Environmental effects of rodent Talon® baiting

Part I: Monitoring for toxic residues

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Part II: Impacts on invertebrate populations

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Part I Monitoring for toxic residues

Abstract

Although Talon® baits containing brodifacoum have been used successfully in eradicating rats from some of New Zealand's offshore islands, little is known about any environmental effects of this toxin. We sampled invertebrates, blackbirds, soil, and water at intervals of 2 days to 9 months to determine whether brodifacoum residues were present after aerial distribution of Talon® 20P cereal pellets on Red Mercury Island and after bait-station use of Talon® 50WB wax-coated cereal blocks on Coppermine Island. No brodifacoum residues were found in soil, water, or most (99%) invertebrate samples. Low to moderate residues were found in one sample of slugs collected 2 days after aerial sowing. Tissues from all birds (n=4) and rats (n=3) found dead and livers from all six birds collected alive 8 months after aerial baiting also contained low to moderate residues. These preliminary results suggest that few invertebrates are likely to be contaminated as a result of Talon® baiting. Tentatively, we suggest that although some invertebrates may eat Talon® baits, it appears that the brodifacoum is either metabolised and/or excreted within a few days. The dead blackbirds found, therefore, were more likely to have been killed by primary than by secondary poisoning. Further monitoring for brodifacoum residues after Talon® operations should be undertaken to confirm that contamination of invertebrates, soil, and water is unlikely. Some bird species may be at risk from Talon® baiting. Likely effects on population levels of such species should be considered to help assess the risk and benefits of Talon® use in rodent eradication.

1. Introduction

The environmental effects of baiting for rodent control with Talon® were investigated in two studies for the Department of Conservation by Manaaki Whenua – Landcare Research, Lincoln. Part I of this report describes monitoring for toxic residues of brodifacoum after control operations using Talon® on Red Mercury Island (aerial control) and Coppermine Island (bait-station control). The work was conducted during August 1992–July 1994. The impact of Talon® baiting on invertebrate populations is detailed in Part II (Spurr 1996).

1.1 BACKGROUND

Although Talon® 20P and Talon® 50WB have been used successfully to eradicate rats from islands (Buckle & Fenn 1992), little is known about the environmental effects of control operations using these types of toxic bait in New Zealand. It has been suggested that invertebrates are unlikely to be directly killed by brodifacoum (Shirer 1992), but invertebrates are known to feed on Talon® baits (Wright & Eason 1991, unpublished Forest Research Institute contract report; Morgan 1994, unpublished Landcare Research contract report). Consequently, invertebrates may pose a risk of secondary poisoning to insectivorous birds. The preliminary review on brodifacoum toxicity to birds and bats that preceded this study (Eason & Spurr 1995) recommended that the risk of secondary poisoning of insectivorous non-target species from brodifacoum should be assessed by conducting residue analyses for the toxin in invertebrates, water, and soil. A monitoring study was therefore conducted to provide information that will contribute towards an assessment of the possible environmental hazards posed by use of Talon® baits.

1.2 OBJECTIVE

To determine residue levels and persistence of brodifacoum in invertebrates, rodents, birds, soil, and water after aerial and bait-station Talon® operation for rodent control.

2. Methods

Environmental monitoring of brodifacoum was carried out after two Department of Conservation (DoC) rodent control operations, one using aerially sown bait, the other using baits in bait stations.

Talon® 20P was aerially sown at 15 kg/ha on Red Mercury Island on 1 October 1992. Live invertebrate samples (Table 1) were collected randomly by hand at up to six widely distributed circular plots of 10 m radius (selected for relative abundance of invertebrates) 4–8 days before and 2–3, 9, 30, and 240 days after baits were sown. Samples were frozen shortly after collection using liquid nitrogen and returned to our laboratory for sorting and assay. Dead blackbirds and rodents were collected during ground searches in the week after aerial sowing. Six live blackbirds were collected 9 months afterwards (four in mist nets, two by shooting). Soil and water samples were collected 1 month after aerial sowing. Samples (200 g) of topsoil were collected in plastic bags at nine widely distributed sites, and water samples (200 ml) were collected in glass bottles from small streams in different parts of the island. The sampling schedule is summarised in Figure 1.

Talon® 50WB baits were placed in tunnel-type bait stations on Coppermine island from September 1992 to May 1993. Live invertebrates were collected by searching vegetation 0–1 m above ground within 12 m of six bait stations, 16–19 days before and 13, 27–31, 57, and 101 days after baiting started. Soil samples (200 g) were collected under five bait stations and at five sites equidistant

TABLE 1. NUMBERS OF SAMPLES OF INVERTEBRATE TYPES COLLECTED ON RED MERCURY AND COPPERMINE ISLANDS. EACH VALUE INDICATES THE NUMBER OF SAMPLES POOLED FOR AN INDIVIDUAL ASSAY.

INVERTEBRATE TYPE ORDER)	RED MERCURY ISLAND					COPPERMINE ISLAND (AND				
	Days before	Days after sowing				Days before	Days after start			
	4-8	2-3	9	30	240	16-19	13	27-31	57	101
Slater (Isopoda)	11	6	5	3	0	4	2	3	6	<1
Spider (Araneae)	7	3	4	6	4	4	3	6	4	4
Millipede (Diplopoda)	11	2	2	2	4	12	5	8	5	7
Centipede (Chilopoda)	4	1	1	2	0	2	3	4	5	6
Cockroach (Blattodea)	6	0	1	0	2	8	3	5	6	7
Ant (Hymenoptera)	0	0	1	1	0	0	0	0	0	0
Beetle (Coleoptera)	2	0	1	0	1	13	2	6	3	5
Insect larvae (unidentified)	5	0	5	1	0	2	1	4	3	0
Wasp (Hymenoptera)	0	0	0	0	0	1	0	0	1	0
Ground weta (Orthoptera)	0	0	0	0	0	4	4	5	2	9
Cave weta (Orthoptera)	4	1	1	1	4	11	2	2	4	2
Slug (Gastropoda, order unknown)	0	2	1	2	1	0	0	0	0	0
Snail (Gastropoda, order unknown)	1	1	1	0	3	0	2	1	1	0
Worm (Opisthopora)	4	4	5	7	4	0	4	6	6	7

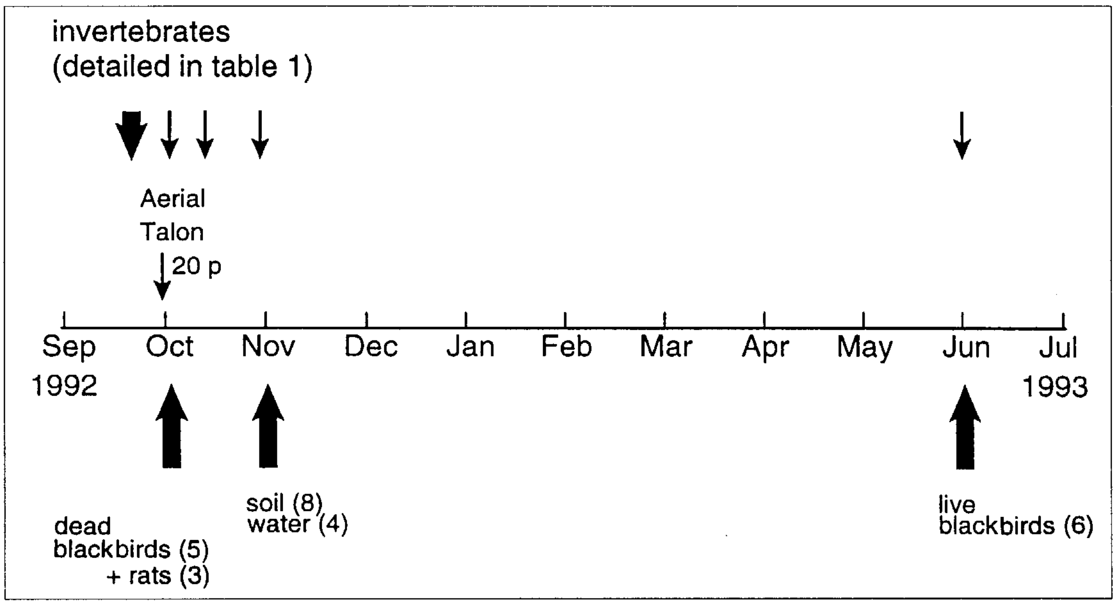

FIGURE 1. SCHEDULE FOR COLLECTION OF SAMPLES ON RED MERCURY ISLAND.

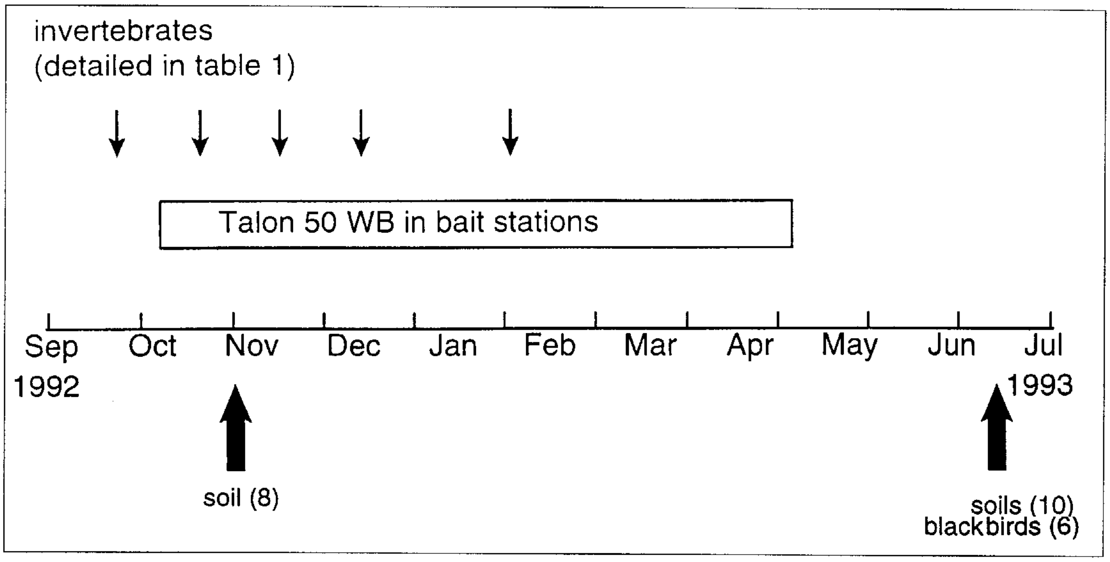

FIGURE 2. SCHEDULE FOR COLLECTION OF SAMPLES ON COPPERMINE ISLAND.

between bait stations, 1 and 9 months after bait stations were established. The sampling schedule is summarised in Figure 2.

Invertebrate samples were sorted in the laboratory into orders (Table 1). Depending on abundance at sampling sites, samples comprised from 1 to 8 individual animals. To provide sufficient material for analysis, the invertebrate types (i.e., as orders) collected from all sites on each sampling occasion were pooled. Samples from the two islands were, however, sorted and pooled separately.

Samples from the two islands were assayed separately for brodifacoum content using high-performance liquid chromatography, which can detect brodifacoum at 0.0001 Mg/ml in water, 0.004 Mg/g in vertebrate tissues (liver or gizzard), 0.02 Mg/g in soil, and 0.05 Mg/g in invertebrate tissues. Consumption of 0.002 g of Talon© 20P bait by a 1-g invertebrate (or pooled sample of invertebrates) would result in a concentration of 0.05 Mg/g.

3. Results

No residues of brodifacoum were found in soil, water, or most (99%) invertebrate samples from Red Mercury and Coppermine Islands. One sample of slugs, collected on Red Mercury Island 2 days after aerial sowing, contained 0.12 Mg/g brodifacoum. All tissues from birds (n=4) and rats (n=3) found dead after aerial sowing contained low to moderate levels of brodifacoum (0.6-11.0 Mg/g), and livers from all six birds collected alive contained low to moderate levels of brodifacoum (0.004-0.2 Mg/g).

4. Conclusions

The invertebrate analyses contrast with a previous field finding, at Puketi Forest, of 1080 residues in invertebrates after aerial poisoning (Eason et al 1993). Our study suggests that few invertebrates are likely to be found contaminated with brodifacoum as a result of bait station use of Talon® 50WB or aerial sowing of Talon® 20P. This could be because:

- Invertebrates do not find baits.
- The baits are unpalatable to invertebrates.
- Brodifacoum is readily metabolised and/or excreted by invertebrates.
- The brodifacoum assay is too insensitive.

Failure to find baits was improbable, especially after aerial sowing, where baits were distributed on average at approximately 1 bait/1.3 m^2. Failure to feed on baits is also an unlikely reason for the lack of residues in invertebrates. In a related investigation, 14 out of 22 weta (*Hemideina crassidens* and *Gymnoplectron edwardsii*) fed on Talon® 20P, and 5 of them ate 50WB. Fifteen of 15 ground beetles (*Megadromus bullatus*) fed on 20P, and 7 of them fed on 50WB. Talon® 20P was clearly the bait type preferred by these species.

It is therefore possible that some invertebrates did feed on Talon® baits, but the brodifacoum was eliminated quickly. In another recent preliminary study, orally administered brodifacoum was eliminated from large-headed bush weta (*Hemideina crassidens*) within 4 days (Eason & Wright, unpublished data). This is more rapid than elimination of brodifacoum in vertebrates, but the result requires further verification in weta allowed free access to baits.

The sample pooling procedure we adopted was designed to increase the chances of detecting brodifacoum contamination, and although contamination of individual animals may be diluted by pooling with uncontaminated animals, we believe the procedure is more likely to detect residues than the same amount of laboratory analysis applied to spot-sampling of individual animals. The limit of detection equates to consumption of 0.002 g of bait by a large invertebrate, such as a weta, weighing 1 g, or a pooled 1 g sample of a smaller invertebrate, such as millipedes. Even if it is assumed that all invertebrate tissues contained brodifacoum at a concentration of 0.045 µg/g, which is just below the lower limit of detection (i.e., 0.05 µg/g), the risks of secondary poisoning are very low. For example, a southern black-backed gull (the most susceptible avian species for which data are given in Eason & Spurr (l995)) weighing 1 kg would have to consume 16.6 kg of such contaminated invertebrates to receive an LD_{50} dose of the toxin. Therefore, even if our laboratory assay for brodifacoum in invertebrate tissues was too insensitive, it is extremely unlikely that undetected levels of brodifacoum presented a hazard to insectivorous birds.

As so few invertebrates were found contaminated on the two islands, the brodifacoum residues found in dead blackbirds and those collected alive probably resulted from direct consumption of bait rather than from feeding on contaminated invertebrates. Since no dead birds with brodifacoum residues were found on Coppermine Island, it appears that the risk of poisoning birds can be reduced by placing bait in bait stations. However, this may be impractical on larger islands with inaccessible terrain. The possibility of non-target kills occurring after aerial operations may be outweighed by the benefits of habitat improvement gained by rapid removal of rodents. Nevertheless, such a management decision should be supported by information on the likely response of populations of non-target species to Talon® 20P baits.

As no residues were detectable in the soil or water samples, significant soil and water contamination appear unlikely as a result of Talon® baiting, either from aerial or bait station applications.

5. Recommendations

Further monitoring for brodifacoum in invertebrates, soil, and water under normal operational use should be undertaken at other sites to determine the general applicability of the findings to date.

The metabolism and/or excretion of brodifacoum by captive weta should be further investigated to determine the fate of the toxin.

Studies should be done to determine which bird species in the wild feed on Talon® baits, and the likely impact on bird populations.

We emphasise the preliminary nature of this study and caution against extrapolating our findings to other situations where Talon® baits may be used.

6. Acknowledgements

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Part II Impacts on invertebrate populations

Abstract

Talon® 20P and Talon® 50WB containing brodifacoum have been used successfully to eradicate rodents from islands in New Zealand, but little is known about the effects of the toxin on non-target invertebrates. Invertebrates could decrease as a result of being poisoned or increase as a result of reduced rodent predation. To ascertain any effects, ground-dwelling invertebrate populations were sampled by pitfall traps set in four small isolated forest reserves near Pelorus Bridge, Nelson. Each area received different treatments: in the first, Talon® 20P was distributed by hand to simulate aerial distribution at 10 kg/ha; in the second, Talon® 50WB was placed in bait stations on a 50 × 50 m grid; in the third, rat and mouse traps were set on a 50 × 50 m grid; and in the fourth, there was no treatment. Traps were emptied and re-set monthly for 1 year before and after initiation of treatments. Trapped invertebrates were counted and sorted into orders and/or families. Analysis of variance of results for16 invertebrate taxa had the power to detect decreases of >67% and increases of >200% in their abundance. Changes as great as these occurred in about 5% of the month-to-month comparisons, but these were attributed to chance, not to the effects of Talon® baiting.

1. Introduction

The environmental effects of Talon® baiting for the control of rodents (*Rattus exulans, R. norvegicus, R. rattus*, and *Mus musculus*) have been investigated in three studies for the Department of Conservation by Manaaki Whenua - Landcare Research, Lincoln. The first study reviewed the literature on the toxicity and sub-lethal effects of brodifacoum, the active ingredient in Talon® baits, in birds and bats (Eason and Spurr 1995). The second study, which forms Part I of this publication (Morgan and Wright 1996), monitored residues of brodifacoum in invertebrates, birds, soil, and water after control operations on Red Mercury Island (baits applied aerially) and Coppermine Island (baits in bait stations). The third study, reported here, monitored impacts of rodent control operations on invertebrate populations in four forest reserves near Pelorus Bridge, Nelson, between October 1992 and October 1995.

1.1 BACKGROUND

Talon® 20P and Talon® 50WB baits containing brodifacoum have been used successfully to eradicate rodents and brushtail possums (*Trichosurus vulpecula*) from islands in New Zealand (e.g., Taylor 1984, Moors 1985, Thomas and Taylor 1988, Towns 1988, Taylor and Thomas 1989, 1993, Brown 1993, Towns et al. 1993). Invertebrates (e.g., ground beetles, earwigs, slugs, snails, spiders, weta, woodlice, and worms) have been seen feeding on Talon® baits intended for rodents (see Appendix 8.1 for scientific names of invertebrates), and residues of brodifacoum have been found in ground beetles collected from bait stations containing Talon® 50WB (Wright and Eason 1991, unpublished Forest Research Institute contract report) and in slugs collected after aerial application of Talon® 20P (Morgan and Wright 1996). However, little is known about the environmental effects of Talon® baiting. Do invertebrates that have eaten Talon® bait pose a risk of secondary poisoning for insectivorous bats, birds, or lizards? At the maximum concentration of brodifacoum detected in the beetles, a 10 g bird such as a tomtit (*Petroica macrocephala*) would have to eat about 3 g of beetles (i.e., about 30 beetles) to receive a lethal dose of brodifacoum (Wright and Eason 1991, unpublished Forest Research Institute contract report). Does brodifacoum kill invertebrates? No data are available, but anticoagulants are generally considered unlikely to affect invertebrates, which have different blood-clotting systems from vertebrates (Shirer 1992). The toxicity of brodifacoum to invertebrates is being investigated with funding from the Foundation for Research, Science and Technology (C.T. Eason, pers. comm.). Even if brodifacoum does not kill invertebrates directly, does it affect their behaviour or breeding? Are invertebrate population numbers affected? Do they decrease as a result of Talon® poisoning, or do they increase as a result of reduced rodent predation? This study addresses the last two questions.

1.2 OBJECTIVE

To determine the impact on invertebrate populations of aerial baiting and bait station operations using Talon® for rodent control.

2. Methods

Because of the difficulty of obtaining regular samples from islands, invertebrate populations were monitored in four small isolated forest reserves near Pelorus Bridge, Nelson, selected with the assistance of the Department of Conservation, Nelson. Each study area received a different procedure:

(i) Talon® 20P was distributed by hand on 22 November 1993, one bait/2 m^2, to simulate aerial distribution at 10 kg/ha, in Carluke Scenic Reserve (4.8 ha), bounded by the Rai River, roads, and farmland.

(ii)Talon® 50WB was placed in 60 “Novacoil” rodent bait stations (Taylor and Thomas 1989) on a 50 m × 50 m grid, in the Circle Walk part of Pelorus Bridge Scenic Reserve (c. 18 ha), bounded by the Pelorus River, roads, and farmland; two baits were placed daily from 22 to29 November 1993, then six baits monthly from the end of November 1993 until the end of June 1994.

(iii)Rat and mouse snap traps (one of each) were placed in 50 aluminium tunnels on a 50 m × 50 m grid, in an isolated part of Brown River Scenic Reserve (c.10 ha), bounded by the Brown River, roads, and farmland. The traps were baited with a mixture of peanut butter and rolled oats and set on 23 November 1993. They were checked daily until 29 November l993, then weekly until 21 December 1993, and then finally a month later on 27 January 1994. The trapping was done in an attempt to reduce rodent population pressure on invertebrates without the use of poisons.

(iv)No treatment was used in the Totara Path part of Pelorus Bridge Scenic Reserve (c. 10 ha).

It was expected that the isolation of the study areas would at least slow down reinvasion by rodents.

In each area, population trends of ground-dwelling invertebrates were monitored using pitfall traps (after Moeed and Meads 1985). Pitfall trap catches are influenced by a range of factors (e.g., invertebrate species, sex, and activity) apart from population size (Topping and Sunderland 1992). However, when they are used in paired treatment and non-treatment areas before and after application of a treatment, and analyses are restricted to within species, factors apart from population size cancel out unless there is an interaction between a factor such as activity and treatment (Heneghan 1992).

Pitfall traps were 110 mm deep and had an interior diameter of 73 mm. They were one-third filled with a mixture of 50% ethylene glycol and water and a few drops of detergent. Small holes (<1 mm diameter) were drilled 40 mm from the top of the traps to drain excess rainwater. The traps were covered with bird-netting to prevent them filling up with leaves and give some protection from birds such as weka (*Gallirallus australis*). Twenty traps were set 50 m apart on two or three lines 50–100 m apart in November 1992. They were open continuously and were emptied monthly until November 1994; i.e., for 1 year before and after initiation of rodent control. Five pitfall traps were selected at random in each area (the same traps each month), and the monthly collections from them, from December 1992 to February 1993 and September 1993 to June 1994, were then counted and sorted into orders and/or families. The collections from only one to three pitfall traps were processed for September 1994 to November 1994, resulting in wider confidence limits for the means of these samples.

The effect of each treatment was determined from a repeated-measures analysis of variance (Green 1993) of the month vs month counts for each invertebrate taxon in treatment vs non-treatment areas. The counts were transformed with $\ln(x+1)$ to normalise the data for analysis, and back-transformed for graphing. Least significant differences were calculated from the formula given by Andrews et al. (1980). The time × treatment interaction term was used to determine whether there were significant differences ($P<0.05$) in the monthly population trends in the treatment vs non-treatment areas. With the probability of concluding there was a difference when really there was no difference set at 5%

(i.e., $\alpha = 0.05$) and the probability of concluding there was no difference when really there was a difference set at 20% (i.e., $\beta = 0.20$), the analysis had the power to detect decreases of >67% and increases of >200% (Green 1994).

3. RESULTS

3.1 CONTROL OPERATIONS

In Carluke Scenic Reserve, the Talon® 20P baits had all disappeared 1 month after the simulated aerial application. Three dead possums but no dead rodents or birds were found. In Pelorus Bridge Scenic Reserve, the Talon® 50WB baits disappeared from 95% of the bait stations 1 week after first baiting, and when replenished continued to disappear until the end of June 1994. Re-baiting was stopped because of the high bait take. In total, more than 3000 Talon® 50WB baits disappeared. Ship rats and possums were observed coming to the bait

TABLE 1. PROBABILITY VALUES FROM ANALYSIS OF VARIANCE FOR SIGNIFICANT DIFFERENCES (P <0.05) IN THE MONTH-TO-MONTH POPULATION TRENDS OF INVERTEBRATES IN THE AREA TREATED WITH TALON® 20P, CARLUKE SCENIC RESERVE, COMPARED WITH TRENDS IN THE NON-TREATMENT AREA, TOTARA PATH, PELORUS BRIDGE SCENIC RESERVE, DECEMBER 1992 TO NOVEMBER 1994. DECREASES IN BOLD. ONLY P VALUES <0.05 ARE SHOWN. - = P VALUE >0.05.

INVERTEBRATE ORDER - FAMILY	PRE-POISON				POISON	POST-POISON						
	Dec-Jan	Jan-Feb	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan	Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Sep-Nov
Acari	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda - Talitridae	-	-	-	-	-	-	-	-	-	-	-	-
Aranaea	-	-	-	0.004	**0.049**	-	-	-	-	-	-	-
Coleoptera - Carabidae	-	-	-	-	-	-	**0.026**	-	-	-	-	-
Coleoptera - Curculionidae	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera - Pselaphidae	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera - Scarabaeidae	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera - Scydmaenidae	-	-	-	-	**0.028**	0.014	-	-	0.035	-	-	-
Coleoptera - Staphylinidae	-	-	-	0.047	**0.021**	-	-	-	-	-	-	-
Coleoptera - others	0.004	-	-	-	-	-	-	-	-	-	-	-
Coleoptera larvae*	-	-	-	-	-	-	-	0.019	-	-	-	-
Collembola	-	-	-	-	-	-	-	-	-	-	-	-
Diplopoda	-	-	-	0.049	**0.008**	-	-	-	-	-	-	-
Hymenoptera - Formicidae	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda - Armadillidae	-	-	**0.048**	-	-	-	-	-	-	-	-	-
Opiliones	-	-	-	-	-	-	-	-	-	-	-	-

* includes Diptera and Lepidoptera larvae

stations, and sometimes crumbs of baits were left outside bait stations. One dead possum was found and other dead animals could be smelt. However, the continued bait take indicates that the baits did not eradicate either rodents or possums, presumably because of rapid reinvasion of animals from surrounding (non-forest) habitat. In Brown River Scenic Reserve, snap traps caught five ship rats and 14 mice in about 4500 trap nights. Trapping was stopped because of the low capture rate.

3.2 IMPACT OF CONTROL OPERATIONS ON INVERTEBRATE POPULATIONS

The control operations had no obvious impacts on any invertebrate taxa (Appendices 8.2–8.4). Population trends in treatment and non-treatment areas were not visibly different before and after treatment.

Sixteen taxa were present in sufficient numbers to statistically analyse the impacts of control operations on their month-to-month population trends (Tables 1–3). Other taxa, including centipedes, cockroaches, earthworms,

TABLE 2. PROBABILITY VALUES FROM ANALYSIS OF VARIANCE FOR SIGNIFICANT DIFFERENCES (P <0.05) IN THE MONTH-TO-MONTH POPULATION TRENDS OF INVERTEBRATES IN THE AREA TREATED WITH TALON 50WB IN BAIT STATIONS, CIRCLE WALK, PELORUS BRIDGE SCENIC RESERVE, COMPARED WITH TRENDS IN THE NON-TREATMENT AREA, TOTARA PATH, PELORUS BRIDGE SCENIC RESERVE, DECEMBER 1992 TO NOVEMBER 1994. DECREASES IN BOLD. ONLY P VALUES <0.05 ARE SHOWN. - = P VALUE >0.05.

INVERTEBRATE ORDER - FAMILY	PRE-POISON				POISON							POST-POISON	
	Dec-Jan	Jan-Feb	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan	Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Sep-Oct	Oct-Nov
Acari	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda - Talitridae	-	-	-	-	-	-	-	-	-	-	-	-	-
Aranaea	-	-	-	-	-	-	-	0.009	-	-	-	-	-
Coleoptera - Carabidae	-	-	-	-	-	-	**0.026**	-	-	-	-	-	-
Coleoptera - Curculionidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera - Pselaphidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera - Scarabaeidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera - Scydmaenidae	-	-	-	-	**0.014**	0.049	-	-	-	-	-	-	-
Coleoptera - Staphylinidae	-	-	-	0.007	**0.015**	-	-	-	**0.047**	-	-	-	-
Coleoptera - others	0.001	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera larvae*	0.005	-	-	-	-	-	-	-	-	-	-	-	-
Collembola	-	-	-	-	-	-	-	-	-	-	-	-	-
Diplopoda	-	-	-	0.025	-	-	-	-	-	-	-	-	-
Hymenoptera - Formicidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda - Armadillidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Opiliones	-	-	-	-	-	-	-	-	-	-	-	-	-

* includes Diptera and Lepidoptera larvae

TABLE 3. PROBABILITY VALUES FROM ANALYSIS OF VARIANCE FOR SIGNIFICANT DIFFERENCES (P <0.05) IN THE MONTH-TO-MONTH POPULATION TRENDS OF INVERTEBRATES IN THE AREA TRAPPED FOR RATS AND MICE, BROWN RIVER SCENIC RESERVE, COMPARED WITH POPULATION TRENDS IN THE NON-TREATMENT AREA, TOTARA PATH, PELORUS BRIDGE SCENIC RESERVE, DECEMBER 1992 TO NOVEMBER 1994. DECREASES IN BOLD. ONLY P VALUES <0.05 ARE SHOWN. - = P VALUE >0.05.

INVERTEBRATE ORDER - FAMILY	PRE-TRAPPING				TRAPPING		POST-TRAPPING						
	Dec-Jan	Jan-Feb	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan	Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Sep-Oct	Oct-Nov
Acari	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda - Talitridae	-	-	-	-	-	-	-	-	-	-	**0.025**	-	-
Aranaea	-	-	-	-	-	-	-	0.028	-	-	-	-	-
Coleoptera - Carabidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera - Curculionidae	-	-	-	-	-	-	-	-	-	0.042	-	-	-
Coleoptera - Pselaphidae	-	-	-	0.036	-	-	-	-	-	-	-	-	-
Coleoptera - Scarabaeidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera - Scydmaenidae	-	-	-	-	**0.019**	0.011	-	**0.009**	0.027	-	-	-	-
Coleoptera - Staphylinidae	-	-	-	0.046	-	-	-	-	-	-	-	-	-
Coleoptera - others	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera larvae*	-	-	-	-	-	-	-	-	-	-	-	-	-
Collembola	-	-	-	-	-	-	-	-	-	**0.009**	-	-	-
Diplopoda	-	-	-	0.048	**0.026**	-	-	-	-	-	-	-	-
Hymenoptera - Formicidae	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda - Armadillidae	-	-	**0.001**	-	-	-	-	-	-	-	-	-	-
Opiliones	-	-	**0.009**	-	-	-	-	-	-	-	-	-	-

* includes Diptera and Lepidoptera larvae

slugs, snails, and weta, were caught too infrequently to determine the impacts of control operations on their population numbers.

Month-to-month population trends of the 16 invertebrate taxa in the treated areas differed statistically from those in the non-treated area for 37 (or 5.9%) of the 624 comparisons (3 treatment areas × 16 taxa × 13 month-to-month comparisons) (Tables 1–3, Appendices 8.2–8.4). However, this is about the number expected by chance. Twenty were population increases (>200%) and 17 population decreases (>67%) in the treatment area compared to the non-treatment area. Eight of the statistically significant differences (all decreases in the treatment populations) occurred from pre- to post-poison (November to December 1993) — four in the area treated with Talon® 20P, and two in both the area treated with Talon® 50WB and the area trapped for rodents. These statistically significant decreases involved four taxa. For spiders (Aranaea), rove beetles (Staphylinidae), and millipedes (Diplopoda), the decreases were preceded by increases in the treatment populations immediately before poisoning (i.e., from October to November 1993) (Tables 1–3, Appendices 8.2–8.4). Scydmaenid beetles (Scydmaenidae) increased from December 1993 to January 1994, immediately after poisoning.

4. Conclusions

This study had the power to detect only statistically major changes (greater than 67% decreases and 200% increases) in invertebrate populations. This power is similar to that in the study investigating the impacts of 1080-poisoning for possum control on non-target invertebrate populations (Spurr 1994). I do not know what magnitude of statistical change would be biologically significant to different invertebrate taxa nor what time it would take them to recover from a one-off decrease of 67%. However, although some invertebrate taxa in this study decreased significantly (by >67%) one month and increased significantly the next month, none showed the same population trend (decrease or increase) for two consecutive months. Also, the total number of statistically significant month-to-month changes (decreases and increases) in invertebrate populations in this study was similar to the number expected by chance (about 5%).

The statistically significant decreases detected in populations of four taxa (Aranaea, Scydmaenidae, Staphylinidae, and Diplopoda) from pre- to post-treatment (November to December 1993) are unlikely to have been caused by the treatments:

- Similar statistically significant month-to-month decreases occurred in other taxa before treatments were applied (i.e., before November 1993).
- The decreases occurred in the area trapped for rodents as well as in the areas treated with Talon® 20P and Talon® 50WB.
- Statistically significant month-to-month increases in population numbers preceded more than half the decreases.
- Aranaea, Scydmaenidae, and Staphylinidae are all carnivorous invertebrates. Only Diplopoda are likely to have eaten baits directly.

Probably little bait was available to be eaten by invertebrates in this study. This is usual for operations using Talon® 20P. On Stanley Island, for example, Talon® 20P also disappeared within about 1 month (Towns et al. 1993). Talon® 50WB, on the other hand, is normally available in bait stations for several months after rodents are eradicated. On Hawea Island, for example, baits were left in the bait stations for at least 18 months (Taylor and Thomas 1989). However, in my study, although baits were put out for 6 months they disappeared rapidly. They would not have been available to invertebrates for as long as is usual on islands.

The relative population densities of invertebrates in treatment and non-treatment areas 1 year after poisoning were similar to those before poisoning, suggesting that poisoning rats and mice had neither a detrimental nor beneficial effect on invertebrate populations. However, this conclusion is unlikely to be relevant to rodent eradication operations on islands, because I was unable to eradicate rodents from my study areas. The large number of Talon® 50WB baits that disappeared from bait stations indicates rapid reinvasion of rats and mice from surrounding habitat. Presumably the same occurred with Talon® 20P. On islands, eradication of rodents should benefit invertebrate populations by reducing predation.

The lack of a detectable impact of poisoning with Talon® 20P and Talon® 50WB on non-target ground-dwelling invertebrate populations is consistent with the view that invertebrates are unlikely to be killed by brodifacoum (Shirer l992).

5. Recommendations

The toxicity of brodifacoum should be determined for a range of invertebrate species (e.g., beetles, cockroaches, millipedes, weta) that are likely to eat baits to test the assumption that it is unlikely to kill invertebrates.

Invertebrate populations should be monitored on islands, perhaps annually, for several years before and after rodents have been eradicated to establish whether Talon® baiting operations benefit invertebrates.

6. Acknowledgements

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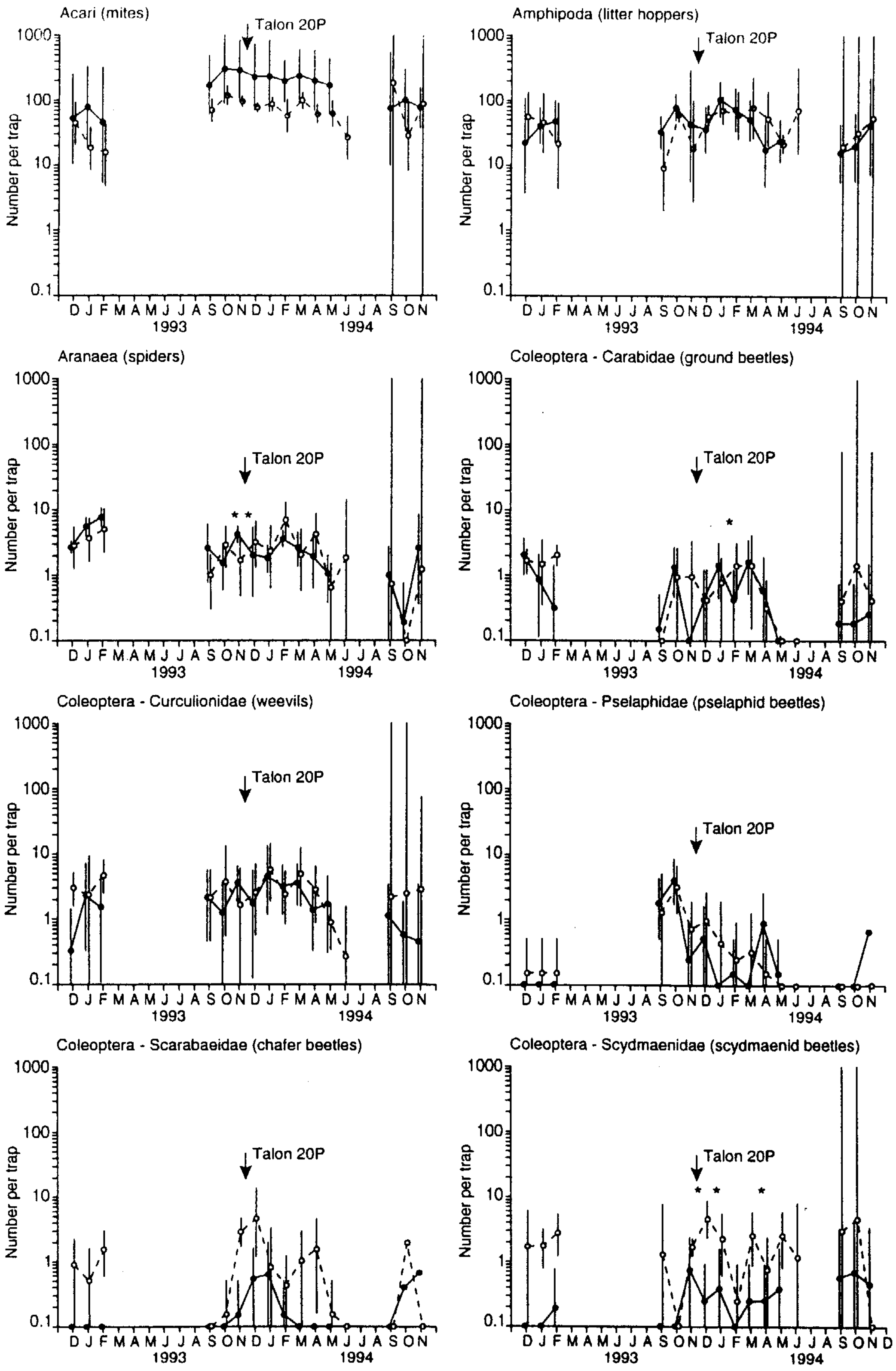
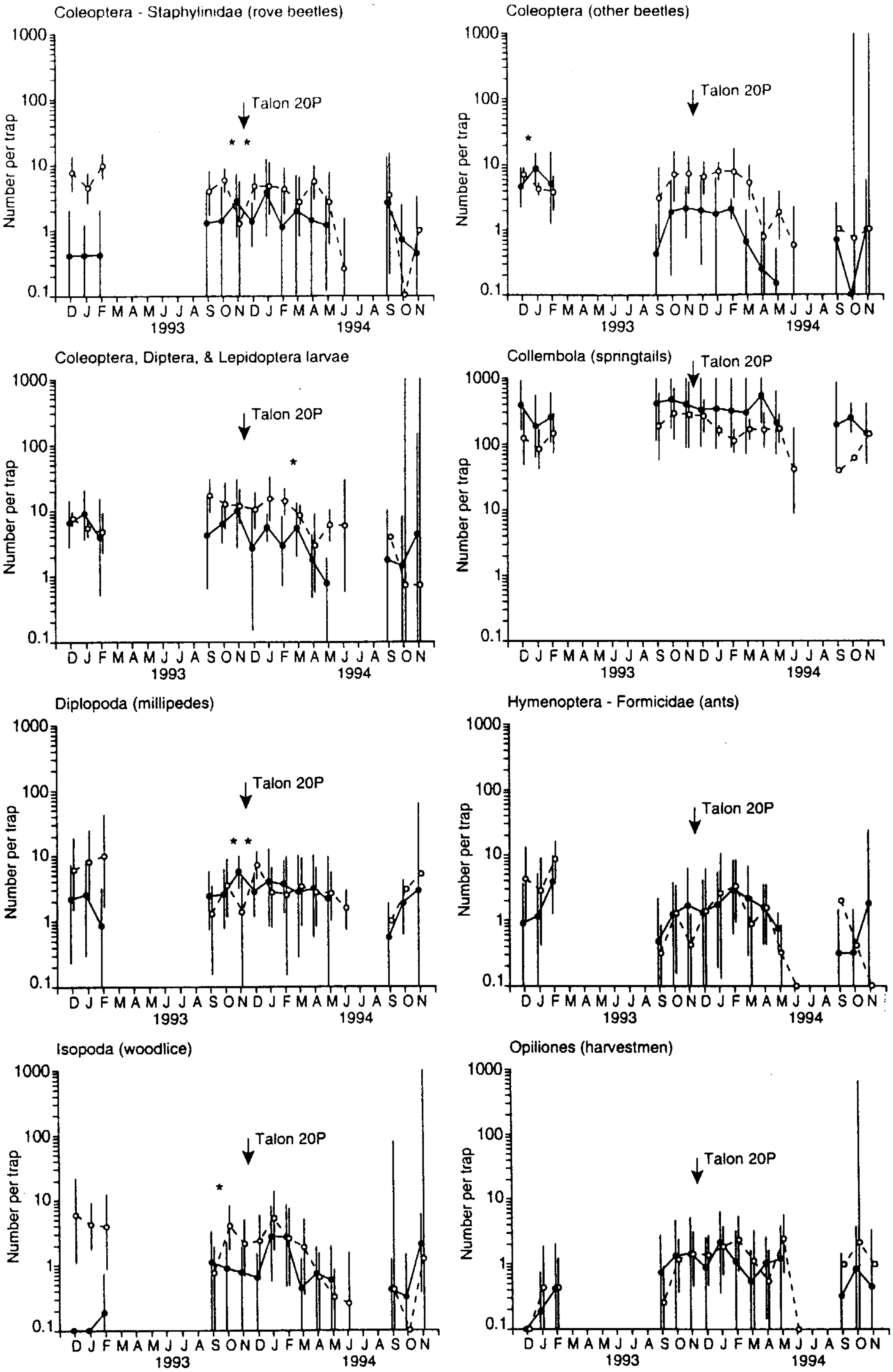
8. Appendices

8.1 ORDERS AND FAMILIES OF INVERTEBRATES CAUGHT IN PITFALL TRAPS IN BROWN RIVER, CARLUKE, AND PELORUS BRIDGE SCENIC RESERVES, NELSON

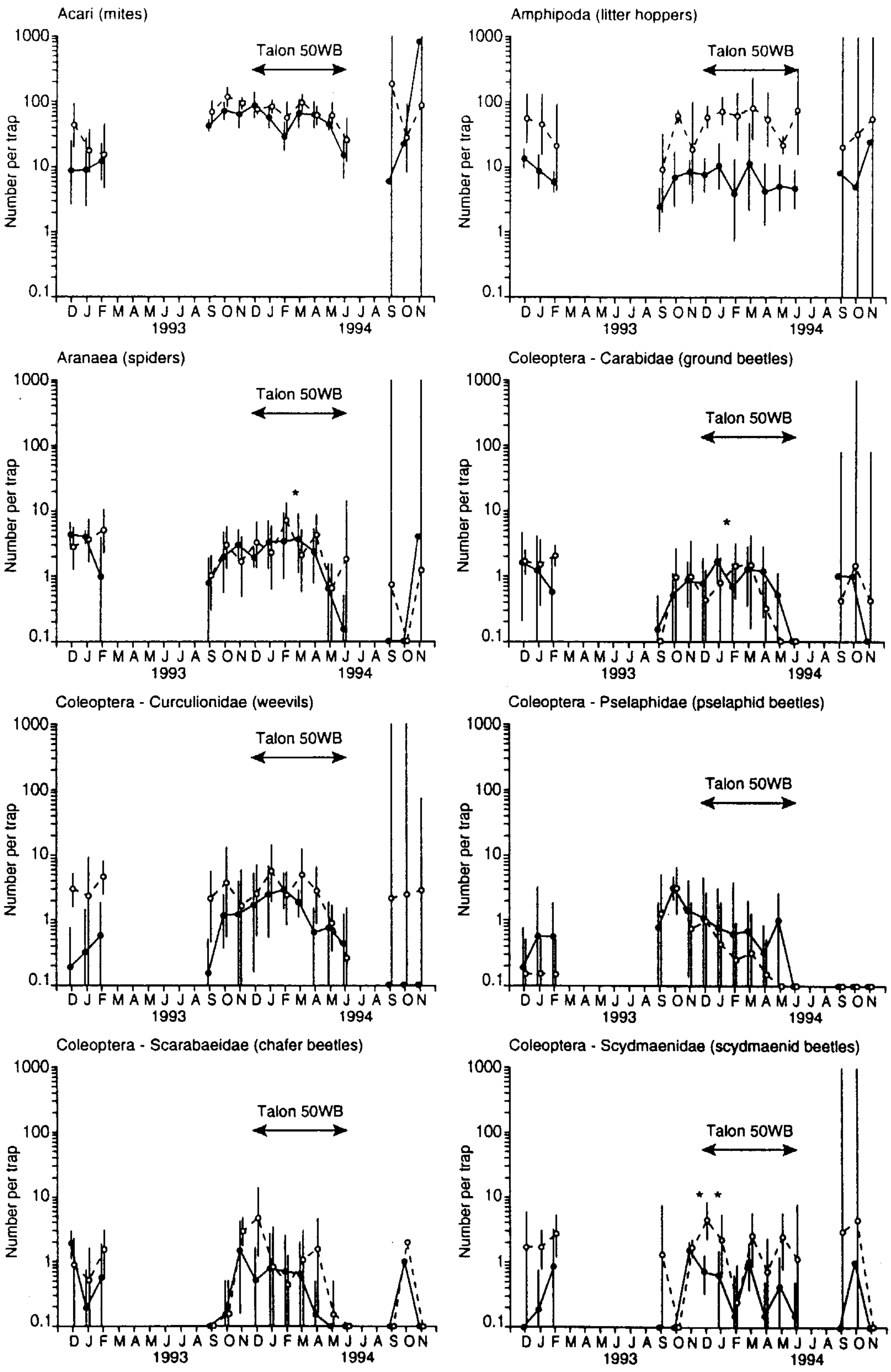
ORDER	FAMILY	COMMON NAME
Acari		mites
Amphipoda	Talitridae	litter hoppers
Araneae		spiders
Blattodea		cockroaches
Chilopoda		centipedes
Coleoptera	Carabidae	ground beetles
Coleoptera	Cerambycidae	longhorn beetles
Coleoptera	Colydiidae	
Coleoptera	Corylophidae	
Coleoptera	Curculionidae	weevils
Coleoptera	Elateridae	click beetles
Coleoptera	Hydrophilidae	
Coleoptera	Lathridiidae	
Coleoptera	Leiodidae	
Coleoptera	Nitidulidae	
Coleoptera	Pselaphidae	
Coleoptera	Ptiliidae	
Coleoptera	Scarabaeidae	chafer beetles
Coleoptera	Scirtidae	
Coleoptera	Scydmaenidae	
Coleoptera	Staphylinidae	rove beetles
Dermaptera		earwigs
Collembola		springtails
Diplopoda		millipedes
Diptera		flies
Hemiptera		plant bugs
Hymenoptera	Formicidae	ants
Hymenoptera		wasps bees
Isopoda	Armadillidae	woodlice, etc.
Lepidoptera		butterflies, moths
Oligochaeta		earthworms
Opiliones		harvestmen
Orthoptera		cave weta, grasshoppers
Pseudoscorpiones		pseudoscorpions
Psocoptera		book lice
Pulmonata		slugs, snails
Thysanoptera		thrips
Thysanura		bristle-tails
Trichoptera		caddis flies

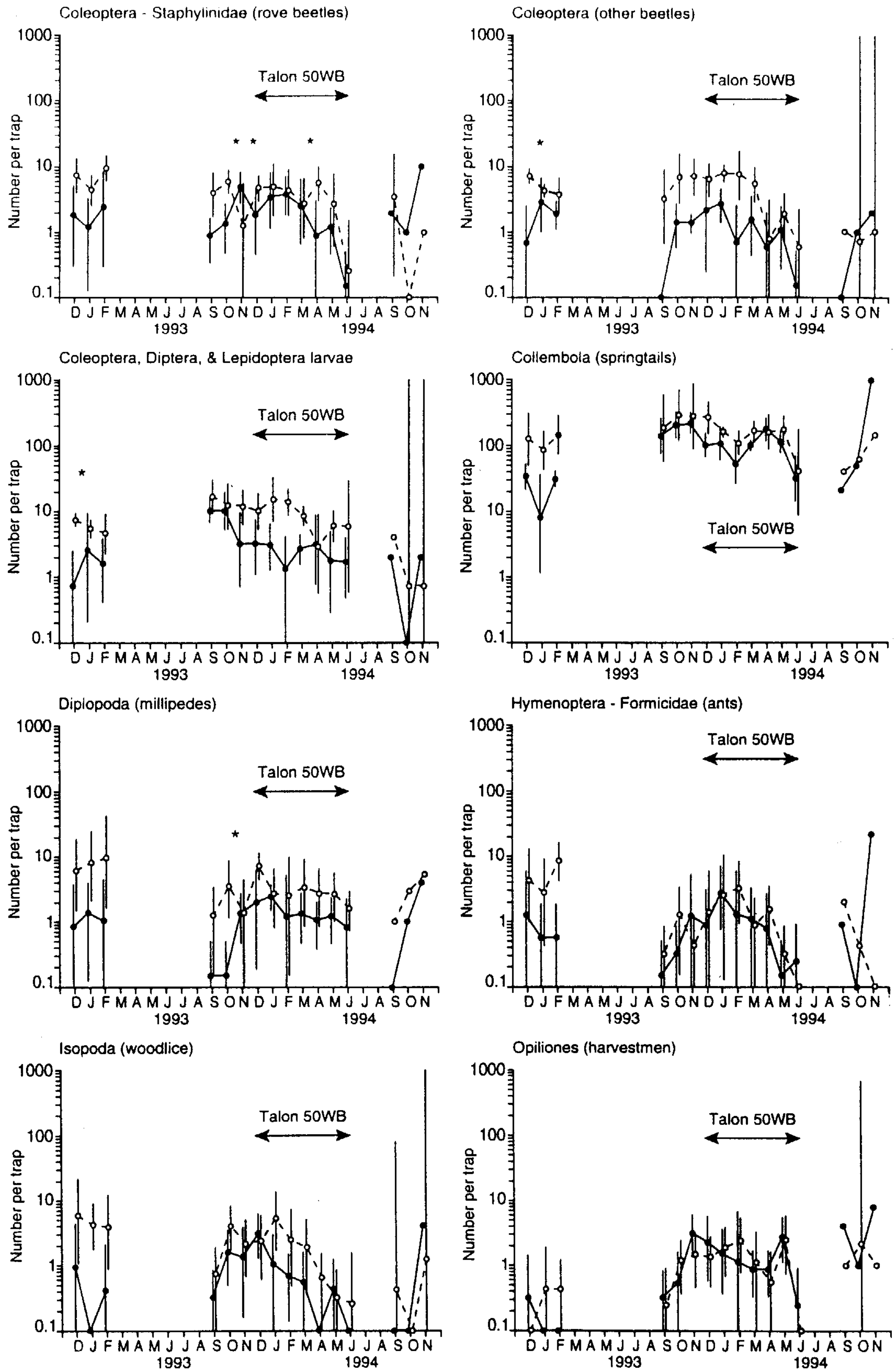
8.2 NUMBER OF INTEBRATES CAUGHT IN PITFALL TRAPS AT MONTHLY INTERVALS BEFORE AND AFTER SIMULATED AERIAL DISTRIBUTION OF TALON® 20P IN CARLUKE SCENIC RESERVE (BLACK CIRCLES) AND IN A NON-TREATMENT AREA IN TOTARA PATH, PELORUS BRIDGE SCENIC RESERVE, NELSON (OPEN CIRCLES). VERTICAL LINES REPRESENT LEAST SIGNIFICANT DIFFERENCE AN ASTERISK DENOTES A SIGNIFICANT DIFFERENCE BETWEEN AREAS (P <0.05).



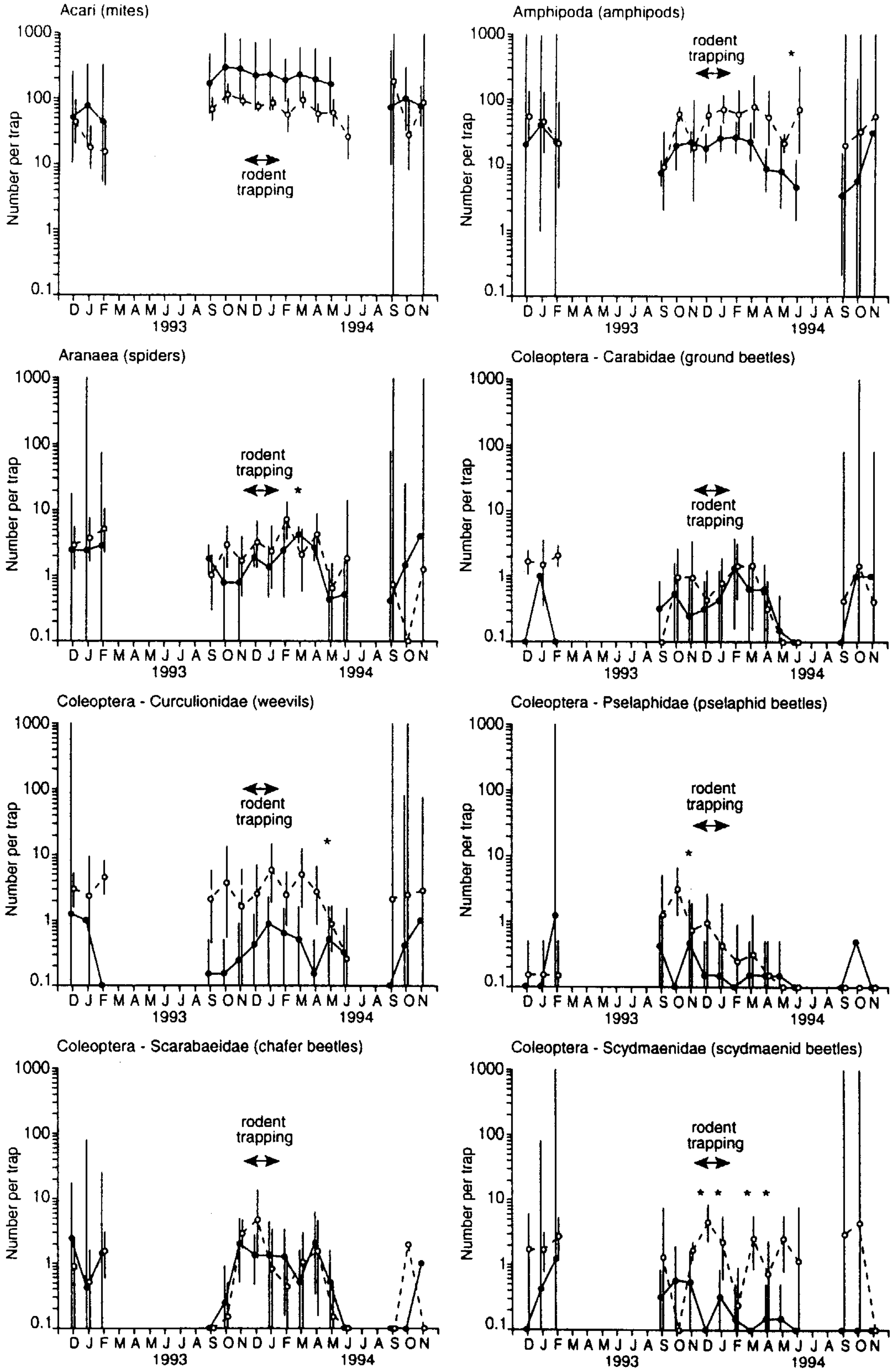

Coleoptera - Staphylinidae (rove beetles)
Coleoptera (other beetles)
Coleoptera, Diptera, & Lepidoptera larvae
Collembola (springtails)
Diplopoda (millipedes)
Hymenoptera - Formicidae (ants)
Isopoda (woodlice)
Opiliones (harvestmen)
Talon 20P
Number per trap
1000
100
10
1
0.1
D J F M A M J J A S O N D J F M A M J J A S O N
1993
1994

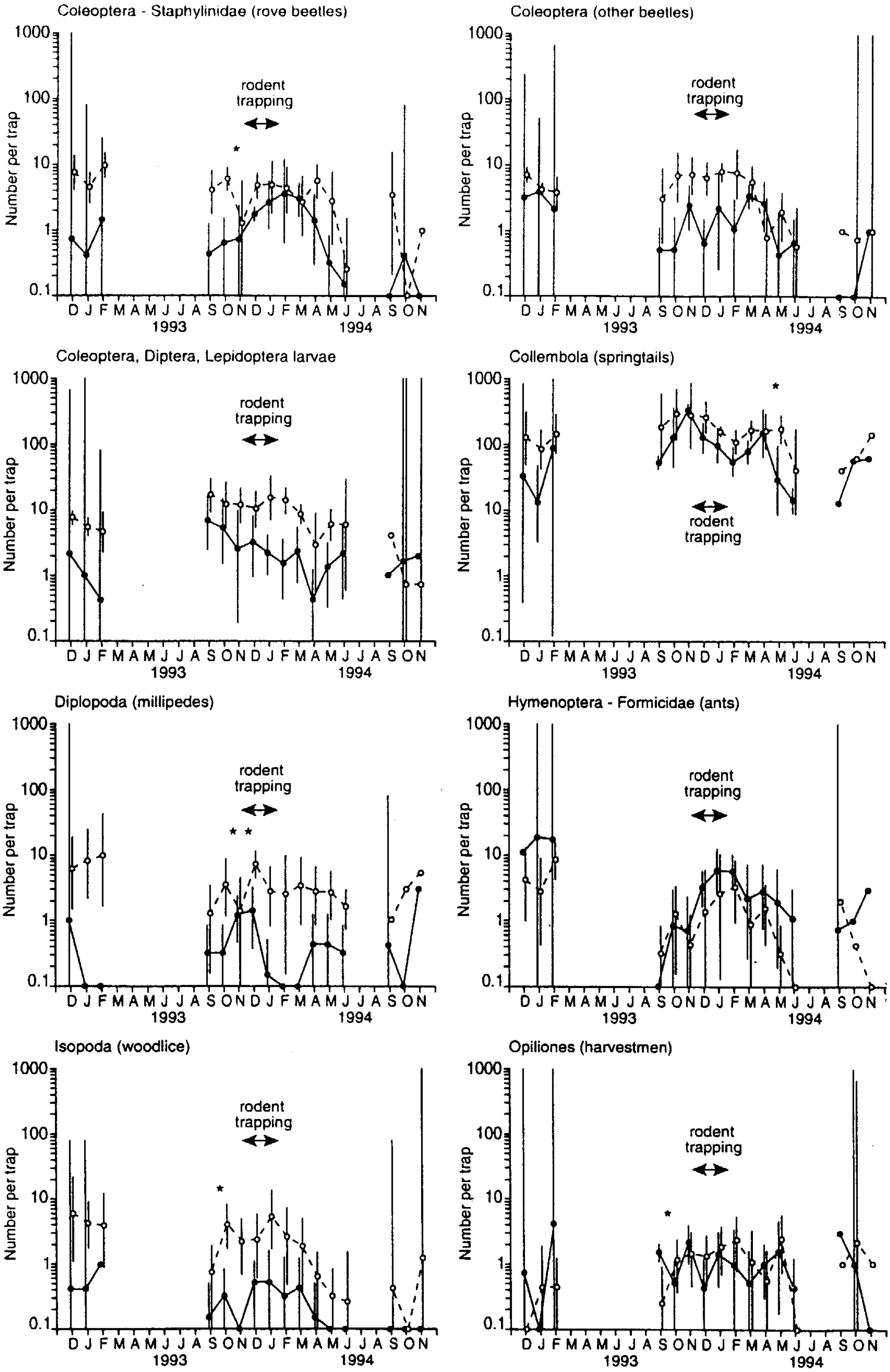
8.3 NUMBER OF INTEBRATES CAUGHT IN PITFALL TRAPS AT MONTHLY INTERVALS BEFORE AND AFTER APPLICATION OF TALON(R) 50WB IN CIRCLE WALK, PELORUS BRIDGE SCENIC RESERVE (BLACK CIRCLES) AND IN A NON-TREATMENT AREA IN TOTARA PATH, PELORUS BRIDGE SCENIC RESERVE, NELSON (OPEN CIRCLES). VERTICAL LINES REPRESENT LEAST SIGNIFICANT DIFFERENCES AN ASTERISK DENOTES A SIGNIFICANT DIFFERENCE BETWEEN AREAS (P <0.05).




Coleoptera - Staphylinidae (rove beetles)
Coleoptera (other beetles)
Coleoptera, Diptera, & Lepidoptera larvae
Collembola (springtails)
Diplopoda (millipedes)
Hymenoptera - Formicidae (ants)
Isopoda (woodlice)
Opiliones (harvestmen)
Talon 50WB
Number per trap
1000
100
10
1
0.1
D J F M A M J J A S O N D J F M A M J J A S O N
1993
1994

8.4 NUMBER OF INTEBRATES CAUGHT IN PITFALL TRAPS AT MONTHLY INTERVALS BEFORE AND AFTER SNAP-TRAPPING RATS AND MICE IN BROWN RIVER SCENIC RESERVE (BLACK CIRCLES) AND IN A NON-TREATMENT AREA IN TOTARA PATH, PELORUS BRIDGE SCENIC RESERVE, NELSON (OPEN CIRCLES). VERTICAL LINES REPRESENT LEAST SIGNIFICANT DIFFERENCES AN ASTERISK DENOTES A SIGNIFICANT DIFFERENCE BETWEEN AREAS (P (0.05).




Coleoptera - Staphylinidae (rove beetles)
Coleoptera (other beetles)
Coleoptera, Diptera, Lepidoptera larvae
Collembola (springtails)
Diplopoda (millipedes)
Hymenoptera - Formicidae (ants)
Isopoda (woodlice)
Opiliones (harvestmen)
rodent trapping
Number per trap
1000
100
10
1
0.1
D J F M A M J J A S O N D J F M A M J J A S O N
1993
1994