

**Abundance of Ragwort Flea Beetle (*Longitarsus jacobaeae*) at  
Five Sites on the West Coast, South Island, New Zealand**

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## Summary

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### Project and Client

Field studies were conducted on the West Coast of the South Island to determine why the ragwort flea beetle has not established and why it has not affected ragwort populations there. The work was carried out by Landcare Research, Lincoln, for the West Coast Ragwort Control Trust, between September 2003 and August 2004.

### Objectives

- To measure the abundance of ragwort plants and number of ragwort flea beetles per plant at five release sites on the West Coast.
- To determine the life cycles of flea beetles and ragwort plants at each site.
- To determine whether rainfall affects flea beetle success and impact on ragwort.

### Results

- Flea beetles were not detected at two sites during the 12 months of recordings. At these sites the density of ragwort plants ranged between 0 and 22 plants/m<sup>2</sup>.
- Flea beetles were present at 3 surveyed sites ranging in density from 0 to 8 per plant. At these sites the density of ragwort plants ranged between 0 and 24 plants/m<sup>2</sup>.
- Multi-crown plants were recorded at one site only, over a 2-month period.
- Rainfall patterns suggested that high rainfall reduces flea beetle density.
- Plant density was not related to flea beetle density.
- There is only one generation of flea beetles per year, but individual adult beetles survived for at least a year.

### Conclusion

- Flea beetle populations on the West Coast cannot grow large enough to significantly affect ragwort plant populations.

### Recommendation

- Further biocontrol agents are needed and the two potential new biocontrol agents should be imported. The crown boring moths *Cochylis atricapitana* and *Platyptilia isodactyla* are better adapted to wet climates like those on the West Coast and southern regions of the South Island and the lower and western North Island.

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## 1. Introduction

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Field studies were conducted on the West Coast of the South Island to determine why the ragwort flea beetle has not reduced ragwort plant populations there. The work was carried out by Landcare Research, Lincoln, for the West Coast Ragwort Control Trust, from September 2003 to August 2004.

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## 2. Background

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The biological control programme against ragwort began in the 1920s and was one of the first biocontrol programmes implemented in New Zealand. Four biocontrol insects have been released: two seed-feeding flies, one foliage-feeding moth, and a root-feeding flea beetle. Only one of the seed-feeding flies has established (*Botanophila seneciella*) and just in the central North Island. The foliage-feeding moth (*Tyria jacobaeae*) has established sporadically throughout both islands, but, although reducing plant seeding and height, has had little impact on plant populations. However, the flea beetle (*Longitarsus jacobaeae*) has established in many areas of New Zealand and has had a major impact on ragwort plant populations. Reductions of 90–100% in plant density have been recorded at many sites in the 2–10 years after initial release and establishment. There are two main exceptions to the successful establishment of the flea beetle and the reduction in ragwort populations—on the West Coast and southern regions of the South Island, and in western parts of the North Island.

Ragwort is a biennial or perennial herb. Early in winter, plants develop into a leafy rosette 2–5 cm high and up to 15 cm in diameter. Daisy-like bright yellow flowers bloom from November to January. Stems are reddish purple and can grow up to 60 cm. Each plant can produce up to 250,000 seeds a year; these can lie dormant in the soil for up to 16 years (Meander Valley Weed Strategy, Tasmania). Ragwort seeds are dispersed by wind and water, on vehicles, machinery, clothing, and in hay and chaff, but the plant can also reproduce vegetatively from cut root fragments.

Ragwort was introduced into New Zealand in 1870 in contaminated seed (Syrett 1983) reaching epidemic proportions during the intensive dairying practices of the 1920s and 30s. Ragwort is a problem on dairy and deer farms because cattle and deer do not eat ragwort, and if they do, its toxic alkaloids can cause liver damage. During the 1930s attempts at control commonly used sodium chlorate. Unfortunately for one farmer, Richard Buckley, when this chemical came into contact with cotton material (namely, his trousers) it explosively combusted (Anon. 2004).

Costs associated with the control and loss in production from ragwort infestations on dairy farms and in conservation areas of New Zealand have not been estimated, although Syrett et al. (1984) stated that \$600,000 of public money was spent on ragwort control in that year. In Oregon, USA, costs associated with lost production, stock health, and herbicide application due to the presence of ragwort have been calculated at US\$5 million per annum (Oregon Department of Agriculture, cited in Syrett 1996).

In Australia, ragwort has reduced milk production by 2% of total production: AU\$1.6 million per annum. The environmental costs of ragwort control were quoted at AU\$1.5–2.0 million per annum. The annual cost of ragwort control and lost production in Australia is conservatively calculated at AU\$4 million per annum (McLaren 1995).

McGregor (2001) reported on field experiments conducted at 11 sites in New Zealand where, in paired plots, ragwort plants were sprayed to remove flea beetles and compared with ragwort on unsprayed plots. The density of ragwort plants and flea beetles in each plot was measured over 2 years at each site. In some cases these plots have been monitored for a further 2 years although spraying was discontinued in 2003. Analysis of data from these sites shows that the flea beetle significantly reduces ragwort plant density within 1–2 years. Once established the flea beetle continues to keep ragwort plant densities at low levels.

Our study was initiated because it was not clear why this success is not reflected at release sites in western areas of New Zealand.

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### **3. Objectives**

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- To measure the abundance of ragwort plants and number of ragwort flea beetles per plant at five release sites on the West Coast.
- To determine the life cycles of flea beetles and ragwort plants at each site.
- To determine whether rainfall affects flea beetle success and impact on ragwort.

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## 4. Methods

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In an earlier study (Smith 2003), beetles had been detected at five release sites on the West Coast. We visited these monthly for one year, from September 2003. The sites were chosen because flea beetles had persisted there for at least 10 years under varying land management practices, from intensive dairying to conservation land. These sites also represented diverse geographical and climatic areas throughout the West Coast region.

**Table 1** Site information and locality.

Site name	Location (NZMG)	Annual rainfall (mm)	Land use	Date of original flea beetle release	Beetle abundance Averaged over the year (adults/rosette)
Tauranga Bay Westport	E2381961 N5932893	2622	dairy	1997 onwards	1.26
Landsborough Valley Haast River	E2221002 N5682600	4478	cattle	7 March 1995	1.24
Cook River Flat	E2256670 N5743842	3421	cattle	4 March 1991	0.02
Porika Hills, Howard Valley	E2482182 N5940632	1784	sheep & cattle	7 April 1988	0.68
Red View Farm, Inchbonnie	E2384366 N5831130	4346	dairy	20 April 1983	0.02

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- At each site 20 juvenile (rosette), 20 mature (bolting), and 20 multi-crown ragwort plants were selected and adult flea beetles collected from them using a leaf sucker. Beetles were counted per plant.
- At 20 randomly selected locations at each site, we counted the total number of juvenile (rosette), mature (bolting), and multi-crown ragwort plants per 0.25-m<sup>2</sup> quadrat.
- At each site we measured and recorded the rosette diameter of 50 juvenile plants, the basal diameter of 50 mature plants, and the total basal diameters of 50 multi-crown plants, to determine the total dry biomass of ragwort per size class of plant per quadrat. Where multi-crown plants occurred, 30 plants, including roots, were collected to calculate the total dry biomass of multi-crown plants.
- Monthly rainfall data were collected for each site and a maximum daily rainfall event was also retrieved from NIWA's National Climate Database (via the CliFlo Web Access Service). Data for daily temperatures was not available for these sites.
- Twenty beetles from each site were placed in vials of 70% alcohol and later dissected in the laboratory to determine the state of the wing muscles: newly emerged adults have

wing muscles but older beetles lose their wing muscles after summer aestivation and mating.

- Landowners were asked if any weed control, or other relevant treatments, had taken place on the pasture. During sampling we noted the weather and recorded an estimate of soil moisture content. Other features of the pasture were also recorded, (e.g. pasture length, how heavily grazed the pasture was, snow fall, extreme weather events, and spraying)
- To compare data on ragwort and beetle numbers elsewhere in New Zealand, information was extracted from McGregor (2001) on the density of ragwort plants and the mean number of flea beetles recorded per rosette.

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## 5. Results

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### Ragwort plant densities and life stages

Ragwort population densities varied considerably between the five sites and over the duration of the study (Fig. 1). Adult flowering plants were only present from Nov/Dec through to Apr/May, after which all adult flowering plants had senesced and died. Juvenile plants were present during most of the year at most sites. Ragwort plants can live longer than two years if adult plants are damaged as they flower; typically, such plants produce multi-stemmed crowns the following season. In this study, only two such plants were recorded, at just one site (Tauranga Bay), suggesting that most ragwort plants at the study sites were destined to be biennial. Juvenile plants were generally recorded at much higher densities than adult plants at four of the five sites. Indeed, adult plants were absent from the Howard Valley site (this was true across the entire site, not just within the sampling quadrats, because no adult plants could be found to sample beetles from). The only site where juvenile and adult plant numbers were sometimes equally abundant was Cook River Flat (equal densities of adults and juveniles recorded in Dec 2003 and Feb 2004).

Some variation in ragwort densities could have been caused by weather. For example, the monthly low in the density of juvenile plants in July 2004 at Landsborough Valley might have been caused by recent heavy snow. Some frost damage to ragwort plants was also noted in July 2004 at Cook River Flat. Otherwise, there was no apparent effect of abiotic factors on the abundance of ragwort plants or our ability to sample them (except when sampling was prevented by snow in July at Howard Valley). None of the rainfall measurements (daily peak per month, monthly total, and total for year) were correlated with ragwort density. The rainfall data are summarised in Table 2.

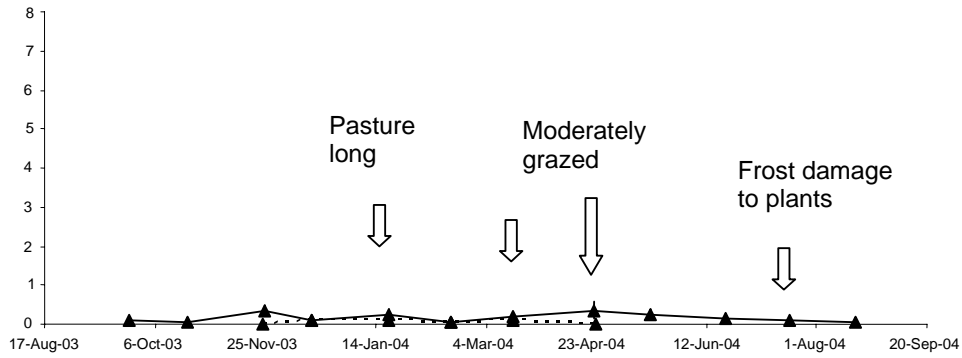
**Table 2** Monthly rainfall in mm.

Site/Month	Tauranga Bay	Landsborough Pleasant Flat	Cook River Flat	Porika Howard Valley	Hills	Red Farm	View
Sept 2003	199	630	588	22		(no record)	
Oct 2003	181	200	422	124		310	
Nov 2003	144	410	484	127		412	
Dec 2003	164	318	476	108		374	
Jan 2004	265	511	728	118		585	
Feb 2004	234	493	783	260		746	
Mar 2004	86	382	491	38		484	
Apr 2004	105	76	122	28		136	
May 2004	230	460	606	158		400	
Jun 2004	323	555	618	(no record)		677	
Jul 2004	133	158	277	86		190	
Aug 2004	201	430	446	178		563	
Yearly Total	2265	4623	6041	1247		4877	

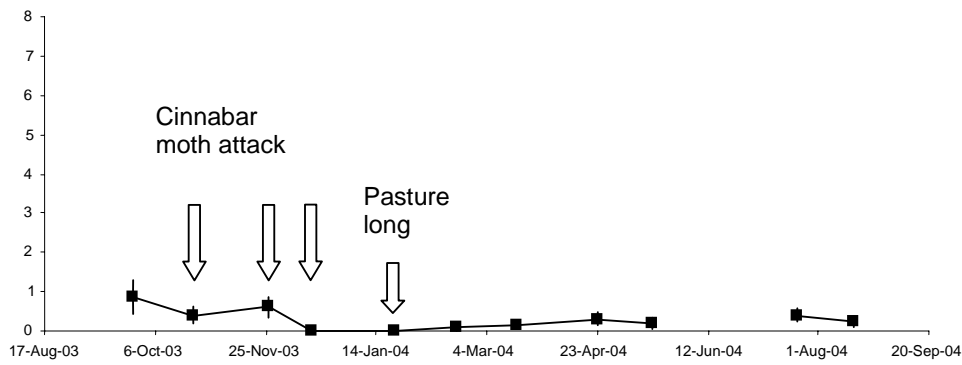
In May at Tauranga Bay, ragwort may have been reduced by very heavy grazing pressure, with actual grazing damage to ragwort plants being reported (the only time this was reported in the study). This direct stock feeding and/or pasture damage at Tauranga Bay may explain why this was the only site having multi-crowned ragwort plants. Furthermore, this very heavy grazing, which included high levels of hoof damage to the pasture, may explain why this site had the highest abundance of juvenile rosette plants by the end of the study period. Heavy grazing and hoof damage open up the pasture, creating suitable microsites for ragwort seeds to germinate and seedlings to develop. The grazing patterns and final densities of juvenile ragwort plants at the other sites are consistent with this hypothesis. Thus, at the end of the study period, abundance of ragwort rosettes was low or very low at Cook River Flat, Howard Valley and Inchbonnie. These were the only three sites where long pasture was reported during the study, and where heavy grazing was not reported (although it was moderate on one date at Cook River Flat) (Fig. 1).

At Inchbonnie rosette plants were most abundant at the start of sampling (Sept/Oct 2003). Pasture Kleen® was applied at the end of November, and may have reduced the number of juvenile plants, but the grass was very long at this time so interspecific competition was also probably high. However, this site still had the highest densities of adult flowering plants in the study, and thus, probably the highest seed production. The scarcity of juvenile ragwort plants at the end of the study period at this site was surprising, especially since no flea beetles were collected there on any sampling date. This scarcity of juvenile plants could be due to a long-lasting effect of the herbicide on ragwort seedling recruitment from seed, and/or a result of low stock grazing pressure during the study.

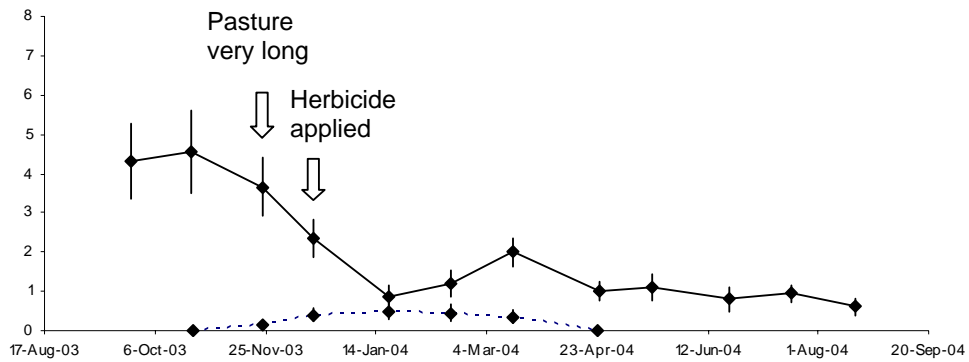
**a) Cook River Flat**



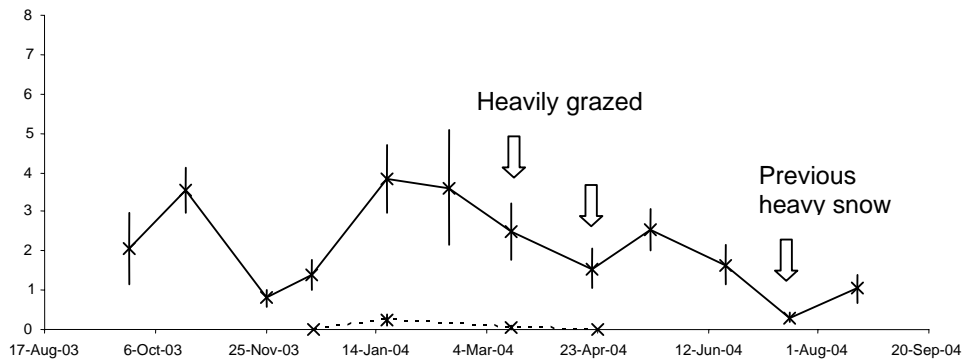
**b) Howard Valley**



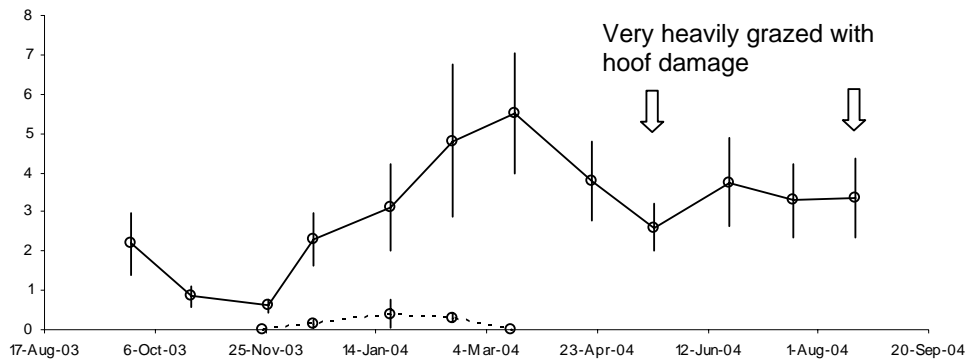
**c) Inchbonnie**



## d) Landsborough

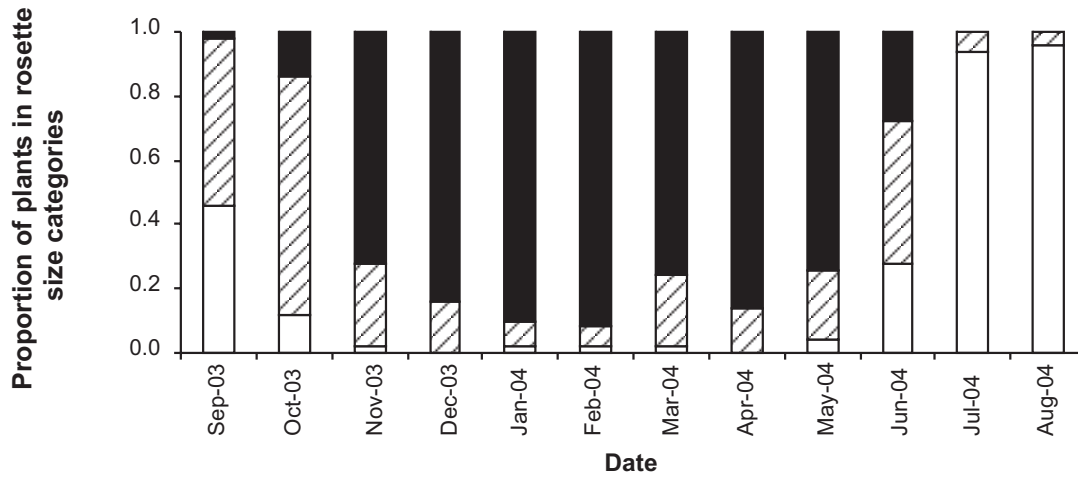


## e) Tauranga Bay

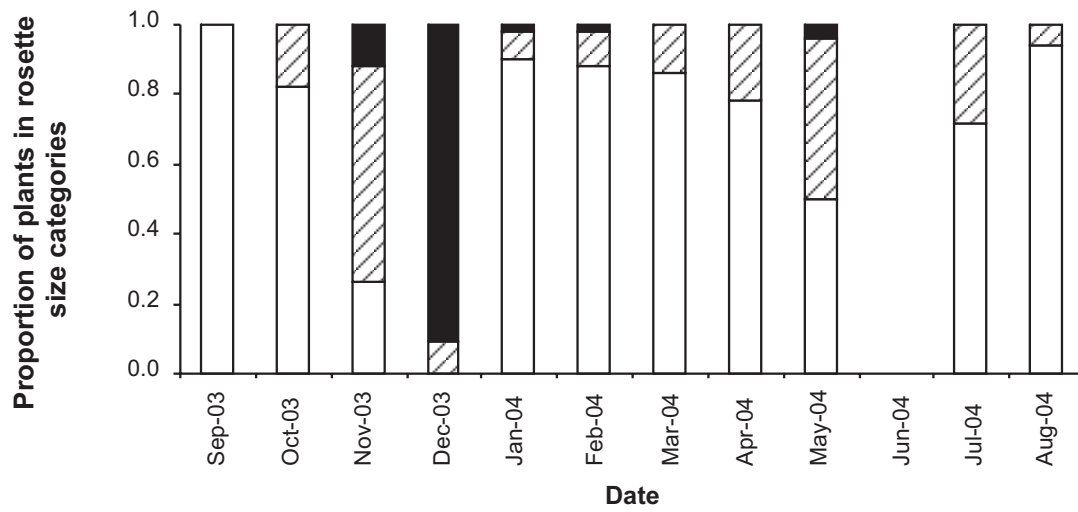


**Fig. 1** The number of ragwort plants per 0.25 m<sup>2</sup> quadrat during the study period. Plants were recorded as juvenile (rosette stage) shown as solid lines, or as adults with flowering stem(s) shown as dotted lines. Each point is a mean of 20 quadrats per date per site; bars are  $\pm$  one SEM.

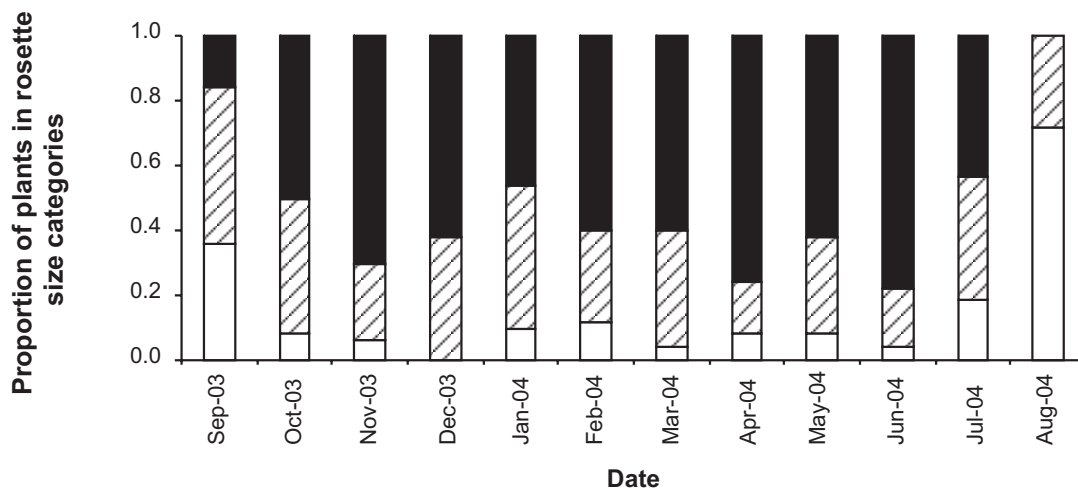
**a) Cook River Flat**

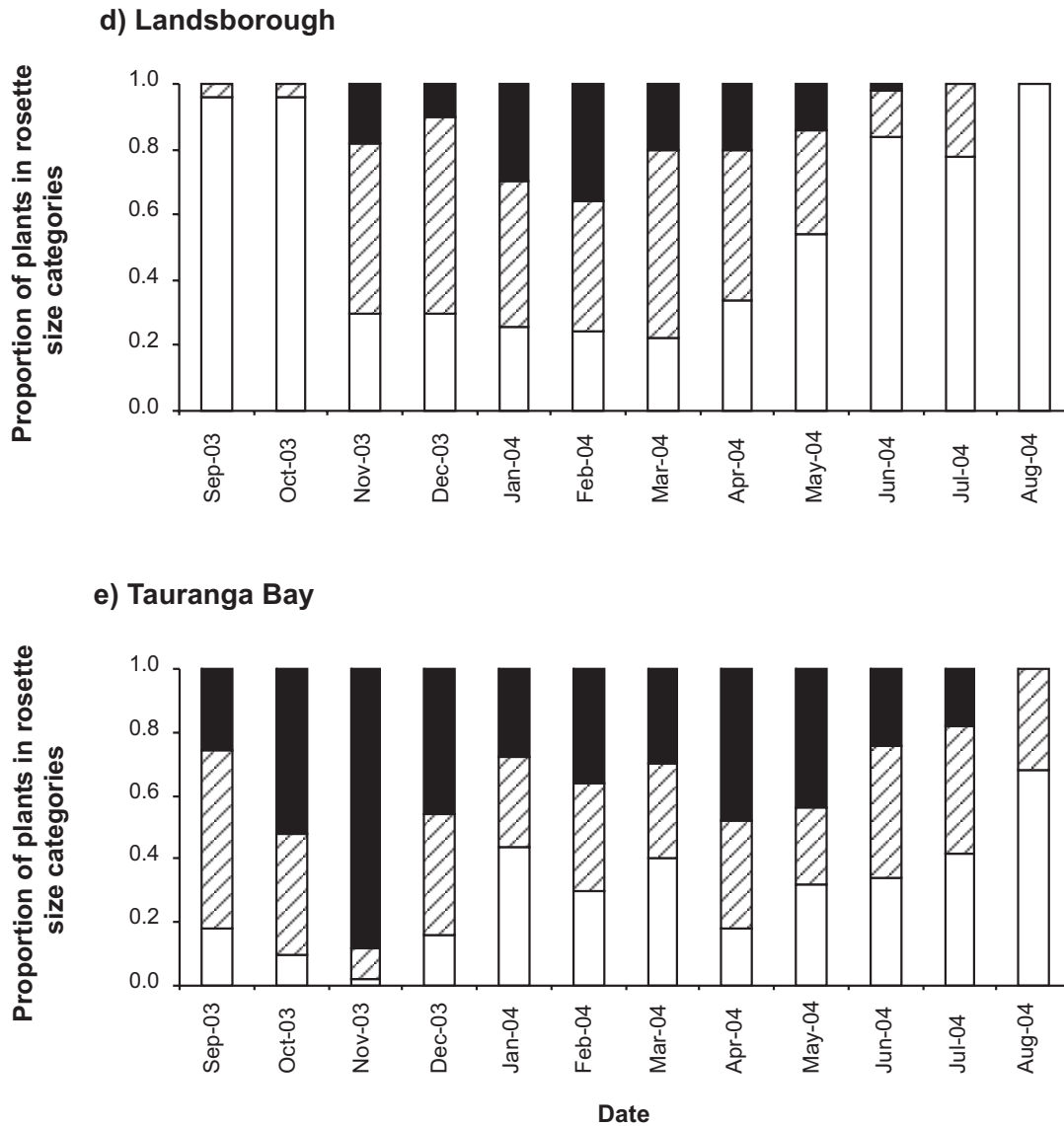


**b) Howard Valley**



**c) Inchbonnie**





**Fig. 2** The proportions of juvenile plants at the five sites with rosette diameters  $\leq 10$  cm (clear bars),  $>10$ – $\leq 20$  cm (hatched bars) and  $>20$  cm (solid bars) through the sampling period. All samples comprised 50 plants except for Howard Valley in Dec 2003 when only 11 plants could be found at the site. Data are absent for Howard Valley in June 2004 because snow prevented sampling.

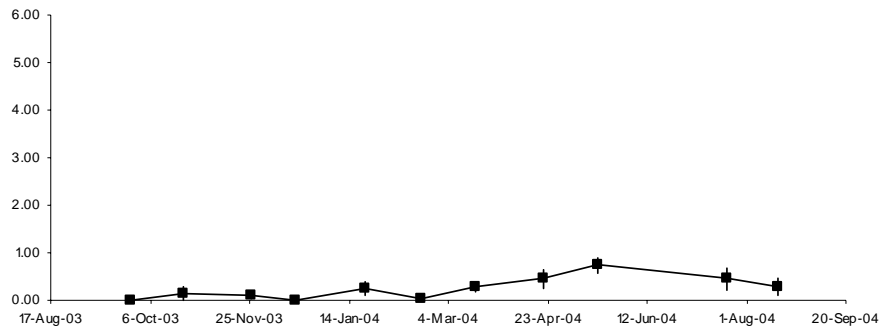
At the two sites where heavy grazing was reported, namely, Landsborough and Tauranga Bay, rosettes persisted throughout most of the year (Fig 2d and 2e). This suggests that seedlings were recruited over a much longer period than at some other sites. At two sites (Cook River Flat and Inchbonnie) where grazing levels were low and grass was long at least once during the study period, the proportion of juvenile ragwort plants was high only over winter, particularly July, August and September. This suggests that recruitment mostly occurs during these months and that those high levels of competition from pasture species and a lack of microsites for seedling establishment restricted recruitment at other times of the year.

These patterns also suggest that small rosette plants suffered high mortality at Landsborough and to a lesser extent at Tauranga Bay, because the proportion of medium and large rosettes was low. This mortality could have been caused by the same high level of grazing and trampling that opens up pasture and allows seed germination and recruitment. Some flea beetles were present at these two sites during these periods of suspected high seedling recruitment and mortality, with beetle numbers at Tauranga Bay reaching about 2 per rosette; although this was still well below the effective numbers recorded by McGregor (2001), it could perhaps have affected small plants.

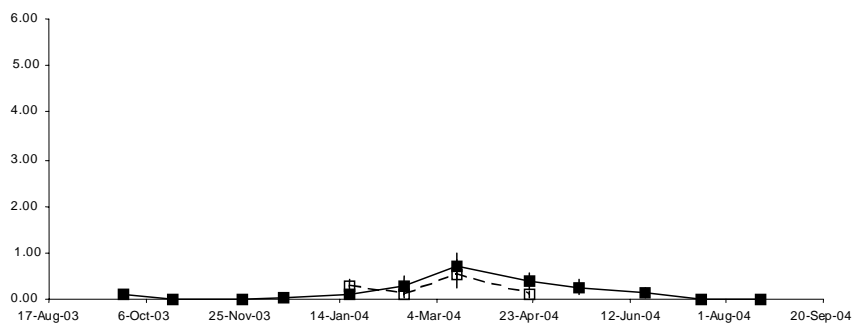
However, the Howard Valley results are not consistent with the above reasoning, with a very different pattern of the relative proportions of small to medium to large ragwort rosettes (Fig. 2c). Given the high proportion of small rosettes throughout most of the year, it appears that recruitment from seed, and probably young rosette mortality, was high for much of the year. There were no reports of heavy grazing or other pasture damage at this site, but many cinnabar moth larvae were reported in Oct 2003, with extremely high levels of attack by cinnabar moth larvae in Dec 2003. Then, nearly all the ragwort plants at the study site had been killed by cinnabar moth larvae and in fact only 11 plants could be located for the measurement of rosette size (normal sample size 50). None of these 11 rosettes flowered at this site; indeed, after several months no large rosette plants were recorded in the 50 plant samples. Therefore, it seems unlikely that any of the remaining large rosettes recorded in December survived the cinnabar attack (previous reports often suggest that ragwort rosettes can recover later in the year, and produce large, multi-crowned plants the following summer). At this site, in late 2003, cinnabar moth larvae may have destroyed all large rosettes thus achieving at least a temporarily successful level of control (no adult plants were produced at this site in summer 03/04). The long pasture in Jan 2004 probably contributed to suppression of ragwort by the biocontrol agent. Subsequently, monthly densities of ragwort plants remained very low (Fig 1c) and nearly all plants were less than 20 cm diameter until May 2004 (Fig 2c). Few of these small rosettes appeared to develop into larger rosettes, probably due largely to competition from pasture grasses: there were no reports of any high levels of grazing at this site during the study period. The number of flea beetles reported over this period never exceeded 1 per plant; however, with the small average rosette size, this might have been sufficient to have some synergistic impact with interspecific competition.

## Flea beetle densities and life stages

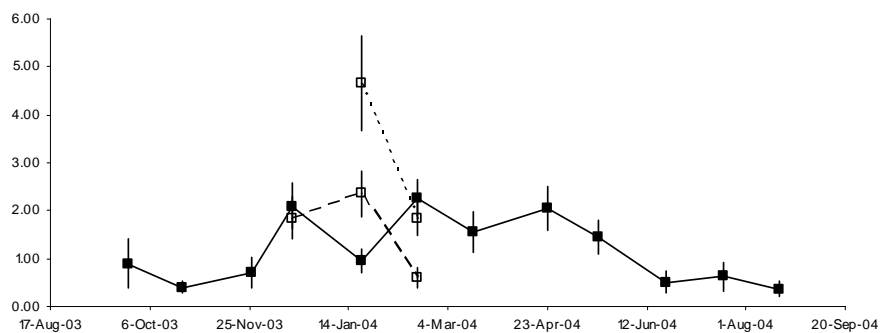
## a) Howard Valley



## b) Landsborough



## c) Tauranga Bay



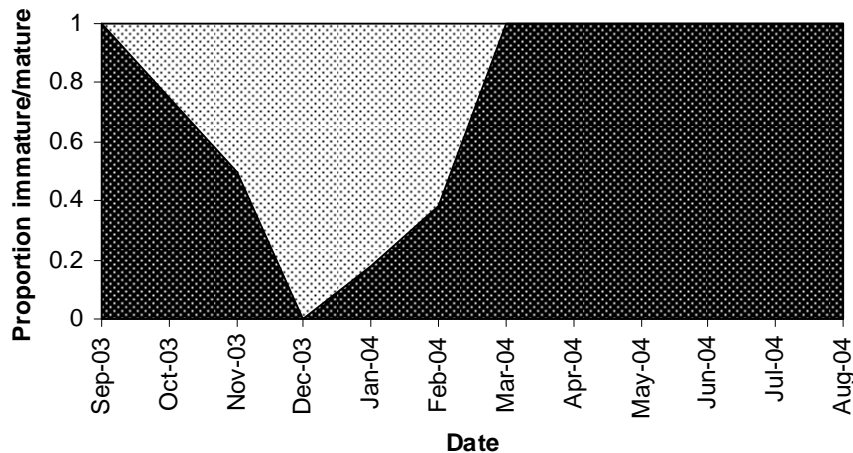
**Fig. 3** Mean number ( $\pm$  SEM) of beetles per plant at the three sites where they were found. Samples were from 20 plants except on a few occasions when fewer than 20 could be located. Three plant types were sampled: juveniles (rosettes)—solid lines; adults (one flowering stem)—dashed lines; multi-stemmed adults—dotted lines (these only occurred at Tauranga Bay). In 2003–2004 no ragwort plants matured at the Howard Valley site.

Plant density and flea beetle density were not related at any of the sites sampled. The highest numbers of beetles recorded were from multi-crowned plants (mean peak of over 4 per plant—Tauranga Bay Jan 2004). Also, numbers of beetles on single-stemmed adult plants peaked on this date, coinciding with a marked decrease in the number of beetles collected from juvenile plants. This suggests that multi-crowned plants attracted beetles from the smaller single-stemmed and rosette plants. However, previous studies show that although adult beetles can be abundant on large, multi-crowned plants, the number of larvae inside the roots is low per gram of dry weight, compared to rosette plants.

In general, beetle numbers at the three sites were lowest in winter/spring and increased over summer/autumn. The numbers of beetles collected was not related to monthly rainfall, peak daily rainfall (per month), or weather conditions. However, there was a trend towards high annual rainfall and flea beetle density suggesting that beetle density was lower at high annual rainfall sites. The only time weather interfered with beetle collection was when sampling was impossible due to snow cover (July 2004, at Howard Valley).

The ratio of males to females in each sample was approximately 1:1 at the Howard Valley site and did not differ significantly over the year. However, at Tauranga Bay and Pleasant Flat Valley twice as many males as females were collected during the year.

Dissections showed that new adults were present from September to March, peaking in December (when no sexually mature adults were collected at any site).



**Fig. 4** The proportion of dissected adult female beetles that were mature (dark areas) and immature (pale areas) during the study period.

Oviposition by adult beetles occurs after aestivation, when the adults are sexually mature, and would probably be around March to August each year.

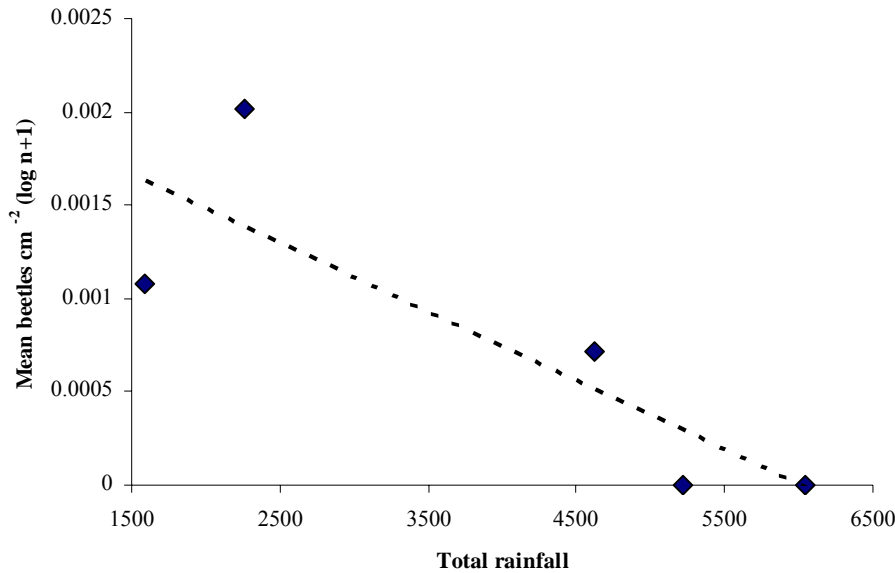
To determine whether the beetle numbers per rosette shown in Fig 3 are in the range where impacts on individual plants might be expected, we can examine the data from impact experiments carried out by Regional Council staff in collaboration with Landcare Research (McGregor 2001).

With the exception of the Southland site, all sites above the dotted line (with maximum beetle numbers  $\geq 8$  per rosette) showed changes in plant density consistent with successful suppression by the flea beetle. Conversely, all the sites with maximum beetle numbers per rosette  $\leq 4$  showed no indication of any effective suppression of plant density by ragwort flea beetle.

Table 3 suggests that the impacts of the flea beetle on ragwort plant density are only likely when beetle numbers per rosette exceed 4 (McGregor 2001). However, the mean beetle numbers per rosette in our West Coast study never exceeded 3 per rosette. The numbers per individual rosette plant only exceeded 4 at one site, Tauranga Bay and this threshold was exceeded on only 7 out of the 12 monthly sampling dates, although only on 15 rosettes out of the total of 240 sampled during the study year. The highest number of beetles recorded from a single rosette was 10 beetles at Tauranga Bay on 25 Sept 2003, which is still relatively low compared to the numbers in Table 3 (McGregor 2001).

**Table 3** Maximum ragwort density and maximum beetle numbers per rosette, from McGregor (2001). The comments refer to the results at each site (see text or McGregor (2001) for further details).

Site	Max ragwort density	Max beetle numbers	Comments
Orere Farms (Auckland)	2.3	50	Dramatic drop in plant numbers in water sprayed plots compared with plots treated with Hallmark insecticide
Southland	1.8	25	Fluctuating numbers of ragwort plants but no effects of Hallmark insecticide despite large beetle numbers
H/I BoP	1.3	15	Large drop in plant numbers before Hallmark insecticide used
Wellington	1.6	11.2	Large drop in plant numbers before Hallmark insecticide used
Manawatu-Wanganui	0.4	10.6	Ragwort numbers very low at start, but significant increase in plant density when Hallmark insecticide applied
Sisam, BoP	3.5	8	Large drop in plant numbers before Hallmark insecticide used
McCann BoP	1.1	4	No significant changes in plant numbers, over time or in presence/absence of Hallmark insecticide
Alcove Properties	2.4	3	Complex patterns perhaps due to Kikuyu grass competition
Nett. BoP	1.4	1	No significant changes in plant numbers, over time or in presence/absence of Hallmark insecticide
Taranaki	1.3	1	No significant changes in plant numbers, over time or in presence/absence of Hallmark insecticide
West Coast	13	1	No significant changes in plant numbers, over time



**Fig. 5** Mean number of ragwort flea beetles collected per unit area (square cm) of juvenile plant plotted against the total recorded rainfall for the study year at each of the five sites. The relationship approaches statistical significance ( $P = 0.07$ ,  $r^2 = 0.61$ ,  $y = -3.7 \times 10^{-7}x + 0.0022$ ,  $F_{(1,3)} = 7.20$ ).

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## 6. Discussion

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The presence of wing muscles in adult beetles in spring indicates that adults are newly emerged from pupae in the soil; these adults usually disperse, feed briefly, then aestivate or rest over the summer months. During this time the wings disappear and their muscles atrophy. In autumn the rested adults mate and begin to lay eggs on leaves of rosette plants. The pattern of wing muscle appearance in adult beetles on the West Coast shows that the flea beetle has a single generation per year, that the females live for about a year and that they are capable of laying eggs throughout the rest of the winter and following spring (Fig.1).

When rainfall for each site was overlaid onto the graphs of beetle and plant density, these events appeared not related. Thus, although the high rainfall on the West Coast may affect beetle density, this remains unproven.

Ragwort typically has a biennial life cycle, but will behave as a perennial if the flowering stalk is cut, grazed, mowed, trampled, or mechanically injured while flowering. After such damage, the plant can regenerate from crown buds, root fragments or intact roots. When flowers are removed before they set seed, the plant can reflower later the same season. Defoliated rosettes will continue to grow indefinitely as vegetative perennials. The heavy stocking regime at the Tauranga Bay site appears to have allowed perennial plants to survive

and set much seed; it may also have created gaps in the pasture and allowed substantial seedling recruitment throughout the year.

The density of ragwort populations was much higher at sites on the West Coast (up to 16/m<sup>2</sup> at Landsborough and 22/m<sup>2</sup> at Tauranga Bay, with an average of 13/m<sup>2</sup> for all sites) compared to sites on the East Coast (maximum of 14/m<sup>2</sup> at one site, but an average of 5/m<sup>2</sup>). The comparison also shows that the density of flea beetles is much the same on East Coast sites, where ragwort has been controlled by the flea beetle (a mean of 40 beetles per plant at one site), than West Coast sites (a maximum of 10 but an average of 1 beetles per plant) (McGregor 2001).

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## 7. Conclusion

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The most likely explanation for the inability of the ragwort flea beetle to reduce ragwort populations on the West Coast is because of the overwhelming density and growth of ragwort plants. High rainfall promotes ragwort plant growth and seedling germination while at the same time having a possible negative effect on flea beetle populations. The level of beetles per plant was lower at the West Coast sites than some East Coast sites where control has been achieved by the flea beetle. This suggests that under West Coast conditions, where soils favour ragwort growth and rainfall is plentiful, ragwort can compensate for flea beetle damage through recruitment; moreover, it seems flea beetle populations under West Coast conditions do not increase sufficiently to affect ragwort populations.

Overseas studies have shown that ragwort populations increase with increased rainfall and ground disturbance. Both these events are common on the West Coast. These studies have also shown that flea beetle larval density per plant drops as plants become larger. We do not have data from several sites to compare average plant size, but if plants growing in the favourable West Coast conditions are larger and live longer than plants elsewhere in New Zealand this would also limit the ability of the flea beetle to reduce ragwort populations.

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## 8. Recommendation

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Because flea beetle populations on the West Coast seem unable to increase to levels high enough to affect ragwort plant populations, further biocontrol agents are needed.

Two new potential biocontrol agents should be imported. These are the crown boring moths *Cochylis atricapitana* and *Platyptilia isodactyla*, which are better adapted to wet climates such as those on the West Coast, in Southland, and in the lower and western North Island.

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## 9. Acknowledgements

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My grateful thanks go to the farmers, farm owners, land managers and farm managers who allowed us to visit their properties and conduct these surveys.

Thanks to Guy Forrester, Biometrician, Landcare Research whose valuable advice assisted with the data collection and analysis.

This project was funded by the West Coast Ragwort Control Trust.

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## 10. References

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