Assessing the impact of honeybees on invertebrate communities in mānuka shrublands in New Zealand

Supplementary material

Appendix S1. Modified counting technique for small (<5 mm) Hymenoptera and Diptera.
Initially, one plot from each of the three plots at each site was randomly selected to be measured in more detail. A volume of 1 ml of small (<5 mm) specimens was poured into a glass measuring cylinder and allowed to settle for 12 hours. The numbers of specimens from Hymenoptera, Diptera, and other taxa were then counted to give a total number of small specimens per 1 ml. This process was repeated 5 times for the selected plot, giving values presented in the table below.

These values were not found to differ statistically between the three site pairs. Therefore, using these values, the numbers and composition of small (< 5 mm) specimens collected within all the plots at each site were inferred from the total volume of these specimens settled overnight in a measuring cylinder.

The mean number of individuals per ml, and the percentages of Diptera, Hymenoptera, and any other taxa within the pools of small (<5 mm) specimens.

Site pair	Site	Apiary status	Mean individuals per ml	Diptera (%)	Hymenoptera (%)	Others (%)
Tuawhenua	Parahaki	None	67	47	43	9
	Te Waiiti	Apiaries	65	48	40	5
Tongariro Frost Flat	Pukehinau	None	60	50	42	8
	Ketetahi	Apiaries	57	46	51	3
Tongariro Alpine	Mangatepopo	None	60	50	42	8
	Rangipo	Apiaries	57	46	51	3

Appendix S2. Composition of specimens, species, and amplicon sequence variants (ASVs).

Overall taxonomic composition of conventionally identified invertebrate specimens and species collected in Malaise traps; invertebrate COI ASVs derived from DNA metabarcoding of the same bulk invertebrate specimens, and bulk flower samples collected from the same sites. Only specimens of Coleoptera, Diptera, and Hymenoptera were identified to species by conventional (non-DNA metabarcoding) methods. 'Unidentified' indicates specimens not identified to the level of order by conventional methods due to their small size (< 5 mm).

		Conventional ids		DNA metabarcoding ASVs		
Class	Order	Specimens	Species	Bulk invertebrates	Bulk flowers	Total ASVs
Arachnida	Araneae	76	-	25	6	25
	Opiliones	3	-	3	-	3
	Sarcoptiformes	-	-	3	4	6
	Trombidiformes	-	-	3	5	5
Collembola	Symphypleona	-	-	1	-	1
	Poduromorpha	-	-	-	1	1
Insecta	Blattodea	6	-	3	-	3
	Coleoptera	839	55	15	4	15
	Diptera	17,466	45	3,682	388	3,682
	Ephemeroptera	9	-	1	-	1
	Hemiptera	65	-	41	46	56
	Hymenoptera	16,063	37	279	57	283
	Lepidoptera	420	-	436	76	442
	Mantodea	1	-	-	-	-
	Neuroptera	15	-	1	-	1
	Orthoptera	161	-	75	11	75
	Plecoptera	8	-	2	-	2
	Psocoptera	-	-	1	1	1
	Thysanoptera	-	-	21	85	85
	Trichoptera	-	-	9	2	9
Myriapoda		1	-	-	-	-
Malacostraca	Amphipoda	-	-	1	-	1
Unidentified		1,748	-	-	-	-
Total		36,881	137	4,602	686	4,697

Appendix S3. Conventionally identified species.

(a) Conventionally identified species of Coleoptera, Diptera and Hymenoptera (≥ 5 mm in body length or easily recognisable) collected in Malaise traps in mānuka shrublands. The description "sp." refers to a single unidentified or unidentifiable (most likely undescribed) species, "spp." refers to more than one unidentified or unidentifiable species and "sp(p.)" refers to when it is unknown whether there is one or more unidentified or unidentifiable species in that family/sub-family/tribe/genus in a sample.

Order	Family	Species	Biostatus
Coleoptera	Anthicidae	*Zealanthicus sulcatus*	Native
		Liromus pardalis	Native
	Cantharidae	*Asilis* sp(p.)	Native
	Carabidae	*Neocicindela parryi*	Native
		Neocicindela tuberculata	Native
		Platynus macropterus	Native
	Cerambycidae	*Hybolasius* sp.	Native
		Coptomma lineatum	Native
	Chrysomelidae	*Arnomus* sp.	Native
		Bruchidius villosus	Introduced
		Eucolaspis sp.	Native
		Lochmaea suturalis	Introduced
		Trachytetra rugulosa	Native
	Cleridae	*Lemidia* sp.	Native
		Phymatophaea sp.	Native
	Coccinellidae	*Rhyzobius* sp.	Native
		Adoxellus sp.	Native
		Coccinella leonina	Native
		Coccinella undecimpunctata	Introduced
	Corylophidae	*Holopsis* sp.	Native
	Cryptophagidae	*Micrambina* sp.	Native
	Curculionidae	*Brachyolus* sp.	Native
		Catoptes binodis	Native
		Cossoninae spp.	Native
		Pachycotes peregrinus	Native
		Praolepra sp.	Native
		Rhopalomerus sp.	Native
		Sitona obsoletus (=*lepidus*)	Introduced
		Storeini spp	Native
	Elateridae	*Conoderus* sp.	Native
		Elateridae spp.	Native
	Hydrophilidae	*Cercyon* sp(p.)	Introduced
		Cyloma sp.	Native
	Latridiidae	Corticariinae spp.	Native
		Enicmus sp.	Native
	Leiodidae	*Alsobius* sp.	Native
		Agyrtodes nebulosus	Native
		Colon hirtale	Native
		Isocolon sp.	Native
	Lycidae	*Porrostoma rufipenne*	Introduced
	Melyridae	Melyridae spp.	Native
	Mordellidae	*Stenomordellaria neglecta*	Native
	Mycetophagidae	*Nototriphyllus* sp.	Native
	Nitidulidae	*Hisparonia hystrix*	Native
		Homepuraea amoena	Native
	Oedemeridae	Oedemeridae spp.	Native

Order	Family	Species	Biostatus
		Selenopalpus cyaneus	Native
	Scarabaeidae	*Odontria* sp(p.)	Native
		Pyronota sp(p.)	Native
	Scirtidae	*Amplectopus* sp.	Native
		Scirtidae spp.	Native
	Silvanidae	*Dendrophagella* sp.	Native
	Staphylinidae	*Falagria* sp.	Unknown
		Paederinae	Unknown
		Staphylininae spp.	Unknown
Diptera	Acroceridae	*Helle* sp.	Native
		Ogcodes sp.	Native
	Anisopodidae	*Sylvicola* sp(p.)	Native
	Asilidae	Asilidae spp.	Native
		Saropogon spp.	Native
	Bibionidae	*Dilophus* sp(p.)	Native
	Calliphoridae	Calliphoridae spp. (mainly Pollenia spp.)	Native
		Pollenia pernix.	Native
	Ceratopogonidae	*Palpomyia* sp.	Native
	Ditomyiidae	*Nervijuncta* sp.	Native
	Dolichopodidae	Dolichopodidae spp.	Native
		Parentia spp.	Native
		Sympycnus sp.	Native
	Empididae	*Chelipoda* sp(p.)	Native
		Empididae spp.	Native
	Empidoidea Incertae Sedis	*Homalocnemis* sp.	Native
	Heleomyzidae	*Allophylopsis* sp.	Native
	Helosciomyzidae	Helosciomyzidae sp(p.)	Native
	Hybotidae	*Oropezella* sp.	Native
	Keroplatidae	Keroplatidae spp.	Native
	Lauxaniidae	*Poecilohetaerella* sp.	Native
		Trypetisoma sp.	Native
	Limoniidae	*Gynoplistia* spp.	Native
		Limoniidae sp(p.)	Native
	Muscidae	*Calliphoroides antennatis*	Native
		Muscidae spp. (some may be Fanniidae)	Native
	Mycetophilidae	Mycetophilidae spp.	Native
	Phoridae	*Diplonevra* sp.	Native
		sp(p.)	Unknown
	Pipunculidae	Pipunculidae spp.	Native
	Sarcophagidae	Sarcophagidae spp.	Unknown
	Sciomyzidae	Sciomyzidae sp(p.)	Native
	Sepsidae	*Lasionemopoda hirsuta*	Introduced
	Stratiomyidae	Beridinae spp.	Native
		Odontomyia sp.	Native
	Syrphidae	*Eristalis tenax*	Introduced
		Helophilus sp(p.)	Native
		Orthoprosopa bilineata	Native
		Syrphinae spp. (including *Eumerus* sp. and *Psilota decessa*)	Unknown
	Tabanidae	Tabanidae spp.	Native
	Tachinidae	*Huttonobesseria verecunda*	Native
		Tachinidae spp.	Native
	Tephritidae	*Urophora* sp. (*stylata*)	Introduced
	Therevidae	Therevidae sp(p.)	Native
	Tipulidae	Tipulidae sp(p.)	Native
Hymenoptera	Apidae	*Apis mellifera*	Introduced

Order	Family	Species	Biostatus
		Bombus terrestris	Introduced
	Braconidae	*Ascogaster* sp.	Native
		Braconidae spp.	Native
		Euphorinae spp.	Native
	Chalcidoidea	Chalcidoidea spp.	Native
	Colletidae	*Hylaeus* sp(p.)	Native
		Leioproctus sp(p.)	Native
	Crabronidae	*Argogorytes carbonarius*	Native
		Pison sp.	Native
		Podagritus cora	Native
		Podagritus/Rhopalum sp(p.)	Native
		Rhopalum aucklandi	Native
		Tachysphex nigerrimus	Native
	Diapriidae	Diapriidae spp.	Native
	Dryinidae	*Gonatopus alpinus*	Native
	Formicidae	Dolichoderinae spp. (male)	Introduced
		Monomorium sp.	Native
	Gasteruptiidae	*Gasteruption* sp.	Native
		Pseudofoenus sp(p.)	Native
	Halictidae	*Lasioglossum* sp(p.)	Native
	Ichneumonidae	*Anacis* sp. (female)	Unknown
		Diplazon laetatorius	Introduced
		Echthromorpha intricatoria	Introduced
		Eutanyacra licitatoria	Introduced
		Ichneumonidae spp.	Native
		Xanthocryptus novozealandicus	Introduced
		Xanthopimpla rhopaloceros	Unknown
	Megaspilidae	Megaspilidae spp.	Native
	Platygastridae	*Baeus* sp.	Unknown
		Platygastridae spp.	Native
	Pompilidae	*Epipompilus insularis* (females)	Native
		Pompilidae spp.	Native
		Priocnemis monachus	Native
	Proctotrupidae	Proctotrupidae spp.	Native
	Vespidae	*Vespula germanica*	Introduced
		Vespula vulgaris	Introduced

(b) Biostatus summary of conventionally identified Coleoptera, Diptera and Hymenoptera species and specimens. Values are numbers of species with numbers of specimens in brackets.

Order	Native	Introduced	Unknown
Coleoptera	46 (803)	6 (31)	3 (5)
Diptera	39 (4,702)	3 (5)	3 (253)
Hymenoptera	25 (2,375)	9 (42)	3 (657)

Appendix S4. Results of statistical tests for apiary and site pair effects on biodiversity.

(a) Results of ANOVA tests for apiary effects on the amplicon sequence variant (ASV) richness of invertebrate groups detected by DNA metabarcoding of bulk flower and bulk invertebrate samples.

Data component	Taxon	Term	Df	Sumsq	Meansq	Statistic	P.value
Bulk flower ASV richness	Araneae	Apiary status	1	0.0	0.0	0.000	0.9923
		Site pair	2	0.1	0.03	0.140	0.8708
		Apiary status:Site pair	2	0.03	0.01	0.062	0.9403
		Residuals	12	2.9	0.2		
	Diptera	Apiary status	1	580.1	580.1	15.823	0.0018
		Site pair	2	257.6	128.8	3.514	0.0629
		Apiary status:Site pair	2	332.5	166.2	4.535	0.0341
		Residuals	12	439.9	36.7		
	Hemiptera	Apiary status	1	249.8	249.8	14.204	0.0027
		Site pair	2	26.4	13.2	0.752	0.4924
		Apiary status:Site pair	2	94.0	47.0	2.673	0.1096
		Residuals	12	211.0	17.6		
	Hymenoptera	Apiary status	1	38.1	38.1	9.855	0.0085
		Site pair	2	3.0	1.5	0.388	0.6864
		Apiary status:Site pair	2	8.0	4.0	1.033	0.3855
		Residuals	12	46.4	3.9		
	Lepidoptera	Apiary status	1	46.0	46.0	6.727	0.0235
		Site pair	2	26.9	13.4	1.966	0.1826
		Apiary status:Site pair	2	7.9	4.0	0.580	0.5750
		Residuals	12	82.0	6.8		
	Orthoptera	Apiary status	1	0.3	0.3	0.948	0.3495
		Site pair	2	0.9	0.4	1.597	0.2428
		Apiary status:Site pair	2	0.3	0.2	0.542	0.5953
		Residuals	12	3.3	0.3		
	Others	Apiary status	1	1.5	1.5	4.632	0.0524
		Site pair	2	11.6	5.8	17.406	0.0003
		Apiary status:Site pair	2	5.1	2.6	7.654	0.0072
		Residuals	12	4.0	0.3		
	Thysanoptera	Apiary status	1	1389.2	1389.2	109.403	<0.0001
		Site pair	2	1952.3	976.2	76.876	<0.0001
		Apiary status:Site pair	2	693.0	346.5	27.288	<0.0001
		Residuals	12	152.4	12.7		

Data component	Taxon	Term	Df	Sumsq	Meansq	Statistic	P.value
Bulk invertebrate ASV richness	Araneae	Apiary status	1	1.5	1.5	0.454	0.5134
		Site pair	2	3.9	2.0	0.596	0.5663
		Apiary status:Site pair	2	11.4	5.7	1.731	0.2185
		Residuals	12	39.3	3.3		
	Diptera	Apiary status	1	101741.0	101741.5	1.158	0.3031
		Site pair	2	220707.1	110353.9	1.256	0.3198
		Apiary status:Site pair	2	235491.2	117745.6	1.340	0.2984
		Residuals	12	1054652.1	87887.7		
	Hemiptera	Apiary status	1	14.6	14.6	0.826	0.3814
		Site pair	2	88.1	44.0	2.487	0.1248
		Apiary status:Site pair	2	44.4	22.2	1.253	0.3205
		Residuals	12	212.5	17.7		
	Hymenoptera	Apiary status	1	32.9	32.9	0.043	0.8400
		Site pair	2	7765.9	3883.0	5.026	0.0260
		Apiary status:Site pair	2	6478.8	3239.4	4.193	0.0416
		Residuals	12	9270.5	772.6		
	Lepidoptera	Apiary status	1	236.8	236.8	0.178	0.6802
		Site pair	2	11828.3	5914.2	4.456	0.0357
		Apiary status:Site pair	2	3905.3	1952.7	1.471	0.2682
		Residuals	12	15925.1	1327.1		
	Orthoptera	Apiary status	1	97.0	97.0	0.824	0.3819
		Site pair	2	1332.8	666.4	5.663	0.0185
		Apiary status:Site pair	2	300.8	150.4	1.278	0.3139
		Residuals	12	1412.1	117.7		
	Others	Apiary status	1	0.1	0.07	0.017	0.8990
		Site pair	2	4.9	2.4	0.576	0.5767
		Apiary status:Site pair	2	31.6	15.8	3.739	0.0547
		Residuals	12	50.7	4.2		
	Thysanoptera	Apiary status	1	8.5	8.5	6.944	0.0218
		Site pair	2	6.1	3.03	2.483	0.1252
		Apiary status:Site pair	2	5.0	2.5	2.044	0.1722
		Residuals	12	14.7	1.2		

(b) Results of ANOVA tests for apiary effects on conventionally identified specimen abundance and species richness of invertebrate groups.

Data component	Taxon	Term	Df	Sumsq	Meansq	Statistic	P.value
Conventionally identified specimen abundance	Araneae	Apiary status	1	26.9	26.9	2.766	0.1222
		Site pair	2	40.4	20.2	2.080	0.1677
		Apiary status:Site pair	2	19.1	9.6	0.983	0.4024
		Residuals	12	116.7	9.7		
	Coleoptera	Apiary status	1	3444.5	3444.5	2.747	0.1233
		Site pair	2	4000.4	2000.2	1.595	0.2430
		Apiary status:Site pair	2	18396.0	9198.0	7.335	0.0083
		Residuals	12	15047.3	1253.9		
	Diptera	Apiary status	1	13338.9	13338.9	0.069	0.7978
		Site pair	2	1785216.3	892608.2	4.592	0.0330
		Apiary status:Site pair	2	564061.4	282030.7	1.451	0.2727
		Residuals	12	2332651.3	194387.6		
	Hemiptera	Apiary status	1	24.5	24.5	1.018	0.3328
		Site pair	2	68.1	34.1	1.416	0.2805
		Apiary status:Site pair	2	97.0	48.5	2.016	0.1758
		Residuals	12	288.7	24.1		
	Hymenoptera	Apiary status	1	33540.5	33540.5	0.129	0.7253
		Site pair	2	3294222.1	1647111.1	6.355	0.0131
		Apiary status:Site pair	2	99307.0	49653.5	0.192	0.8281
		Residuals	12	3110166.7	259180.6		
	Lepidoptera	Apiary status	1	854.2	854.2	8.566	0.0127
		Site pair	2	3850.3	1925.2	19.305	0.0002
		Apiary status:Site pair	2	784.8	392.4	3.935	0.0485
		Residuals	12	1196.7	99.7		
	Orthoptera	Apiary status	1	16.1	16.1	0.596	0.4551
		Site pair	2	165.4	82.7	3.070	0.0838
		Apiary status:Site pair	2	18.1	9.1	0.336	0.7211
		Residuals	12	323.3	26.9		
	Others	Apiary status	1	9.4	9.4	0.695	0.4206
		Site pair	2	80.1	40.1	2.967	0.0897
		Apiary status:Site pair	2	14.8	7.4	0.547	0.5923
		Residuals	12	162.0	13.5		
	Unidentified	Apiary status	1	26912.0	26912.0	5.522	0.0367
		Site pair	2	61900.4	30950.2	6.350	0.0131
		Apiary status:Site pair	2	7401.3	3700.7	0.759	0.4892
		Residuals	12	58486.0	4873.8		

Data component	Taxon	Term	Df	Sumsq	Meansq	Statistic	P.value
Conventionally identified species richness	Coleoptera	Apiary status	1	6.72	6.72	0.413	0.5326
		Site pair	2	114.11	57.06	3.505	0.0633
		Apiary status:Site pair	2	70.78	35.39	2.174	0.1564
		Residuals	12	195.33	16.28		
	Diptera	Apiary status	1	8.00	8.00	0.676	0.4270
		Site pair	2	13.78	6.89	0.582	0.5737
		Apiary status:Site pair	2	145.33	72.67	6.141	0.0146
		Residuals	12	142.00	11.83		
	Hymenoptera	Apiary status	1	34.72	34.72	2.854	0.1169
		Site pair	2	106.78	53.39	4.388	0.0371
		Apiary status:Site pair	2	10.11	5.06	0.416	0.6691
		Residuals	12	146.00	12.17		

(c) Results of manyglm tests for apiary and site pair effects on overall invertebrate communities and individual amplicon sequence variants (ASVs) and species (only ASVs/species with p.values < 0.05 for apiary status, site pair, or interaction effects are shown).

Overall tests	**Component**	**Df**	**Df.diff**	**Dev**	**P.value**
Bulk flower ASVs	Apiary status	16	1	400.27	0.003
	Site pair	14	2	761.28	0.001
	Apiary status:Site pair	12	2	694.36	0.001
Bulk invertebrate ASVs	Apiary status	16	1	2148.9	0.34
	Site pair	14	2	9876.03	0.009
	Apiary status:Site pair	12	2	14168.09	0.001
Conventionally identified species	Apiary status	16	1	99.41	0.082
	Site pair	14	2	355.75	0.001
	Apiary status:Site pair	12	2	335.21	0.001

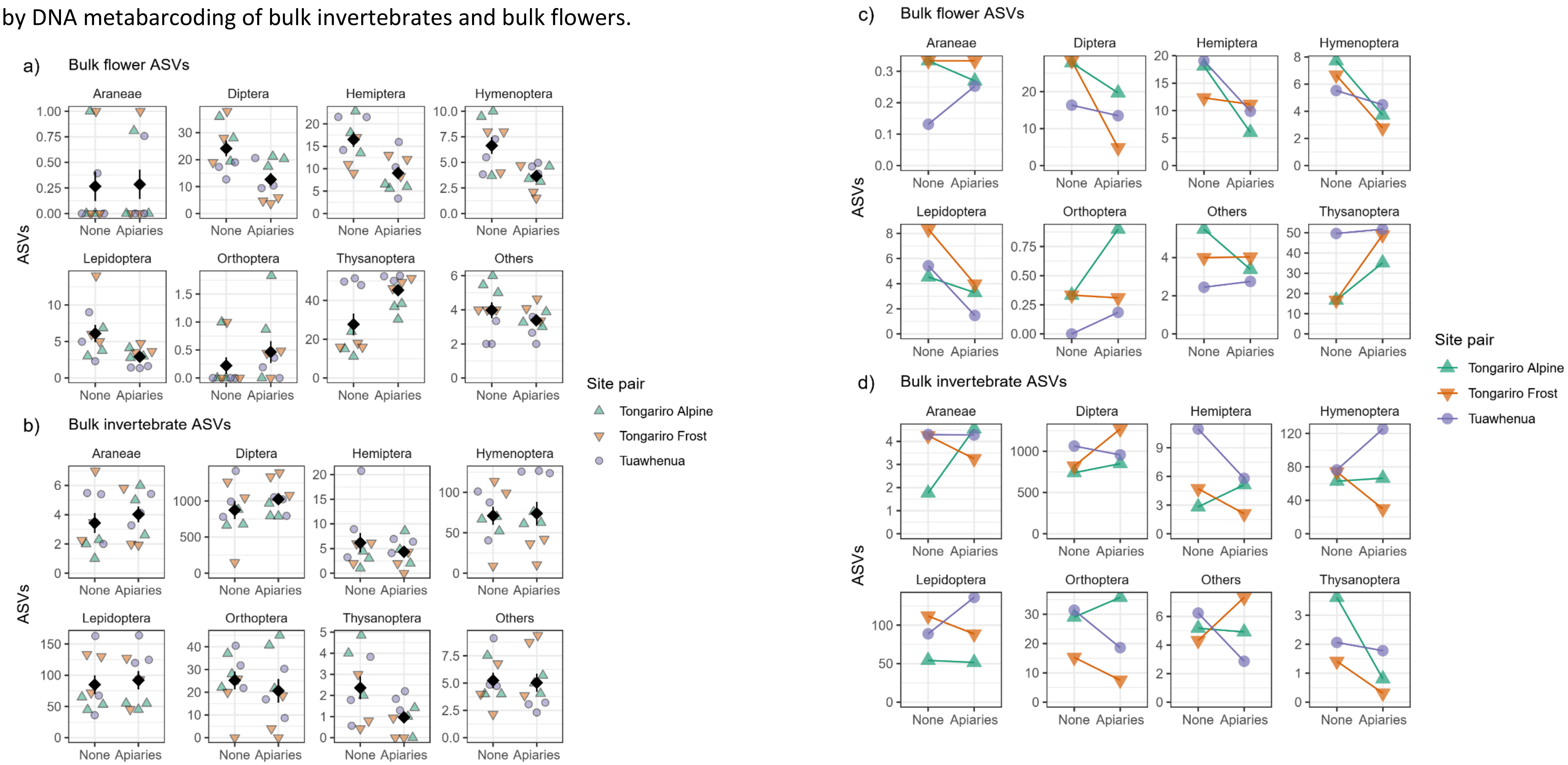
Tests per ASV/species	**Order**	**Family**	**ASV or species**	**Apiary status p.value**	**Site pair p.value**	**Apiary status:Site pair p.value**
Bulk flower ASVs	Thysanoptera	Thripidae	ASV6207	1	0.001	1
	Thysanoptera	Thripidae	ASV11507	1	0.003	1
	Thysanoptera	Thripidae	ASV4656	1	0.001	1
	Thysanoptera	Thripidae	ASV12171	1	0.001	1
	Thysanoptera	Thripidae	ASV11503	1	0.002	1
	Thysanoptera	Thripidae	ASV12158	1	0.009	1
	Thysanoptera	family	ASV6487	1	0.001	1
	Thysanoptera	Thripidae	ASV12379	1	0.005	1
	Thysanoptera	Thripidae	ASV12	1	0.001	1
	Thysanoptera	Thripidae	ASV7242	1	0.003	1
	Trombidiformes	Eriophyidae	ASV231	0.999	0.001	0.954
	Thysanoptera	Thripidae	ASV15	0.124	1	0.004
	Thysanoptera	family	ASV1955	0.019	1	0.019
	Thysanoptera	family	ASV3268	0.019	0.967	0.303
	Thysanoptera	family	ASV1438	0.017	0.992	0.841
Bulk invertebrate ASVs	Diptera	Tachinidae	ASV378	1	1	0.002
	Diptera	Sarcophagidae	ASV2882	1	1	0.046
	Diptera	Tipulidae	ASV9030	1	1	0.023
	Diptera	Tachinidae	ASV4683	1	1	0.043
	Diptera	Muscidae	ASV10161	1	1	0.049
	Diptera	Mycetophilidae	ASV735	1	1	0.021
	Diptera	Ephydridae	ASV2363	1	1	0.045
	Diptera	Dolichopodidae	ASV3253	1	0.047	1
	Diptera	Tachinidae	ASV12745	1	0.046	1
	Diptera	Milichiidae	ASV1362	0.886	0.019	1
Conventionally identified species	Hymenoptera	Braconidae	Braconidae sp.	1	0.034	0.945
	Diptera	Dolichopodidae	Parentia sp.	0.998	0.024	0.947
	Hymenoptera	Ichneumonidae	Ichneumonidae sp.	0.987	0.017	0.996
	Diptera	Stratiomyidae	Beridinae sp.	0.979	0.024	0.891
	Diptera	Empididae	Empididae sp.	0.718	0.754	0.029
	Hymenoptera	Crabronidae	*Tachysphex nigerrimus*	0.682	0.909	0.019

(d) Results of PERMANOVA tests for apiary and site pair effects on the community structure of invertebrate groups, based on amplicon sequence variants (ASVs) detected by DNA metabarcoding of bulk flower samples and of bulk Malaise-trapped invertebrate samples, and Malaise-trapped insects conventionally identified as species of Coleoptera, Diptera, or Hymenoptera.

				Jaccard distance				Bray-Curtis distance			
Data component	**Taxon**	**term**	**Df**	**SumSq**	**R2**	**F**	**P.value**	**SumSq**	**R2**	**F**	**P.value**
Bulk flower ASVs	Diptera	Apiary status	1	0.444	0.057	0.988	0.513	0.344	0.049	0.868	0.772
		Site pair	2	1.025	0.131	1.141	0.01	0.939	0.135	1.184	0.094
		Apiary status:Site pair	2	0.992	0.126	1.104	0.037	0.931	0.134	1.174	0.111
		Residual	12	5.392	0.687			4.759	0.682		
		Total	17	7.854	1.000			6.973	1.000		
	Hemiptera	Apiary status	1	0.385	0.095	1.951	0.012	0.206	0.121	2.682	0.004
		Site pair	2	0.655	0.161	1.659	0.019	0.359	0.211	2.340	≤0.001
		Apiary status:Site pair	2	0.655	0.161	1.658	0.029	0.212	0.125	1.385	0.103
		Residual	12	2.369	0.583			0.921	0.542		
		Total	17	4.064	1.000			1.698	1.000		
	Hymenoptera	Apiary status	1	0.217	0.041	0.693	0.935	0.141	0.038	0.658	0.797
		Site pair	2	0.712	0.134	1.136	0.22	0.432	0.117	1.006	0.413
		Apiary status:Site pair	2	0.642	0.120	1.025	0.403	0.533	0.145	1.239	0.224
		Residual	12	3.761	0.705			2.579	0.700		
		Total	17	5.333	1.000			3.686	1.000		
	Lepidoptera	Apiary status	1	0.420	0.054	1.059	0.311	0.323	0.045	0.946	0.509
		Site pair	2	1.617	0.209	2.037	0.001	2.173	0.300	3.181	≤0.001
		Apiary status:Site pair	2	0.944	0.122	1.189	0.076	0.653	0.090	0.956	0.513
		Residual	12	4.763	0.615			4.098	0.566		
		Total	17	7.744	1.000			7.247	1.000		
	Thysanoptera	Apiary status	1	0.639	0.195	5.818	0.001	0.351	0.109	2.862	0.005
		Site pair	2	0.828	0.253	3.766	0.002	0.857	0.266	3.493	≤0.001
		Apiary status:Site pair	2	0.487	0.149	2.215	0.023	0.547	0.169	2.229	0.007
		Residual	12	1.319	0.403			1.473	0.456		
		Total	17	3.272	1.000			3.229	1.000		
Bulk invertebrate ASVs	Araneae	Apiary status	1	0.422	0.061	1.134	0.307	0.443	0.064	1.231	0.263
		Site pair	2	0.952	0.137	1.279	0.167	0.983	0.141	1.366	0.121
		Apiary status:Site pair	2	1.123	0.161	1.511	0.036	1.204	0.173	1.673	0.027
		Residual	12	4.462	0.641			4.320	0.621		
		Total	17	6.959	1.000			6.950	1.000		
	Diptera	Apiary status	1	0.445	0.080	1.952	0.008	0.501	0.087	2.340	0.007
		Site pair	2	1.147	0.207	2.511	0.001	1.306	0.227	3.050	≤0.001
		Apiary status:Site pair	2	1.214	0.219	2.660	0.001	1.374	0.239	3.209	≤0.001
		Residual	12	2.739	0.494			2.568	0.447		
		Total	17	5.545	1.000			5.749	1.000		
	Hemiptera	Apiary status	1	0.193	0.039	0.624	0.856	0.045	0.014	0.241	0.972
		Site pair	2	0.859	0.174	1.390	0.106	0.510	0.161	1.378	0.173

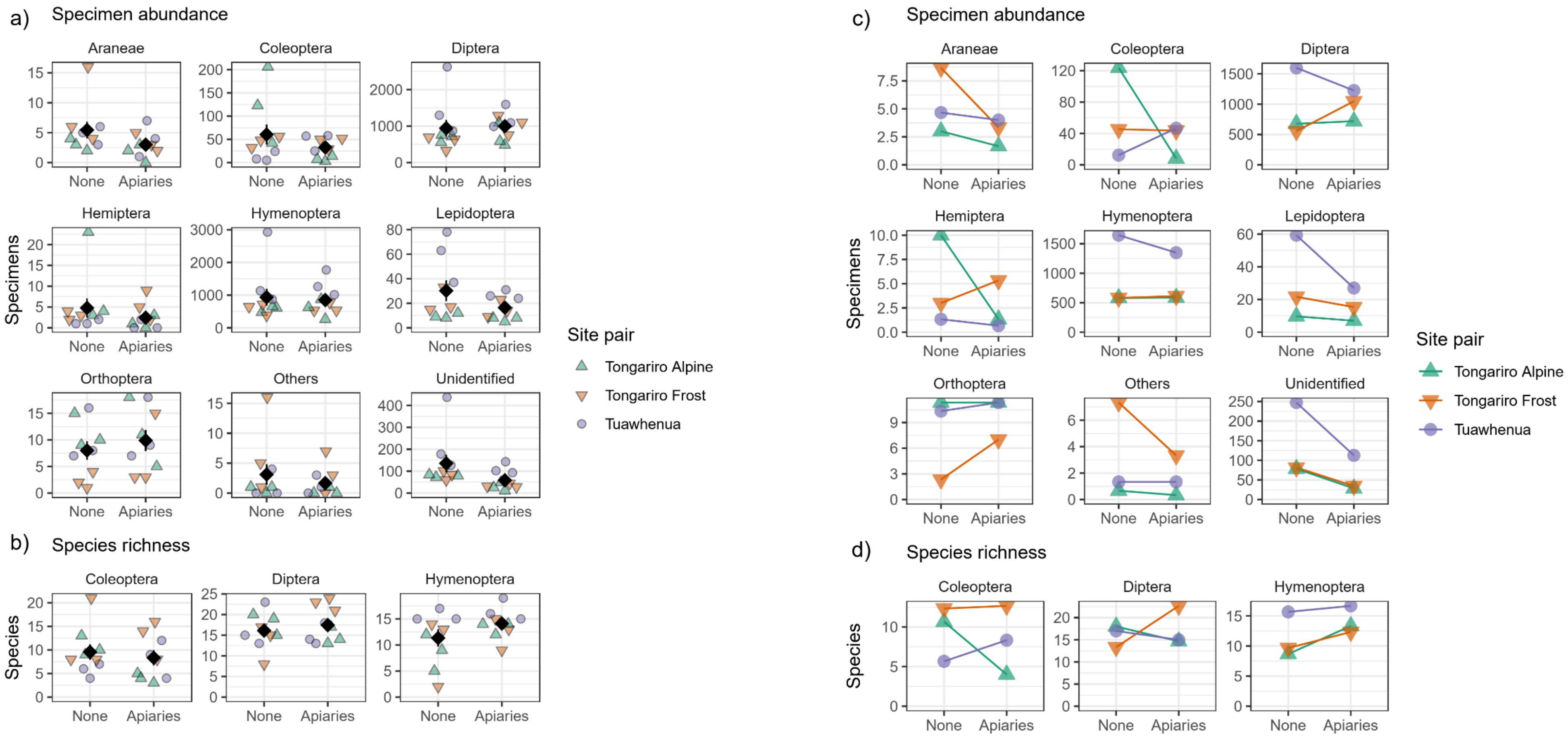
		Apiary status:Site pair	2	0.485	0.098	0.786	0.762	0.570	0.180	1.539	0.131
		Residual	11	3.396	0.689			2.036	0.644		
		Total	16	4.933	1.000			3.160	1.000		
	Hymenoptera	Apiary status	1	0.242	0.044	0.908	0.549	0.228	0.045	0.962	0.485
		Site pair	2	1.099	0.201	2.065	0.002	1.178	0.231	2.480	≤0.001
		Apiary status:Site pair	2	0.941	0.172	1.769	0.002	0.833	0.164	1.753	0.008
		Residual	12	3.192	0.583			2.850	0.560		
		Total	17	5.473	1.000			5.089	1.000		
	Lepidoptera	Apiary status	1	0.304	0.050	0.951	0.53	0.421	0.064	1.250	0.158
		Site pair	2	1.043	0.171	1.630	0.013	1.108	0.167	1.642	0.010
		Apiary status:Site pair	2	0.920	0.151	1.437	0.036	1.047	0.158	1.553	0.010
		Residual	12	3.840	0.629			4.047	0.611		
		Total	17	6.107	1.000			6.623	1.000		
	Orthoptera	Apiary status	1	0.212	0.056	0.988	0.43	0.265	0.068	1.404	0.192
		Site pair	2	0.728	0.191	1.693	0.056	0.736	0.190	1.948	0.051
		Apiary status:Site pair	2	0.726	0.190	1.689	0.07	0.985	0.254	2.608	0.012
		Residual	10	2.149	0.563			1.889	0.487		
		Total	15	3.816	1.000			3.876	1.000		
	Others	Apiary status	1	0.307	0.046	0.848	0.658	0.392	0.058	1.164	0.263
		Site pair	2	0.987	0.148	1.360	0.079	1.142	0.169	1.695	0.017
		Apiary status:Site pair	2	1.018	0.153	1.403	0.045	1.197	0.177	1.777	0.008
		Residual	12	4.351	0.653			4.044	0.597		
		Total	17	6.663	1.000			6.776	1.000		
Conventionally identified species	Coleoptera	Apiary status	1	0.363	0.061	1.360	0.107	0.248	0.053	1.357	0.19
		Site pair	2	1.297	0.218	2.427	0.001	1.454	0.312	3.972	≤0.001
		Apiary status:Site pair	2	1.094	0.183	2.046	0.001	0.768	0.165	2.099	0.013
		Residual	12	3.207	0.538			2.196	0.471		
		Total	17	5.962	1.000			4.667	1.000		
	Diptera	Apiary status	1	0.276	0.090	2.434	0.005	0.287	0.135	4.786	0.001
		Site pair	2	0.805	0.262	3.550	0.001	0.566	0.267	4.714	≤0.001
		Apiary status:Site pair	2	0.626	0.204	2.757	0.001	0.548	0.258	4.565	≤0.001
		Residual	12	1.361	0.444			0.720	0.340		
		Total	17	3.069	1.000			2.121	1.000		
	Hymenoptera	Apiary status	1	0.395	0.117	2.745	0.001	0.188	0.089	3.219	0.012
		Site pair	2	0.638	0.189	2.216	0.001	0.894	0.421	7.637	≤0.001
		Apiary status:Site pair	2	0.609	0.181	2.113	0.001	0.340	0.160	2.901	0.004
		Residual	12	1.728	0.513			0.702	0.331		
		Total	17	3.371	1.000			2.125	1.000		

Appendix S5. Apiary and site pair effects on the richness of taxa detected by DNA metabarcoding of bulk invertebrates and bulk flowers.



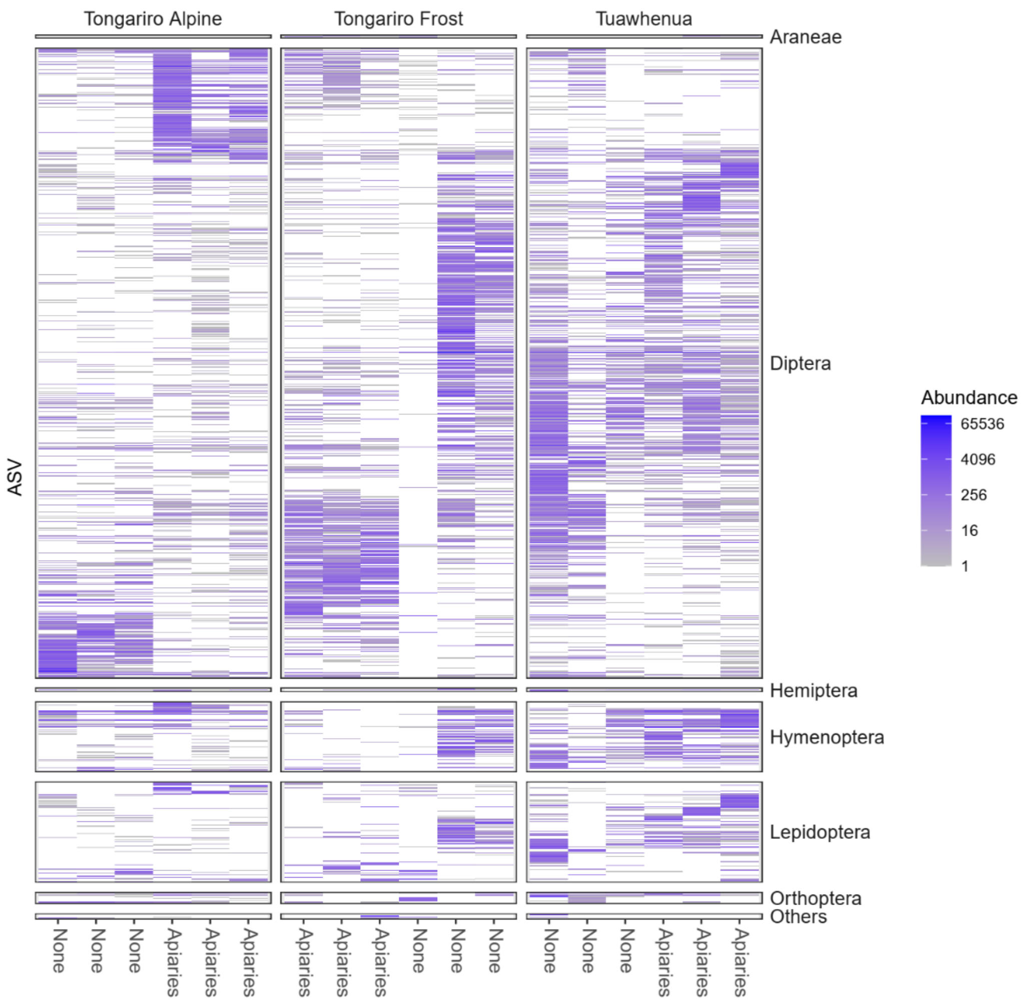
Apiary and site pair effects on amplicon sequence variant (ASV) richness of invertebrate taxonomic orders detected by DNA metabarcoding of (a) bulk flower samples and (b) Malaise-trapped bulk invertebrate samples, and interactions between apiary status and site pair for (c) bulk flower samples and (d) Malaise-trapped bulk invertebrate samples, from three pairs of sites. 'Others' consists of taxonomic orders representing < 0.5% of ASVs. Black diamonds with vertical lines in (a) and (b) represent mean values +/- standard errors.

Appendix S6. Apiary and site pair effects on the abundance and richness of conventionally identified specimens and species.



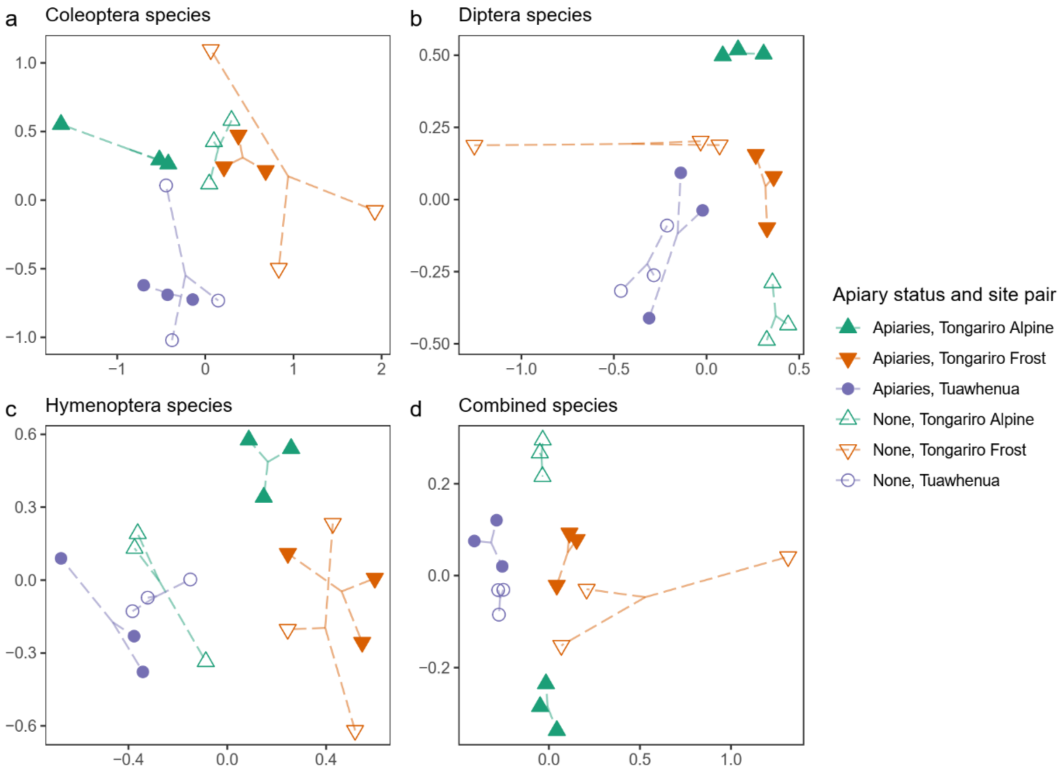
Apiary and site pair effects on (a) specimen abundances and (b) species richness values, and interactions between apiary status and site pair for (c) specimen abundances and (d) species richness values, for conventionally identified invertebrate taxa from three pairs of sites. 'Unidentified' consists of specimens not identifiable due to small size; 'Others' consists of seven orders representing < 0.1 % of specimens. Black diamonds with vertical lines in (a) and (b) represent mean values +/- standard errors.

Appendix S7. Apiary effects on the structure of bulk invertebrate communities.

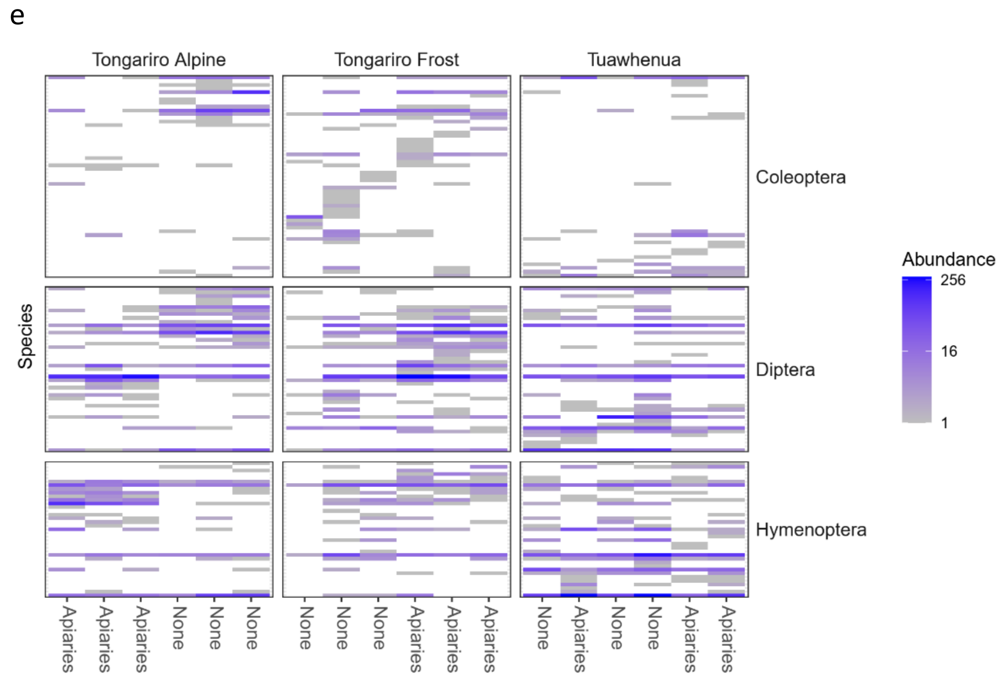


Heatmap showing relative abundances and distributions of the 1,000 most abundant invertebrate amplicon sequence variants detected by DNA metabarcoding of bulk invertebrate samples from sites with and without apiaries at three different locations.

Appendix S8. Apiary effects on the structure of conventionally identified insect communities.



NMDS ordinations showing apiary effects on the community structure of conventionally identified insect species of three orders at three pairs of sites, based on Bray-Curtis dissimilarities: (a) Coleoptera, (b) Diptera, (c) Hymenoptera, (d) all three orders together. Dashed lines link individual samples to centroid points for each site.



Heatmap showing relative abundances (i.e. number of specimens) and distributions of 137 conventionally identified species of Coleoptera, Diptera, and Hymenoptera in plots with and without apiaries at three pairs of sites.