped area is shown on Fig. 10.

Bay. Snails have been recorded for several kilometres around the base of Mt Burnett and also from the top of the mountain at 650 m.

Mt Burnett has been modified over many years. There is a road to the top of the mountain to service a television translator and an open-cast dolomite quarry; it has reduced the habitat and provides easy access for snail collectors. Rainfall is high and the mixed podocarp/broadleaf/beech forest is lush and tangled with supplejack and kiekie. Much of the forest has been cut over for podocarps. The forest around the bottom of the mountain is open to stock wandering in from neighbouring farms and this, together with the presence of feral pigs and goats, has affected adversely the understorey and forest floor.

Elliott (1970) reported that "snails were plentiful at the top and that despite pigs, *P. g. gilliesi* is easy to find". In February 1972, 62 determinable shells were collected (5) at Mt Burnett. Of these only 11% had been killed by predators (6% by rats 5% by pigs). In December 1979 we collected at the base of the tramline up Mt Burnett, a favourite site for collectors and a collection (7) was made in March 1980 at the top of Mt Burnett and around the base of the mountain. The pooled sample was 97 determinable shells, of which 58% had been damaged by predators, mainly pigs (40%) but also rats (8%), wekas (8%), and stock (1%). Pig numbers should be controlled in this area.

P. gilliesi subfusca The type locality for this snail is Kaihoka Lakes, a scenic reserve near the coast at Westhaven Inlet, Nelson. The subspecies is also found in many other bush remnants for several kilometres around the Kaihoka Reserve.

The vegetation in this area is a lush mixture of coastal broadleaf and podocarp species, growing on old dunes and on the limestone formations which face the West Coast from Kahurangi Point to Cape Farewell.

Despite the presence of wekas, rats, and cattle in many of the remnants, *P. g. subfusca* appears to be relatively secure, with little predation and there are several colonies. During 1979 and 1980, 281 shells were collected from 5 different remnants. Of the 222 determinable shells, 30% had been killed by predators (17% by rats, 10% by wekas, 3% by thrushes or blackbirds). At the Kaihoka Lakes Reserve, 27 live snails were found in 1 h of intensive searching.

This snail has a low conservation priority at present. However, these bush remnants require monitoring; they could be opened up and destroyed by cattle or wind. A small population of *P. g. subfusca* has become established in the Drumduan forest, north of Nelson. Details of the transfer are not known.

P. gilliesi kahurangica The type locality for this subspecies is Kahurangi Point on the western coast of north-western Nelson. The known populations are restricted to the immediate vicinity of the Point. They have been collected only within a narrow coastal strip between Big River and Kahurangi River, probably because of the difficult terrain.

Kahurangi Lighthouse is on a limestone cliff to the south of which is a precipitous, windswept coastline. The area around the light and the lighthouse-keeper's house is a reserve owned by the Ministry of Transport and leased by a local farmer for grazing. The bush where *P. g. kahurangica* is found is a thick, tangled, almost impenetrable mass of regenerating broadleaf/podocarp forest at the edge of the farm. Pigs are numerous in the area, domestic stock have free access to the bush, rats are present, but wekas are either absent or scarce for they were not seen by any of the 3 recent expeditions to Kahurangi Point.

We made a collection in January 1980, and another (7) in April 1980 in a different locality. Of the 98 determinable shells, in the combined sample, 73% had been damaged by predators (pigs 57%, rats 14%, thrushes or blackbirds 2%). This is a high rate of predation.

Control of pigs is urgently required, but would probably have to be repeated regularly as the large area of forested land behind Kahurangi Point would provide a 'reservoir' of animals.

P. gilliesi brunnea Formerly found in coastal bush (5–20 m above MSL) northwards from the Paturau River for at least 3 km (Powell 1979), *P. g. brunnea* is now confined to a single remnant of coastal forest of less than 1 ha.

The forest comprises mainly mahoe, kawakawa, pigeonwood, and some cabbage trees, with tangled kiekie at the northern end and a border of flax on the higher western side. It is close to farm buildings and is unfenced, so stock (mainly dairy cattle) have ready access and use it for shelter. The small population of snails appears to be confined to the flax belts, which afford the only protection and cover from stock and rats. Three separate, timed collections made between December 1979 and July 1980 produced 171 shells in 5 man-hours of searching (37.6 shells h^{-1}). Of these shells, 32% were undamaged, 56% had been preyed on by rats, and 9% had been trampled by stock. During a 4 man-hour search for live snails made at night in 1979, 11 were found, measured, weighed, and returned to the flax 'skirts' where they were found. All age classes were represented, (shell length, 9–47 mm), indicating that there is some recruitment.

Of all the *Powelliphanta*, this subspecies is one of the most threatened, particularly because the population is confined to a small patch of flax within a small forest remnant. During November and December 1980, this area was fenced by the Wildlife Service, Department of Internal Affairs (see 'Recommendations'), to exclude cattle and sheep.

P. gilliesi aurea This subspecies is found west of Mangarakau, about 4 km from the *P. g. brunnea* colony. The habitat consists of steep limestone bluffs covered with dense mixed forest. There are large patches of kiekie and supplejack and a deep litter layer.

A 2.5 h search over about 1 ha produced 12 live snails and 64 shells (30 h^{-1}). However, this collection rate, although appearing lower than average, does not reflect the true density of the population. Searching was difficult in a dense, damp, gloomy area and the 12 live specimens found exposed on the litter give a more accurate indication of the health of the population. Deer, goats, pigs, possums, wekas, and rats are present, but they are in low numbers on the lower slopes. Pigs are the most serious predator, accounting for 23 (36%) of the shells collected. Rats had preyed upon 12 (19%).

Because of the 'moderate' predation rate and limited distribution, *P. g. aurea* scores highly on our ranking system. Pig control and restraints on collectors are necessary.

P. gilliesi fallax This snail is found in the Parapara Valley, and on the northern and eastern slopes of Parapara Peak as far south as the Pupu powerhouse on the Waikoropupu Stream. *P. g. fallax* has a very wide altitudinal range, being found from sea level to 1300 m in mixed beech/podocarp/broadleaf forest, and in manuka, gorse, or bracken scrub. It appears to be thinly scattered within this range and is never very easy to find. The collection rate of 9 shells h^{-1} was the third lowest we recorded.

Collections were made in 1979/80 at the Pupu powerhouse, on an outcropping ridge of limestone on the Parapara Peak track, and near Tukurua Stream and Parapara River. Of the 30 determinable shells from Parapara Peak (at over 600 m), 16 were intact and 14 (47%) had been damaged by wekas. In the lowland area, where 38 determinable shells were collected, 10 were intact and 27 (72%) had been gnawed by rats. In 1974–75, 66 shells were collected (2) from the lowland, in manuka scrub near Puramahoi, of which 12 were intact, 24 (36%) had been killed by wekas and 30 (45%) by rats.

Little can be done about the 'moderate' weka predation in upland areas and indeed the snails

should be able to cope with this 'natural' predation as the forest is relatively intact and neither pigs nor rats seem to be active there. The lowland colonies are suffering from rat and weka predation and destruction or modification of the habitat. The soils in the Parapara and Onekaka area are generally poor and many of the forested areas were burned to make way for pasture and have reverted to thick scrub, often gorse. Fortunately this scrub seems to have provided enough cover to maintain a fairly moist litter, and snails still exist in scattered populations, but they are never numerous.

P. gilliesi montana This subspecies appears to be strictly montane, living at altitudes above 850 m. The only definitely known locality is the eastern face of Bock Peak in the Wakamarama Range in Golden Bay.

The rainfall is very high and the mixed beech/broadleaf/podocarp forest is luxuriant. There are many goats on the middle slopes, and they have 'opened out' the forest.

P. g. montana is sympatric with the much larger *P. s. superba*. Collecting both species during our timed search probably lowered the search rate for each. We collected on Bock Peak in December 1979, and found many empty *P. g. montana* shells (335 shells at 34 h^{-1}; 89% of these were damaged by predators, mainly by either kakas or keas (85% by parrots as against 4% by wekas).

Elliott (1970) said after collecting on Bock Peak, "our 'friends' the wekas have been extremely busy here and it is most discouraging to find dozens of snails, both *P. s. superba* and *P. g. montana*, with their tops pecked out. A few are undamaged but live snails are rare". The damage she attributed to wekas may have been caused by parrots, but the observation certainly agrees with our finding hundreds of holed shells in the area (although parrots seldom 'hole' through the top, and wekas nearly always do).

The large numbers and high predation rate are discussed under *P. superba*. *P. g. montana* is apparently restricted to a relatively small area and the subspecies requires further investigation. The goats should be controlled.

P. gilliesi jamesoni This, another montane form of *gilliesi*, is found at and above 600 m in the pockets of beech forest in the Gouland Downs area and in the headwaters of the Saxon River (where it is sympatric with *P. s. mouatae*). Kakas and keas are common throughout the area.

We made several collections in the Saxon River area and in the forest beside the Gouland Downs hut in December 1980. Of the 68 shells found, 32% were intact and 67% had been damaged by predators — 57% by parrots, 10% by rats (all from Gouland Downs).

The small patch of forest on a limestone outcrop beside the Gouland Downs hut is a well-known locality of *P. g. jamesoni*, but the forest has been kept open by deer, trampers, and cavers, and snails are not common. Rats are a major problem, perhaps because the hut is so close and ground cover is absent. Snails were more abundant in the Saxon Creek area, although parrots killed many there — this will be discussed later.

Although *P. g. jamesoni* is moderately common and its major predator is natural, deer numbers should be reduced to allow the undergrowth to increase and improve the habitat for *Powelliphanta*.

P. gilliesi compta This subspecies is found in a very limited area on the eastern side of the Aorere Valley in Golden Bay (Fig. 6). There is an outcrop of limestone on the western edge of the sloping peneplain which dominates the eastern Aorere Valley, and *P. g. compta* seems to be restricted to the mixed beech/broadleaf forest on this limestone. This area, known as "The Castles", is at an altitude of 600 m.

Elliott (1970) commented: "I had been told *P. g. compta* was extremely rare and so was delighted to find a dozen good specimens without any difficulty and even more on later trips". In 1979 most of the shells we found had been damaged by predators.

We made a collection in April 1979 and found 2 rat accumulations containing 62 shells, but only 5 other shells. In March 1980, a more representative collection from a different locality contained 27 determinable shells, of which 7 were intact, 8 had been gnawed by rats, 4 had been damaged by wekas, and 8 by parrots. Of the combined sample of 94 determinable shells from the 2 collections, 92% had been killed by predators (74% by rats, 9% by wekas, and 9% by parrots).

P. g. compta appears to be neither numerous nor widely distributed but more information is needed before its status can be properly assessed.

Powelliphanta superba

P. superba is a very large species found in the silver beech, rata, and *Dracophyllum* forest above 450 m in the Heaphy-Aorere area.

The forest over most of its range is relatively intact, but the understorey is sparse in places because of moderate numbers of deer and, in some localities, goats. Rats, wekas, thrushes, and blackbirds are present but their effect on *P. superba* is generally slight. The most significant predators of *P. superba* are parrots; kakas and keas are common throughout its range, though keas only moved into the Nelson area about 70–80 years ago (Falla et al. 1966).

There were many empty shells at most of the places where we collected, but frequently many of

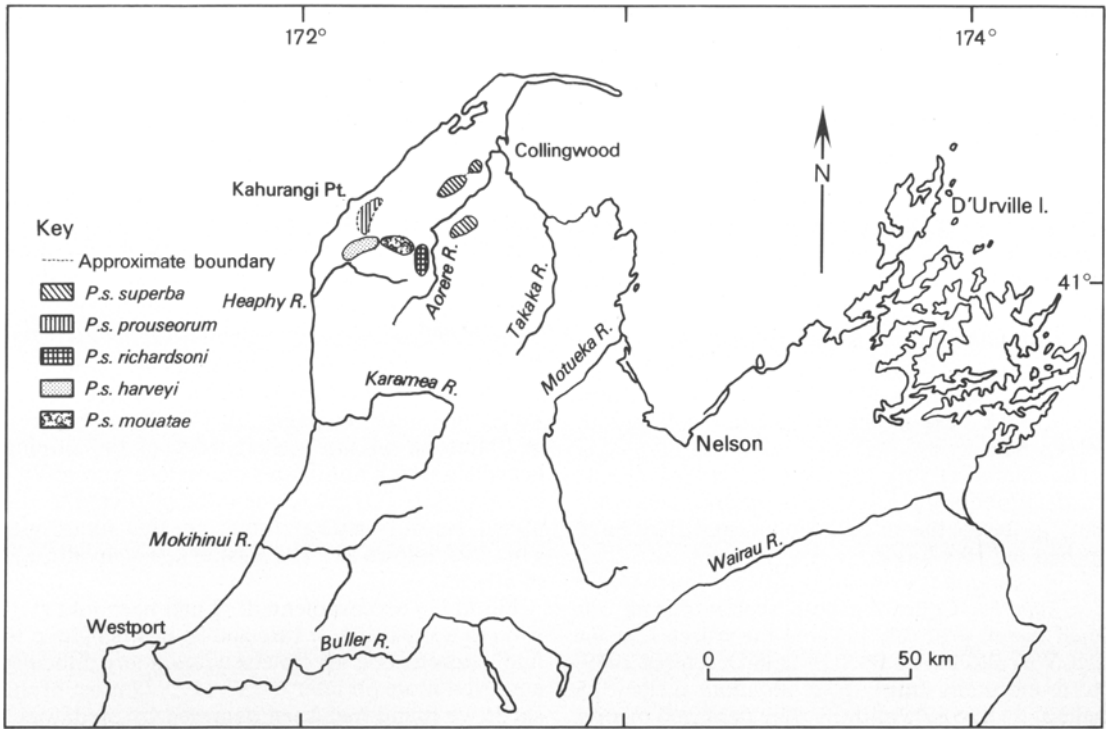


Fig. 7 Distribution of *Powelliphanta superba*.

them (up to 96%) had been damaged by parrots. It is difficult to understand how such a high rate of predation could be maintained without the snail population being drastically reduced. Such large numbers of shells damaged by parrots suggest that either this type of predation is recent and very heavy, or that the shells accumulated over many years. To test this, we revisited a colony after a year and collected all the shells that had accumulated in that time. We were still able to collect moderate numbers of shells, though fewer were found than on the first visit. We cannot say whether the population is stable, decreasing, or increasing, but there has been no catastrophic decrease. Although more needs to be known about the live populations, none of the subspecies of *P. superba* is considered to need active conservation urgently. All are found in good numbers within large areas of relatively unmodified forest, and the major predator is natural.

Powell (1979) recognised 5 subspecies of *P. superba*, but from our collections it seems that some of these are indistinct. We collected snails intermediate between *P. s. harveyi* and *P. s. mouatae*, *P. s. harveyi* and *P. s. prouseorum*, *P. s. richardsoni* and *P. s. prouseorum*, and *P. s. superba* and *P. s. richardsoni*. A thorough investigation of the whole range of this species may well reveal a continuum rather than distinct subspecies. We use Powell's classification for convenience.

P. superba superba This subspecies is found above 750 m on the eastern and western sides of the Aorere Valley in Golden Bay (Fig. 7); on the eastern side from Cedar Creek Ridge (the type locality) to Parapara Peak, and on the Wakamarama Range on the western side, from the Gorton Downs to Mt Burnett. The Wakamarama Range has a high rainfall, is frequently cloud-covered, and the forest is lush, but goats have 'opened out' the understorey on the middle slopes. Except for a few cut tracks this area is not easily accessible because the terrain is steep and heavily bushed, so knowledge of the distribution of *P. s. superba* is incomplete.

In 1978, a collection (3) of 36 shells was made at Cedar Creek Ridge. All of the shells had been damaged by predators, 33 by parrots, and 3 by rats. We collected many shells on Bock Peak in December 1979, including 394 *P. s. superba* and 388 *P. g. montana*. In a timed collection of 6 man-hours, we collected 188 *P. s. superba* (30 h^{-1}), and 171 *P. g. montana* shells (34 h^{-1}). Of 358 determinable *P. s. superba* shells, 93% had been damaged by predators — 82% by parrots, 11% by wekas — and only 7% were intact.

We collected 63 *P. s. superba* (31h^{-1}) and 99 *P. g. montana* (50 h^{-1}) at the same locality on Bock Peak in January 1981. Only 4% of the *P. s. superba* and *P. g. montana* shells were intact; the rest had been damaged by parrots.

P. superba prouseorum According to Powell (1979) the shell of *P. s. prouseorum* is, apart from the parietal callus being finely but distinctly granulated, identical to that of typical *P. s. superba.* Many shells of *P. s. prouseorum* had pale reddish-brown axial streaks.

This subspecies also lives in remote and inaccessible country, and the information on distribution is consequently incomplete. It is found in forest above 450 m between Kahurangi and Rocks Point and probably for several kilometres on either side of this area (Fig. 7).

F. M. Climo found very large numbers of empty shells in the upper Kahurangi River area in 1964. He collected 34 intact shells and 1 which had been damaged by a parrot. This collection was probably biased in favour of whole shells. We collected 80 shells from a similar area in December 1980: only 26% were intact; 74% had been damaged by parrots.

P. superba richardsoni The shell of *P. s. richardsoni* seems to be intermediate between *P. s. prouseorum* and *P. s. superba*; its colouring (old-gold) and form are very similar to those of *superba* and *prouseorum*, but it differs from *prouseorum* in not having a granulated parietal callus, and from *superba* by some shells having pale reddish-brown axial streaks.

It is found on the southern side of Perry Saddle on the Gouland Range but its full distribution is not known. Of 26 shells collected (4) in January 1972, 4 (15%) were intact and 22 (85%) had been damaged by parrots. Nine years later, in December 1980, we collected 48 shells, of which 56% had been damaged by parrots, 38% by thrushes (we found 3 'anvil' sites), and 6% were intact.

P. superba harveyi This subspecies never attains the enormous size of *P. s. superba*, *P. s. prouseorum*, or *P. s. richardsoni*; the diameter is 65 mm at most. The shell is yellowish brown with broad axial streaks of reddish-brown, and has a granulated parietal callus.

It is found at the southern end of the MacKay Downs and has usually been collected around the MacKay hut on the Heaphy Track but, as few searches have been made away from this main thoroughfare, the full range of *P. s. harveyi* is unknown. A few can be found all over the open tussock country of the MacKay Downs, but towards the north and west *harveyi* merges into *P. s. prouseorum* and towards the Saxon River in the east it merges into *P. s. mouatae.*

We collected it in December 1980 in a low-growing forest of mountain beech, manuka, celery pine, and bog pine near the MacKay hut. Many snails were found and the collection rate was very high (159 shells h^{-1}). Of 134 determinable shells, 67% had been killed by predators: 58% by parrots, 8% by wekas, 1% by rats.

P. superba mouatae Although it is very similar to *P. s. harveyi*, *mouatae* is a more uniform cinnamon brown and the parietal callus is not granulated. It is found in the headwaters of the Saxon River which divides the Gouland from the MacKay Downs, but its full range is unknown.

We collected it in tall silver and mountain beech forest near the junction of Blue Duck Creek and Saxon River in December 1980 (at 86 shells h^{-1}); most shells were found around 3 thrush anvils. Of 93 determinable shells, 61% had been killed by a predator (42% by thrushes, 16% by parrots, 2% by wekas, 1% by rats).

Powelliphanta hochstetteri

This group of large snails (maximum diameter 75 mm) is found on the high forested peaks throughout the Marlborough Sounds, the eastern ranges of Nelson, the Mt Arthur-Pikikiruna ranges, and in the Anatoki area (Fig. 8). In the Pikikiruna and Mt Arthur ranges the parent rock is mainly marble, but in the Anatoki area, the ranges east of Nelson, and in the Marlborough Sounds it is mainly greywacke, argillite, and sandstone.

Most populations are found at altitudes above 300 m. The exceptions are on Blumine and Arapawa islands, where both forest and snails occur down to sea level.

Pigs and wekas are present throughout most of the range of *P. hochstetteri*, but pigs are absent in the Anatoki area and on Blumine Island. Pigs cause serious problems for some of the populations in the Marlborough Sounds. Shells damaged by parrots have been found in most areas, and parrots were the major predator at Tennyson Inlet.

Powell (1979) recognised 5 subspecies of *P. hochstetteri*, but *P. h. obscura* (found west of the Crail Bay/St Omer Saddle) and *P. h. bicolor* (east of the saddle) overlap with *P. h. consobrina* in the south-west of their ranges. We have taken the line of demarcation between *P. h. consobrina* and the other 2 as being State Highway 6, as most of the snails that we collected to the north of it showed characteristics of either *obscura* or *bicolor.*

P. hochstetteri hochstetteri This subspecies is found from the Mt Arthur Tablelands to the northern end of the Pikikiruna Range (Fig. 8), but the exact distribution patterns within the area are not known. In the south, part of the range lies within

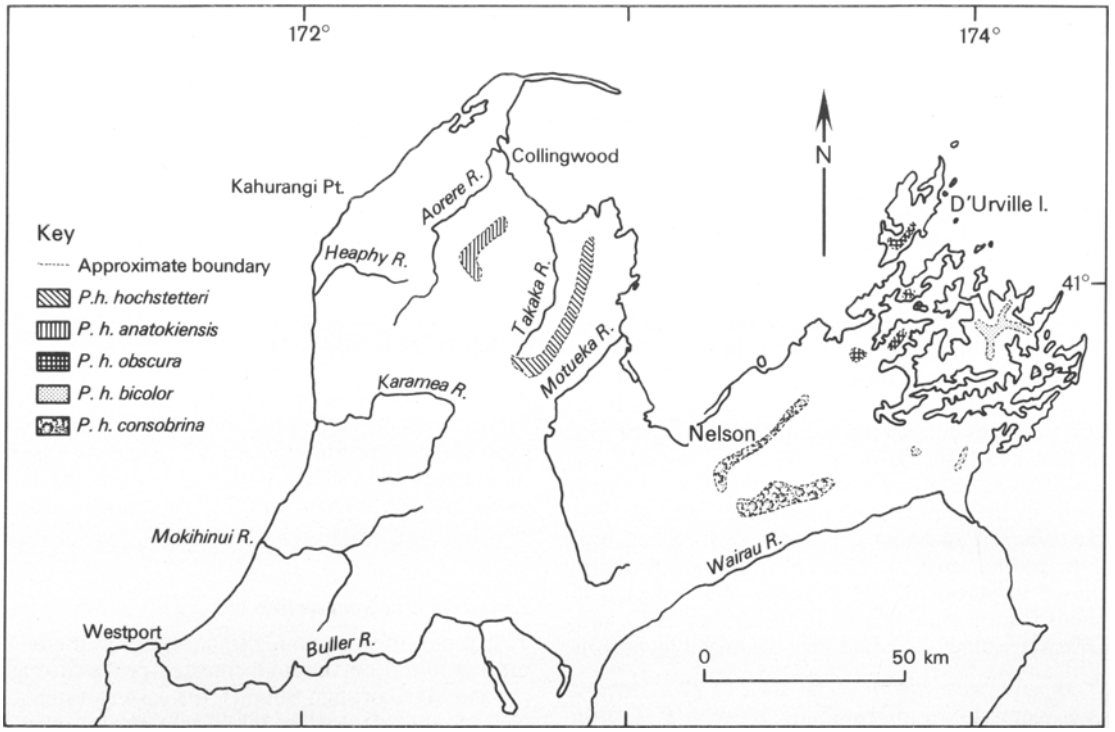


Fig. 8 Distribution of *Powelliphanta hochstetteri.*

the North West Nelson Forest Park and in the north, part is within the Abel Tasman National Park; the remainder is State Forest or freehold land.

There are 2 distinct forms: yellow-based *P. h. hochstetteri* to the north of Mt Pikikiruna and brown-based *P. h. hochstetteri* to the south. As with most of this series, *P. h. hochstetteri* is restricted to altitudes above 600 m, where cloud and mist persist.

The vegetation is basically silver and red beech forest, with the occasional celery pine, cedar, Hall's totara, and rata in the canopy, on marble or limestone; *Dracophyllum*, broadleaf, stinkwood, and mingimingi are common understorey plants.

Deer, pigs, goats, wekas, rats, and stoats are present throughout most of the area and the first 3 have 'opened up' the forest floor considerably in places. Cattle have access to the forest at many points along the pasture/forest interface and have contributed to habitat degradation by trampling the litter and by browsing. Some beech forest on private land near Mt Pikikiruna and Canaan is being clear-felled.

In 1972, a collection (5) was made on Takaka Hill; of the 78 shells, 45% had been damaged by predators (23% by wekas, 22% by rats). We made collections during 1979 and 1980 near the Cobb Road trig, on the old Upper Takaka Track, in the Flora Stream area, in the forest remnants on either side of the Takaka Hill Road summit, at the road end at Canaan, and in the Wainui Saddle-Evans Ridge area. Of 325 determinable shells collected, 58% had been killed by predators (31% by wekas, 17% by pigs, 6% by rats).

Though *P. h. hochstetteri* is not in imminent danger, there is an urgent need to protect and improve the habitat and to decrease predation by reducing the numbers of pigs and goats and by fencing parts of the Canaan area to exclude stock.

P. hochstetteri anatokiensis This subspecies is distinguishable from *P. h. hochstetteri* only by its generally more reddish colouring. It is found in beech forest from about 600 m to the bushline on the eastern side of the Haupiri Range from the Anatoki Forks and Yuletide Peak to Parapara Peak (Fig. 8).

In September 1979 and January 1981 we collected 195 shells, of which 149 were determinable; 64% had been damaged by predators (45% by parrots, 15% by wekas, 4% by rats).

Despite the high rate of predation, this subspecies is still numerous over a large area of remote, relatively unmodified forest, and its main predators are natural, so there is no urgent need for conservation measures.

P. hochstetteri obscura This subspecies is found in the western Marlborough Sounds near Admiralty Bay and Tennyson Inlet, as well as on D'Urville and Maud islands. These areas are treated separately.

(a) Admiralty Bay We have collected only from Mt Shewell in this area; none were found on other peaks. Mt Shewell is forested, and isolated from other snail habitat by sea and farmland. Forest is confined to the higher altitudes on the western faces of the mountain but it descends lower on the eastern side. There is a heavily browsed tight scrub at the edge of the forest, but further into the forest this gives way to silver beech and rata forest which is much less affected by browsing.

In August 1979 we collected 63 determinable shells from the eastern bush edge at 600 m up to the summit of Mt Shewell at 750 m. Of these, 89% had been damaged by predators (56% by pigs, 25% by wekas, 8% trampled). Despite a collection rate of 36 shells h^{-1}, this population is not secure; it is both isolated and subject to heavy predation by pigs and — less importantly — by wekas. The pig population should be reduced urgently.

(b) Tennyson Inlet There is a large area of continuous forest around Tennyson Inlet but snails are confined to peaks above 750 m. The forest is dominated by silver and mountain beech. Goats and pigs have modified the vegetation on the middle slopes but have had less effect on forest above 750 m. Kakas, wekas, and rats are present.

We collected 422 determinable shells from Mt Stanley and Editor Hill in November 1980 at 82 shells h^{-1}. Of these, 88% had been damaged by predators (86% by parrots, 1% by rats, 1% by wekas).

There are quite extensive areas of suitable habitat near Tennyson Inlet, and the predation rate, though high, is 'natural'; this snail does not, therefore, have a high conservation priority. Control of goats and pigs is, however, required to improve the forest habitat.

(c) D'Urville Island *Powelliphanta* snails are found on the 3 highest peaks of D'Urville Island; Attempt Hill (700 m), Wells Peak (600 m), and Mt Maude (650 m). During December 1978 and January 1979, the other high wooded peaks of D'Urville Island were searched, without success (Buckingham & Elliott 1979).

The forest above 600 m on the island is predominantly beech and kamahi. This is replaced on the shady slopes and in gullies by broadleaf species such as mountain fivefinger and raurekau. The many pigs and deer have browsed and trampled much of the understorey and this, as well as pig rooting, has dried out the litter and topsoil layer. Kakas, kiore, mice, stoats, hedgehogs, and cats are also present on the island.

Timed collections (6) were made from all 3 peaks during December 1978 and January 1979 and a further collection (15) was made in June 1980 on Attempt Hill. Of 178 determinable shells collected, 81% had been killed by predators (39% by wekas, 28% by pigs, 10% by kakas, 4% by kiore). The low collection rate (12 h^{-1} as against the average of 50.4 h^{-1}) and high rate of predation on this population give cause for concern. The pig and deer populations should be reduced urgently, to reduce the predation pressure and to improve the forest habitat for snails.

(d) Maud Island Maud Island lies in Pelorus Sound. It was farmed until 1975, and is now predominantly scrubby grassland, with a small (14.6 ha) remnant of kohekohe/broadleaf forest. Until the late 1960s, when the forest was fenced, sheep, cattle, and domestic pigs had access to the bush; goats and wekas were also present. Goats were eliminated by October 1977 and the removal of wekas began in 1974 when 80 ha (encompassing the forest) were gazetted a nature reserve. The remaining 229 ha were gazetted as a reserve in 1980.

P. h. obscura is found only in the uppermost part of the forest and numbers have declined drastically over the past 20 years (Meads & Moller 1978). Collections (8) made in 1976 and 1977 revealed only 25 shells, despite 30 h of searching. Further collections (9) produced 4 shells in 3 h in December 1980 and a further 2 shells in 4 h in January 1980. No shells were found in a 3 h search in September 1981.

Apart from an adult female stoat which arrived in 1982 there are no mammalian predators on Maud Island, and with the removal of wekas and the building of a kiwi-proof fence around the snail colony in June 1980 the island could have supported a secure *P. h. obscura* population. Unfortunately, because of its small size after the farming era, and the very poor state of the forest remnant, the Maud Island population may not recover. Encounters between the few remaining snails may now be too infrequent for adequate reproduction to reverse the decline (see Appendix 1).

P. hochstetteri bicolor The subspecies *bicolor* is found in the eastern Marlborough Sounds, on Blumine Island, Arapawa Island, in the Mt Stokes area, and around Picton.

(a) Arapawa Island Most of Arapawa Island is now covered with pasture, scrub, or exotic pine forest, and only 3 or 4 small patches of native forest still exist at altitudes suitable for *Powelliphanta*. One of the patches is in a scenic reserve. Unfortunately, these remnants of mixed beech/broadleaf forest remnants have been heavily browsed and trampled by large numbers of pigs, cattle, goats, and sheep for many years and there is consequently very little understorey and undisturbed litter.

We made several timed collections in "Heberley's Bush" and the scenic reserve during August 1979. In 18.5 h searching only 76 shells were found (4 h^{-1}). Compared with the average rate for *Powelliphanta* of 50.4 shells h^{-1}, this figure is disturbingly low and was the lowest recorded in the entire survey. Of the 76 determinable shells, 93% had been killed by predators (89% by pigs, 4% by rats). The New Zealand Forest Service has recently begun a goat control programme in the scenic reserve on Arapawa Island. Unfortunately, the *Powelliphanta* population may now have dropped below the point where recovery is possible. Fencing to exclude stock, though difficult in this steep terrain, is necessary. A constant campaign against feral animals is also needed to allow an understorey and a litter layer to develop and the forest to survive. The pig and goat populations should be reduced urgently.

(b) Blumine Island This island reaches a height of 300 m. It was grazed for many years until, in 1946, it was purchased by the Crown and designated a scenic reserve. Bell & Roderick (1963) reported that there were about 25 pigs on the island, and instigated an eradication programme. By 1970 the pigs had gone and Blumine Island was free of snail predators until 1972, when a weka with 3 chicks was sighted on the island (K. R. Johnson pers. comm.). The Wildlife Service began to remove wekas from the island in 1982. About two-thirds of the island (1100 ha) is covered in regenerating manuka and kanuka scrub, with many broadleaf species underneath. The southern end of the island is covered with a dense broadleaf forest dominated by kohekohe, tawa, karaka, and hinau, with patches of beech on the higher ridges. The only mammals present are stoats and mice.

In 1930 Powell noted that "The *Paryphanta*s were so abundant on this island that the dead shells were to be found everywhere on the ground, and little searching was necessary to locate the live ones, which occurred in great numbers under dead leaves and around the roots of ferns. Even the high-tidal drift-line was strewn with the empty shells washed down by small streams and storm water" (Powell 1932).

A collection (14) of 55 shells was made on Blumine Island in October 1978. Of the 47 determinable shells (collected in about 1.5 h) only 2 (4%) were damaged, both by wekas. The collecting was possibly biased towards large and whole shells, because of their abundance. Snails appear to be still numerous, despite the presence of wekas, In March 1981 we collected 424 shells at the very rapid rate of 164 shells h^{-1}. Of these, only 25% had been killed by predators, mainly by wekas (22%), but also by kakas (2%), and thrushes or blackbirds (1%).

The level of predation differed in different parts of the island. In the more open, regenerating kanuka forest, 37% of 193 shells collected (93 h^{-1}) had been damaged by wekas; in the older forest, of 206 shells collected (231 h^{-1}), only 9% were damaged by wekas, but 83% of the 71 snails with shells < 40 mm in diameter had been damaged by wekas.

The presence of wekas on Blumine Island is very disturbing because of its value as the largest area of predator-free habitat for *Powelliphanta* left in New Zealand. All other populations of *P. h. bicolor* are in areas in which high numbers of pigs have seriously degraded the habitat, so it is essential to maintain a healthy population on Blumine Island. Wekas should therefore be removed from Blumine Island urgently. The island is protected by its status as a scenic reserve, and it could be an excellent reserve for *Powelliphanta*. The unusual occurrence of a *hochstetteri*-type snail near sea level makes Blumine Island. interesting, as well as valuable.

Blumine Island has been considered as a new home for the little spotted kiwi (*Apteryx owenii*). It is not known whether these kiwis eat snails, but the possibility should be explored before any kiwis are liberated on Blumine Island.

(c) Mt Stokes area As in most of the Sounds, the valleys and lower, gentler slopes around Mt Stokes are farmed whereas the steeper high country is forested, here with silver and red beech, kamahi, and some rata. In most places the forest floor appears dry and the litter layer is shallow. Goats and pigs have been present in high numbers and have modified the forest understorey and litter layer considerably. Where forest meets farmland, cattle and sheep have modified the forest even more.

P. h. bicolor occupies only a small part of the large area of apparently suitable habitat. Between Mt Stokes and Puzzle Peak, snails are found in 5 discrete colonies at points where the ridge rises above 600 m.

In February 1976, 18 determinable shells were collected (1) on Puzzle Peak; of these, 11 were whole, and 7 had been damaged by wekas. We made a timed collection on Mt Stokes and Puzzle Peak and all the high points on the ridge between them in September 1979. Of 127 determinable shells found, 87% had been killed by predators. Most (66%) had been killed by pigs, and the rest by wekas. Although ship rats were known to be present, no shells showed signs of rat damage.

The scarcity of snails, their discontinuous distribution, and the heavy predation emphasise the need to protect this population. Already the New Zealand Forest Service has been successful in reducing the numbers of goats and pigs in the area, and we can expect some improvement in the habitat in the future and a reduction in the predation by pigs. More could be done by fencing the forest, especially at Puzzle Peak where it is surrounded by pasture and the snail population is very low.

(d) Picton area Snails are found in the high-altitude silver and mountain beech forests around Mt Cullen to the west of Picton, and on Mts Robertson and Piripiri east of Picton. Goats, pigs, deer, rats, wekas, kakas, and keas are present, and browsing mammals, especially pigs, have disturbed the understorey and litter greatly.

John Marston (in litt.), collecting in the Mt Robertson-Piripiri area during April 1970, said of the snails "... thrashed by wild pigs. I have only one unbroken shell from this block ...".

We collected 38 determinable shells from the Mt Cullen area in March 1981: all had been damaged by predators (95% by pigs, 5% by rats). This extreme predation pressure will require an immediate reduction in the numbers of browsing mammals, particularly pigs, in the area to ensure the long-term survival of both the forest habitat and the *Powelliphanta* snails.

P. hochstetteri consobrina In the Bryant and Richmond ranges of eastern Nelson, *P. h. consobrina* has a discontinuous distribution within the continuous forest cover below the bush line. The snails are found only above 750 m in predominantly mountain and silver beech forest. In about 1930 snails were present as far south as Gordons Knob (Powell 1930) but recent reports and collections have come only from between Mts Stewart and Duppa on the Bryant Range, and Mts Richmond and Baldy on the Richmond Range.

Pigs and goats are numerous in this area, especially at lower altitudes, and their browsing, trampling, and rooting have seriously depleted the understorey and disturbed the litter in places. Wekas, kakas, keas, and rats are also present.

In 1979 and 1980, we made several collections from both the Bryant and Richmond ranges. All the collections from each range were combined.

(a) Bryant Range Only 5% of the 148 determinable shells collected were undamaged. Of the remainder, 34% had been killed by pigs, 32% by rats, 19% by parrots, and 9% by wekas. The heavy predation by introduced predators (66%) gives cause for concern, and pig control seems to be the most practicable way to reduce it.

(b) Richmond Range Of the 188 determinable shells collected, 23% were undamaged. Most of the rest had been killed by native predators (wekas 43%, parrots 14%); pigs had killed 19%, and rats 1%. Control of pigs and goats is needed to allow the habitat to improve, but it does not have a high priority at present.

Powelliphanta lignaria

These snails are found in northern Westland in the South Island (Fig. 9). In many respects the physical conditions here seem to be nearly optimal for *Powelliphanta*. The area has a high rainfall and moderate temperatures throughout the year and the broadleaf/podocarp forest is lush, and has a deep litter. The parent rock throughout much of the area where snails are found is limestone.

Rats and wekas are present throughout most of the area, but there are no pigs. The effect of these 2 predators on snail populations seems to be less here than elsewhere, perhaps because the forest habitat is very large and relatively intact.

P. lignaria lignaria The nominate subspecies is found in the Karamea Bluffs area, between the Mokihinui River and about Six Mile Creek. Snails north of Six Mile Creek belong to the subspecies *lusca*. The pattern of distribution of *P. l. lignaria* within its range is not known.

In 1972, a small collection (5) of 19 shells was made at Gentle Annie Point. Only 1 shell in this collection had been damaged by a predator (a weka). We made a timed collection just north of Gentle Annie Point in December 1979. Of 59 determinable shells, only 24% had been damaged by predators — a relatively low predation rate — 19% by rats, and 5% by wekas. Consequently, *P. l. lignaria* is ranked as having a low conservation priority.

P. lignaria lusca This subspecies is found in the catchments of Falls Creek and Glasseye Creek north of Six Mile Creek, in the Karamea Bluffs area. Many live snails were seen in January 1972 and 50 shells were collected (5) at Glasseye Creek, the type locality for *lusca*. Of these, 70% had been damaged by predators (45% by wekas, 20% by rats, 4% by parrots). This is a fairly high rate of predation.

We collected 133 determinable shells in the same locality in November 1979 and 35% had been damaged by predators. Rats had taken 28%, thrushes or blackbirds 6%, and only 1% were attributable to wekas, as against the 45% recorded 8 years previously.

The physical environment is good and the predation pressure is moderate; *P. l. lusca* has been allotted a relatively low conservation priority here.

P. lignaria unicolorata The typical *unicolorata* snail has a plain olive-brown shell. However, the topographic obstacle of the Mokihinui River does not isolate *unicolorata* completely and most colonies have some *P. l. ruforadiata* influence, i.e. "a darker raw umber colour with an axial pattern of broad, rather sparse irregular dark reddish brown streaks" (Powell 1979).

P. l. unicolorata is found at Seddonville Flat on the southern side of the Mokihinui River, on the southern side of the Mokihinui Gorge, and on the western side of the South Branch of Mokihinui

River beyond the Forks. Whereas most of Seddonville Flat has been cleared for farming, primary and secondary mixed beech/podocarp/broadleaf forest covers the slopes in the Mokihinui Gorge and the South Branch. There is a deep litter layer where the slope allows, and the area has a very high rainfall.

In May 1971, 42 determinable shells were collected (5) near the Mokihinui Forks; only 19% had been damaged by predators (14% by wekas, 2% by rats, 2% by thrushes or blackbirds). In December 1979, we collected empty shells from the Mokihinui Gorge track, from a swampy area near the mouth of Limestone Creek, and from the mouth of Mountain Creek. Of 253 determinable shells, 63% had been damaged by predators, a moderate predation rate. Rats had killed 47%, thrushes or blackbirds 13%, and wekas 3%.

An increase in the rat population may account for increased predation on snails since 1972; but this subspecies still survives in reasonable numbers and it is not in urgent need of conservation measures.

P. lignaria ruforadiata This subspecies has a shell similar to but darker than that of *P. l. unicolorata*, and it occurs on the northern side of the Mokihinui River (Powell 1979). We have not collected it.

P. lignaria johnstoni This snail is found in the catchment of Charming Creek in the Mokihinui State Forest, north of Westport. According to Powell (1979), it was "confined to a block of mountainous coastal country, isolated by the sea to the west, the Mokihinui River to the north, the Ngakawau River to the south and two deeply cut streams, Chasm and Charming Creek combine to form the eastern boundary". A detailed survey of the distribution of *P. l. johnstoni*, showed that Powell's boundaries were incorrect. *P. l. johnstoni* was found beside the Ngakawau River, Charming Creek and its tributaries (Watson, Fletcher, Muir, and Frank streams) and on the north-eastern face of Radcliffe Ridge. Its range abuts that of *P. l. rotella*, but no hybrids were found.

Population density varied considerably throughout the range of *P. l. johnstoni*, but it was very high in one small locality. Many empty whole shells were collected in this locality in 1972 (M. G. Efford pers. comm.). In 1977, 54 shells were collected (10), of which 17% were damaged, mainly by wekas. In 1979, we collected 90 shells in 30 min (180 h^{-1}) . Of 85 determinable shells, 19% had been damaged by predators (9% by wekas, 6% by rats, 3% by thrushes or blackbirds). In the same locality in 1981, 102 shells were collected (16) in 10 minutes (612 h^{-1}!), of which 12% had been damaged by predators, mainly wekas (11%). However, densities were much lower in all other localities; for example, 9 shells collected in 30 min (18 h^{-1}), of which 8 had been damaged by parrots.

P. l. johnstoni was generally found in rimu/yellow silver pine forest, but it was also present in beech forest. Much of the former range of *P. l. johnstoni* has been logged, and parts of the area are being converted to exotic pine plantations. As little of the habitat for *P. l. johnstoni* remains intact — and that is zoned for logging (NZFS 1981) — it is important that some areas be reserved for snails.

P. lignaria rotella Subspecies *rotella* is found on the western slopes of the Glasgow Range, in the Mokihinui State Forest. When *P. l. rotella* and *P. l. johnstoni* were surveyed by the Wildlife Service in December 1981 (Walker 1982a), *P. l. rotella* was almost confined to pakihi and rimu/yellow silver pine forest between 310 m and 460 m beside St Andrews Stream, although another, isolated, colony was found in similar forest on the ridge between Coal and Chasm creeks.

During this survey, snails were collected (16) at several places. Snails killed by fire were collected from areas of burned forest and pakihi. Apart from the burned snails, 68 determinable shells were collected; 75% had been killed by parrots, 4% by wekas, and 1% by rats.

The moderate collection rate and the 'natural' predation give no cause for concern, but logging and conversion of the indigenous forest to exotic plantation seriously threaten this subspecies. Nearly half of the range of *P. l. rotella* has been logged and about half of the logged forest has been burned and planted in exotics. The pakihi between St Andrews and St Davids Stream has also been burned, ploughed, and planted in exotics. All of the remaining habitat of this subspecies is zoned for logging (NZFS 1981).

To ensure the survival of *P. l. rotella* the remaining unlogged forest should be reserved.

P. lignaria oconnori This subspecies lives in a relatively remote region of the north-western Nelson mountains. It is found in the headwaters of the Karamea and the Leslie Rivers on the northern and western flanks of the Mt Arthur Range, in an area of large limestone bluff formations. Cattle were grazed in this area during the late 1800s, and large numbers of goats are present today. *P. l. oconnori* has also been recorded from the lower Karamea River; on the northern side at Virgin Creek, and on the southern side in the Paryphanta Saddle/Stormy Range/Kakapo River area.

In 1973 a collection (5) was made at Virgin Creek and at Slippery Creek in the upper Karamea. At Virgin Creek, 34 shells were collected, 85% of them damaged by predators (rats 79%, wekas 6%). In the Slippery Creek area 71 shells were collected, of

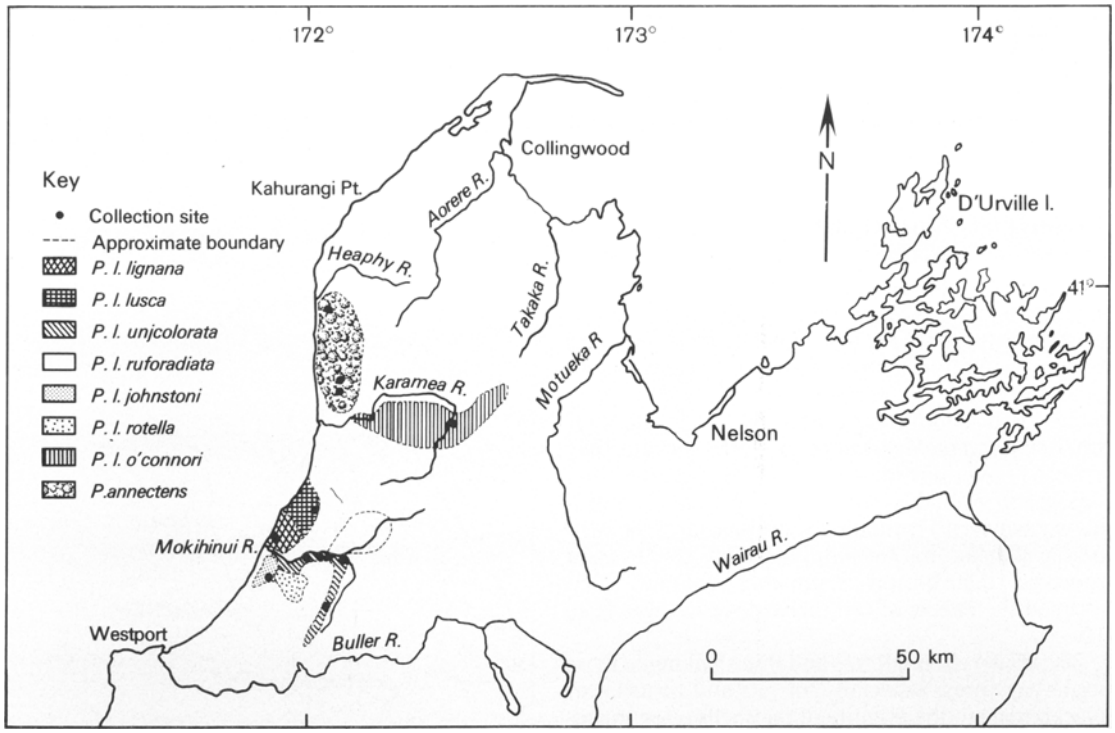


Fig. 9 Distribution of *Powelliphanta lignaria* and *P. annectens.*

which 61% had been killed by predators (rats 52%, wekas 9%).

In May 1980 we collected 34 shells at Slippery Creek. All except 5 (1 gnawed by a rat, 1 damaged by a weka, 3 whole) were found near 1 of 3 thrush anvils (i.e. 85% of all snails found had been killed by thrushes). We collected 55 determinable shells near the junction of the Crow and Karamea Rivers in April 1981. Of these, only 38% had been damaged by predators, mainly by rats (26%). These shells were collected at the relatively rapid rate of 89 h^{-1}.

A belt of limestone bluffs runs from near the Crow River mouth to the upper Leslie Valley and *P. l. oconnori* is reasonably common on the warm moist slopes and flats below these bluffs at 610 m, and is in lesser numbers above them at 1150 m. No snails were found on the granite country above the lower Crow River. The slopes and flats are mostly covered with tall podocarp forest (matai, miro, kahikatea, and rimu) and, with the abundance of seed and fruit that these trees provide for rats, it was not surprising that many shells had also been gnawed by rats.

Although there is considerable predation of *P. l. oconnori* by rats and thrushes or blackbirds, the snail appears to be quite widely distributed in an area which still retains its natural forest cover, and so has a low conservation priority.

Powelliphanta annectens

This species is found to the north-east of Karamea, in the Oparara Basin and western Gunner Downs area of North West Nelson Forest Park (see Fig. 9).

In April 1974, 59 determinable shells were collected (12) near "The Arches", a limestone formation in the Oparara Basin. Of these shells, 91% had been damaged by predators (69% by parrots, wekas 10%, rats 9%, thrushes or blackbirds 3%).

The distribution and population density of *P. annectens* were surveyed in detail by the Wildlife Service in February and March 1982 (Walker 1982). The distribution was found to be very uneven, with the highest densities of snails being found on the limestone flats beside the mid-reaches of the Oparara River and between 600 m and 900 m on the western slopes of the Gunner Downs. Collections were made throughout the survey; of those determinable out of 541 shells collected (16), at 39 shells h^{-1}, 31% had been damaged by parrots, 9% by rats, and 9% by thrushes or blackbirds.

The Oparara Basin colonies are distributed unevenly and are subject to high rates of 'natural' predation. Parts of the habitat of *P. annectens* in the Oparara have been logged and some of these have been converted to exotic forests. This process is continuing and is a cause for concern.

Powelliphanta rossiana and *Powelliphanta spedeni*

These species are characterised by their relatively small size (30 mm diameter as adults), their greenish or brownish colour (often axially streaked), and by their relatively thin ostracum. They occur, probably in low numbers, at high altitude, usually under tussock above the timber line. This, and their small size and inconspicuous coloration, means they are easily overlooked. Powell (1979) suggested that this group probably was once distributed continuously between Fiordland, Southland, and the Millerton Plateau in Nelson, and that the present sporadic distribution represents colonies that escaped the effects of the Pleistocene ice ages (Fig. 10).

The relatively small size and thin shell make these snails easy prey, especially for rats and thrushes or blackbirds, but the fragility of the shells often makes it difficult to determine the predator responsible.

P. rossiana rossiana This subspecies has been recorded from several peaks between Ross and Harihari, and from the Haast Range in Westland (Fig. 10). In 1967 and 1973, 108 shells were collected (10) on Mt Greenland (near Ross) of which 90% had been damaged by rats. Of 27 shells collected (11) in high-altitude forest and scrub at 800 m on Mt Bonar (near Harihari) in 1980, 85% had been killed by rats.

Four collections (13) were made in southern Westland between 1968 and 1973, at altitudes of 1400–1500 m. Of the 126 shells collected, only 6% were damaged, and these probably by thrushes or blackbirds.

Though widespread, *P. r. rossiana* is known only from several small, isolated colonies. This, and the severe predation by rats in the northern populations, causes concern. More knowledge of this subspecies is needed.

P. rossiana patrickensis This subspecies has been reported from the Mt Arthur Range as far north as Mt Lodestone, from the Mt Owen area, the Matiri Range, and the Denniston Plateau (Fig. 10). Similar snails reported from elsewhere in north-western Nelson may prove to belong to this subspecies, and it may be present in many more places in the area.

It is best known from the Denniston Plateau, where 125 determinable shells were collected in May 1972 (5), of which 90% had been killed by rats. This heavy predation is perhaps offset by the very wide distribution of this subspecies.

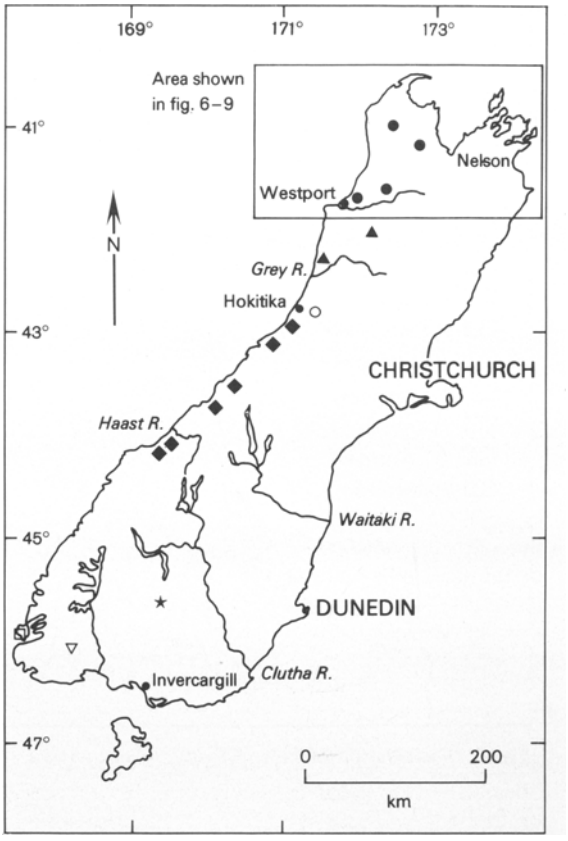


Fig. 10 Distribution of *Powelliphanta rossiana, P. spedeni* and *P. fiordlandica*: ●, *P. r. patrickensis*; ▲, *P. r. gagei*; ○, *P. r. fletcheri*; ♦, *P. r. rossiana*; ★, *P. s. spedeni*; ▽, *P. s. lateumbilicata*; □, *P. fiordlandica*. (symbols not to scale).

P. rossiana gagei Although it is similar in shape and colouration to *P. r. fletcheri*, *P. r. gagei* reaches a larger adult size (Powell 1979). It has been recorded from Rewanui, Greymouth, at 860 m (type locality) and from Kirwan's Hill, at 1076 m, northeast of Reefton. Twenty-six shells were collected (10) near the headwaters of Coal Creek, Brunner Range in April 1976, only 3 of which were damaged, 2 by thrushes or blackbirds.

P. rossiana fletcheri Although it closely resembles *P. r. rossiana* and *P. r. gagei*, *P. r. fletcheri* has a much flatter spire. It has been recorded only from tussock grassland on Mt Tuhua, near Lake Kanieri, Westland at 1135 m (Powell 1979). The only collection we have seen was made in January 1969

(13) and consists of 18 shells, of which only 1 is damaged (possibly trampled). Twenty-nine live snails were seen when the collection was made. Finding more live snails than empty shells is most unusual. The status of this subspecies should be investigated.

P. spedeni spedeni This *Powelliphanta* has a globose, narrowly umbilicated shell. It has been recorded from the Mataura Range (935 m) on the western side of the Mataura Range in Southland (Powell 1979). We have no collections from the area. The colony was visited several times between 1967 and 1970 and was in good condition — live snails were found more readily than empty shells (I. Payton pers. comm.).

P. spedeni lateumbilicata This subspecies, which is very similar to *P. s. spedeni*, is found at 920 m near the south-western shore of Lake Monowai, Otago (type locality) (Powell 1979), and at the bush line of the Hunter Range on the north-western shore of the lake. A short survey made on Mt Hindley in 1968 revealed 18 live snails; 5 undamaged and 3 decayed shells were collected (13).

Powelliphanta fiordlandica

P. fiordlandica differs from its nearest neighbours, *P. rossiana* and *P. spedeni*, in having a relatively wide umbilicus. It was first found in 1971 in dry, open beech forest below 150 m on Resolution Island in Fiordland. In 1983 it was discovered on the mainland, at 800 m, just below the scrub zone on the southern side of Dusky Sound. *Powelliphanta* snails probably exist on other coastal tongues of land which were between valley glaciers during the Pleistocene, but few searches have been made in these difficult areas. Insufficient specimens of *P. fiordlandica* have been collected for its status to be determined.

Note added in press

Small *Powelliphanta* snails showing affinities to *P. lignaria* have been found near Professor Creek, north-western Fiordland (F. M. Climo pers. comm.).

DISCUSSION

Our study examined 3 main factors which affect the current status of the populations of *Powelliphanta* snails: the degree of habitat modification; the extent of their distribution; and the level of predation.

Habitat modification

The highest densities of snails were found in relatively unmodified native forest with a deep, moist litter layer. Where forests are browsed by ungulates the litter is disturbed and dried out, and often the understorey and ground cover are removed, exposing the snails to predators. Some of the severest predation was recorded in forests highly modified by introduced mammals, including goats, pigs, deer, cattle, sheep, and possums.

Deer and goats were present in most of the large forest tracts we visited. Whereas deer are fairly scarce at present because of commercial hunting, and many forests are recovering from the damage inflicted by former high populations, goats are not subject to the same hunting pressure and in places they are abundant.

Of all the ungulates, pigs appear to have the greatest effect on populations of *Powelliphanta*. They not only root up and often completely destroy the litter layer in which the snails live, but they also eat them. Pigs are most numerous in scrub at the edge of forest, and consequently cause most damage in small forest remnants which have a high ratio of 'edge' to 'forest'.

The Marlborough Sounds, where the small forest remnants are surrounded by large areas of scrub, has the greatest pig problem. Here, and in the Richmond Range, *P. hochstetteri obscura*, *P. h. bicolor*, and to a lesser extent *P. h. consobrina*, are seriously affected by pigs, as are *P. gilliesi kahurangica*, *P. g. gilliesi*, *P. g. aurea*, and *P. h. hochstetteri* in north-western Nelson.

Domestic stock generally penetrate only a short distance into native forest and their effect is minimal, except in small remnants surrounded by pasture. However, where domestic stock do occur in small bush remnants, their trampling and browsing seriously affect snail populations (e.g., the lowland forms of *P. traversi* on the Horowhenua Plains and *P. gilliesi* in north-western Nelson.)

The brush-tailed possum (*Trichosurus vulpecula*) contributes to the opening up and drying out of the forest (McKelvey 1959).

Distribution

The theory of island biogeography predicts that populations of snails found in large continuous tracts of suitable habitat should be more secure than those confined to small isolated habitats. Before the European settlement of New Zealand, most forms of *Powelliphanta* existed in large, continuous tracts of forest and only a few were confined to isolated habitats, notably those on islands — *P. h. obscura* on D'Urville and Maud islands, and *P. h. bicolor* on Arapawa and Blumine islands. The destruction of forest that has occurred since European settlement has meant, however, that more and more forms of *Powelliphanta* have become confined to isolated habitats. This has been especially so with those snails confined to lowland forests (such as

some forms of *P. traversi* and some subspecies of *P. gilliesi*), as most of these forests have been cleared.

The continuing destruction of forest in Buller and Nelson is gradually reducing the ranges of *P. annectens*, *P. lignaria johnstoni*, *P. l. rotella*, and *P. h. hochstetteri*. If the destruction continues these forms will also become confined to isolated and vulnerable forest remnants.

Predation

During this study we found evidence of snails having been killed by native predators (kakas, keas, and wekas), introduced predators (pigs, rats, blackbirds, and thrushes) (Fig. 11), and by collectors. Powell (1946) mentions another introduced predator, the European hedgehog.

Introduced predators

Powelliphanta snails have not had long to adapt to introduced predators and it is therefore conceivable that they alone could seriously threaten some forms of the genus.

Feral pigs Pigs are a serious problem to *Powelliphanta* snails. Not only do they eat the snails and their eggs, but they also eat potential food for snails and destroy the snail habitat by rooting up the litter and low vegetation.

Rats We found evidence that all 3 local species of rat — ship rat, Norway rat, and kiore — eat snails.

In lowland forest remnants, such as the habitats of *P. traversi* on the Horowhenua Plains and *P. gilliesi brunnea* in north-western Nelson, predation, probably by Norway rats, is heavy. Given that these remnants are small and modified this predation is seriously threatening the survival of the snails.

In high country forests, the ship rat is probably the only rat present, but they are usually too scarce to pose a serious threat. Several high country snails (*P. g. compta*, *P. r. rossiana* and *P. r. patrickensis*) do, however, suffer heavy predation by rats but this is mitigated by the extent of the forests in which these snails live.

Blackbirds and thrushes We found a few snails eaten by blackbirds or thrushes in most places. Snails killed by thrushes may be over-represented in some collections as thrushes bring snails to tracks to bash them on exposed roots and rocks, or they may be under-represented, as blackbirds and thrushes invariably take small snails which are hard to find. For these reasons we cannot measure predation by blackbirds or thrushes accurately. Our impression is that although blackbirds and thrushes are predators of all *Powelliphanta*, their effect is small.

Other possible predators Hedgehogs, stoats, brush-tailed possums, cats and house mice possibly prey on *Powelliphanta* snails. Powell (1946) recognised hedgehogs as being predators of *Powelliphanta* and Brockie (1959) records hedgehogs eating the native snail *Wainuia urnula*, but we found no evidence of hedgehogs eating *Powelliphanta*. Three shells showing marks which fitted the canine teeth of a stoat were examined (shells held at the National Museum). We found no evidence that any of the animals listed is a significant predator of *Powelliphanta* snails.

Native predators

In general, we would not expect native predators by themselves to seriously threaten any of the forms of *Powelliphanta*, as the snails have been subject to such predation for so long that they have probably adapted to it. Where, however, native predators act in concert with introduced predators, modification of habitat, and loss of habitat, the combined effects could be serious.

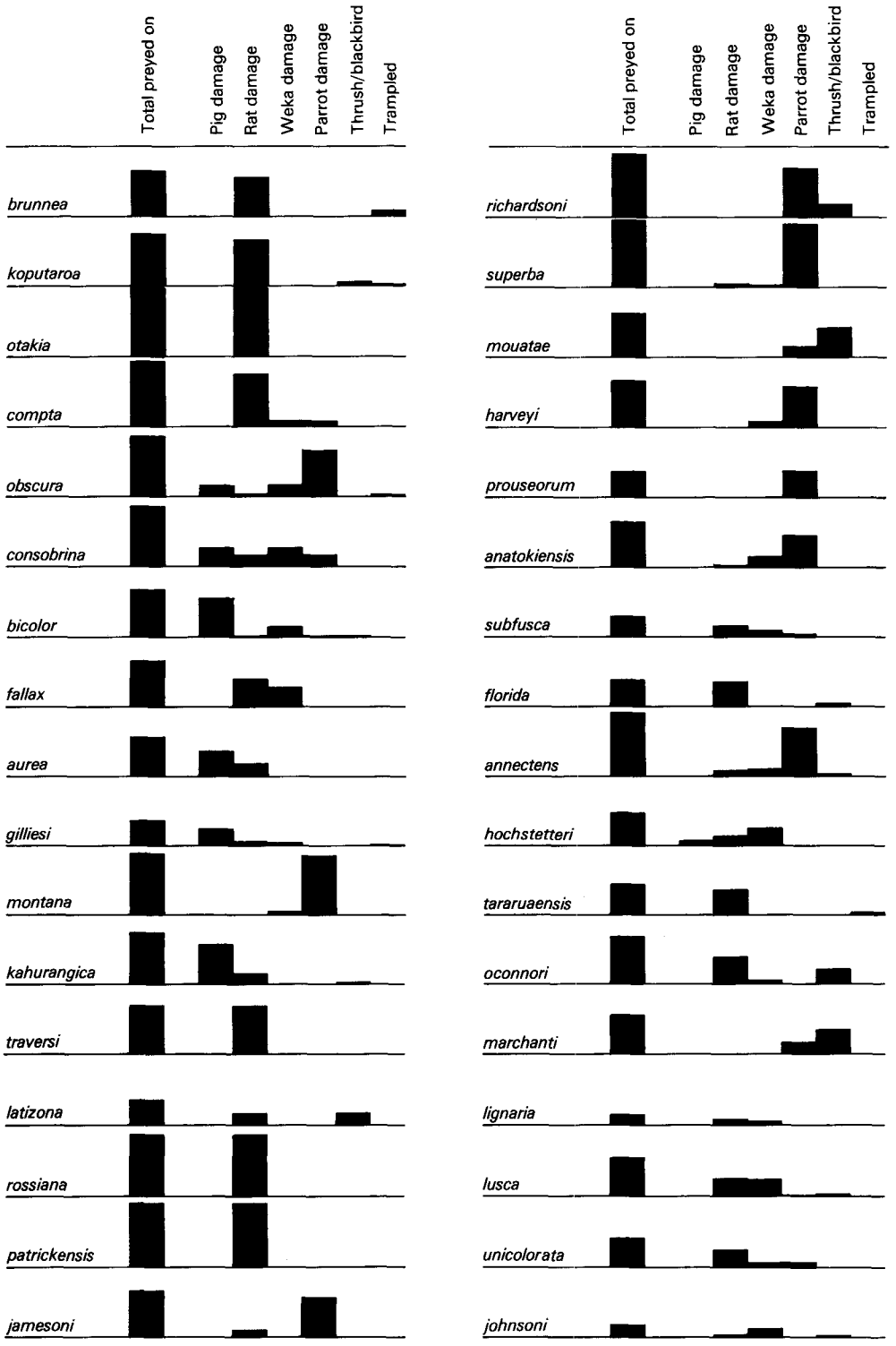
Kakas and/or keas Although it is not conclusive, our evidence strongly suggests that kakas, keas, or both, may be important predators of *Powelliphanta* snails. All *Powelliphanta* in areas where either or both are found (i.e. in all the larger forest tracts) are taken by them. In places where numbers of introduced predators are low, the parrots are often the only important predators.

In most places where we found shells damaged by parrots, both species were present and there was no way of telling whether 1 or both were responsible. There are, however, no keas in the North Island or on D'Urville Island, so in these places it is kakas that are preying on snails.

Wekas Wekas are important predators of snails in Nelson and Marlborough, but in these areas their numbers have fluctuated widely. They decreased rapidly in Marlborough early this century, possibly because of disease (Falla et al. 1970), and recolonised or were reintroduced to these areas in the 1940s: 1946 at Karamea (J. Marston, pers. comm.) and about 1940 on D'Urville Island (Buckingham & Elliott 1979).

Despite the absence of wekas from many areas early this century, they cannot be considered a 'new' predator on snails. In places where predation by wekas occurs in concert with that by 'new' introduced predators, the combined effects are severe.

Fig. 11 (*opposite page*) Taxa of *Powelliphanta* (listed in order of conservation priority) showing percentage of damage inflicted by predators.



Collectors

The effect of professional and amateur collectors is easily overlooked and difficult to assess. In the 1930s and 1940s when men such as Powell, Prouse, and O'Connor were investigating the taxonomy of *Powelliphanta*, they collected hundreds of live snails to obtain perfect specimens. Powell's publications gave precise localities for each colony, which helped enthusiastic shell collectors to gather their own shells. Collectors sought perfect shells and they collected living snails.

Many shell collectors joined the conchology sections of the Auckland and Dominion (now National) Museums, and the collecting of land snails peaked during the 1960s, as shown by records in the shell club publications (*Poirieria* and *Cookia*). Little concern was shown for the conservation of our land snail fauna, and specimens of *Powelliphanta* were sought particularly for their attractive patterns and colours. The individual shell patterning within a single colony, and differences between colonies, meant that there were no limits to the number of shells collected. By 1970 the shell club publications had almost ceased to feature large land snails, and the number of collectors declined, probably because good specimens were increasingly difficult to obtain, and because of a new awareness that collecting should be done in moderation.

Because *Powelliphanta* snails may live for 40 years or more and because they have low generative powers, the removal of so many mature animals between 1930 and 1970 may have significantly altered the population structure of some colonies, particularly in accessible lowland forest remnants on the Horowhenua Plains and in north-western Nelson.

All *Powelliphanta* snails are now fully protected under the Wildlife Amendment Act 1980.

The many forms of *Powelliphanta* and their wide distribution has meant that our time spent surveying each was necessarily short and this limited our ability to assess their individual status. Another major limitation was the almost complete lack of knowledge of the biology of *Powelliphanta*; until the basic biology is better known, estimates of the status of populations and the effects of management must be approximate.

Our assessment of the distribution of each form came largely from the literature. For only a few subspecies did we attempt to determine the exact distribution, although we often tried to define their range more accurately. Our assessment of the degree of modification of the habitat of each subspecies or form was limited to recording the presence of modifying agents (e.g., browsing ungulates), and to making a subjective statement about the extent of modification. Our assessments of predation rates from collections of empty shells was our only quantitative measure, but even this was subject to the following biases:

(i) small samples from a small part of the range of a form may not be representative. In forms with wide distributions we tried to minimise this possibility by collecting from several places;
(ii) small snails eaten whole by pigs were probably under-represented in some samples;
(iii) snails were not equally conspicuous at all sites, the great differences in colour and size between various subspecies and forms of *Powelliphanta*, together with differences in habitat, mean that they are not all equally easy to find;
(iv) undamaged empty shells gave no indication as to the cause of death, and any predator able to remove snails from their shells without damaging the shells would not have been detected by our methods;
(v) effects of differences between collectors were minimised by our collecting about 90% of the snails we examined.

Despite these limitations, we believe we can rank the various subspecies and forms in an order of priority for conservation and management.

RANKING FOR CONSERVATION PRIORITY

To determine priorities for conserving and managing the various *Powelliphanta*, we scored populations for 4 criteria: predation, habitat condition, habitat size, and distribution. Each variable was given an integral value (0, 1, or 2) using the following classes:

(a) **Predation**

0 0–32% Percentage of the snails collected killed by predators in our samples.
1 33–66%
2 67–100%

(b) **Habitat condition**

0 Relatively unmodified forests, or modified forests with a good understorey and litter layer.
1 Modified forests with a reduced understorey and litter layer.
2 Highly modified forests with little or no understorey or litter layer.

(c) **Habitat size**

0 Large, more or less continuous areas of suitable habitat, or 3 or more moderate-sized blocks.

Table 7 Ranking of *Powelliphanta* taxa in order of conservation priority. (Higher score = greater need for conservation measures.)

Taxon	Predator pressure (0–2)	Habitat condition (0–2)	Habitat size (0–2)	Distribution (0–2)	Total (0–8)	
P. g. brunnea	2	2	2	2	8	Group 1
P. t. t. fa. 'koputaroa'	2	2	2	2	8	
P. t. otakia	2	1	2	2	7	
P. g. compta	2	1	1	2	6	Group 2
P. g. aurea	1	1	1	2	5	
P. g. gilliesi	1	1	1	2	5	
P. g. montana	2	1	1	1	5	
P. t. traversi	2	1	1	1	5	
P. t. t. fa. 'florida'	1	1	2	1	5	
P. t. t. fa. 'latizona'	1	1	1	2	5	
P. t. tararuaensis	1	1	1	1	4	
P. g. fallax	1	1	1	1	4	
P. g. kahurangica	2	1	0	1	4	
P. g. jamesoni	2	0	1	1	4	
P. h. obscura	2	1	1	0	4	
P. h. consobrina	2	1	1	0	4	
P. h. bicolor	2	1	1	0	4	
P. l. rotella	1	1	1	1	4	
P. g. subfusca	0	1	1	1	3	Group 3
P. l. johnstoni	0	1	1	1	3	
P. r. rossiana	2	0	1	0	3	
P. r. patrickensis	2	0	1	0	3	
P. s. superba	2	0	0	1	3	
P. s. richardsoni	2	0	0	1	3	
P. s. prouseorum	2	0	0	1	3	
P. s. harveyi	2	0	0	1	3	
P. s. mouatae	1	0	0	1	2	
P. annectens	1	1	0	0	2	
P. h. hochstetteri	1	1	0	0	2	
P. h. anatokiensis	1	0	0	1	2	
P. l. lusca	1	0	0	1	2	Group 4
P. l. lignaria	1	0	0	1	2	
P. l. oconnori	1	0	0	0	1	
P. l. unicolorata	1	0	0	0	1	
P. marchanti	1	0	0	0	1	
P. r. fletcheri						Group 5
P. r. gagei						
P. s. spedeni						
P. s. lateumbilicata						
P. fiordlandica						
P. l. ruforadiata						

Group 1 (7–8) Close to extinction, require urgent, active management.
Group 2 (4–6) Vulnerable, require management (primarily habitat enhancement, and/or habitat reservation).
Group 3 (2–3) Reasonable numbers in modified conditions. Require monitoring and some efforts to improve conditions.
Group 4 (1–2) Relatively secure.
Group 5 Insufficient information, require survey of status.

1 One or 2 moderate-sized blocks, or 3 or more small patches of suitable habitat.
2 One or 2 small patches of suitable habitat.

(d) **Distribution**

0 Wide distribution: colonies within a radius of > 8 km.
1 Moderate distribution: all colonies within a radius of < 8 km but > 2 km.
2 Small distribution: all colonies within a radius of 2 km.

The scores for the 4 variables were added to give each form a total score. The list of *Powelliphanta* was then divided into 5 groups of conservation priority, based on their scores (Table 7).

Summary

Conditions for the *Powelliphanta* snails have seriously deteriorated since the introduction of rats and pigs to New Zealand in the 19th century, and with the continuing destruction of large areas of native forest. However, except where the habitat has been almost destroyed (e.g., on Stephens Island, some localities in Horowhenua, and at the Paturau River mouth), all the subspecies and forms are still extant, although reduced in range. We hope that this paper will provide a basis for measuring any changes in their status in the future.

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APPENDIX 1

RECOMMENDATIONS FOR CONSERVATION OF *POWELLIPHANTA* SNAILS

1. Most forms of *Powelliphanta* restricted to small remnants of lowland forest require some management:

(a) Rat control. This was begun for *P. t. otakia* by the Wildlife Service in September 1980. We recommend that rats should also be controlled at the colony of *P. g. brunnea*.

(b) Formal reservation of habitat. This is required urgently for most of the *P. traversi* series, for the lowland forms of *P. gilliesi* and for *P. lignaria rotella*, *P. l. johnstoni*, and *P. annectens*.

(c) Habitat enhancement. The colony of *P. g. brunnea* at Paturau was fenced by the Wildlife Service in 1980 to exclude stock. Flax should be planted inside the enclosure to provide more shelter from rats. The forest remnants containing the 'koputaroa' form of *P. traversi traversi* require fencing urgently.

(d) If these measures are ineffective, consideration should be given (as a last resort) to transferring some snails to safe refuges.

2. Most colonies of the subspecies of *P. hochstetteri* and several of the *P. gilliesi* subspecies are seriously affected by feral pigs. A programme to control pigs should begin immediately in the *Powelliphanta* areas of the Marlborough Sounds (particularly on Arapawa Island, in the Mt Stokes area, on Mt Cullen, Mt Robertson-Piripiri, D'Urville Island, and on Mt Shewell), on the Bryant Range, the Mt Burnett area of the Wakamarama Range, the Mangarakau Scenic Reserve, and at Kahurangi Point.

3. Wekas should be removed from Maud and Blumine islands in the Marlborough Sounds.

4. Predation by parrots should be investigated further.

5. Shells of the *Powelliphanta* listed in Group 5 (Table 7) should be collected to provide the information on their status that was unavailable to us.

6. Long-term studies of live populations of *Powelliphanta* should be undertaken.

APPENDIX 2

Scientific names of plants mentioned in text

Bracken	*Pteridium esculentum*
Broadleaf	*Griselinia littoralis*
Cabbage tree	*Cordyline australis*
Celery pine	*Phyllocladus trichomanoides*
Dracophyllum	*Dracophyllum traversii*
Flax	*Phormium tenax*
Gahnia	*Gahnia xanthocarpa*
Gorse	*Ulex europaeus*
Hall's totara	*Podocarpus hallii*
Hangehange	*Geniostoma ligustrifolium*
Hinau	*Elaeocarpus dentatus*
Kahikatea	*Dacrycarpus dacrydioides*
Kamahi	*Weinmannia racemosa*
Kanuka	*Leptospermum ericoides*
Karaka	*Corynocarpus laevigatus*
Kawakawa	*Macropiper excelsum*
Kiekie	*Freycinetia baueriana* ssp. *banksii*

Kohekohe	*Dysoxylum spectabile*
Leatherwood	*Olearia colensoi*
Mahoe	*Melicytus ramiflorus*
Manuka	*Leptospermum scoparium*
Matai	*Prumnopitys spicatus*
Mingimingi	*Cyathodes* spp.
Miro	*Prumnopitys ferruginea*
Mountain beech	*Nothofagus solandri* var. *cliffortioides*
Mountain cedar	*Libocedrus bidwillii*
Mountain fivefinger	*Pseudopanax colensoi*
Nikau	*Rhopalostylis sapida*
Pigeonwood	*Hedycarya arborea*
Pine	*Pinus radiata*, or other commercial spp.
Pukatea	*Laurelia novae-zelandiae*
Putaputaweta	*Carpodetus serratus*
Raupo	*Typha orientalis*
Rata	*Metrosideros umbellata*; *M. robusta*
Raurekau	*Coprosma grandifolia*
Red beech	*Nothofagus fusca*
Rewarewa	*Knightia excelsa*
Rimu	*Dacrydium cupressinum*
Silver beech	*Nothofagus menziesii*
Stinkwood	*Coprosma foetidissima*
Supplejack	*Ripogonum scandens*
Tawa	*Beilschmiedia tawa*
Titoki	*Alectryon excelsus*
Totara	*Podocarpus totara*
Tree ferns	*Dicksonia* sp., *Cyathea* spp.
Tradescantia	*Tradescantia fluminensis*
Yellow silver pine	*Lepidothamnus intermedius*

APPENDIX 3

Key to collectors and collections

(1) C. C. Ogle, private collection;
(2) M. Wells, National Museum collections M52 572—M52 575;
(3) F. M. Climo, National Museum collection M58 071;
(4) National Museum Collection M26 012;
(5) M. G. Efford & B. McCulloch, private collection, held by Ecology Division, DSIR;
(6) R. P. Buckingham & G. P. Elliott, Ecology Division collection;
(7) K. L. Owen, Wildlife Service, collection held by Ecology Division, DSIR;
(8) M. J. Meads & H. Moller, National Museum collection M52 419;
(9) Gavin Smith, collection held by Ecology Division, DSIR;
(10) B. & J. McCulloch, private collection;
(11) K. D. Smith, collection held by Ecology Division, DSIR;
(12) B. F. Hazelwood, National Museum collection M62 318;
(13) I. J. Payton, private collection;
(14) C. D. Roderick, I. A. E. Atkinson, collection held by Ecology Division, DSIR;
(15) A. J. Beauchamp, A. Cox, J. N. Jolly, collection held by Ecology Division, DSIR;
(16) Wildlife Service, Department of Internal Affairs, collection held by Wildlife Service, Wellington.