Invertebrate communities in a modified isolated raised bog compared to an intact raised bog in New Zealand

C.H. Watts[1], B.R. Clarkson[1], V.M. Cave[2], D. Thornburrow[1], S. Thorpe[3]

[1] Manaaki Whenua - Landcare Research, Private Bag 3127, Hamilton, New Zealand
[2] AgResearch Ltd., Private Bag 3115, Hamilton, New Zealand
[3] Independent researcher, Auckland, New Zealand

SUMMARY

The effect of modifying New Zealand's threatened peat bogs on invertebrate communities is poorly known, despite their susceptibility to disturbance and their ecological significance. Using Malaise traps, we surveyed and compared terrestrial invertebrates in a remnant modified bog (Moanatuatua) isolated in an agricultural landscape and a community in an intact large bog (Kopuatai) in New Zealand. On average, more invertebrates were caught in the modified bog than in the intact bog. In addition, observed mean abundances for Diptera were higher at the modified bog. In contrast, total and geometric mean abundance of Coleoptera was significantly lower in the modified bog compared to the intact bog. We found no evidence of differences in species richness of Coleoptera, Lepidoptera, Diptera, Hymenoptera between the two bogs. Introduced species were more common in the modified bog. Ordination results indicated a difference in invertebrate community composition between the two bogs, and in addition the modified bog plots separated according to their distance from the wetland edge. Our results indicate that, within a modified isolated bog, native invertebrates can survive, and that some specialised and threatened species can thrive. However, the lower proportion of native Diptera and Lepidoptera taxa abundance in the modified bog is reason for concern.

KEY WORDS: assemblages, Coleoptera, Lepidoptera, Malaise traps, restiad peatlands

INTRODUCTION

There is a vast literature outlining the global importance of peatlands for carbon storage and biodiversity (for a review see Joosten 2016). In the Northern Hemisphere, raised peat bogs are dominated by *Sphagnum* moss with scattered or clumped ericaceous shrubs (Rydin & Jeglum 2013). Information on their biodiversity (e.g. they are characterised by species-poor communities whose taxa have highly specific habitat requirements, such as acidic or nutrient-poor conditions), and rates and patterns of decline, have been quantified (Laine *et al*. 1995, Talbot *et al*. 2010, Rydin & Jeglum 2013). In contrast, much less is known about the peat bogs of the Southern Hemisphere. This is particularly true for the floristically distinct peat bogs of New Zealand (Clarkson *et al.* 2004, Clarkson *et al*. 2013). In northern New Zealand, peat bogs are characterised by the peat-forming plants *Sporadanthus ferrugineus* and *Empodisma robustum* from the family Restionaceae (restiads). Despite their ecological significance, many have been drained for agricultural conversion over the last 150 years and are now highly modified (Clarkson *et al.* 2017). *Sporadanthus* raised bogs represent one of New Zealand's most threatened ecosystems, with only 3 % of their former extent remaining at the last available assessment (de Lange *et al*. 1999).

Invertebrates are important components of these threatened peat bog ecosystems and perform significant functional roles (e.g. predator-prey relationships, decomposers, and pollinators; Watts *et al*. 2008). However, little is known about the invertebrate communities associated with New Zealand restiad peat bogs. The fauna of these bogs is relatively depauperate but includes some specialised species (Watts *et al*. 2008, Watts *et al*. 2013). A preliminary survey of New Zealand's most intact raised bog (Kopuatai) revealed a low species diversity but with a number of native specialised taxa present (i.e. those whose only host plants were peat bog species), of which two were previously undescribed (Watts & Hoare 2009). Many taxa known from New Zealand peat bogs remain undescribed, with only a few new species been described in the past few decades (e.g. Hoare *et al*. 2006).

The effect of modifying and isolating New Zealand's remaining peat bogs on their invertebrate communities is still poorly understood. Previous studies have indicated that modified bogs have higher invertebrate abundance and species richness, mainly due to an influx of introduced species from surrounding modified habitats, such as willows and pasture (Watts *et al*. 2008, Watts 2009). Given the limited published information, as well as the vulnerability and ecological significance of this threatened ecosystem, we surveyed invertebrates in a remnant modified bog isolated in an agricultural landscape, compared to a reference community in an intact large bog. Specifically, we hypothesised that (1) the abundance and species richness of the terrestrial invertebrate community, in particular the four most common Orders, sampled using Malaise traps would be higher in a modified isolated bog than in the intact large bog; (2) the community composition would differ between the two bogs; and 3) introduced taxa will be more prevalent, particularly on the bog edge, in the modified isolated bog. While information regarding the invertebrate communities inhabiting New Zealand peat bogs is inadequate, we do know that the Lepidoptera associated with bogs often have specialised taxa, probably because they utilise specific host plants that are found only in bogs (Watts *et al*. 2013). We finally hypothesised, therefore, that (4) there will be less specialised peatland Lepidoptera taxa present in the modified isolated bog.

METHODS

Study site

The study was conducted at Moanatuatua and Kopuatai raised bogs, which are located approximately 55 km apart in the Waikato region, New Zealand. These sites lie within a lowland area with moderate temperatures (annual mean 13.6 and 14.3 °C at Moanatuatua and Kopuatai, respectively), high humidity (83 and 80 %, respectively), and moderate rainfall (1252 and 1339 mm yr^{-1}, respectively). The Moanatuatua Peat Scientific Reserve (114 ha) is protected and administered by the New Zealand Department of Conservation. This raised bog remnant contains a representative example of the *Sporadanthus/Empodisma* restiad bog type. The vegetation at Moanatuatua is dominated by the cane-like *S. ferrugineus* (up to 2.5 m in height) and the heath shrub *Epacris pauciflora*, which overtops a dense lower layer of intertwining, wiry-stemmed *E. robustum*. A sparse ground cover is present including a few ‘dryland’ or non-bog species (e.g. *Pteridium esculentum* and *Histiopteris incisa*). Moanatuatua is currently ring-drained, lacks buffer zones, and is surrounded by intensive agricultural land. As a result, the remnant is vulnerable to nutrient inputs from agricultural practices on adjacent land, such as from aerial drift of fertiliser. Kopuatai is a mainly intact, large (9,000 ha) bog surrounded by pasture. It is the largest raised bog in New Zealand and is designated as a Government Purpose Reserve (New Zealand Department of Conservation) and a Ramsar site. The vegetation is dominated by erect clumps of *S. ferrugineus* up to 2.5 m tall, over a dense layer of *E. minus*. Three woody species, *Leptospermum scoparium*, *Dracophyllum lessonianum* and *Epacris pauciflora*, occur in sparse patches within Kopuatai, but are more common near the bog margins. Liverworts (*Goebelobryum unguiculatus*), mosses (*Sphagnum cristatum*), carnivorous herbs (*Drosera binata*) and lycopods (*Lycopodiella lateralis*) occur where open ground is present (Clarkson *et al*. 2004). This bog was chosen as our reference site.

At Moanatuatua, one 5 × 5 m plot was placed at 28, 55, 105, 225 and 335 m (5 plots in total) from the wetland edge into the bog along an east–west transect. At Kopuatai, we selected a similar vegetation type (late-successional *Sporadanthus/ Empodisma*) and established one 5 × 5 m plot at 975, 1000, 1850 and 2005 m (4 plots in total) along a transect from the wetland edge to the approximate centre of the bog. Only four plots could be discretely placed without being near the edge of the selected vegetation type at Kopuatai.

Invertebrate sampling, sorting and identification

Invertebrates were collected using a modified mini Malaise trap (Watts *et al*. 2012) placed in the centre of each 5 × 5 m plot. The mini Malaise trap is the most efficient trapping technique for sampling flying invertebrates in the very windy environment and wet ground found within the low stature vegetation of New Zealand peat bogs (Watts 2009, Watts & Hoare 2009). The Malaise trap collecting jar was orientated along a north-south axis with the jar opening to the north and contained 150 ml of 50 % monopropylene glycol. Traps were set for approximately one month, from 10 February to 06 March 2017 (late austral summer). Invertebrates were preserved in 70 % ethanol and transported back to the laboratory at Manaaki Whenua - Landcare Research, Hamilton for identification and counting.

Invertebrates were sorted to Order level and counted using a binocular microscope. The four most common Orders caught and those that are most taxonomically well known in New Zealand (Coleoptera, Lepidoptera, Hymenoptera, and Diptera) were sorted according to their morphological characteristics and identified to recognised taxonomic units (hereafter referred to as “species”) and, where possible, identified to generic and species level. Coleoptera, Hymenoptera, and Diptera were identified by ST and Lepidoptera were identified Dr Robert Hoare (Invertebrate Systematist, Manaaki Whenua - Landcare Research, Auckland, New Zealand). Coleoptera, Hymenoptera, Diptera, and Lepidoptera were classified as native or introduced according to MacFarlane *et al*. (2010) and knowledge from ST and RH.

Data analysis

For each of the four most common Orders, species abundance and species richness were compared between the modified bog at Moanatuatua and the intact bog at Kopuatai. Species abundance per plot was quantified for each of the four most common Orders by calculating the total number of invertebrates caught and the geometric mean number of each species caught.

The geometric mean was used because the underlying count data tended to be right-skewed. To accommodate zero values, the geometric mean was applied to the counts following addition of one, and then one was subtracted from the result. For each of the four most common Orders, species richness at each plot was quantified by calculating the number of unique invertebrate species caught. Two-sample 2-sided t-tests were then used to compare the mean total abundance, geometric mean abundance and species richness per plot between the two bogs separately for each of the four most common Orders. Dot-plots grouped by site were inspected for departures from normality and equality of variance. The standard F test of homogeneity was used to assess equality of variance. When evidence of heterogeneity was present, the t-test used separate variance estimates for each bog; otherwise a pooled variance estimate was used. Additionally, for total abundance, the proportion of native species caught was compared between the two bogs using logistic regression. As nearly all Coleoptera caught were native, only summary statistics for this Order are presented.

The data from all Orders were also analysed. The number of invertebrates caught per Order was calculated for each peat bog. As above, total abundance and geometric mean Order abundance per plot were quantified and two-sample 2-sided t-tests were used to compare the means for the two bogs.

To further compare the invertebrate communities at the two peat bogs, a species-level ordination was performed on the data from the four most common Orders. Non-metric multidimensional scaling (NMDS), based on the Bray-Curtis dissimilarity matrix of the square-root transformed species count data (i.e. the number of invertebrates of each species caught per plot), was used as the ordination method. Ordinations were performed using the metaMDS function of the R package vegan version 2.5-6 (Oksanen *et al*. 2019). The functions ordiplot and ordihull were used to create two-dimensional ordination plots with convex hulls for the two bogs. The centroids for the two bogs were compared using the envfit function after 999 permutations.

Unless otherwise stated, all statistical analyses were performed using Genstat for Windows 19th Edition, with a 5 % significance level.

RESULTS

In total, 1,434 invertebrates were collected from the five Malaise traps in the modified bog at Moanatuatua and 705 invertebrates from the four Malaise traps in the intact bog at Kopuatai. The same ten Orders - Araneae, Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Mantodea (*Orthodera novaezealandiae*, New Zealand praying mantis), Neuroptera, and Orthoptera - were collected at both bogs (see Appendix). At the modified bog, Diptera (62 % of total catch), Coleoptera (11 %), Lepidoptera (11 %), and Hymenoptera (7 %) were the most common Orders found. These Orders were also common at Kopuatai but in slightly different proportions: Diptera (41 %), Coleoptera (24 %), Hymenoptera (11 %), and Lepidoptera (9 %). Both bogs recorded the same most common invertebrates, including the introduced striped dung fly (*Oxysarcodexia varia*: Sarcophagidae: Diptera), the Scirtidae beetle family, the introduced cabbage white butterfly (*Pieris rapae*; Pieridae: Lepidoptera) and the Hymenoptera Ichneumonidae spp. Many undescribed taxa were found. This was particularly true for Diptera and Coleoptera, with only 45 and 39 %, respectively, of species found being previously described.

Invertebrate abundance and species richness

The combined analysis of data from all Orders provided evidence that total invertebrate abundance was higher at the modified bog (mean per plot = 286.8 ± SE = 24.1) than in the intact bog (mean per plot = 176.2 ± 8.7; $t = 3.9$, df = 7; $p = 0.006$), but there was no evidence that the geometric mean Order abundance was different between the two peat bogs (modified mean per plot = 8.4 ± 1.1, intact mean per plot = 8.4 ± 1.1, $t = 0.09$, df = 7; $p = 0.930$).

The observed total and geometric mean species abundance for Diptera, Lepidoptera, and Hymenoptera were higher at the modified bog than in the intact bog, but these differences were statistically significant only for Diptera (Table 1). In contrast, total and geometric mean abundance of Coleoptera was significantly lower at the modified bog than in the intact bog (Table 1).

There was no evidence that species richness differed between the two bogs for any of the four most common Orders (Coleoptera, Lepidoptera, Diptera, Hymenoptera; Table 1).

Community composition

All Coleoptera species caught in the intact bog were native, as were 97 % of the Coleoptera in the modified bog (see Appendix). The percentage of native Diptera and Lepidoptera species caught was significantly higher in the intact bog than at the modified bog (Table 2). Of the native Lepidoptera species captured in the Malaise traps, 50 % were considered peatland specialists across both sites, with all being found within the intact bog, while only one species (*Ericodesma scruposa*; Tortricidae; Lepidoptera) was caught in the modified bog. Although a higher percentage of native Hymenoptera were caught at the intact bog than at the modified bog, this difference was not statistically significant (Table 2).

The NMDS ordination plot is given in Figure 1. The stress of the ordination was 0.036, indicating that the two dimensions summarise the observed distances among the plots reasonably well. The centroids for the two peat bogs were significantly different, and the convex hulls were non-overlapping, indicating a difference in community composition between the two bogs. In addition, the plots within the modified bog at Moanatuatua were separated on the ordination plot by distance from the bog edge (Figure 1).

Table 1. Observed means per plot of total abundance, geometric mean species abundance and species richness sampled using Malaise traps at intact and modified raised peat bogs in New Zealand for the four most common Orders. Also given is the results of two-sample 2-sided t-tests for differences between these sites (SED = standard error of the difference; df = degrees of freedom). * denotes that the t-test used separate variance estimates for each peat bog rather than a pooled variance estimate. p-values ≤ 0.05 are in bold. Invertebrates were sampled using a mini Malaise trap placed in the centre of each study plot (4 plots at Kopuatai and 5 plots at Moanatuatua).

	Kopuatai (intact)	Moanatuatua (modified)	SED	test statistic (t)	df	p-value
	Total Abundance					
Coleoptera	41.3	30.2	4.1	2.67	7	**0.032**
Lepidoptera	16.5	30.2	8.1	1.69	7	0.135
Diptera	72.5	176.4	31.5	3.30	7	**0.013**
Hymenoptera	19.0	21.8	4.1	0.68	7	0.518
	Geometric Mean Species Abundance					
Coleoptera	0.70	0.53	0.05	3.11	7	**0.017**
Lepidoptera	0.44	0.63	0.14	1.33	7	0.266
Diptera	0.59	0.81	0.07	3.30*	4.64	**0.024**
Hymenoptera	0.56	0.61	0.08	0.67	7	0.522
	Species Richness					
Coleoptera	8.0	7.8	0.8	0.24	7	0.817
Lepidoptera	4.8	5.4	0.9	0.74	7	0.482
Diptera	14.8	16.2	1.7	0.83	7	0.434
Hymenoptera	6.5	6.2	1.1	0.28	7	0.787

Table 2. Mean percentage of native species per plot sampled using Malaise traps at intact and modified raised peat bogs in New Zealand for the four most common Orders. For Lepidoptera, Diptera and Hymenoptera this includes Wald test statistics for differences between these sites (SED = standard error of the difference; df = degrees of freedom). These are not given for Coleoptera as nearly all Coleoptera caught were native. p-values ≤ 0.05 are in bold.

	Kopuatai (intact)	**Moanatuatua (modified)**	**SED**	**test statistic**	**p-value**
Coleoptera	100.0	97.4			
Lepidoptera	89.4	24.5	5.2	54.5	**<0.001**
Diptera	35.9	15.5	3.1	52.4	**<0.001**
Hymenoptera	64.5	60.6	7.2	0.3	0.588

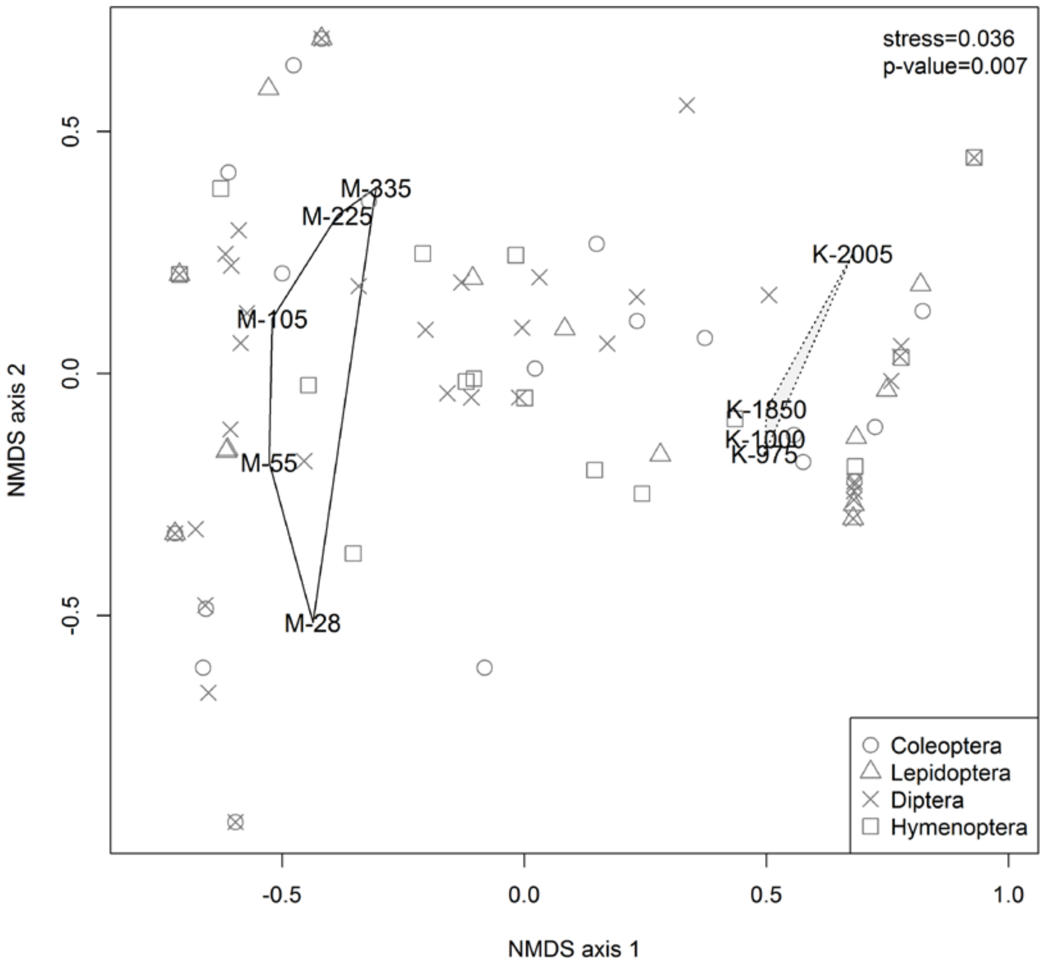

Figure 1. Non-metric multidimensional scaling (NMDS) ordination with the Bray-Curtis dissimilarity matrix between the square-root transformed total abundance of different Coleoptera, Lepidoptera, Diptera and Hymenoptera invertebrate species at four study plots within an intact raised peat bog (Kopuatai) and five study plots with a modified raised peat bog (Moanatuatua) in New Zealand. Scores for the Kopuatai plots are labelled 'K' and scores for Moanatuatua plots are labelled 'M'. Numbers indicate distance (m) from the wetland edge. The lines represent the convex hull for the two bogs, dashed for Kopuatai and solid for Moanatuatua. The NMDS stress value and the p-value for a test of difference between the centroids for the two bogs are given.

DISCUSSSION

Typically, the invertebrate communities observed in New Zealand peatlands are characterised by a low abundance and species diversity (Watts *et al*. 2008). Similar trends of low invertebrate species diversity have also been observed in Northern Hemisphere peat bogs (Spitzer & Danks 2006, Batzer *et al*. 2016, Sushko et al. 2017). Relating to our first hypothesis, on average, more invertebrates were caught in the Malaise traps in the modified bog at Moanatuatua than in the intact bog at Kopuatai, and observed mean abundances for Diptera were significantly higher at the modified bog than in the intact bog. In contrast, total and geometric mean abundance of Coleoptera was significantly lower at the modified bog than at the intact bog. However, contrary to expectations, we found no evidence of a difference in species richness of the four most common Orders (Coleoptera, Lepidoptera, Diptera, Hymenoptera) between the two bogs. New Zealand peatlands are also characterised by having many undescribed taxa. This was observed in the present study, in which we found that for Diptera and Coleoptera only 45 and 39 %, respectively, of species were taxonomically described. In contrast, in a study by Sushko (2017) of Coleoptera from a bog in Belarus, all 99 species found were described and identified to species level.

In support of our second hypothesis, the ordination results indicated that invertebrate community composition differed between the two bogs. Other studies have demonstrated that invertebrate communities in temperate wetlands are strongly correlated with differences in the structural complexity and composition of the vegetation communities (Watts *et al*. 2012, Sushko 2017). Clarkson *et al*. (2020) have shown that Moanatuatua has experienced significant decreases in water table and increases in N and P levels over the last 40 years, which has resulted in changes in vegetation composition and structure, and loss of some plant species. These vegetation changes and the differences observed between the modified Moanatuatua and the intact Kopuatai (Clarkson *et al*. 2020) could also be causing the differences in terrestrial invertebrate communities observed in this study.

As predicted in our third hypothesis, introduced taxa for some Orders were more common in the modified isolated bog at Moanatuatua, compared with the intact bog at Kopuatai. The percentages of introduced Diptera (dominated by the striped dung fly) and Lepidoptera (dominated by the cabbage white butterfly) caught in the Malaise traps were significantly higher at the modified bog, particularly in plots on the peatland edge, than at the intact bog, probably due to the influence of surrounding land use (e.g. introduced pasture). Interestingly, all Coleoptera caught at the intact bog were native and the majority (97 %) of the Coleoptera caught at modified bog were also native. The few other published New Zealand studies indicate that, if there is native wetland vegetation present, then the native beetle communities appear to be 'resistant' to factors such as changes in surrounding land use, degree of isolation and wetland size (Watts *et al*. 2012, 2015). These trends have also been observed in studies from other ecosystems (e.g. forest fragments) which show that small fragments of habitat dominated by native vegetation are important refuges for the persistence of indigenous insect communities (Harris & Burns 2000, Didham *et al.* 2009, Watts *et al*. 2016). The data collected here were too sparse to specifically analyse species prevalence in relation to distance from the bog edge. However, the ordination results for the four most common Orders showed the plots within the modified bog at Moanatuatua were separated by distance from the bog edge, indicating there is likely to be an edge effect on community composition. Further research into invertebrate prevalence in relation to the bog edge is required.

In support of our fourth hypothesis, some specialised peatland Lepidoptera were missing from the modified bog at Moanatuatua, compared with intact bog samples. For example, *Ichneutica similis* (Noctuidae) is known as a very localised New Zealand moth species, associated with peatlands in Waikato and Southland (Robert Hoare, pers. comm., 2019). A few specimens of this moth have been recorded historically from Moanatuatua in the New Zealand Arthropod Collection, Ko te Aitanga Pepeke o Aotearoa (Manaaki Whenua - Landcare Research, Auckland, New Zealand). Further surveys are needed to determine whether this moth is still present in modified bog at Moanatuatua, or whether it is now locally extinct following the ecological changes at the site. In contrast, one specialised and threatened species known to be present at the modified Moanatuatua bog is the moth *Houdinia flexilissima* (also found at the intact Kopuatai bog). The only known host of *H. flexilissima* is the plant, *S. ferrugineus*, which is also threatened (Hoare *et al*. 2006). The moth appears to have a two-year life cycle, with the larvae feeding on the green photosynthetic layer in the *Sporadanthus* stem, leaving star-shaped excavation tunnels (Hoare *et al*. 2006). This moth was not found in the present study due to the moths being active only in spring and early summer.

Clarkson *et al*. (2020) suggested that an ecological tipping point for the vegetation communities at the modified Moanatuatua bog may be imminent, which will favour faster-growing, nutrient-demanding woody plants over restiad species. Therefore, restoration actions - such as raising and stabilising the water table, and extending the bog area - should be considered at the modified Moanatuatua bog. Longer-term monitoring of the terrestrial invertebrate communities is required to determine if this trend also applies to the invertebrate fauna, in particular obligate restiad feeders, and to monitor the prevalence of native versus introduced species. In addition, terrestrial invertebrate communities should be monitored to assess the effect of any restoration or management actions undertaken at the modified Moanatuatua bog.

In conclusion, this study presents new data regarding the invertebrate communities of a modified bog isolated in an agricultural landscape compared with an intact large bog in New Zealand. To the authors' knowledge, this is the first comparative study in New Zealand on the invertebrate communities within a matched pair (modified versus intact) of raised bogs. Our results indicate that within a modified isolated bog, native invertebrates can survive. In addition, it is reassuring from a conservation perspective that specialised and threatened species, such as the moth *H. flexilissima*, are present and thriving within the modified remnant at Moanatuatua. However, the lower proportions of native Diptera and Lepidoptera taxa at the modified Moanatuatua bog is reason for concern. The little-known invertebrate fauna within this threatened ecosystem warrants further investigation, with particular focus on the impact of factors such as surrounding land use, degree of isolation, wetland size and influence of edge effects. The current study presented a preliminary investigation into the specialised Lepidoptera fauna within the two bogs, with 50 % of the native Lepidoptera species found considered to be peatland specialists and only one of these species being found at the modified bog. To further examine these trends, we recommended a targeted survey using appropriate sampling techniques (e.g. light trapping) and timing for the species of interest.

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AUTHOR CONTRIBUTIONS

CHW designed the research; CHW, BRC and DT conducted the field research; VMC undertook the data analysis; ST identified the invertebrates; CHW and VMC wrote the draft manuscript; and all authors contributed to the final version of the manuscript.

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Author for correspondence:
Dr Corinne Watts, Manaaki Whenua - Landcare Research, Gate 10, Silverdale Road, Hillcrest 3216, Hamilton, New Zealand. Tel: +64-7-8693706; Email wattsc@landcareresearch.co.nz

Appendix: Invertebrates collected from the modified Moanatuatua bog and the intact Kopuatai bog in New Zealand.

Order	Family	Species	Status	Modified peat bog (Moanatuatua)	Intact peat bog (Kopuatai)
Araneae				X	X
Blattodea				X	X
Coleoptera	Anthicidae	*Sapintus pellucidipes*	Native		X
Coleoptera	Anthribidae	*Androporus discedens*	Native	X	X
Coleoptera	Carabidae	*Neocicindela tuberculata*	Native	X	
Coleoptera	Carabidae	*Notagonum* sp.	Native	X	
Coleoptera	Carabidae	*Notagonum submetallicum*	Introduced	X	
Coleoptera	Chrysomelidae	*Arnomus* sp.	Native	X	
Coleoptera	Chrysomelidae	*Longitarsus jacobaeae*	Introduced	X	
Coleoptera	Clambidae	*Sphaerothorax tierensis*	Introduced	X	
Coleoptera	Coccinellidae	*Adoxellus* sp.	Native		X
Coleoptera	Coccinellidae	*Halmus chalybeus*	Introduced	X	
Coleoptera	Curculionidae	Cossoninae spp.	Native		X
Coleoptera	Curculionidae	*Hoplocneme squamosa*	Native	X	
Coleoptera	Elateridae	*Conoderus exsul*	Native	X	X
Coleoptera	Elateridae	Elateridae spp.	Native	X	X
Coleoptera	Elateridae	*Ochosternus zealandicus*	Native	X	
Coleoptera	Erotylidae	*Loberus depressus*	Native	X	
Coleoptera	Latridiidae	Corticariinae spp.	Native	X	
Coleoptera	Mordellidae	*Mordella jucunda*	Native	X	X
Coleoptera	Oedemeridae	*Selenopalpus cyaneus*	Native	X	X
Coleoptera	Scarabaeidae	*Odontria* sp(p.)	Native	X	X
Coleoptera	Scirtidae	Scirtidae spp.	Native	X	X
Coleoptera	Staphylinidae	Xantholini spp.	Native	X	X
Coleoptera	Zopheridae	*Bitoma insularis*	Native	X	
Diptera	Acroceridae	*Ogcodes* sp.	Native	X	
Diptera	Agromyzidae	*Cerodontha* sp.	Native	X	
Diptera	Agromyzidae	*Liriomyza* sp.	Native	X	

Order	**Family**	**Species**	**Status**	**Modified peat bog (Moanatuatua)**	**Intact peat bog (Kopuatai)**
Diptera	Anthomyiidae	*Anthomyia punctipennis*	Introduced	X	
Diptera	Anthomyiidae	Anthomyiidae spp.	Native	X	
Diptera	Brachystomatidae	*Ceratomerus crassinervis*	Native	X	
Diptera	Ceratopogonidae	Ceratopogonidae spp.	Native	X	
Diptera	Chironomidae	Chironomidae spp.	Native		X
Diptera	Chloropidae	Chloropidae spp.	Native	X	
Diptera	Chloropidae	*Gaurax* sp.	Native	X	
Diptera	Dolichopodidae	Dolichopodidae spp.	Native	X	X
Diptera	Dolichopodidae	*Parentia restricta*	Native	X	
Diptera	Dolichopodidae	*Parentia* sp.	Native	X	
Diptera	Drosophilidae	*Scaptomyza* sp(p.)	Introduced	X	
Diptera	Empididae	*Chelipoda* sp.	Native	X	
Diptera	Ephydridae	*Ditrichophora flavitarsis*	Native		X
Diptera	Ephydridae	*Hydrellia* sp.	Native	X	X
Diptera	Ephydridae	*Hydrellia tritici*	Introduced	X	X
Diptera	Ephydridae	*Parahyadina* sp.	Native	X	
Diptera	Ephydridae	*Psilopa metallica*	Native	X	X
Diptera	Ephydridae	*Scatella* sp.	Native		X
Diptera	Helosciomyzidae	Helosciomyzidae spp.	Native		X
Diptera	Keroplatidae	Keroplatidae spp.	Native		X
Diptera	Keroplatidae	*Macrocera* sp.	Native	X	X
Diptera	Lauxaniidae	*Poecilohetaerella* sp.	Native	X	
Diptera	Limoniidae	Limoniidae spp.	Native		X
Diptera	Lonchopteridae	*Lonchoptera bifurcata*	Introduced	X	
Diptera	Muscidae	Muscidae spp.	Native		X
Diptera	Mycetophilidae	Mycetophilidae spp.	Native	X	X
Diptera	Periscelididae	*Cyamops alessandrae*	Native		X
Diptera	Phoridae	*Megaselia* spp.	Native	X	X
Diptera	Phoridae	Phoridae spp.	Native		X
Diptera	Pipunculidae	Pipunculidae spp.	Native		X

Order	Family	Species	Status	Modified peat bog (Moanatuatua)	Intact peat bog (Kopuatai)
Diptera	Sarcophagidae	*Oxysarcodexia varia*	Introduced	X	X
Diptera	Sciaridae	Sciaridae spp.	Unknown	X	X
Diptera	Sepsidae	*Lasionemopoda hirsuta*	Introduced	X	X
Diptera	Sphaeroceridae	Limosininae spp.	Unknown	X	X
Diptera	Syrphidae	*Melanostoma fasciatum*	Native	X	
Diptera	Tachinidae	*Chaetophthalmus bicolor*	Introduced	X	X
Diptera	Tachinidae	Tachinidae spp.	Native	X	X
Hemiptera				X	X
Hymenoptera	Bethylidae	*Sierola* sp.	Native	X	
Hymenoptera	Braconidae	Alaysinnae spp.	Unknown	X	X
Hymenoptera	Braconidae	Braconidae spp.	Unknown		X
Hymenoptera	Braconidae	Microgastrinae spp.	Unknown	X	X
Hymenoptera	Chalcidoidea	Chalcidoidea spp.	Unknown	X	X
Hymenoptera	Diapriidae	Diapriidae spp.	Unknown	X	X
Hymenoptera	Dryinidae	*Gonatopus alpinus*	Native	X	X
Hymenoptera	Formicidae	*Austroponera* sp.	Native	X	X
Hymenoptera	Formicidae	Formicidae spp.	Unknown	X	X
Hymenoptera	Formicidae	*Monomorium antarcticum*	Native		X
Hymenoptera	Ichneumonidae	Ichneumonidae spp.	Native	X	X
Hymenoptera	Megachilidae	*Anthidium manicatum*	Introduced	X	
Hymenoptera	Pompilidae	*Cryptocheilus australis*	Introduced	X	
Hymenoptera	Proctotrupidae	Proctotrupidae spp.	Unknown		X
Hymenoptera	Vespidae	*Ancistrocerus gazella*	Introduced	X	X
Hymenoptera	Vespidae	*Polistes chinensis*	Introduced	X	X
Hymenoptera	Vespidae	*Vespula vulgaris*	Introduced		
Lepidoptera	Crambidae	*Clepsicosma* sp. A	Native		X
Lepidoptera	Geometridae	*Chloroclystis filata*	Introduced	X	
Lepidoptera	Geometridae	*Epyaxa lucidata*	Native	X	
Lepidoptera	Lycaenidae	*Zizina labradus labradus*	Introduced	X	
Lepidoptera	Noctuidae	*Agrotis ipsilon*	Introduced	X	

Order	Family	Species	Status	Modified peat bog (Moanatuatua)	Intact peat bog (Kopuatai)
Lepidoptera	Noctuidae	*Graphania* (?)*pelanodes*	Native	X	
Lepidoptera	Noctuidae	*Ichneutica similis*	Native		X
Lepidoptera	Noctuidae	*Mythimna separata*	Introduced	X	X
Lepidoptera	Oecophoridae	*Euchersadaula* sp.	Native		X
Lepidoptera	Oecophoridae	*Tingena ancogramma*	Native	X	
Lepidoptera	Oecophoridae	*Tingena* sp. (basella group)	Native	X	X
Lepidoptera	Oecophoridae	*Tingena* sp. (thin valva)	Native	X	
Lepidoptera	Pieridae	*Pieris rapae*	Introduced	X	
Lepidoptera	Tineidae	*Monopis ethelella*	Introduced		X
Lepidoptera	Tortricidae	(?)*Hendecasticha aethaliana*	Native		X
Lepidoptera	Tortricidae	*Ericodesma scruposa*	Native	X	X
Lepidoptera		[indet.]	Unknown		X
Mantodea				X	X
Neuroptera				X	X
Orthoptera				X	X