CONSERVATION
TE PAPA ATAWHAI

SCIENCE & RESEARCH SERIES N0.57

EFFECT OF SPHAGNUM HARVESTING ON INVERTEBRATE SPECIES DIVERSITY AND COMMUNITY SIZE

by
M.D. Sanders and M.J. Winterbourn

SCIENCE & RESEARCH SERIES NO. 57

EFFECT OF SPHAGNUM HARVESTING ON INVERTEBRATE SPECIES DIVERSITY AND COMMUNITY SIZE

by

M.D. Sanders and M.J. Winterbourn

Zoology Department, University of Canterbury
Christchurch

Published by
Head Office,
Department of Conservation,
PO Box 10-420,
Wellington,
New Zealand

ISSN 0113-3713
ISBN 0-478-01486-4

Edited for publication by Mary
Cresswell

This publication originated from work done under Department of Conservation contract investigation No.S1126, November 1992, and was approved for publication by the Director, Science and Research Division, Department of Conservation, Wellington.

National Library of New Zealand
Cataloguing-in-Publication data

Sanders, Mark. D. (Mark David) Effect of sphagnum harvesting on invertebrate species diversity and community size / M.D. Sanders and M.J. Winterbourn.
1 v. (Science research
series, 01 13-37 13 ;
no. 57)

ISBN 0-478-01486-4

1. Peatland ecology--New Zealand--South Island. 2. Peat mosses--New Zealand--South Island. 3. Invertebrates--New Zealand--South Island--Effect of habitat modification on.
I. Winterbourn, Michael J. (Michael John) II. New Zealand. Dept. of Conservation. III. Title.
IV. Series: Science & Research series ; no. 57.

574.526325099349 (574.52632509937) zbn93-034699

Keywords: *Sphagnum,* invertebrates, moss harvesting, West Coast, Maruia, Acari, Collembola, Arachnida, Coleoptera, Hymenoptera, Diptera, Onycophora.

CONTENTS

EFFECT OF SPHAGNUM HARVESTING ON INVERTEBRATE SPECIES DIVERSITY AND COMMUNITY SIZE

by
M.D. Sanders and M.J. Winterbourn

Zoology Department, University of Canterbury, Christchurch, New Zealand

ABSTRACT

The invertebrate fauna associated with sphagnum moss was investigated at 12 sites in Canterbury and Westland. Over 130 recognizable taxa representing 25 orders in five phyla were found. Mites (Acari), spiders (Araneae), springtails (Collembola), and beetles (Coleoptera) occurred at all sites, and also dominated numerically. Ants (Hymenoptera) were abundant at some sites where nests occurred in Sphagnum. Field experiments showed that taxonomic richness in plots subjected to simulated harvesting was lower than in unharvested controls after 6 weeks (5.8 ± 0.06 cf. 8.9 ± 0.06 taxa per 9.3 cm diameter core sample). The mean density of invertebrates other than mites or springtails was also lower in harvested plots. However, sampling undertaken on a commercial moss farm in Westland indicated that moss harvesting has little effect on invertebrate communities in the medium to long term (7 months to over 4 years since harvesting). In fact, invertebrate communities appeared to have recovered more rapidly than the moss itself. No invertebrate taxa known to be threatened or endangered were recorded at sphagnum sites examined in this study.

1. INTRODUCTION

Harvesting of sphagnum moss is a major industry in parts of the South Island; there are currently over 100 harvesting licences, covering approximately 3900 ha on administered land in the West Coast Conservancy alone (Ted Brennan, DOC, Hokitika; pers. comm.). A similar area of harvestable moss probably occurs on Timberlands land. In addition to the legal moss harvesting industry, an unknown number of unlicensed operators also harvest moss on the DOC estate and on private land. Export of dried sphagnum moss, principally to the Asian market, increased from 125 tonnes in 1981 to 900 tonnes in 1991 (Figure 1). Commercially harvested moss sites usually yield from2.5 to 5.0 tonnes of dried moss per hectare (Buxton, Johnson and Espie 1990) and can be reharvested 18 months to 3 years later.

Five species of sphagnum moss occur in New Zealand; *Sphagnun australe. S. cristatu, S. falcatulum, S. subnitens and S. subsecundum.* Moss exports consist mainly of *S. cristatum,* as this species is most suited to the horticultural requirements of the export market. Commercial operators selectively harvest for *S. cristatum.* Despite the large area of moss being harvested annually, very little is known of the ecology of sphagnum moss in New

Zealand or of the impact of harvesting on plant or associated animal communities. However, growth rates of sphagnum moss and the effects of harvesting on plant communities at sphagnum moss sites on the West Coast of the South Island are the subjects of ongoing research (Buxton *et al.* 1990; Buxton 1991; Buxton *et al.* 1991; and Johnson, Buxton, and Espie in press).

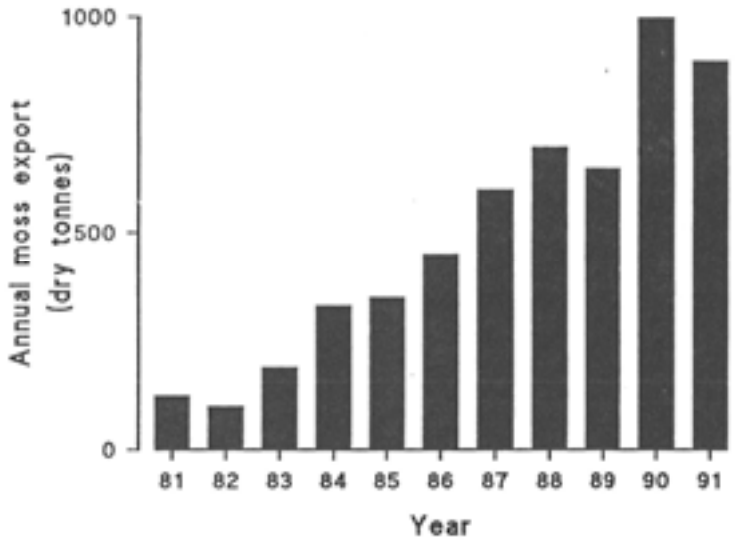


Figure 1. Annual tonnage of sphagnum moss exported from the West Coast of the South Island since 1981 (Source: Sphagnum Moss Producers Association).

The invertebrate fauna of sphagnum moss in New has been referred to only occasionally in the scientific literature (e.g. Johns 1977; Patrick 1991; Miller 1971). However, a recent study of the ecology and conservation of Tasmanian sphagnum peatlands (Whinam *et al.* 1989) includes a chapter on invertebrates, and provides a lead into the international literature. Apart from Grehan and Patrick who investigated four taxa of Hepialidae (Lepidoptera) in sphagnum bogs of Central and South Otago, no New Zealand sphagnum study has on invertebrates. Thus, the first objective of the present study was to survey and describe the invertebrate fauna of sphagnum moss.

Invertebrates are an integral part of most ecosystems and an important component of food webs. Therefore, activities that potentially affect invertebrates, such as moss harvesting, may also affect other components of ecosystems. The second objective of this study was to investigate the effects of harvesting on the composition, taxonomic richness and density of the invertebrate fauna of sphagnum moss.

2. METHODS

2.1 Study Sites

Twelve study sites that incorporated a range of altitudes, climate, plant associations and degree of harvesting were established, mainly on the West Coast of the South Island (Table 1 and Figure 2).

2.2 Sampling Methods

Invertebrates at all but two sites were sampled by taking five core samples of moss. Core samples were 9.3 cm in diameter, and were taken to the depth at which the moss was decayed enough to break off easily (7 cm to 20 cm). Sphagnum moss rarely grows in completely homogeneous stands; other plants species such as *Empodisma minus, Juncus* spp., *Baumea* sp. and *Gahnia rigida* are usually interspersed amongst the sphagnum. Thus, core samples usually contained other plant species in addition to *Sphagnum* spp. Samples were returned to the laboratory in sealed plastic bags. Invertebrates were extracted with Tullgren funnels under 60 W incandescent light bulbs for three days. Careful hand sorting of three samples confirmed that the Tullgren funnels successfully extracted more than 95 percent of macroinvertebrates. In addition to core samples, three grab samples were included in the invertebrate survey; Arthur's Pass and Ianthe (sites 11 and 12) were represented in the survey only by grab samples (n=2 and n=1, respectively). Grab samples consisted of two to three large handfuls of moss, and were equivalent in size to three or four core samples.

2.3 Identification of Invertebrates

All invertebrates were identified to family level, except for arachnids, which were identified to order, and Collembola which were simply grouped as a class. Formal identification below family level was usually not possible. However, separate species were distinguishable, and have been recognised in analyses as separate taxa. For example, two distinguishable but unidentifiable species of Schedotrigonidae (Diplopoda [millipedes]) were found in sphagnum moss (Table 2).

2.4 Effects of Harvesting

2.4.1 Commercial Harvesting

Seth Robinson's moss farm in the Arahura Valley, near Hokitika, provided an excellent opportunity to investigate the medium to long term effects of moss harvesting on invertebrate communities. Three sites that had been harvested commercially 7 months, 2 years, and more than 4 years previously, and one unharvested site were sampled on 8 April 1992 and 21 May 1992. The unharvested site and the site harvested 7 months previously were located in regenerating podocarp forest. Sites harvested 2 and 4+ years previously were situated in (Table 1). Thus, the density and taxonomic richness of invertebrate communities that had been subjected to harvesting at three different times were compared with those of a community unaffected by harvesting.

2.4.2 Harvesting Experiments

Experiments in which harvesting was simulated enabled the short term (6 weeks) effects of harvesting to be investigated in a controlled manner, and at a wider range of sites than are currently harvested commercially. Experiments were established in sphagnum moss beds

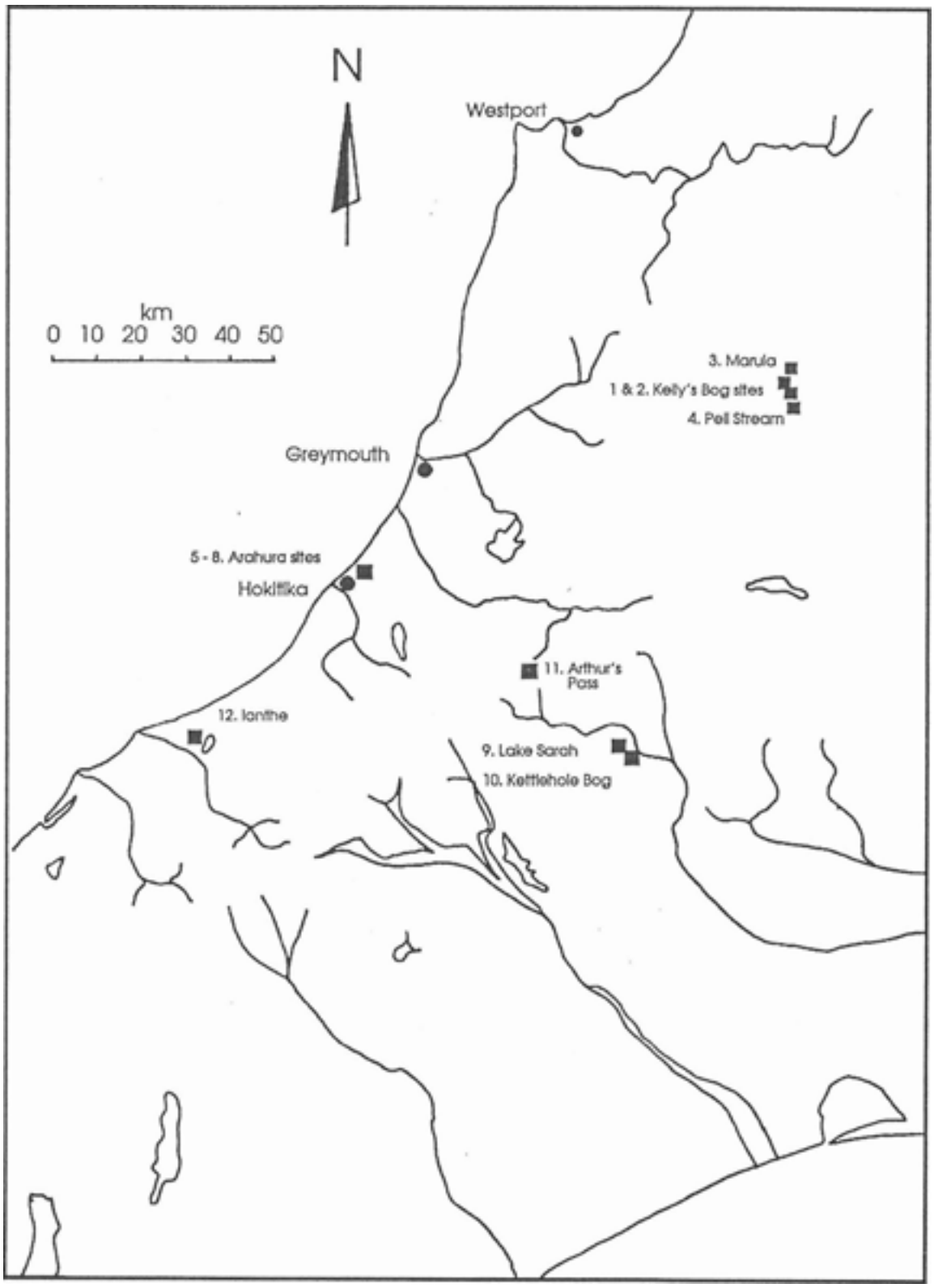


Figure 2 Location of study sites, South Island, New Zealand.

Table 1 Locations and brief descriptions of the study sites. * Experimental harvesting sites. † Commercial moss farm. Conductivity and pH of standing water, where present, are also shown.

Site & Grid reference	Elevation a.s.l (m)	Approx. annual rainfall (mm)	Mean annual daily temp (°C)	pH	Conductivity ($\mu S.cm^{-1}$)	Site description
1.* Kelly's Bog open NZMS 260 L31 457824	400	2400	11.0	4.7	21.5	Dense *Sphagnum* spp. interspersed with *Empodisma minus.*
2.* Kelly's Bog scrub. As above	400	2400	11.0	4.9	35.8	*Sphagnum* spp. and *Juncus* sp. under manuka
3.* Maruia NZMS 260 L31 478894	410	2400	11.0	-	-	*S. australe* 5 to 10 cm deep in wet depressions in red/silver beech forest. Much leaf litter.
4. Pell Stream NZMS 260 L31 495753	590	2400	11.0	-	-	Thick carpet of *S. cristatum* and *S. australe* in a clearing in mountain beech forest.
5. † Arahura rushland. 2 yr. NZMS 260 J32 476337	10	2800	11.0	3.9	63.8	*Sphagnum* spp. amongst *Juncus gregiflorus, Baumea* sp. and *Gahnia rigida*. Harvested 2 years before this study commenced.
6. † Arahura rushland 4+ year As above	″	″	″	″	″	As for site 5 but harvested more than 4 years ago.
7. † Arahura regen. 7 months As above	″	″	″	-	-	*Sphagnum* spp. in regen. podocarp forest. Harvested 7 months ago.
8. † Arahura regen. Unharvested As above	″	″	″	-	-	As for site 7 but unharvested.
9.* Lake Sarah NZMS 260 L34 106947	580	1000	12.5	6.5	109	Mounds of dense *Sphagnum* spp. amongst tussocks. Boggy.
10. Kettlehole Bog NZMS 260 L34 115938	″	″	″	-	-	*Sphagnum* spp. bog in moraine depression. No cover.
11. Arthur's Pass NZMS 1 S59 053326	923	5600	8.5	-	-	Exposed boggy site among tussocks. On the Pass.
12. Ianthe NZMS 1 S57 2100205	20	4000	11.0	4.4	58.8	*S. cristatum* under *Coprosma* spp. Cutover podocarp forest.

at Kelly's Bog (mainly *S. cristatum)* Maruia (*S. australe*) and lake Sarah (*S. australe*) (Sites 1,2,3 and 9, respectively, Table 1). Kelly's Bog is an extensive moss bog with commercial potential, whereas the Maruia site (red beech forest) and the Lake Sarah site (tussock grassland) are not commercially viable.

At each site, five plots were established, each consisting of two contiguous 0.25 m^2 quadrats; one control and one experimental. Experimental quadrats were 'harvested' in a manner that simulated commercial harvesting. Large handfuls were gathered by sliding

Table 2 Invertebrates found in a survey of twelve sphagnum moss sites in the South Island. L= larvae, A= adult.

PHYLUM: ARTHROPODA			
Class: Arachnida			
Order: Acari			10+ spp.
Order: Araneae			15+ spp.
Order: Opiliones			5+ spp.
Order: Pseudoscorpiones			1+ spp.
Subphylum: Crustacea			
Order: Isopoda	**Family:**	Styloniscidae	1 sp.
Order: Amphipoda	**Family:**	Talitridae	*Parorchestia tenuis*
Class: Chilopoda	**Family:**	Chilenophilidae	*Zelanion* sp.
		Henicopidae	1 sp.
Class: Diplopoda	**Family:**	Schedotrigonidae	*Schedotrigona*: 2 spp.
		Cambalidae	*Eumastigonus*?: 1 sp.
		Dalodesmidae	1 sp.
		Habrodesmidae	1 sp.
Class: Symphyla	**Family:**	Scutigerellidae	*Hanseniella*: 1 sp.
Class: Collembola			6+ spp.
Class: Diplura	**Family:**	Japygidae	1 sp.
Class: Insecta			
Order: Hymenoptera	**Family:**	Formicidae	5 spp. L A
		Ichneumonidae	1 sp. A
	Superfamily:	Chalicidoidea	2 spp. A
Order: Diptera	**Family:**	Sciaridae	2 spp. A
		Ceratopogonidae	4 spp. A
		Chironomidae	7 spp. A
		Tipulidae	*Gynoplistia magnifica* A
		Dolichopodidae	1 sp. A
		Mycetophilidae	*Mycetophila* sp.
		Tachinidae	1 sp. A
		Unidentified	3 spp. L

both hands under the moss, palms up, fingers apart, and pulling off the top layer of moss. These handfuls of moss were then shaken over the quadrat, to dislodge small fragments, and discarded. One core sample (9.3 cm diameter) was taken from each control quadrat at the beginning of the experiment, and from each control and harvested quadrat six weeks later. Thus, invertebrate communities in recently harvested quadrats were compared to those in adjacent, unharvested quadrats.

Table 2 ***(Continued)*** **L = larvae, A = Adult.**

Order: Lepidoptera	**Family:**	Oecophoridae	*Gymnobathra* sp. L
			Tingena spp. L
		Crambidae	Scopariinae L
			(?*Eudonia* sp.)
			Orocrambus sp. L
		Psychidae	*Mallobathra* sp. L
			Gryptotheca sp. L
		Noctuidae	1 sp. L
Order: Trichoptera	**Family:**	Leptoceridae	*Triplectidina* sp. L
		Hydroptilidae	*Paroxyethira hendersoni* L
		Philopotamidae	*Hydrobiosella stenocerca* L
Order: Coleoptera	**Family:**	Elateridae 3 spp. L	
		Pselaphidae	7 spp. L A
		Carabidae 5 spp. L A	
		Tenebrionidae	1 sp. L A
		Staphylinidae	10 spp. L A
		Ptilidae 1 sp. A	
		Curculionidae	6 spp. A
		Coccinellidae	*Coccinella leonina* A
		Scirtidae 1 sp. A	
		Unidentified	11 spp. L A
Order: Hemiptera	**Family:**	Pseudococcidae	5 spp. A
		Cicadellidae	1 sp. A
	Superfamily:	Aphoidea	1 sp. A
		Unidentified	12 spp. A
Order: Orthoptera	**Family:**	Gryllidae	1 sp. A (undescribed)
			Pteronemobius sp. A
Order: Blattodea	**Family:**	Blattidae	*Celatoblatta vulgaris*
PHYLUM: ANNELIDA			
Class: Oligochaeta	**Family:**	Lumbricidae	1 sp.
PHYLUM: MOLLUSCA			
Class: Gastropoda			1 minute sp.
PHYLUM: ONYCOPHORA	**Family:**	Peripatopsidae	*Ooperipatellus insignis*
PHYLUM: PLATYHELMINTHES			
Class: Turbellaria	**Family:**	Geoplanidae	*Geoplana* cf. *agricolor*

2.5 Invertebrate Survey

Invertebrate surveys were made at four sites (sites 4,10,11 and 12) in addition to the four experimental sites and four commercial sites described above. This ensured that invertebrate communities from as wide a range of conditions as possible were represented in the survey.

3. RESULTS

3.1 Invertebrate Survey

Over 130 taxa were taken in sphagnum moss samples (Table 2). They represented 25 orders in five phyla (Arthropoda, Annelida, Mollusca, Onycophora and Platyhelminthes). The same broad taxonomic groups (Figure 3), in similar densities (Figure 4), were found at all sites, whether harvested or not. Four taxonomic groups, (Acari [mites], Araneae,

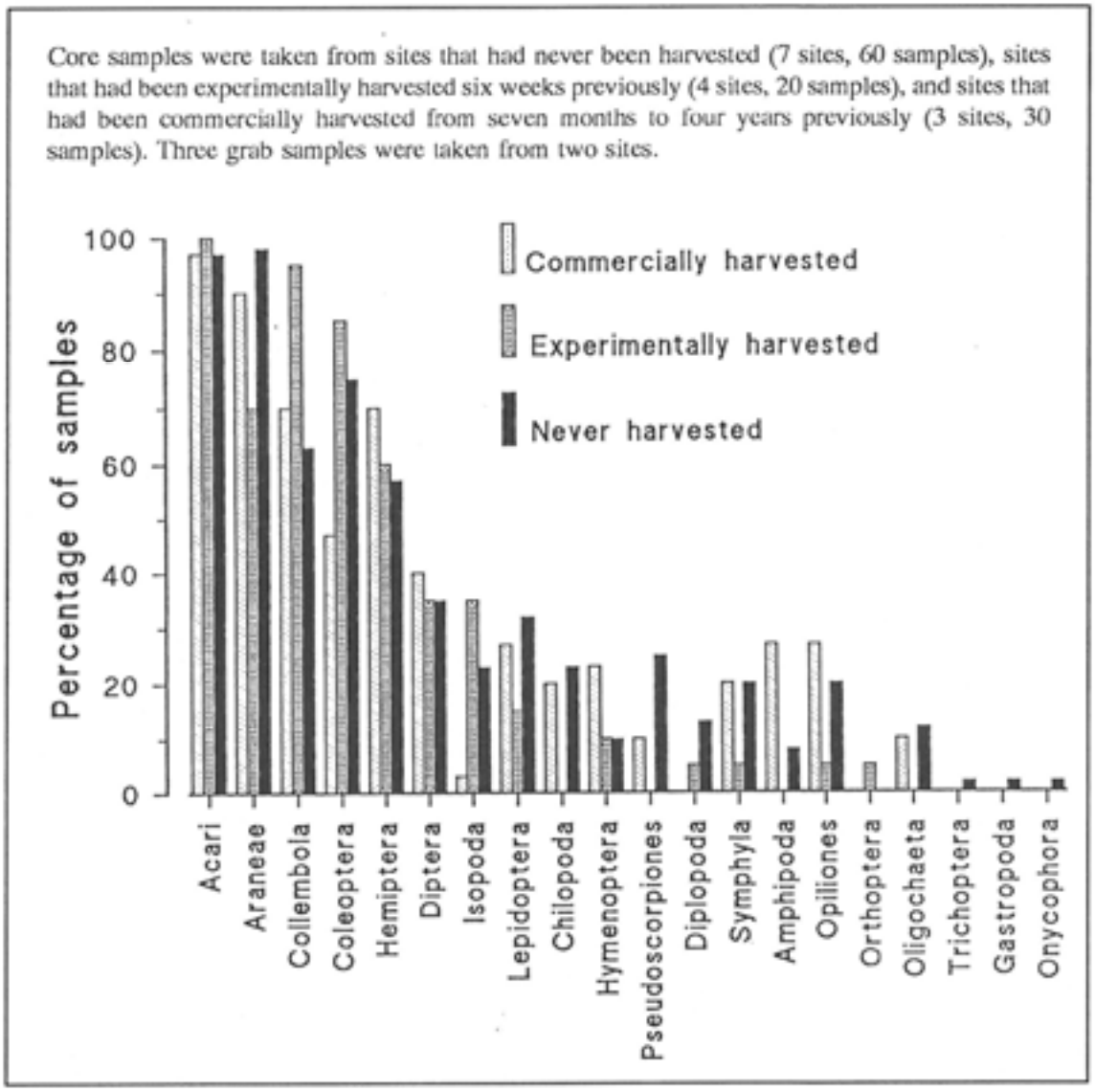


Figure 3 Occurrence of invertebrate taxa in the 113 sphagnum moss samples taken during the course of the study.

[spiders], Collembola [springtails] and Coleoptera [beetles]) occurred at all sites. Diptera (flies) and Hemiptera (bugs) were also widespread, and were found at more than 75 percent of the sites. These six groups also dominated numerically (Figure 4). Mites were particularly abundant (up to several thousand in some samples), and almost always occurred at higher densities than all other invertebrates combined. Springtails were also very abundant (several hundred in many samples). Although not as widespread as the above groups, ants (Hymenoptera) were usually numerous where they did occur, since nests occurred in the moss. Many invertebrate taxa were represented by only one or a few individuals that occurred in only a few samples.

Seventeen aquatic insect species, representing seven families, were taken in moss samples. The larvae of New Zealand's two giant dragonfly species, *Uropetala carovei* and *U. chiltoni* (Odonata: Petaluridae), inhabit mossy bogs and seepages, including sphagnum bogs (Rowe 1987). However, neither was present in moss samples taken from the twelve sites surveyed in this study, and neither was the aquatic *Paraleptamphopus caeruleus.* The latter can be extremely abundant amongst sphagnum where it occurs alongside very acid creeks as on the Larry River terraces north of

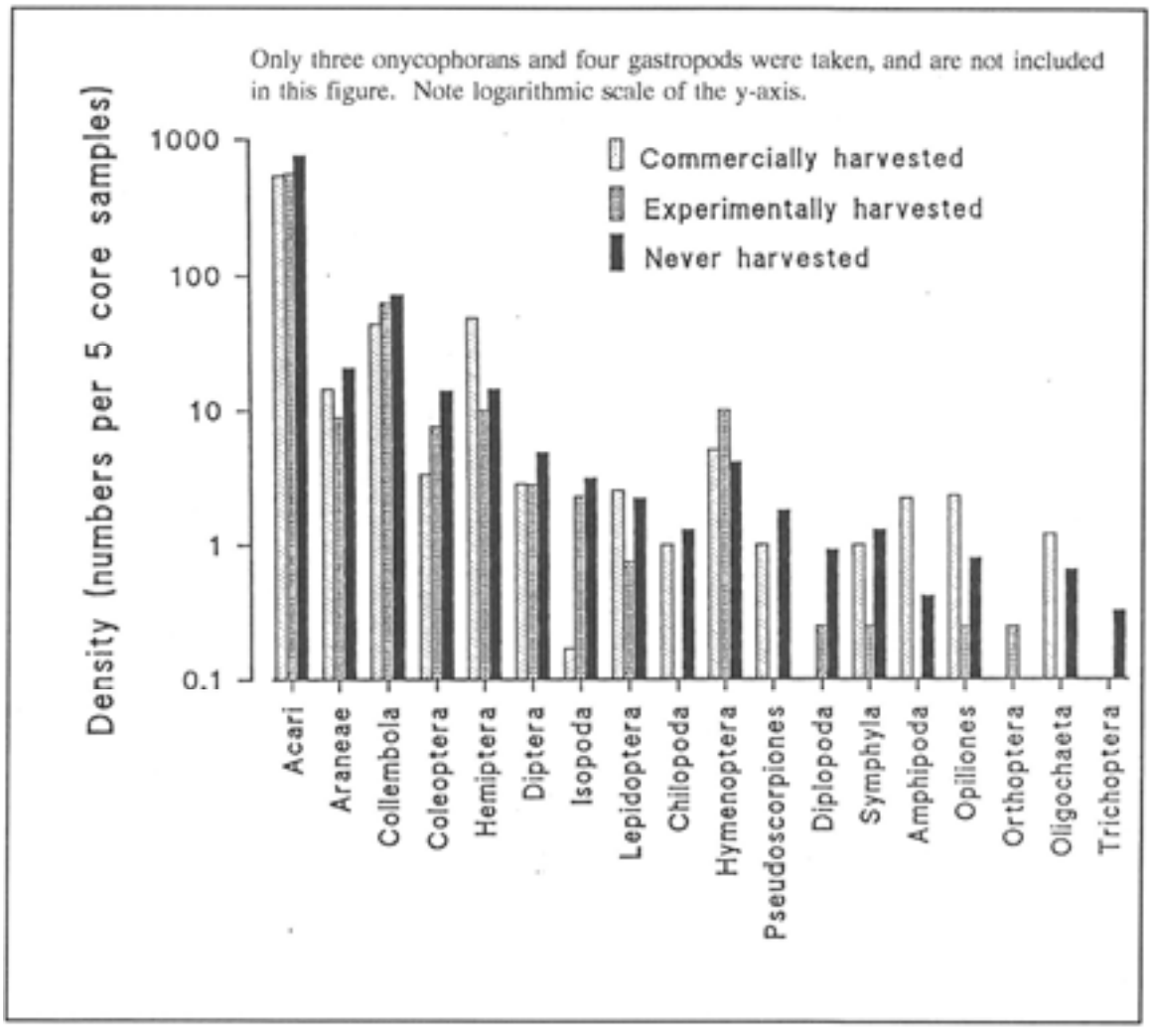


Figure 4 Mean densities (numbers per 5 core samples) of invertebrate taxa in sphagnum moss based on all 110 core samples as detailed in the legend to Figure 3.

Reefton (M.J.W.; pers. Obs.). Two notable occurrences were the rarely seen *Ooperipatellus insignis* (Onycophora) and an undescribed species of cricket (Orthoptera: Gryllidae).

3.2 Effect of Harvesting

3.2.1 Commercial Harvesting

The three sites on Robinson's farm that had been harvested at different times did not differ significantly from each other in taxonomic richness, and neither did they differ in this respect from the site that had never been harvested (ANOVA, p=0.337) (Figure 5). Twenty one to thirty invertebrate taxa were taken from each of the four sites (Figure 5). The six common taxonomic groups identified in the survey also dominated numerically at all four sites on the moss farm.

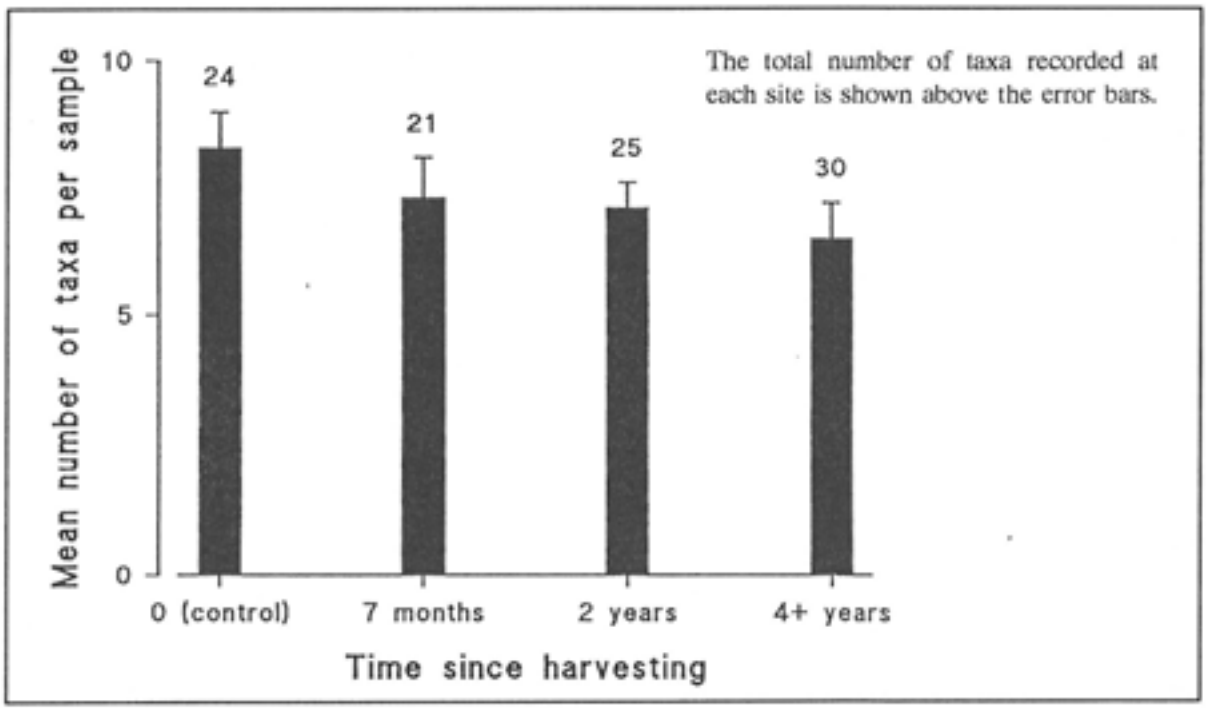


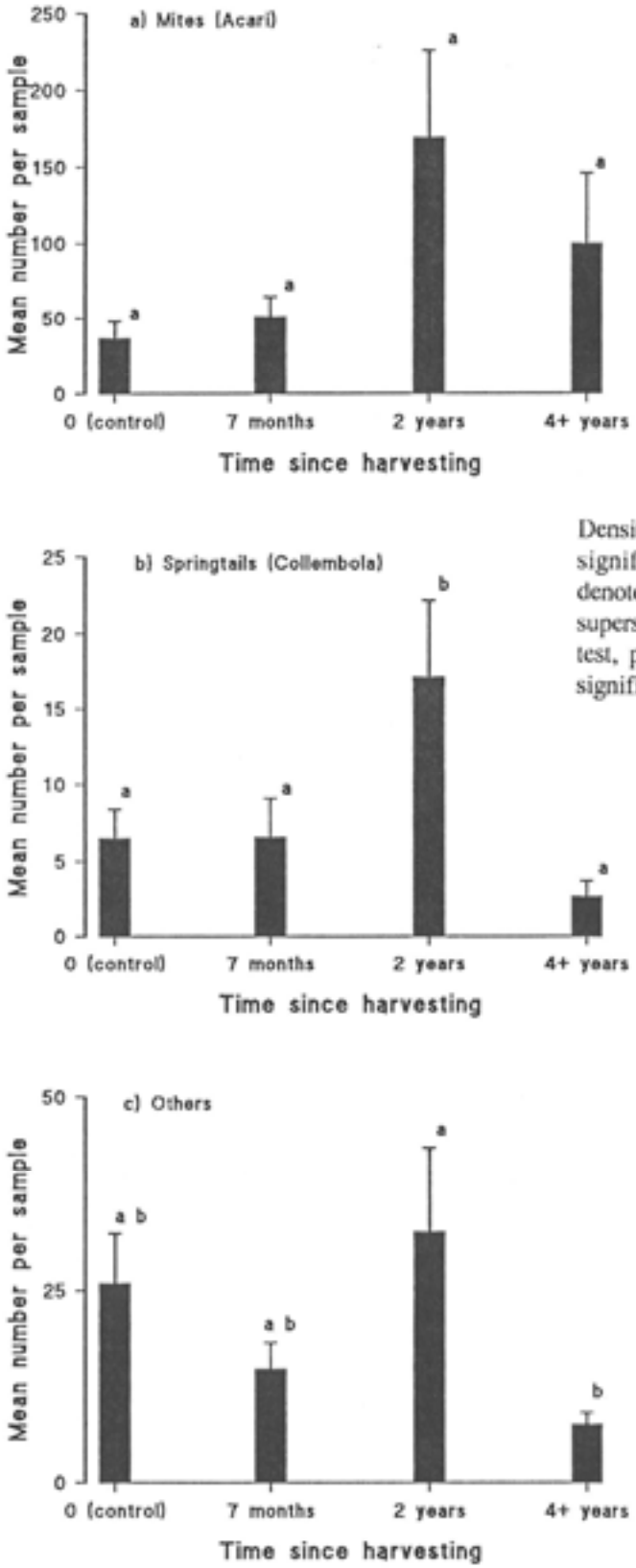
Figure 5. Mean (±S.E.) numbers of invertebrate taxa present in core samples at unharvested site and 3 previously harvested sites.

Densities of mites, springtails, and all other invertebrates combined were compared among the four sites. Mean densities of all three groups were highest at the site harvested two years previously. However, faunal densities varied considerably among replicate samples and only two significant differences ($p < 0.05$) were found (Figure 6).

The similarity of invertebrate assemblages at all pairs of sites at the moss farm was compared with Sørensen's Index:

$$C_s = 2c / (a + b)$$

where a = the number of taxa at the first site,
b = the number of taxa at the second site, and
c = the number of taxa that occurred at both sites.



Densities did not differ significantly at sites denoted by the same superscript letter (L.S.D. test, $p < 0.05$ following a significant ANOVA).

Figure 6. Mean densities of a) mites (Acari), b) springtails (Collembola), and c) all other invertebrates combined, at one unharvested site and three previously harvested sites.

Index values ranged from 0.33 to 0.50 (Table 3) and showed no particular trend in degree of taxonomic similarity between sites with respect to time since harvesting. Similarity was greatest between the control site and the most recently harvested site, and probably reflects their location in regenerating forest rather than rushland.

	0 (control)	7 months	2 years
7 months	0.50		
2 years	0.33	0.40	
4+ years	0.41	0.36	0.39

Table 3 Sørensen's Index of similarity for all possible pairs of sites at the commercial moss farm.

3.2.2 Harvesting Experiments

Harvesting experiments were undertaken at Kelly's Bog (two sites), Maruia and Lake Sarah. Total numbers of taxa found in experimentally harvested quadrats ranged from 9 to 24, whereas 6 to 32 taxa were taken from control (unharvested) quadrats at each of the sites (Figure 7). Numbers of invertebrate taxa found were greatest at Maruia (2 Way ANOVA,

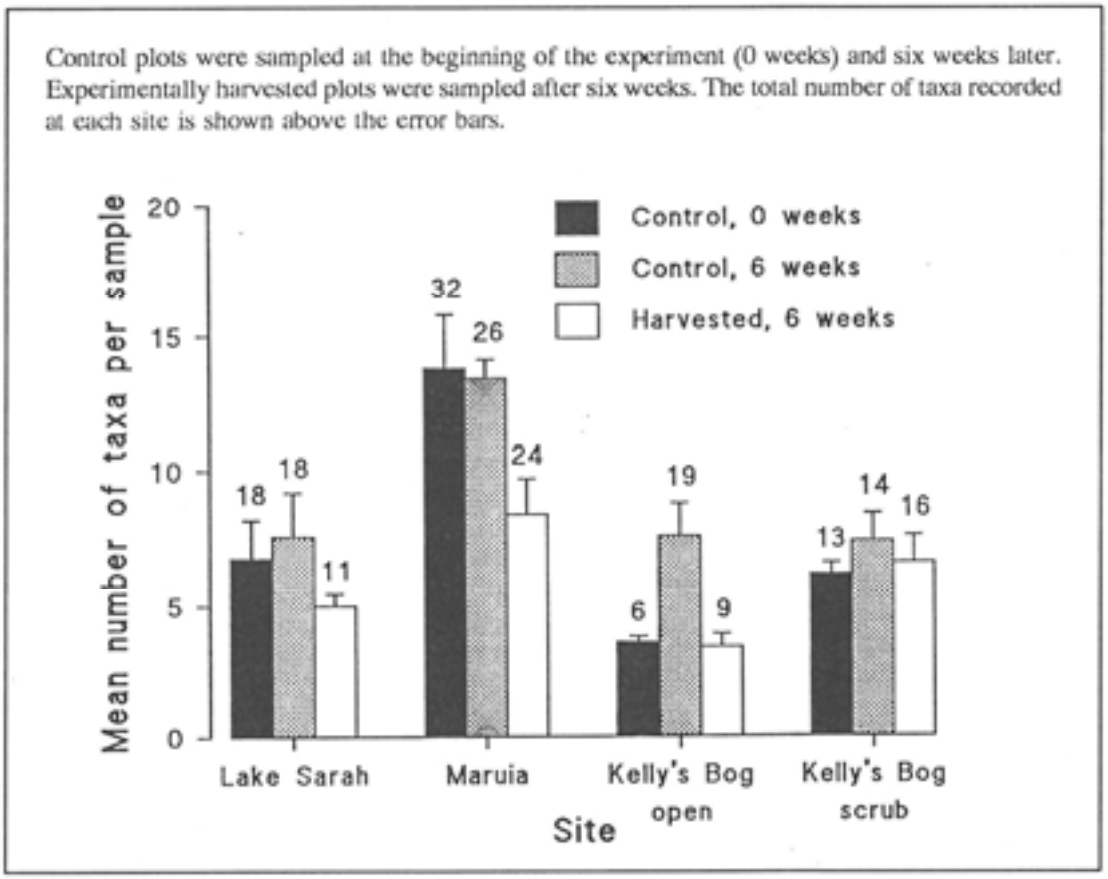


Figure 7 Mean (± 1 S.E.) numbers of invertebrate taxa present in core samples (n=5) at four experimentally harvested sites.

p <0.001; LSD test, p ,0.01), where the sphagnum occupied depressions in the beech forest floor. As well as differeing between sites, the mean number of taxa was significantly lower in harvested quadrats (5.8 ± 0.6 taxa per sample) (2 Way ANOVA, p <0.001; LSD test, p <0.05).

Densities of mites and springtails were highly variable, both among sites, and among control and experimental quadrats (Figure 8). No clear relationship between harvesting and invertebrate density was apparent for these two groups. Other invertebrates, however, occurred at significantly lower densities (7.1 ± 1.4) in harvested quadrats and in control quadrats sampled at the beginning of the experiment (11.6 ± 2.6), than in control quadrats harvested at the end of the experiment (20.9 ± 3.7) (2 Way ANOVA, p <0.001; LSD test, p < 0.01). The mean density of the invertebrates was significantly greater at Maruia (26.9 ± 4.5) than at the other three experimental sites (8.7 ± 1.1).

4. DISCUSSION

A surprisingly rich fauna inhabits sphagnum moss. For example, the total of 137 distinguishable taxa in over 50 families compares with 238 species taken by Moeed and Meads (1985) in pitfall traps in native forest near Wellington, and 73 arthropod families from bracken growing on Banks Peninsula (Winterbourn 1987). In the only comprehensive study of invertebrates associated with bryophytes in New Zealand, Suren (1991) recorded 94 distinguishable taxa on aquatic mosses and liverworts in two mountain streams.

Sphagnum moss provides a stable, humid environment for invertebrates. It is inhabited by a few abundant taxa that were common to most sites, and many scarce taxa that occurred only occasionally. The amount of water present at sphagnum sites undoubtedly influences the composition of the invertebrate fauna. For example, aquatic species occurred only at Kelly's Bog and the Arahura sites, which were very wet. On the other hand, ants, a strictly terrestrial family, inhabited only relatively dry sites, such as forest at Arahura.

No species known to be threatened or endangered were found in sphagnum moss. The Phylum Onycophora has a restricted world-wide distribution and, because of its evolutionary significance in particular, is of outstanding conservation value. The most widespread New Zealand species, *Peripatoides novaezealandiae*, occurs principally in decomposing logs, whereas *Ooperipatellus insignis* appears to be restricted to the western half of the South Island and has been collected from forest litter, under stones and amongst mosses (Ruhberg 1985). We found only three individuals of *O. insignis* during the present study and sphagnum moss is unlikely to be its major habitat.

In Tasmania, Whinam et al. (1989) observed that the structurally simplest and most homogeneous sphagnum mires exhibited the lowest diversity of fauna, and our findings are consistent with this view. Thus, Kelly's Bog a 'clean', homogeneous sphagnum site, had the least diverse fauna, whereas Maruia, a heterogeneous red beech site, had the most diverse

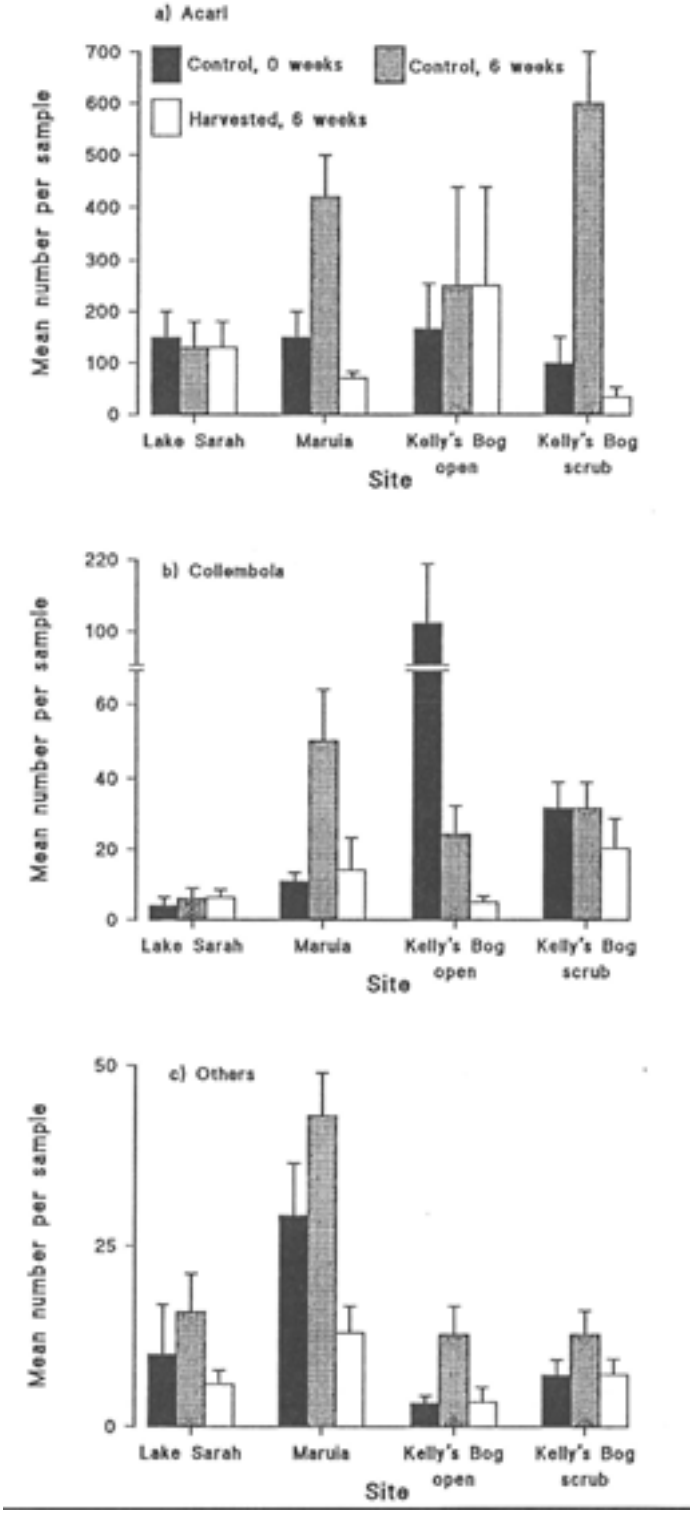


Figure 8 Mean densities of a) mites (Acari), b) springtails (Collembola), and c) all other invertebrates combined, at 4 experimentally harvested sites (see legend to Figure 7).

fauna. Kelly's Bog scrub was intermediate in habitat complexity and in invertebrate diversity. Thus, site specific factors, particularly the presence of closely associated vegetation and or plant detritus (e.g. beech leaves), appear to have a strong influence on the richness of sphagnum moss invertebrate assemblages. The Lepidoptera provide a good example. Of the seven species found, the caterpillars of two are likely to eat bryophytes, whereas the others feed on fallen leaves, and algae (J. Dugdale, pers. comm.).

In contrast, we found that commercial moss harvesting had little apparent effect on invertebrate communities. Comparisons of community composition, taxonomic richness, and invertebrate densities at a moss farm revealed few differences between sites that could be considered the direct result of moss harvesting.

However, our short term experimental study did reveal a small decrease in taxonomic richness and density of invertebrate assemblages at some sites, six weeks after simulated harvesting. This probably reflected the removal of invertebrates, by simulated harvesting, rather than changes in fauna induced by alteration to the habitat. Nevertheless, the presence of a fauna little different from that in control plots only six weeks after harvesting suggests that significant numbers of invertebrates were left behind, and/or that recolonization from surrounding undisturbed patches of moss was rapid. Either way, it appears that the invertebrate community recovers from sphagnum moss harvesting more quickly than the moss itself.

RECOMMENDATIONS

Commercial harvesting appears to pose little or no threat to invertebrate communities associated with sphagnum moss. We therefore recommend that the sustainable management of sphagnum should provide adequate protection of invertebrates. Nevertheless, we strongly recommend that sphagnum moss harvesting continue to be prohibited in reserves and National Parks in order to fully protect sphagnum wetlands and their diverse associated faunas.

6. ACKNOWLEDGEMENTS

We thank Dr Colin Miskelly, then DOC, Hokitika, who initiated the project, and Kath Walker, DOC, Nelson, for providing an introduction to the literature. We also thank Rowan Buxton for assistance with fieldwork, and Seth Robinson for permission to work on his property. Thanks to John Dugdale for identification of Lepidoptera, and Raphael Didham and Peter Johns for assistance with the identification of other arthropods.

7. REFERENCES

Buxton, R.P. 1991. Upper Buller Sphagnum Survey. DSIR contract report no. 91/110

Buxton, R.P,; Espie, P.R.; Johnson, P.N. 1991. Sphagnum moss studies in Westland: 1990-91 botanical report. DSIR Land Resources contract report no. 91/107

Buxton, R.P,; Espie, P.R.; Johnson, P.N. 1990. Sphagnum moss studies in Westland: botanical report. DSIR Land Resources unpublished report.

Grehan, J.R.; Patrick, B.H. 1984. Notes on bog inhabiting Hepialidae (Lepidoptera) of New Zealand. *New Zealand Entomologist 8.* 63-67

Johns, P.M. 1977. The Biology of the Terrestrial Fauna. In Burrows, C.J. (Ed.) Cass: *History and Science in the Cass District, Cantebury, New Zealand.* Pp. 311-328. Botany Department, University of Cantebury.

Johnson, P.N.; Buxton, R.P.; Espie, P.R. in press. *Sphagnum.* An information booklet with identification key.

Miller, D. 1971. *Common insects in New Zealand.* A.H. and A.W. Reed Ltd. Wellington, 179 pp.

Moeed, A.; Meads, M.J.; 1985. Seasonality of pitfall trapped invertebrates in three types of native forest, Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology 12:* 17-53

Patrick, B.H. 1991 Insects of the Dansey Ecological Region. Science and Research Series 32. Department of Conservation, Wellington.

Rowe, R.J. 1987. *The Dragonflies of New Zealand.* Auckland University Press., Auckland, 260 pp.

Ruhberg, H. 1985. Die Peripatopsidae (Onycophora). *Zoologica 137.* 1-181

Suren, A.M. 1991. Bryophytes as invertebrate habitat in two New Zealand alpine streams. *Freshwater Biology 26*: 399-418

Whinam, J; Eberhard, S; Kirkpatrick, J.B.; Moscal, A. 1989. *Ecology and conservation of Tasmanian* Sphagnum *peatlands.* Tasmanian Conservation Trust Inc., Hobart. 107pp

Winterbourn, M.J. 1987. The arthropod fauna of bracken (*Pteridium aquilinum*) on the Port Hills, South Island, New Zealand. *New Zealand Entomologist 10.* 99-104