The Hope River forest fragmentation project

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Introduction

Habitat fragmentation is one of the most important current threats to species survival (Tilman 1994, Vitousek 1994, Riitters *et al.* 2000, Laurance & Cochrane 2001, Laurance *et al.* 2002) and is likely to remain so for the foreseeable future (Vitousek 1994, Pimm *et al.* 1995, Sala *et al.* 2000). Fragmentation causes species extinctions by decreasing the amount of viable 'core' habitat area and increasing edge effects (Saunders 1991, Murcia 1995, Didham *et al.* 1996, Didham 1997, Didham *et al.* 1998a,b). The loss of core area reduces population sizes and exposes species to stochastic and genetic influences that large populations might easily withstand. Edge effects are a diverse mix of altered microclimatic variables (Murcia 1995) and species interactions (Fagan *et al.* 1999) that occur at habitat boundaries.

New Zealand has a very diverse biota with a high proportion of endemic species and has recently been identified as one of the 25 most important biodiversity hotspots in the world (Myers *et al.* 2000). However, nearly 75 % of New Zealand's forests have been destroyed (McGlone 1989, Myers *et al.* 2000) and much of what remains is heavily fragmented (e.g. Norton 2000b). New Zealand's remaining forests make up just one quarter of the country's land area and are fragmented into nearly 120,000 separate remnants with an average size of just 53.9 ha (Table 1).

Table 1. Remaining native forest in New Zealand. Data from the New Zealand TopoMap series 1989.

	Total Land Area (ha)	Forested Area (ha)	% Original Forest Remaining	Number of Fragments	Mean Fragment Size (ha)
North Island	11,373,335	2,717,232	24.3	81,715	33.3
South Island	15,043,689	3,724,617	29.1	37,800	98.5
NZ archipelago	26,417,024	6,441,849	28.2	121,025	53.9

The purpose of this brief report is to introduce a new study on the effects of forest fragmentation on native biodiversity in New Zealand. The Hope River forest fragmentation project is an initiative of the Canopy Research Group at the University of Canterbury to investigate the effects of fragmentation on invertebrate communities in the Hurunui District, South Island, New Zealand. The Hope River project is being conducted at a scale unmatched by other studies of this kind. It covers a far greater range of fragment sizes and far longer edge gradients than previously attempted, and examines edge gradients that extend from the forest edge into forest interiors as well as out into the surrounding pastoral 'matrix'. Furthermore, it is the first study to investigate fragmentation effects on ground- and canopy-dwelling insects simultaneously.

The Hope River project has been designed to address a number of key questions on the nature of fragmentation effects, such as:

- What is the relationship between fragment size and local extinction rates?
- Which species require large tracts of undisturbed forest?
- Do ground- and canopy-dwelling arthropods respond to fragmentation in a similar manner?
- Do fragments influence the arthropod community in the surrounding matrix?
- What traits of species determine their susceptibility to local extinction (e.g. body size, trophic group, rarity)?
- What mechanisms are driving the responses of arthropods to fragmentation (e.g. temperature, light or humidity gradients, microhabitat alterations, resource availability and so on)?

Study site

The Hope River project encompasses 400 km^2 of mountainous terrain on the boundary between the largely deforested Canterbury Plains and the relatively untouched Southern Alps (Fig. 1). Part of the study area is managed by the Department of Conservation and the rest is privately owned on three large sheep and cattle stations, Glynn Wye, Glen Hope and Poplars Stations. We have received considerable support from all the landowners who have readily provided access to sites. Altitude in this region varies from 600 to 1700 m, although all study sites were below 1200 m. With the exception of the high alpine areas (elevation > 1300 m), the region was in continuous beech (*Nothofagus* spp.) forest prior to human settlement. Since settlement, large tracts of forest have been cleared and converted to farmland, leaving remnants of the original forest in isolated patches. Within this landscape, 14 experimental forest fragments were selected spanning six orders of magnitude in size (Table 2). Three control sites were also selected, one in deep continuous forest at least 2 km from the nearest edge, one site crossing the edge between continuous forest and adjacent pasture, and one site in extensive tussock-pasture matrix at least 2 km from the nearest forest remnant.

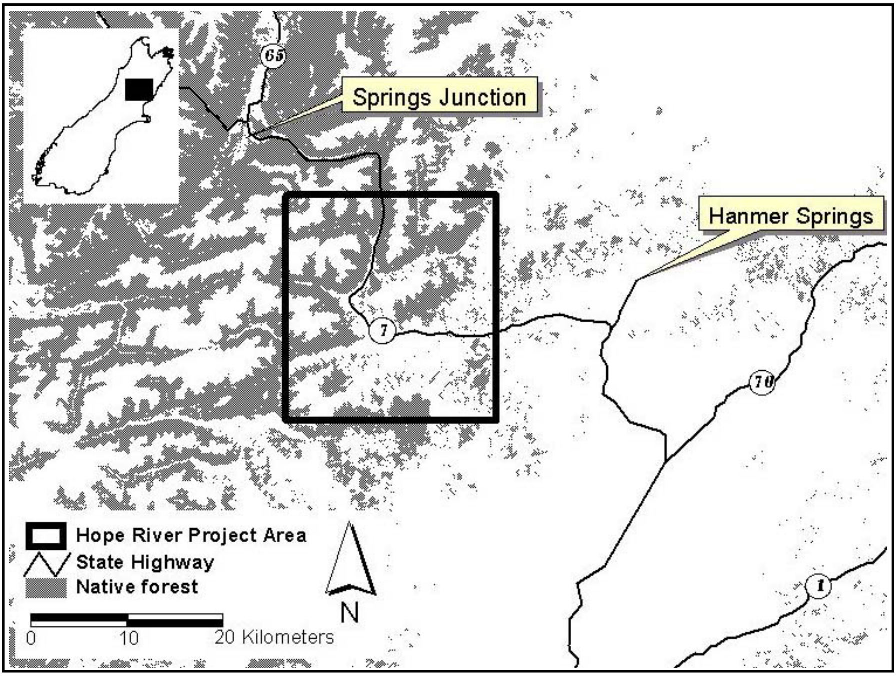

Figure 1. Location of the Hope River forest fragmentation project.

Methods

Selection of an appropriate insect trapping method is always problematic (Basset 1997), especially when sampling at large spatial scales or across contrasting habitat types. We chose a simple, inexpensive FIT modified from the composite intercept trap of Basset (1988). The trap consisted of a rain cover and two 60 cm tall, perpendicular perspex intercept sheets above a 25 cm diameter collecting funnel and preserving jar. A total of 233 flight interception traps (FITs) were placed on the ground at up to 11 distances from forest edges into forest interiors (0, -2, -4, -8, -16, -32, -64, -128, -256, -512 and -1024 m), and at the same series of distances out from these forest edges into adjacent pasture (+2, +4, +8, +16, +32, +64, +128, +256, +512 and +1024 m). Within the forest, a total of 114 FITs were suspended in the canopy at these same distances. In fragments with a minimum diameter of less than 2 km, larger edge distances were sequentially dropped from edge gradients (Table 2). Canopy traps were placed at three-quarters tree height, which in this forest type equates to *ca* 15 m above the forest floor. A unique feature of the ground traps was that they were buried into the forest floor up to the rim of the collecting funnel and thus acted as both flying intercept and ground running intercept traps.

Table 2. Forest fragments sampled in the Hope River region. The Nina and St. James Control sites are *ca* 10 km apart in the same block of continuous forest. Nina Control is the deep forest control site, St. James Control is the forest edge control and Home Range is the pasture control.

Fragment Code	Fragment Area (ha)	Length of Edge Gradient (m)	No. Forest Sites	No. Pasture Sites	No. Sampling Sites
Nina Control	1,060,407.94	-2,048	21	0	21
St. James Control	1,060,407.94	±1,024	11	10	21
Carlyle	3,485.84	±1,024	11	10	21
Kakapo	1,060.87	±1,024	11	10	21
Meat Safe	372.74	±512	10	9	19
Front Dismal	70.68	±256	9	8	17
Bush Hut	44.29	±128	8	7	15
Boil	11.25	±64	7	6	13
Prairie	2.88	±64	7	6	13
Twin	0.92	±32	6	5	11
Donut	0.69	±16	5	4	9
Gully	0.08	±8	4	3	7
High Ridge	0.06	±8	4	3	7
Windy Point	0.04	±8	4	3	7
Umbrella	0.02	±4	3	2	5
Solo	0.01	±4	3	2	5
Home Range Control	n/a	+2,048	0	21	21

The 347 FITs were operated continuously from 30 November 2000 to 10 February 2001. Some trap samples were lost due to damage from high winds, giving a total of 24,794 trap-days sampling effort. All specimens were stored in 100 % ethanol for future molecular phylogenetic analyses.

To overcome the analytical limitation that FIT capture rates are intrinsically activity-based, and thus may bear no direct relationship to absolute invertebrate densities at the trap locality, we sampled 245 leaf-litter quadrats (33 x 33 cm) across a range of sampling sites. In total, 3,878 beetles were extracted from these samples using Berlese funnels operated over a 24 hr extraction period. Trends in fragment area and edge effects will be calibrated between these direct density estimates of ground beetle diversity and the activity-based estimates from FIT samples.

Progress

Sorting of 17,470 trap-days has produced *ca* 700,000 specimens (Tables 3 - 5). The remaining 7,324 trap-days are ground samples that were not subsequently sorted for ecological analyses due to the high sample sizes already obtained. The vast majority (> 500,000) of the invertebrates captured were mites (Acari) and Collembola. However, sample sizes for the focal groups in which we have the taxonomic expertise to conduct species-level analyses are also high (*ca* 50,000 Coleoptera, 40,000 Diptera, 38,000 Araneae and 7,000 Lepidoptera).

Table 3. Ordinal abundance of all invertebrates collected from forest ground FITs in the Hope River forest fragmentation project.

FOREST GROUND	Forest Control	Edge Control	Experimental forest fragments: Large	Medium	Small	**Total**
Area (ha):	1,060,408	1,060,408	3,486-71	44-0.69	0.08-0.01	
No. trap days:	679	228	1138	475	282	2802
No. samples sorted:	68	35	124	99	53	379
Coleoptera adults	6847	3480	9881	6020	1785	28013
Coleoptera larvae	43	49	215	149	70	526
Diptera adults	1733	1178	3899	5165	2575	14550
Diptera larvae	86	63	265	167	39	620
Hymenoptera Formicidae	783	6	429	274	537	2029
Hymenoptera other	1220	431	1611	2359	1345	6966
Lepidoptera adults	86	32	151	149	182	600
Lepidoptera larvae	783	215	955	1109	174	3236
Hemiptera	845	755	1521	1472	1312	5905
Thysanoptera	212	242	272	288	419	1433
Orthoptera	142	91	346	401	285	1265
Psocoptera	136	47	228	363	128	902
Blattodea	8	8	37	36	26	115
Dermaptera	5	0	14	0	5	24
Neuroptera	0	5	4	3	32	44
Ephemeroptera	2	0	1	4	4	11
Odonata	0	0	0	0	0	0
Plecoptera	2	3	3	4	13	25
Isoptera	0	0	0	0	0	0
Mantodea	0	0	0	0	0	0
Phasmatodea	0	0	0	0	0	0
Megaloptera	0	0	0	0	0	0
Strepsiptera	0	0	0	0	0	0
Trichoptera	8	3	1	35	16	63
Mecoptera	0	0	0	0	0	0
Archaeognatha	0	0	1	0	0	1
Thysanura	0	0	0	0	0	0
Collembola	21251	9458	40095	44247	15308	130359
Protura	0	0	0	0	0	0
Diplura	0	0	4	0	0	4
Chilopoda	2	4	70	81	12	169
Diplopoda	64	97	250	369	129	909
Symphyla	0	1	2	3	0	6
Pauropoda	0	1	1	0	0	2
Amphipoda	22	25	236	15	0	298
Isopoda	5	5	22	63	3	98
Araneae	1403	715	3028	2645	2246	10037
Acari	9679	8232	28058	18732	15011	79712
Pseudoscorpiones	28	25	116	101	29	299
Opiliones	57	56	145	77	116	451
Mollusca	25	15	178	30	34	282
Annelida	29	9	33	59	34	164
Nematomorpha	5	3	4	4	2	18
Nematoda	10	0	0	2	5	17
Onychophora	0	0	0	0	1	1
Platyhelminthes	9	0	12	3	2	26
Unknown	69	1	14	4	4	92
Grand Total	**71600**	**50772**	**186674**	**200045**	**83734**	**289272**

Table 4. Ordinal abundance of all invertebrates collected from forest canopy FITs in the Hope River forest fragmentation project.

FOREST CANOPY			Experimental forest fragments			
	Forest Control	Edge Control	Large	Medium	Small	**Total**
Area (ha):	1,060,408	1,060,408	3,486-71	44-0.69	0.08-0.01	
No. trap days:	763	774	2881	2113	1064	7595
No. samples sorted:	54	57	201	150	77	539
Coleoptera adults	3952	1570	4072	2609	776	12979
Coleoptera larvae	4	4	59	29	11	107
Diptera adults	1718	1843	6098	4886	1523	16068
Diptera larvae	10	7	27	54	19	117
Hymenoptera Formicidae	1	2	1	2	0	6
Hymenoptera other	267	185	1616	724	928	3720
Lepidoptera adults	264	103	643	307	153	1470
Lepidoptera larvae	60	27	120	28	17	252
Hemiptera	293	327	1166	1148	503	3437
Thysanoptera	305	616	942	831	1966	4660
Orthoptera	5	1	2	2	2	12
Psocoptera	200	118	438	254	94	1104
Blattodea	2	0	8	3	0	13
Dermaptera	0	0	0	0	1	1
Neuroptera	4	2	6	8	4	24
Ephemeroptera	3	6	5	29	4	47
Odonata	0	1	0	0	0	1
Plecoptera	0	0	3	3	5	11
Isoptera	0	0	0	0	0	0
Mantodea	0	0	0	0	0	0
Phasmatodea	0	0	0	0	0	0
Megaloptera	4	0	2	6	1	13
Strepsiptera	0	0	0	0	0	0
Trichoptera	9	17	20	110	94	250
Mecoptera	0	0	0	0	0	0
Archaeognatha	0	0	0	0	0	0
Thysanura	0	0	0	0	0	0
Collembola	165	126	618	441	125	1475
Protura	0	0	0	0	0	0
Diplura	0	0	0	0	0	0
Chilopoda	0	0	1	0	0	1
Diplopoda	0	0	0	1	0	1
Symphyla	0	0	0	0	0	0
Pauropoda	0	0	0	0	0	0
Amphipoda	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0
Araneae	73	105	364	294	117	953
Acari	2091	782	33845	3404	2317	42439
Pseudoscorpiones	0	1	2	0	3	6
Opiliones	1	0	0	0	3	4
Mollusca	2	1	9	1	1	14
Annelida	0	0	0	0	3	3
Nematomorpha	0	0	0	1	0	1
Nematoda	0	0	0	1	0	1
Onychophora	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0
Unknown	1	1	2	3	0	7
Grand Total	**10251**	**6676**	**53151**	**17442**	**9811**	**89197**

Table 5. Ordinal abundance of all invertebrates collected from pasture ground FITs adjacent to forest fragments of varying sizes in the Hope River forest fragmentation project.

PASTURE GROUND	Pasture Control	Edge Control	Experimental forest fragments Large	Medium	Small	**Total**
Area (ha):	n/a	1,060,408	3,486-71	44-0.69	0.08-0.01	
No. trap days:	494	189	1003	404	174	2264
No. samples sorted:	64	30	106	83	39	322
Coleoptera adults	2256	1208	3444	2082	841	9831
Coleoptera larvae	62	91	75	49	12	289
Diptera adults	1860	1035	3555	2356	1315	10121
Diptera larvae	46	37	94	59	7	243
Hymenoptera Formicidae	291	245	717	420	446	2119
Hymenoptera other	993	1306	2067	1150	814	6330
Lepidoptera adults	129	176	280	153	95	833
Lepidoptera larvae	100	190	259	167	99	815
Hemiptera	2726	1676	2613	2102	567	9684
Thysanoptera	509	2555	1749	573	316	5702
Orthoptera	460	1318	717	1987	752	5234
Psocoptera	17	22	39	114	14	206
Blattodea	33	5	57	30	9	134
Dermaptera	0	13	0	0	9	22
Neuroptera	2	11	0	1	0	14
Ephemeroptera	1	0	2	0	2	5
Odonata	0	0	0	0	0	0
Plecoptera	0	1	17	8	3	29
Isoptera	0	0	0	0	0	0
Mantodea	0	0	0	0	0	0
Phasmatodea	2	0	3	1	0	6
Megaloptera	0	0	0	0	2	2
Strepsiptera	0	0	0	0	0	0
Trichoptera	3	3	8	26	6	46
Mecoptera	0	0	0	0	0	0
Archaeognatha	0	0	1	0	0	1
Thysanura	0	0	0	0	0	0
Collembola	29219	20542	76224	52591	18566	197142
Protura	0	0	0	0	78	78
Diplura	0	0	0	0	0	0
Chilopoda	2	3	12	17	8	42
Diplopoda	131	3	278	140	19	571
Symphyla	1	0	1	1	0	3
Pauropoda	0	0	0	0	0	0
Amphipoda	0	0	36	20	17	73
Isopoda	0	3	21	54	1	79
Araneae	5541	4612	9050	5430	2746	27379
Acari	5902	13716	14765	11020	3027	48430
Pseudoscorpiones	8	2	18	31	11	70
Opiliones	149	283	545	677	348	2002
Mollusca	2	82	24	1	4	113
Annelida	250	144	234	81	7	716
Nematomorpha	0	3	7	10	3	23
Nematoda	0	0	0	0	0	0
Onychophora	0	0	0	0	0	0
Platyhelminthes	25	8	84	11	1	129
Unknown	5	0	4	3	0	12
Grand Total	**72600**	**98805**	**245473**	**163214**	**60503**	**328528**

Species-level identification has been initiated for Coleoptera (RME, RKD; Chrysomelidae: Chris Reed, Australian Museum), Araneae (LHR), Diptera (Mycetophilidae: RKD, Mathias Jaschhof, University of Greifswald, Germany, Uwe Kallweit, Staatliche Museum für Tierkunde, Germany; Cecidomyidae: M. Jaschhof), Lepidoptera (John Dugdale, Landcare Research, Nelson), Trichoptera (John B. Ward, Canterbury Museum) and Ephemeroptera (Terry Hitchings, Canterbury Museum).

Ongoing work

Work on the Hope River project continues to investigate the mechanisms driving community responses to fragmentation. A long-term study is underway to determine above- and below-ground decomposition rates, with 4,660 experimental wood blocks in place. In the upcoming summer, temperature, relative humidity and light intensity will be monitored at each site using dataloggers. These data will be used to establish microclimatic gradients across fragment edges and to investigate diurnal changes, such as temperature inversions, that might occur at these sites. A number of habitat variables will also be quantified, including vegetation composition, canopy cover, biomass of fine litter and coarse woody debris, and ground cover density.

Significance

The Hope River project is addressing some of the problems apparent in biodiversity management strategies worldwide, such as inadequate knowledge of invertebrate diversity and community structure and the assumption that just because insects are small, they only need small areas of natural habitat to preserve viable populations. Through our large-scale, landscape-level approach, we will define the responses of invertebrates to forest fragmentation and relate these findings to national and regional initiatives to maintain native biodiversity on private land (Norton 2000a, 2001).

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