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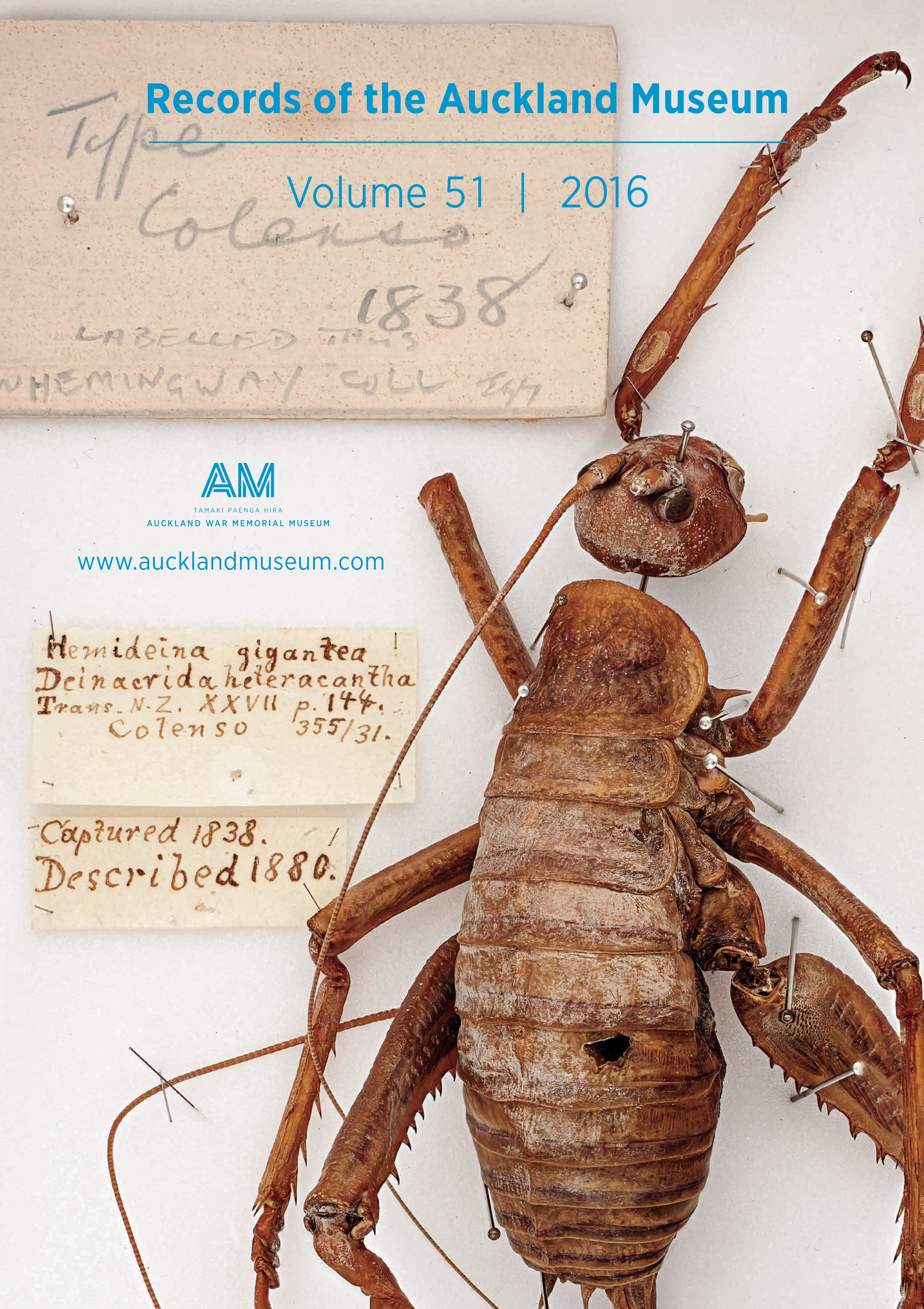

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Cover image: Holotype of *Hemideina gigantea* Colenso, AMNZ21862. Photo: Peter Quin.

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Ostracoda of the Cavalli Islands, Northland, New Zealand

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Abstract

One hundred and twelve species of marine ostracod are recorded from 0-29 m depth around the Cavalli Islands, northeast Northland – the most diverse ostracod fauna from a relatively small area (10 km^2) documented so far from New Zealand. Thirty of these species are additions to the known Recent (living) ostracod fauna of this country, although only ten have been identified to named species – the Recent Australian species *Callistocythere dorsotuberculata paucicostata*, *Callistocythere keiji*, *Callistocythere ventroalata*, *Lankacythere coralloides*, *Neohornibrookella lactea*, *Papillatabairdia elongata*, *Tasmanocypris dietmarkeyseri*, *Xestoleberis posidonicola*, *Yassinicythere bassiounii* and the fossil (early Miocene) New Zealand species *Hemicythere tarakohensis*. This brings the total marine ostracod fauna in the New Zealand EEZ to 496 species, of which 229 (46%) are recorded from shelf depths (0-200 m) in the Aupourian Province, east of northern New Zealand.

Cluster analysis of 113 quantitative ostracod samples from inner-mid shelf depths east of Northland and Auckland resulted in the recognition of 14 subassociations in 4 associations. The majority of the Cavalli faunas cluster together in three subassociations with the most diverse faunas and lowest species dominance, characterised by common *Loxoconcha punctata*. Subdominant in the shallowest subassociation is *Xestoleberis olivacea*, whereas *Neonesidea amygdaloides*, *Quadracythere biruga* and *Ambostracon pumilum* are subdominant in the other two subassociations in coarser sediment in the current-swept Cavalli Passage. One distinctly different unclustered Cavalli Islands ostracod fauna occurs in strong current-swept, shell gravel between rocky islets at 9 m depth and is strongly dominated (48%) by *Xestoleberis chilensis austrocontinentalis* with subdominant *Polycope* sp. and *Parapolycope* cf. *loscobanosi*.

KEYWORDS

New Zealand; Ostracoda; Biodiversity; Cavalli Islands; Aupourian Province.

INTRODUCTION

The highest diversity (267 species) of benthic foraminifera in any small area of New Zealand (Hayward et al. 1999) has been recorded from inner shelf (0-40 m depth) seafloor sediment from around the Cavalli Islands, Northland, New Zealand (Hayward 1982a). The reasons for this are probably a combination of the diversity of sheltered to exposed habitats and their location on the fringes of the warm East Auckland Current (Aupourian Province). Most shallow-marine biotic groups occur in greater diversity in the warm waters of the Aupourian Province than elsewhere in New Zealand. During most of the Holocene (last 10,000 years) the East Auckland Current has originated from the subtropical Tasman Front and surface current eddies from east Australia, Lord Howe, Norfolk or the Kermadec Islands. This current periodically transports subtropical shallow-marine organisms or their juveniles across the ocean barrier and introduces them to New Zealand.

We were encouraged to study the ostracods from around the Cavalli Islands by the existence of picked ostracod faunal slides, made by one of us (BWH) while studying the foraminiferal faunas ~1980 (Hayward 1979, 1982a), and by the expectation that these might contain further species additions to the known New Zealand fauna. The biodiversity of New Zealand marine ostracods is still incompletely documented and their biogeography and ecological distribution is even less well known.

Previous work

The biodiversity and ecological distribution of 124 species of benthic ostracods has been summarised and illustrated for the Hauraki Gulf (Morley and Hayward 2012), with the nearest faunas to the present study coming from off Whangarei Heads and the Mokohinau Islands, ~100 km southeast of the Cavalli Islands (Fig. 1). Study of a smaller and closer area in similar water depths was recently undertaken on 16 faunal samples at Matai Bay, 50 km to the west and yielded 75 species of ostracods – 22 of them additional to those recorded from the Hauraki Gulf. The only other significant study that has included ostracods from the Aupourian Province was the pioneering work of Hornibrook (1952). He recorded 9 species from 25 m depth in Rangaunu Bay and 52 species, including the description of 24 new species, in four samples from 150-300 m water depth off North Cape and the Three Kings Islands, 70 km and 120-200 km northwest of the Cavalli Islands respectively (Fig. 1). Dr Kerry Swanson briefly examined the picked faunas used in the present study in the 1980s and recognised the presence of rare living punciid ostracods. Following additional targeted collecting by Swanson around the Cavalli Islands, he recorded five punciid species (genera *Manawa* and *Puncia*) from 8-17 m depth and described one as new (*Manawa staceyi*) (Swanson, 1989, 1991).

Study area

The Cavalli Islands group (Latitude 35°00'S, longitude 173°57'E) lies approximately 2.5 km from the Northland mainland in the vicinity of Matauri Bay (Fig. 1). The sediment samples used in this study come from the Cavalli Passage between the island group and the mainland. The centre of the passage is underlain by shelly coarse sand (stns 11, 12) to the west of Motukawanui Island. This grades southwards into shelly medium sand (stns 35, 37, 39, 47) to the east of Matauri Bay. Clean shell gravel occupies the floor of the current-swept channel between rocky islets south of Motukawanui (stn. 42). An area of fine and very fine sand occupies the shallows (<5 m) in and around the sheltered bays of southeastern Motukawanui (stns 16, 17, 23, 24, 26, 28). The southern part of Cavalli Passage is only 5-10 m deep between southern Motukawanui and the mainland, but it deepens northwards to >40 m where the seafloor is mantled by fine and very fine sand.

METHODS

Field sampling

Samples were collected during an Offshore Islands Research Group expedition to the Cavalli Islands, by Dr Roger Grace and BWH in the summer of 1978-79 using a small dredge (described by Grace and Whitten 1974) hand-hauled from a dinghy powered by a small outboard motor. Under ideal conditions the dredge sampled approximately 0.075 m^2 of seafloor to a sediment depth of 2-6 cm, and held 4500 cm^3. A sample, comprising approximately 200 cm^3 of sediment, was taken from each dredge haul and preserved in 10% ethanol; the remainder was processed for macrofaunal analysis (Grace and Hayward, 1980). Water depths sampled were from intertidal down to 41 m. Data on dredge stations used in this study are given in Table 1 and locations shown in Figure 1.

Laboratory

On return to the laboratory, approximately 50 ml of the sediment sample from each station was washed over a 63 µm sieve to remove the mud. The sand and fine gravel was dried and divided up using a microsplitter until the quantity of material left contained approximately 100 ostracod valves (in the >125 µm fraction). The ostracods were picked and mounted on slides. In some instances fewer than this number were present in the entire sample (Table 1).

In 2015 the ostracod slides that were picked, but never worked on in the 1980s, were examined. The 15 slides with the most abundant ostracod faunas (Table 1) were selected for study by MSM, who identified and counted the ostracod valves. The samples ranged in depth from 0.5 to 29 m below MLW. Single and double valved ostracods were recorded separately in these census counts and double valved specimens counted as two valves when being converted to relative abundance (%) for data analysis.

Species diversity measures

Four measures of species diversity have been calculated for individual samples using the PAST statistical package (Hammer *et al.* 2001) for each ostracod fauna (Table 1):
Number of species, S = the number of species in each sample, which is strongly dependent on the number of valves counted.
Shannon Diversity Index, $H = -\Sigma p_i \ln p_i$ where p_i is the proportion of the i^{th} species (Hayek and Buzas 1997).
Evenness, E = eH/S where e is the base of the natural logarithms (Buzas and Gibson 1969).
This is solely a measure of species evenness irrespective of the number of species present. For most species abundance distributions E, like S, is a function of the number of specimens counted and thus care must be exercised when comparing between faunas.
Berger-Parker index, BP = the simple proportion of the most abundant species, BP = max pi (Berger and Parker 1970).

STATISTICAL ANALYSES

It was decided that more robust and meaningful results would be obtained if our Cavalli ostracod census count data (15 samples) were combined with census data previously obtained by the same methodology from Matai Bay (16 samples; Morley and Hayward 2014) and the Hauraki Gulf (82 samples, Morley and Hayward 2012). Raw census counts were standardised by converting counts to proportions of sample totals (= relative abundances). The faunal data analysed consisted of the relative abundance of 189 ostracod species in 113 samples. Unweighted pair group Q-mode cluster analysis using arithmetic averages of Bray Curtis Similarity Coefficient distance matrices were used to produce a dendrogram classification. Sample associations and subassociations were subjectively selected from the dendrogram so that they replicated as nearly as possible the previous subassociation

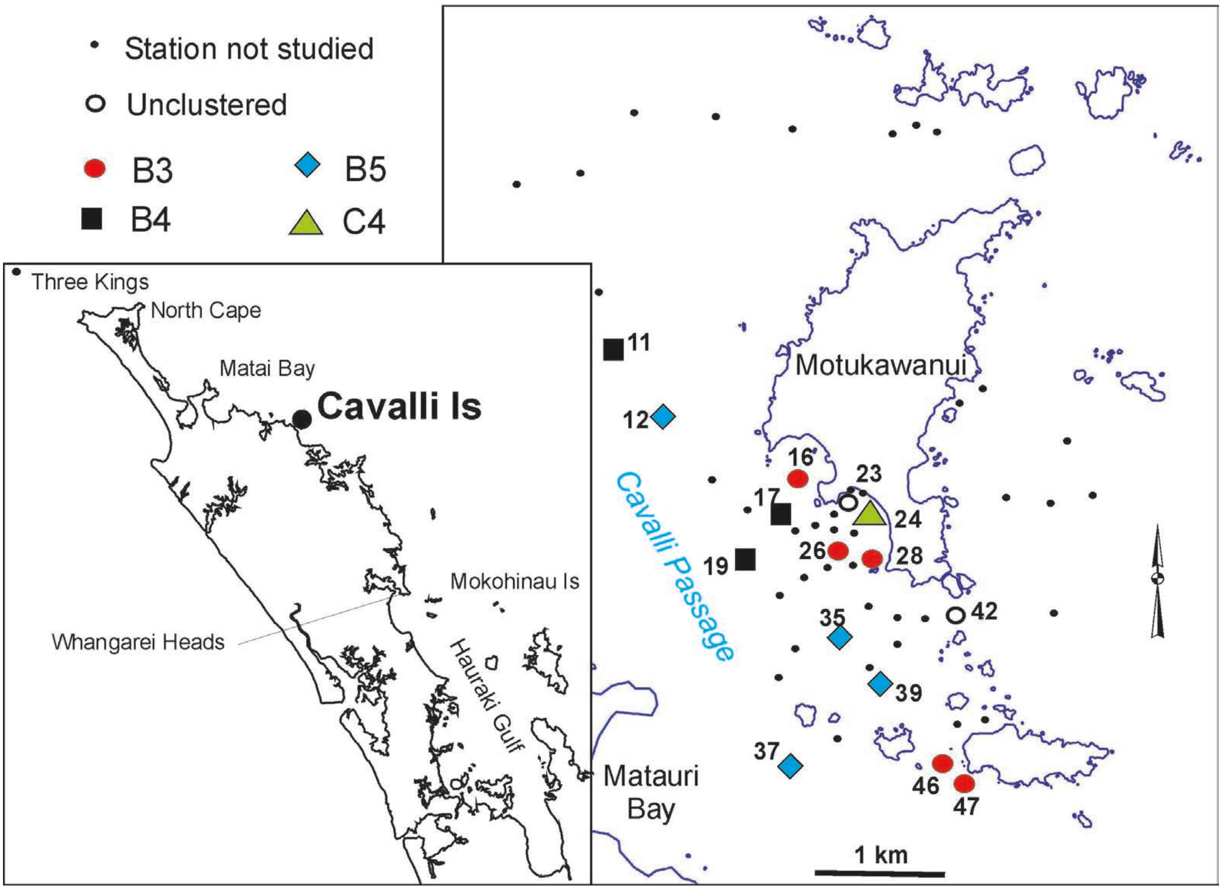

Figure 1. The Cavalli Islands are located off the northeast coast of Northland. Map of the Cavalli Islands shows location of the 15 studied samples and the cluster analysis subassociations of their ostracod faunas.

Table 1. Physical and biological attributes of the seafloor sediment samples used in this study. S, H, E and BP are species diversity measures. Ass = ostracod association (Table 2), f = fine, m = medium, nc = not clustered, vf = very fine, vc = very coarse

Stn	Depth	Cat No.	Lat °S	Long °E	Sediment	S	H	E	BP	Ass
16	0.5 m	F201727	35.008	173.936	fine sand	34	3.1	0.64	0.15	B3
23	1 m	F201734	35.010	173.939	sl muddy vf sand	11	2.3	0.88	0.17	nc
28	1.5 m	F201739	35.015	173.942	sl muddy vf sand	29	3.0	0.71	0.12	B3
24	1.8 m	F201735	35.013	173.940	fine sand	18	2.2	0.48	0.31	C4
26	3 m	F291737	35.014	173.937	fine sand	29	3.0	0.71	0.11	B3
47	3 m	F201758	35.034	173.951	m sand	25	2.6	0.53	0.19	B3
35	5.5 m	F201746	35.023	173.937	shelly m-f sand	24	2.6	0.54	0.28	B5
17	6 m	F201728	35.0 13	173.933	fine sand	35	3.3	0.76	0.08	B4
37	6 m	F201748	35.033	173.933	m sand	16	2.4	0.66	0.19	B5
19	8 m	F201730	35.014	173.930	fine sand	24	2.6	0.57	0.21	B4
39	8 m	F201750	35.028	173.943	shelly m sand	16	2.2	0.56	0.32	B5
46	9 m	F201757	35.034	173.949	fine sand	27	2.8	0.62	0.20	B3
42	9 m	F201753	35.020	173.950	fine shell gravel	10	1.6	0.51	0.48	nc
12	22 m	F201723	35.005	173.918	shelly vc sand	27	2.8	0.60	0.17	B5
11	29 m	F201722	34.997	173.914	shelly vc sand	25	2.8	0.69	0.14	B4

clusters derived from the Hauraki Gulf samples on their own (Morley and Hayward 2012) with additional subassociations where needed for the Matai Bay and Cavalli Island samples. The cluster analysis was computed using the "MVSP" statistical package (Kovach 1993).

Specimens and data

All washed sediment residues and ostracod faunas from the Cavalli Islands are housed in the national paleontology collections at GNS Science, Lower Hutt, with catalogue numbers prefixed by F201 (Appendix 1). All figured ostracods are mounted on single-hole slides (prefixed by MA; Figs 2-3) and lodged in the marine collections of Auckland War Memorial Museum. The full Cavalli Islands and Aupourian Province species list is given in Appendix 1. Raw census, relative abundance and species diversity data are available online at: www.aucklandmuseum.com/research/pub/records/51/sup/morley-hayward-ostracoda

The taxonomy used here largely follows that in the most recently updated New Zealand checklists for Ostracoda (Webber *et al.* 2010; Eagar 2013) and the World Register of Marine Species (http://www.marinespecies.org/).

BIODIVERSITY

Of the 107 species of benthic marine Ostracoda recorded in this study from the Cavalli Islands, 50 are identified to named species previously recorded from the Recent fauna of New Zealand and nine to named species previously recorded only from Australia. We have assigned a further fifteen to unnamed species (sp. 1 etc.) that have been previously recorded from New Zealand. Eighteen species have been left in open nomenclature, because they are different from but have affinities (aff.) to named species or are possibly the same as a named species (cf.). Six of these have not previously been recorded from New Zealand – *Bradleya* aff. *praemckenziei* (Fig. 2), *Hemicythere* aff. *brunnea, Hemicytherura* aff. *lakeillawarraensis* (Fig. 2), *Paradoxostoma* aff. *geraldtonense* (Fig. 2), *Paradoxostoma* aff. *romei,* and *Propontocypris* aff. *subreniformis*. We have only been able to identify to genus level a further twelve unnamed species; one to family level (Trachyleberididae) and one indeterminate.

A further species, *Hemicythere tarakohensis*, has previously been recorded fossil from the early Miocene of New Zealand (Hornibrook 1952), but its presence in Cavalli Passage sediment, which has no nearby outcropping Cenozoic sedimentary rocks, indicates that this is a Recent species. Thus thirty of our Cavalli Islands species appear to be new living records for New Zealand, of which only the fossil species and nine Australian species are named – *Callistocythere dorsotuberculata paucicostata* (Fig. 2), *C. keiji, C. ventroalata, Lankacythere coralloides* (Fig. 2), *Neohornibrookella lactea, Papillatabairdia elongata* (Fig. 2), *Tasmanocypris dietmarkeyseri, Xestoleberis posidonicola* and *Yassinicythere bassiounii* (Fig. 3). Twenty of the species identified are illustrated in Figs 2-3 and the majority of the remainder have previously been illustrated from the Hauraki Gulf and Matai Bay in Morley and Hayward (2012, 2014). None of the five punciid species recorded from the Cavalli Islands by Swanson (1991) was found in our quantitative faunas and thus the total ostracod species from the Cavalli Islands is 112. The additional species recorded here from the Cavalli Islands brings the total known marine ostracod fauna in the New Zealand EEZ to 496 species (updated from Webber *et al*. 2010).

BIOGEOGRAPHY

Thirty of the Cavalli Islands ostracod species are new records for the east coast of Northland, additional to the 151 species previously recorded from the Hauraki Gulf and Matai Bay (Morley and Hayward 2012, 2014). Combined there are now 181 species of Ostracoda recorded from the continental shelf and coast (<130 m water depth) off the east coast of Northland-Auckland. This compares with 63 species recorded from shelf and upper bathyal depths (3-520 m) east of Otago (Swanson 1979a). The diversity difference between eastern northern New Zealand and the Otago shelf probably reflects the greater range of habitats present and sampled off Northland-Auckland, but also the greater biodiversity that occurs beneath the warm East Auckland Current (Aupourian Province) than under the cool Southland Current off Otago (Forsterian Province). The full extent of the Aupourian Province includes ostracod faunas studied by Hornibrook (1952) from Rangaunu Bay, North Cape and Three Kings Islands. When the additional species from these faunas are added, the Aupourian Province currently has a diversity of 229 species (Appendix 1) or 46% of the total recorded New Zealand marine ostracod fauna. Eighty-seven of the 112 ostracod species (78%) from the Cavalli Islands are considered to be endemic to New Zealand. The remainder are mostly shared with southeast Australia.

ECOLOGICAL DISTRIBUTION

In the cluster analysis dendrogram of all 113 Aupourian ostracod faunas four major associations (A-D) and 14 subassociations are recognised (Fig. 4, Table 2). The ten subassociations recognised by Morley and Hayward (2012) based on the same dataset without the Matai Bay and Cavalli faunas are largely replicated. The four additional subassociations (B1-4) mostly cluster Cavalli (B3-5) and Matai Bay (B1) faunas. Twelve of the fifteen Cavalli ostracod faunas cluster together in subassociations B3, B4 and B5, all of which are dominated by *Loxoconcha punctata* (Fig. 5). The shallower subassociation in more sheltered conditions (B3) is co-dominated by *Xestoleberis olivacea.* The other two subassociations occur in coarser sediment further out in the current-swept Cavalli Passage (Fig. 1) with B4 co-dominated by *Neonesidea amygdaloides* and B5 by *Quadracythere biruga* and *Ambostracon pumilum* (Fig. 5).

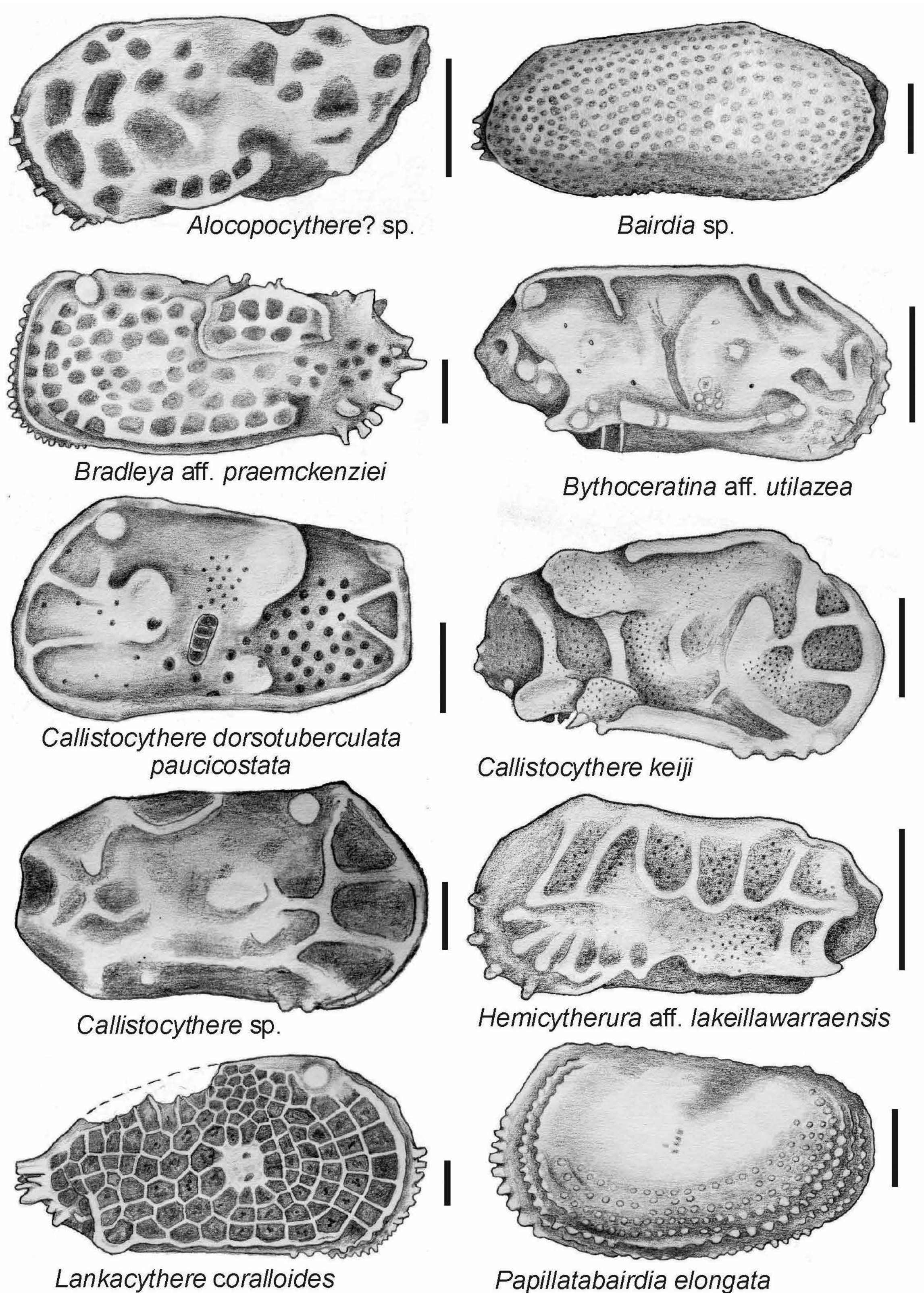

Figure 2. Ostracod taxa from the Cavalli Islands that have not previously been illustrated and recorded from northeast New Zealand (Morley and Hayward, 2012, 2014). *Alocopocythere*? sp., F201730, 8 m depth, MA121776; *Bairdia*? sp., F201757, 9 m depth, MA121804; *Bradleya* aff. *praemckenziei* Whatley and Downing, 1983, F201723, 22 m depth, MA121805; *Bythoceratina* aff. *utilazea* Hornibrook, 1952, F201727, 0.5 m depth, MA121806: *Callistocythere dorsotuberculata paucicostata* Yassini and Jones, 1987, F201730, 8 m depth, MA121807; *Callistocythere keiji* (Hartmann, 1978), F201737, 3 m depth, MA121808; *Callistocythere* sp., F201750, 8 m depth, MA121810; *Hemicytherura* aff. *lakeillawarraensis* Yassini and Jones, 1995, F201723, 22 m depth, MA121811; *Lankacythere coralloides* (Brady, 1886), F201750, 8 m depth, MA121812; *Papillatabairdia elongata* McKenzie, Reyment and Reyment, 1990, F201723, 22 m depth, MA121813. Scale bars 0.1 mm long.

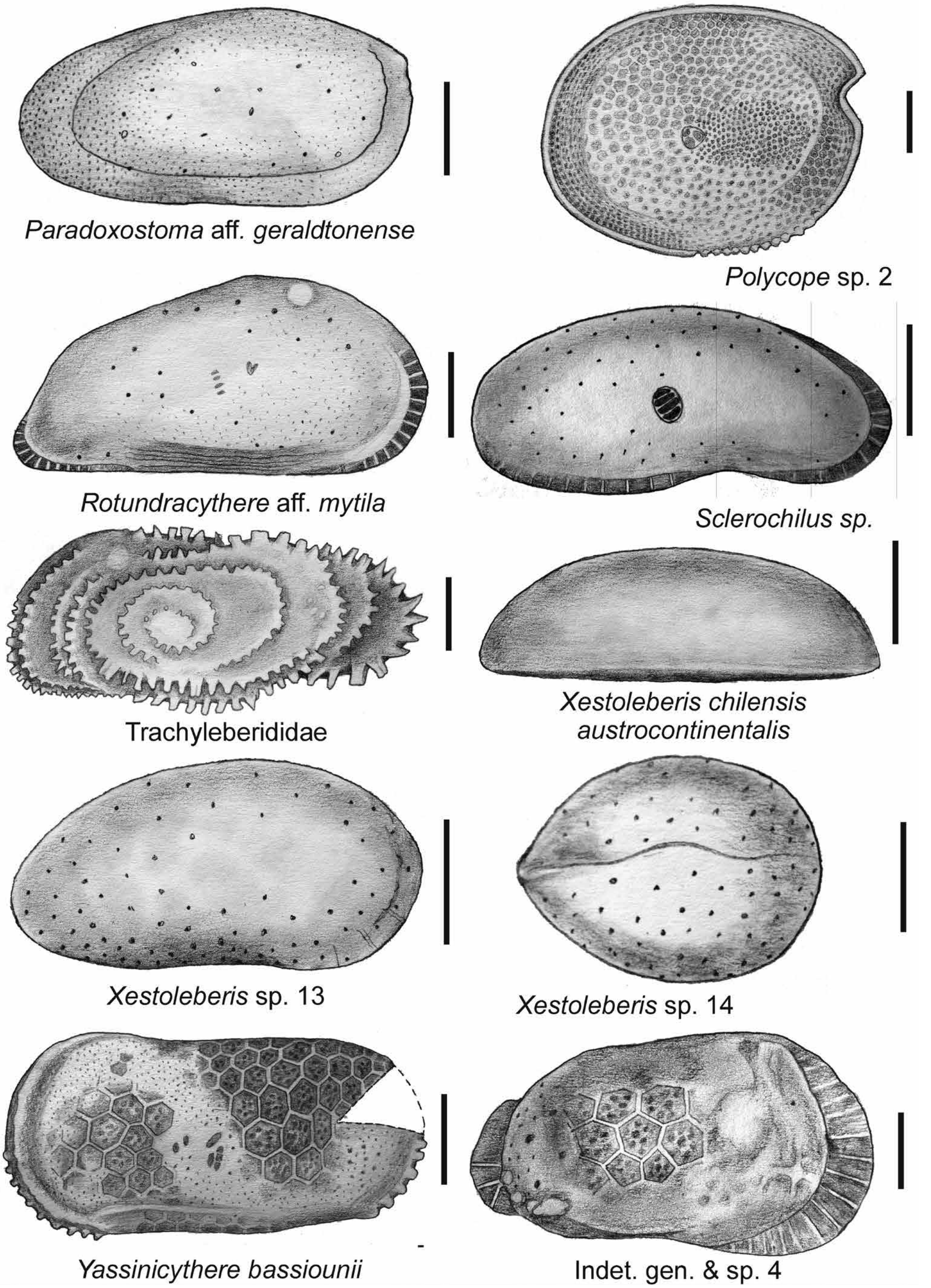

Figure 3. Ostracod taxa from the Cavalli Islands that have not previously been illustrated and recorded from northeast New Zealand (Morley and Hayward, 2012, 2014). *Paradoxostoma* aff. *geraldtonense* Hartmann, 1978, F201727, 0.5 m depth, MA121814. *Polycope* sp. 2, F201753, 9 m depth, MA121835; *Rotundracythere* aff. *mytila* (Hornibrook, 1952), F201727, 0.5 m depth, MA121836; *Sclerochilus* sp., F201753, 9 m depth, MA121837; *Trachyleberididae*, F201722, 29 m depth, MA121838; *Xestoleberis chilensis austrocontinentalis* Hartmann, 1987, F201730, 8 m depth, MA121839; *Xestoleberis* sp. 13, F201727, 0.5 m depth, MA121840; *Xestoleberis* sp. 14, F201753, 9 m depth, MA121841; *Yassinicythere bassounii* Hartmann, 1978, F201727, 0.5 m depth, MA121845. Indeterminate Gen. and sp. 4, F201748, 6 m depth, MA121848. Scale bars 0.1 mm long.

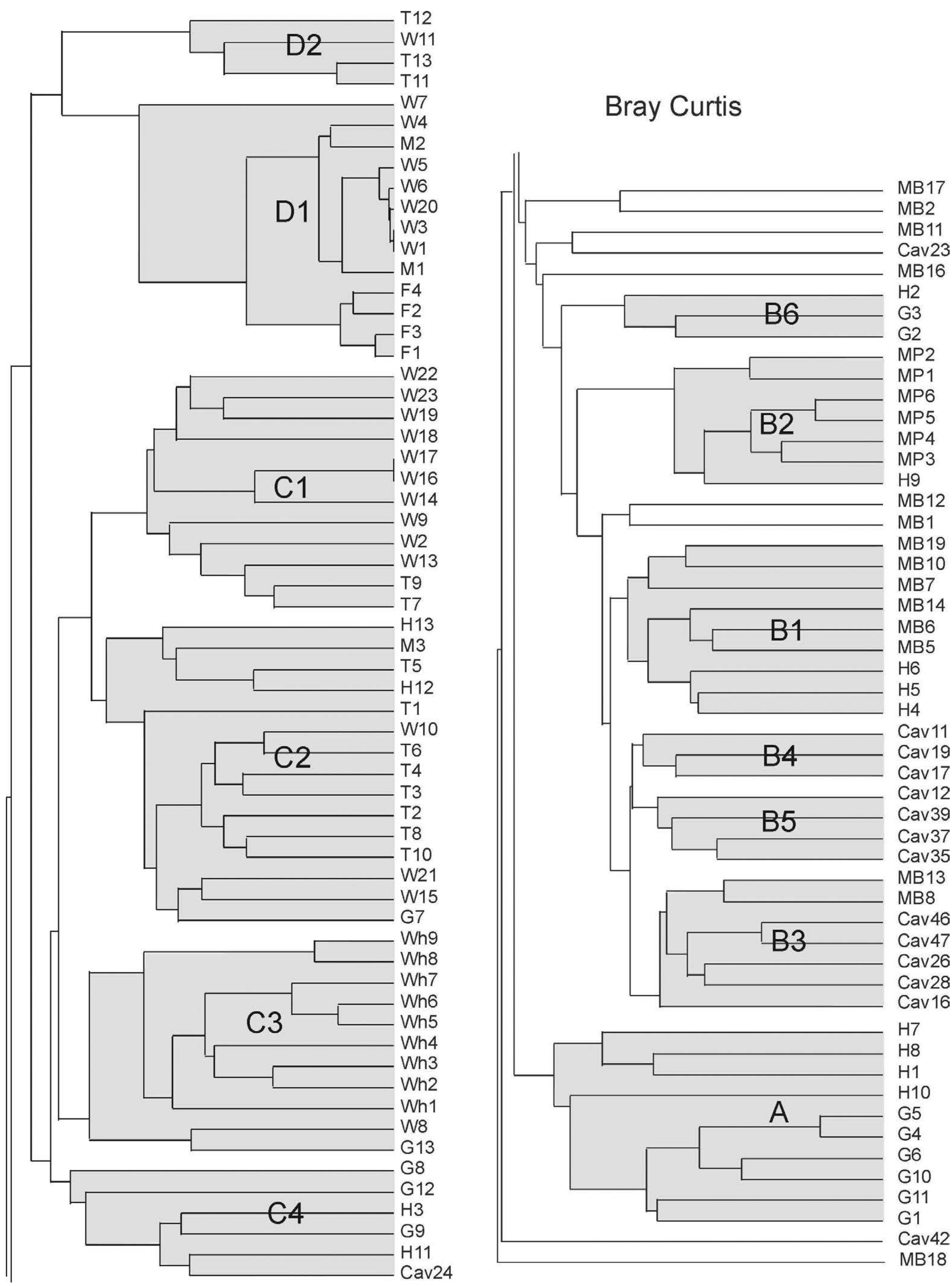

Figure 4. Dendrogram classification of 113 Aupourian ostracod faunas, including the 15 Cavalli faunas, produced by cluster analysis using Bray Curtis Similarity Coefficient (as in Morley and Hayward, 2012). The recognition of associations and subassociations (A1-D2) is based on subjective examination of the dendrogram.

Cav24 fauna (1.8 m depth) clusters in subassociation C4 with five sheltered, nearshore (0-14 m) samples from around the middle and outer Hauraki Gulf because of their dominance by *Paracypris zealandica* and *Swansonites tumida*. One of the unclustered Cavalli samples (Cav23) occurs in the sheltered shallows of the southeastern bay of Motukawanui and is distinguished because of its unusual co-dominance of *Loxocythere crassa* and *Copytus novaezealandiae* (Fig. 5). The other unclustered sample (Cav42) occurs in current-swept shell gravel between rocky islets at 9 m depth (Fig. 1). Its fauna is strongly dominated (48%) by *Xestoleberis chilensis austrocontinentalis* (both live and dead specimens) with unusually subdominant *Polycope* sp. 2 and *Parapolycope* cf. *loscobanosi* (mostly live specimens).

SPECIES DIVERSITY

The three Cavalli Islands subassociations (B3-5), in the shallow inner shelf Cavalli Passage, have the lowest dominance (BP = 0.14-0.24) and B3 and B4 have the highest diversity (S = 28, 30; H = 2.86, 2.92) and most evenly distributed (E) ostracod faunas in the Hauraki Gulf dataset (Fig. 6). In contrast, the lowest diversity (S = 4, 5; H = 0.61, 0.74) ostracod faunas with greatest dominance (BP = 0.70, 0.80) cluster in association D (Fig. 6) which is largely restricted to sheltered intertidal habitats of the inner Hauraki Gulf harbours, especially the Waitemata Harbour. Unclustered Cav23 from the shallows of the sheltered southeastern bay of Motukawanui has moderate diversity (S = 11, H = 2.27) but the most even (E = 0.88)

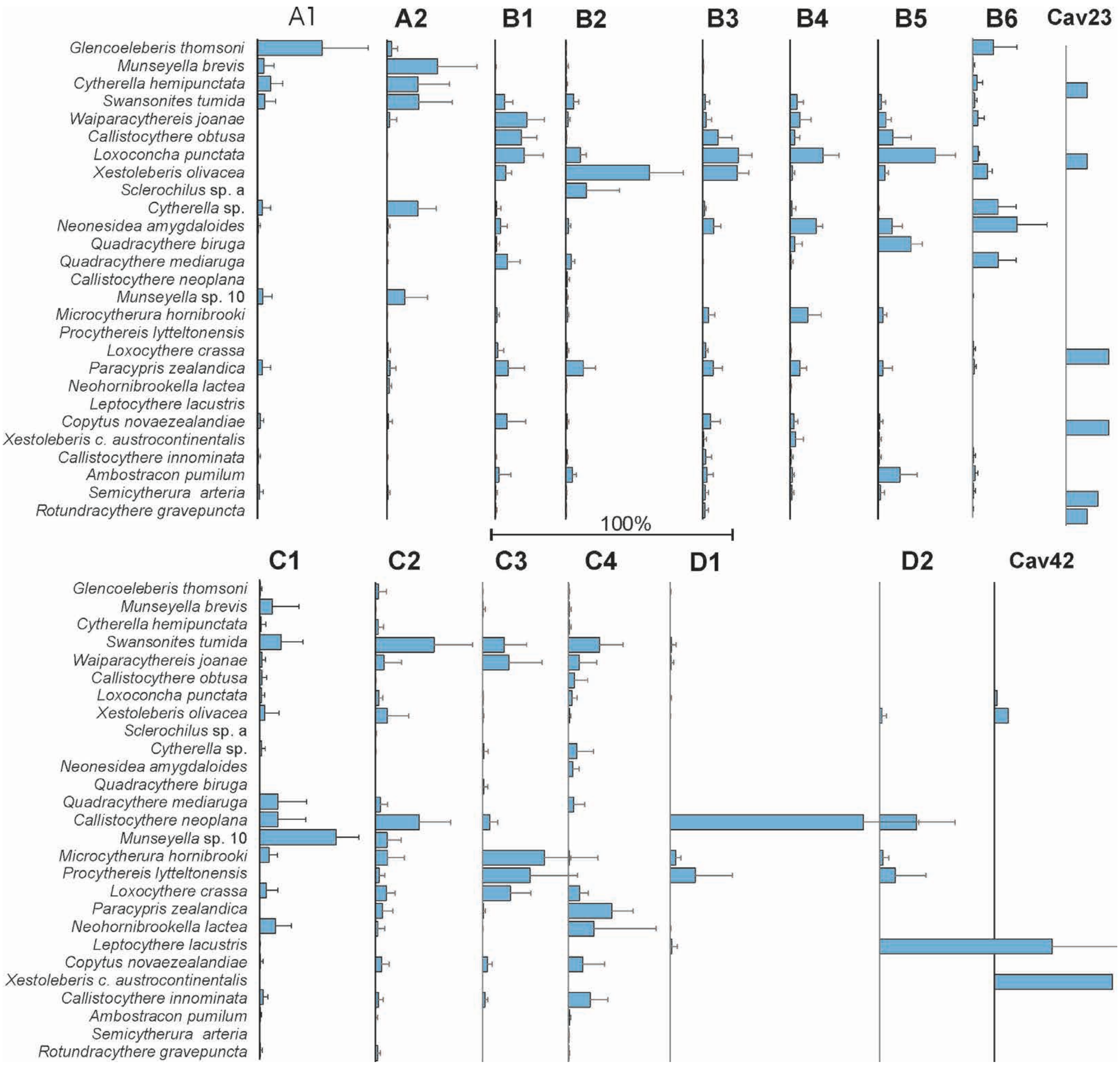

Figure 5. Histograms showing the mean relative abundance with standard deviation of the more common ostracod species in each of the Aupourian subassociations (A1-D2) plus the two unclustered Cavalli samples (Cav23, Cav42).

Table 2. Attributes of the Aupourian ostracod associations recognised on the cluster analysis dendrogram (Fig. 4), plus the two unclustered Cavalli samples. Bolded association codes contain Cavalli Islands faunas.

Ost Ass	No. Stns	Dominant species	Depth Range	Geographic Range
A1	3	*Glencoleberis thomsoni*	46-130 m	mid-outer Hauraki Gulf
A2	7	*Munseyella brevis-Cytherella hemipuncta*	17-50 m	Great Barrier I, Motutapu I.
B1	9	*Waiparacythereis joanae-Callistocythere obtusa*	1-18 m	Matai Bay, Little Barrier I.
B2	7	*Xestoleberis olivacea*	0 m	Hauraki Gulf rock pools
B3	7	*Loxoconcha punctata-Xestoleberis olivacea*	0.5-9 m	Cavalli Is, Matai Bay
B4	3	*Loxoconcha punctata-Neonesidea amygdaloides*	6-29 m	Cavalli Is
B5	4	*Loxoconcha punctata-Quadracythere biruga*	5.5-22 m	Cavalli Is
B6	3	*Neonesidea amygdaloides-Quadracyther mediaruga*	30-50 m	outer Hauraki Gulf
C1	12	*Munseyella* sp.10	0-15 m	Waitemata Harbour
C2	15	*Swansonites tumida-Callistocythere neoplana*	0-30 m	inner Hauraki Gulf
C3	11	*Microcytherura hornibrooki-Procythereis lytteltonensis*	0-3 m	N Coromandel Peninsula
C4	6	*Paracypris zealandica-Swansonites tumida*	0-14 m	mid-outer Hauraki Gulf
D1	13	*Callistocythere neoplana*	0-1.5 m	inner Hauraki Gulf harbours
D2	4	*Leptocythere lacustris*	0 m	Waitemata Harbour
Cav23	1	*Loxocythere crassa-Copytus novaezealandiae*	1 m	Cavalli Is
Cav42	1	*Xestoleberis chilensis austrocontinentalis*	9 m	Cavalli Is

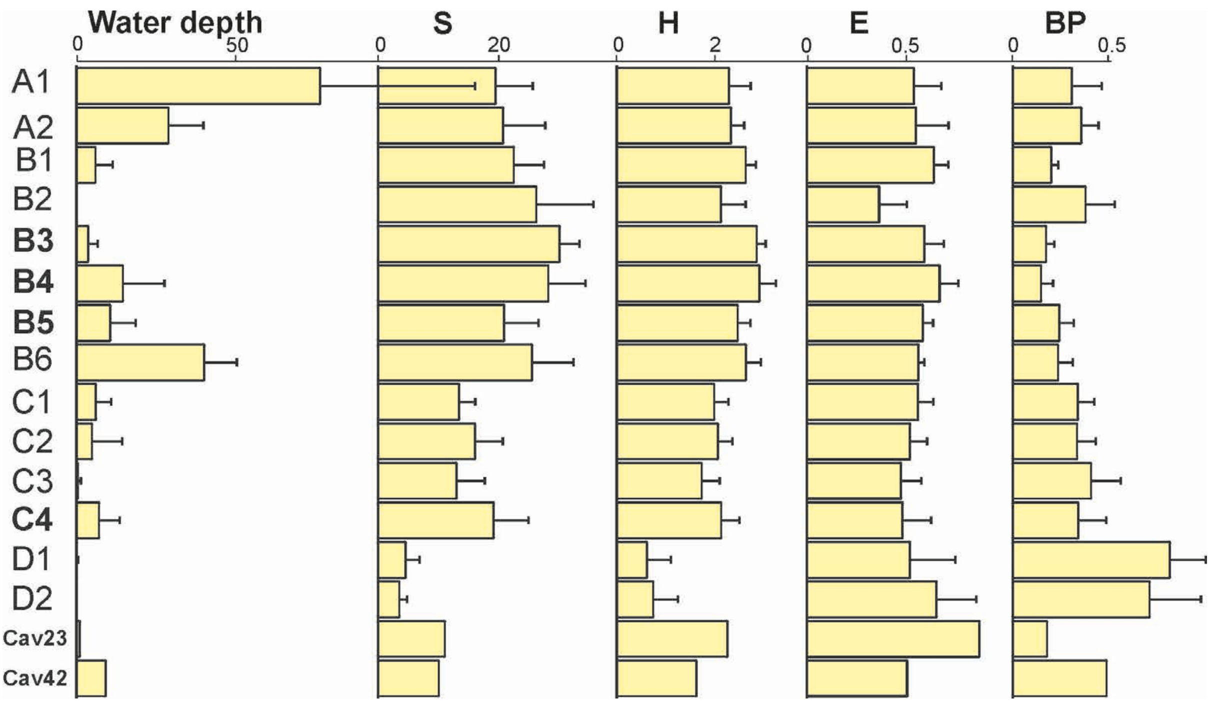

Figure 6. Mean values and standard deviation for water depth and diversity measures for each Aupourian Association plus the two unclustered Cavalli samples (Cav23, Cav42).

and near-lowest dominance (BP = 0.17). Unclustered Cav42 from the channel shell gravel has more average diversity, dominance and evenness values (Table 1, Fig. 6).

DISCUSSION

The Cavalli Islands ostracod faunas were studied because of the expectation that they would be diverse and may include species not previously recorded from New Zealand. As predicted we have documented the most diverse ostracod faunas (in individual samples) and greatest biodiversity (in a small area) so far found in New Zealand. We consider that this is a result of the greater diversity present in the warm Aupourian Province compared with cooler provinces further south around New Zealand and the greater diversity of habitat (sheltered fine sediment to current-swept gravel, proximity to rocks, brown seaweed forest and sea grass meadows) around the Cavalli Islands compared with other studied areas (e.g. Swanson 1979a, b; Hayward 1981, 1982b; Eagar 1995, 1999; Morley et al. 2006; Morley and Hayward 2007, 2010, 2012, 2014).

The relatively large number of species (30) recorded as new to New Zealand in this study reflects the neglected nature of taxonomic research on this country's marine ostracods, as does the large number of species recorded here that we have been unable to assign to a definite species name (47; 42% of taxa). There is clearly a need for a great deal of further research on the taxonomy of New Zealand's Recent ostracods with at least 201 undetermined and undescribed taxa known (out of 496; updated from number in Webber *et al*. 2010). Our studies indicate that most of the more common ostracods have been described and not surprisingly it is the less common that have so far been overlooked.

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APPENDIX 1: Ostracoda species list for New Zealand's Aupourian Province (0-300 m depth), with references to figured New Zealand specimens that illustrate each taxon's features. Bolded species are recorded here from the Cavalli Islands.

* = New Zealand endemic species

\+ = additional species records from New Zealand in this study at the Cavalli Islands

Actinocythereis tétrica (Brady, 1880)
Aglaiella setigera (Brady, 1880)
Agrenocythere reticlava (Hornibrook, 1952). Morley and Hayward, 2012, Fig. 7a.
Alocopocythere? sp.+ This paper Fig. 2.
Ambolus pumilus (Brady, 1866)*
Ambolus aff. *pumilus* (Brady, 1866)* Morley and Hayward, 2014, Fig. 2.
Ambostracon pumilum (Brady, 1866). Morley and Hayward, 2012, Fig. 11c.
Ancohenia sp. Eagar, 1999. Morley and Hayward, 2012, Fig. 7b.
Apatihowella probesioides (Hornibrook, 1952)* Morley and Hayward, 2014, Fig. 2.
Argilloecia clavata (Brady, 1880)*
Argilloecia eburnea Brady, 1880*
Argilloecia* aff. *pusilla (Brady, 1880)* Morley and Hayward, 2012, Fig. 7c.
Argilloecia tumida (Brady, 1880)
Aversovalva aurea (Hornibrook, 1952)* Morley and Hayward, 2012, Fig. 7d.
Aysegulina quadrazea (Hornibrook, 1952)* Morley and Hayward, 2012, Fig. 7e.
***Bairdia* sp**.+ This paper Fig. 2.
Bradleya arata (Brady, 1880), Hornibrook, 1952, Figs 80, 83, 86.
Bradleya dictyon (Brady, 1880). Hornibrook, 1952, Figs 81-82, 84-85.
Bradleya* aff. *praemckenziei Whatley and Downing, 1984+ This paper Fig. 2.
Bradleya sp. 1. Morley and Hayward, 2012, Fig. 7f.
Bradleya? sp. 3. Morley and Hayward, 2012, Fig. 7g.
Bythoceratina decepta Hornibrook, 1952*, Figs 260-262.
Bythoceratina edwardsoni Hornibrook, 1952 . Morley and Hayward, 2012, Fig. 7h.
Bythoceratina fragilis Hornibrook, 1952*, Figs 263, 264, 266.
Bythoceratina maoria Hornibrook, 1952*, Figs 265, 267, 268.
Bythoceratina mestayerae Hornibrook, 1952*, Figs 257-259, 269.
Bythoceratina powelli Hornibrook, 1952*, Figs 270-272.
Bythoceratina* aff. *utilazea Hornibrook, 1952+ This paper Fig. 2.
Bythocypris* aff. *reniformis Brady, 1880* Morley and Hayward, 2012, Fig. 7i; Morley and Hayward, 2014, Fig. 2.
Callistocythere dedeckkeri Yassini and Jones, 1995. Morley and Hayward, 2012, Fig. 7j.
Callistocythere dorsotuberculata Hartmann, 1979+ Morley et al., 2006, Fig. 6.
Callistocythere dorsotuberculata paucicostata Yassini and Jones, 1987+ This paper Fig. 2.
Callistocythere innominata (Brady, 1898)* Morley and Hayward, 2012, Fig. 7k.
Callistocythere keiji (Hartmann, 1978)+ This paper Fig. 2
Callistocythere murrayana (Brady, 1880)
Callistocythere neoplana Swanson, 1979. Morley and Hayward, 2012, Fig. 7l.
Callistocythere obtusa Swanson, 1979* Morley and Hayward, 2012, Fig. 7m.
Callistocythere aff. *obtusa* Swanson, 1979. Morley and Hayward, 2012, Fig. 7n.
Callistocythere* aff. *puri McKenzie, 1967. Morley and Hayward, 2012, Fig. 7o.
Callistocythere ventroalata Yassini and Jones, 1995+. Morley and Hayward, 2012, Fig. 8a.
Callistocythere* aff. *ventroalata Yassini and Jones, 1995. Morley and Hayward, 2012, Fig. 8a.

Callistocythere sp.+ This paper Fig. 2.
Caudites sp. Morley and Hayward, 2012.
Cletocythereis rastromarginata (Brady, 1880)
Cobanocythere navicularis Yassini and Jones, 1995. Morley and Hayward, 2012, Fig. 8b.
Copytus novaezealandiae (Brady, 1898)* Morley and Hayward, 2012, Fig. 8c.
Copytus aff. *novaezealandiae* (Brady, 1898)* Morley and Hayward, 2012, Fig. 8d.
?*Cypris* sp. 1* Morley and Hayward, 2014, Fig. 2.
Cytheralison cosmetica Yassini and Jones, 1987. Morley and Hayward, 2014, Fig. 2.
Cytheralison fava Hornibrook, 1952. Morley and Hayward, 2012, Fig. 8e.
Cytheralison* sp.1. Morley and Hayward, 2014, Fig. 2.
Cythere melobesioides Brady, 1869
Cythereis finlayi Hornibrook, 1952* Morley and Hayward, 2012, Fig. 8f.
Cythereis* aff. *finlayi Hornibrook, 1952*. Morley and Hayward, 2014, Fig. 2.
Cythereis "incerta" Swanson, 1979, Fig. 37*
Cytherella eburnea Brady, 1898*
Cytherella hemipuncta Swanson, 1969. Morley and Hayward, 2012, Fig. 8g.
Cytherella lata Brady, 1880
Cytherella polita Brady, 1868
Cytherella punctata Brady, 1866
?*Cytherella* sp. 2. Morley and Hayward, 2012, Fig. 8i.
***Cytherella* sp**. Swanson, 1979* Morley and Hayward, 2012, Fig. 8h.
Cytherelloidea willetti Swanson, 1969* Morley and Hayward, 2012, Fig. 8j.
Cytheridea aoteana Hornibrook, 1952* Morley and Hayward, 2012, Fig. 8k.
Cytheromorpha robusta Yassini and Jones, 1995. Morley and Hayward, 2014, Fig. 2.
Cytheropteron latiscalpum Hornibrook, 1952* Morley and Hayward, 2012, Fig. 8l.
Cytheropteron obtusalum Hornibrook, 1952* Morley and Hayward, 2012, Fig. 8o (as *Cytheropteron* sp. 1).
Cytheropteron wellmani Hornibrook, 1952*, Figs 154-156.
Cytheropteron willetti Hornibrook, 1952* Morley and Hayward, 2012, Fig. 8n.
Cytherura laticauda Hornibrook, 1952*, Figs 237-239.
Cytherura aff. *taylori* (McKenzie, 1967)* Morley and Hayward, 2012, Fig. 9a.
Debissonia* aff. *pravacauda Hornibrook, 1952*+, Figs 285, 286, 288.
Diasterope grisea (Brady, 1898). Morley and Hayward, 2012, Fig. 9b.
Eucythere inaequa Hornibrook, 1952*, Figs 13-17.
Eucythere rotunda Hornibrook, 1952*, Figs 22, 23, 25
Eucythere subovalis Hornibrook, 1952*, Figs 6-9.
Foveoleberis foveolata (Brady, 1880)
Glencoeleberis thomsoni (Hornibrook, 1952). Morley and Hayward, 2012, Fig. 9d.
Hanaiceratina arenacea (Brady, 1880)
Harbansus sp. 1. Morley and Hayward, 2012.
Harbansus sp. Eagar, 1999. Morley and Hayward, 2012, Fig. 9e.
Hemicythere brunnea (Brady, 1898)* Morley and Hayward, 2012, Fig. 9f; Morley and Hayward, 2014, Fig. 3.
Hemicythere* aff. *brunnea (Brady, 1898)*+
Hemicythere fulvotincta (Brady, 1880)
Hemicythere munida Swanson, 1979* Morley and Hayward, 2012, Fig. 9g.
Hemicythere tarakohensis? Hornibrook, 1952+ Hornibrook, 1952, Figs 141-143.
***Hemicythere*? sp. 1**+
Hemicytheridea mosaica (Hornibrook, 1952)*, Figs 1, 2, 19.
Hemicytherura delicatula Hornibrook, 1952, Figs 213-216.
Hemicytherura fereplana Hornibrook, 1952. Morley and Hayward, 2012, Fig. 9h.
Hemicytherura gravis Hornibrook, 1952* Morley and Hayward, 2012, Fig. 9i.
Hemicytherura* aff. *lakeillawarraensis Yassini and Jones, 1995 This paper Fig. 2.
Hemicytherura pandorae Hornibrook, 1952*, Figs 195-197.
Hemicytherura pentagona Hornibrook, 1952* Morley and Hayward, 2012, Fig. 9k.
Henryhowella rugibrevis (Hornibrook, 1952). Morley and Hayward, 2012, Fig. 13k.
Hermanites andrewsi Swanson, 1978* Morley and Hayward, 2014, Fig. 3.
Hermanites aff. *andrewsi* Swanson, 1979. Morley and Hayward, 2012, Fig. 9m.
***Hermanites* sp. 1**. Morley and Hayward, 2012, Fig. 9n.

Jacobella papanuiensis Swanson, 1979*. Morley and Hayward, 2012, Fig. 9o.
Kangarina radiata (Hornibrook, 1952). Morley and Hayward, 2012, Fig. 9l.
Kangarina? sp. 1. Morley and Hayward, 2012, Fig. 10a.
Keijia demissa (Brady, 1868)
Kotoracythere formosa Swanson, 1979. Morley and Hayward, 2012, Fig. 10b.
Lankacythere coralloides (Brady, 1886)+ This paper Fig. 2.
Leptocythere lacustris McKenzie, Reyment and Reyment, 1990. Morley and Hayward, 2012, Fig. 10c.
Leptocythere sp. 2 Morley and Hayward, 2012
Loxoconcha aff. *abditocostata* Hartmann, 1981. Morley and Hayward, 2012, Fig. 10d.
Loxoconcha punctata Thomson, 1879* Morley and Hayward, 2012, Fig. 10e.
Loxocythere kingi Hornibrook, 1952+ Hornibrook, 1952, Figs 32, 36-37.
***Macrocyprina* sp.** Swanson, 1979* Morley and Hayward, 2012, Fig. 10g.
***Macrocyprina* sp. 1**+
***Macrocypris* sp**. Swanson, 1979. Morley and Hayward, 2012, Fig. 10.h
***Macrocypris* sp. 1**+
Manawa staceyi* Swanson, 1989
Manawa tryphena* Hornibrook, 1949. Hornibrook, 1963, Figs 6-9.
Microceratina cf. *quadrata* Swanson, 1980. Morley and Hayward, 2014, Fig. 3.
Microcytherura crassa (Hornibrook, 1952)* Morley and Hayward, 2012, Fig. 10f.
Microcytherura hornibrooki (McKenzie, 1967)* Morley and Hayward, 2012, Fig. 10i.
Microcytherura sp. 1 Mckenzie, 1967. Morley and Hayward, 2012, Fig. 10j.
Microcytherura sp. 2. Morley and Hayward, 2012, Fig. 10k.
Miracythere novaspecta Hornibrook, 1952*, Figs 248-256.
Munseyella brevis Swanson, 1979* Morley and Hayward, 2012, Fig. 10l.
Munseyella modesta Swanson, 1979, Fig. 23c-d+
Munseyella punctata Whatley and Downing, 1983. Morley and Hayward, 2012, Fig. 10m.
Munseyella? sp. 1. Morley and Hayward, 2012, Fig. 10o.
***Munseyella* sp. 2**. Morley and Hayward, 2012, Fig. 11a.
Munseyella sp. 10 Hartmann, 1982. Morley and Hayward, 2012, Fig. 11b.
Neocytherideis anneclarkeae Yassini and Jones, 1987. Morley and Hayward, 2012, Fig. 11d.
Neohornibrookella lactea (Brady, 1866)
Neonesidea amygdaloides (Brady, 1880)* Morley and Hayward, 2012, Fig. 11e.
Neonesidea fusca (Brady, 1866)
Oculocytheropteron acutangulum (Hornibrook, 1952)* Morley and Hayward, 2012, Fig. 11f.
Oculocytheropteron confusum (Hornibrook, 1952)* Morley and Hayward, 2012, Fig. 11g.
Oculocytheropteron curvicaudum (Hornibrook, 1952)* Morley and Hayward, 2014, Fig. 2.
Oculocytheropteron dividentum (Hornibrook, 1952)* Morley and Hayward, 2014, Fig. 2.
Oculocytheropteron fornix (Hornibrook, 1952)*+ Hornibrook, 1952, Figs 159-161.
Oculocytheropteron improbum (Hornibrook, 1952)* Morley and Hayward, 2014, Fig. 3.
Oculocytheropteron terecaudum (Hornibrook, 1952)*, Morley and Hayward, 2012, Fig. 8m.
Oculocytheropteron vertex (Hornibrook, 1952)*, Figs 177, 179, 180.
Orlovibairdia arcaforma (Swanson, 1979). Morley and Hayward, 2012, Fig. 11h.
Papillatabairdia elongata McKenzie, Reyment and Reyment, 1990+ This paper Fig. 2.
Paracypris zealandica (Brady, 1880)* Morley and Hayward, 2012, Fig. 11i.
Paradoxostoma albaniense Hartmann, 1979* Morley and Hayward, 2012, Fig. 11j.
Paradoxostoma augustense Hartmann, 1979* Morley and Hayward, 2012, Fig. 11k.
Paradoxostoma brevicaudata Yassini and Jones, 1995. Morley and Hayward, 2014, Fig. 3.
Paradoxostoma crustaecola Hartmann, 1980. Morley and Hayward, 2014, Fig. 3.
Paradoxostoma* aff. *geraldtonense Hartmann, 1978+ This paper Fig. 2.
Paradoxostoma posterotruncatum? Yassini and Jones, 1995. Morley and Hayward, 2012, Fig. 11l.
Paradoxostoma romei Mckenzie, 1967* Morley and Hayward, 2012, Fig. 11m.
Paradoxostoma* aff. *romei Mckenzie, 1967*
***Paradoxostoma* aff. *schornikov*i** Yassini and Jones, 1995* Morley and Hayward, 2014, Fig. 3.
Paradoxostoma sp. 1 Morley and Hayward, 2012
Paradoxostoma* sp. 2 Morley and Hayward, 2014, Fig. 3.
Paradoxostoma sp. 3. Morley and Hayward, 2014, Fig. 3.
***Paradoxostoma* sp. 4**+

Parapolycope*? aff. *loscobanosi (Hartmann, 1959). Morley and Hayward, 2012, Fig. 12a.
Parasterope quadrata (Brady, 1898). Morley and Hayward, 2012, Fig. 11n.
Patagonacythere wyvillethomsoni (Brady, 1880)
Philoneptunus gravizea (Hornibrook, 1952)*, Figs 68, 19, 76.
Pleoschisma agilis (Thomson, 1879). Morley and Hayward, 2012, Fig. 9c.
***Polycope* sp. 2**+ This paper Fig. 3.
Polycope sp. 3. Morley and Hayward, 2012, Fig. 11o.
Ponticocythereis aff. *decora* Swanson, 1979* Morley and Hayward, 2014, Fig. 4.
Ponticocythereis militaris (Brady, 1866)* Morley and Hayward, 2012, Fig. 12b.
Ponticocythereis* aff. *militaris (Brady, 1866)* Morley and Hayward, 2014, Fig. 4.
Pontocythere hedleyi (Chapman, 1906)+
Pontocythere aff. *hedleyi* (Chapman, 1906)* Morley and Hayward, 2012, Fig. 12c.
Pontocythere sp. 1. Morley and Hayward, 2012, Fig. 12d.
Procythereis kerguelenensis (Brady, 1880). Morley and Hayward, 2012, Fig. 12e.
Procythereis lytteltonensis Hartmann, 1982*. Morley and Hayward, 2012, Fig. 12f.
Propontocypris* aff. *subreniformis (Brady, 1880)+
Propontocypris sp. 2. Morley and Hayward, 2014, Fig. 4.
Propontocypris sp. 3. Morley and Hayward, 2012, Fig. 12h.
Propontocypris sp. 4 Swanson, 1979. Morley and Hayward, 2012, Fig. 12i.
Pseudocythere sp. 1 Eagar, 1999. Morley and Hayward, 2012, Fig. 12j.
***Puncia novozealandica* Hornibrook, 1949**. Hornibrook, 1963, Figs 3-4.
***Puncia* sp. A**. Swanson 1991, Fig. 2A-E
***Puncia* sp. B**. Swanson, 1991, Fig. 2G
Quadracythere biruga Hornibrook, 1952* Morley and Hayward, 2014, Fig. 4.
Quadracythere aff. *chattonensis* Hornibrook, 1952. Morley and Hayward, 2012, Fig. 12k.
Quadracythere mediaruga Hornibrook, 1952* Morley and Hayward, 2012, Fig. 12l.
Quadracythere truncula (Brady, 1898)* Morley and Hayward, 2014, Fig. 4.
***Quadracythere* sp**. Eagar, 1999* Morley and Hayward, 2012, Fig. 12m.
Quadracythere* sp.1 Morley and Hayward, 2014, Fig. 4.
Quasibradleya cuneazea (Hornibrook, 1952)*, Figs 87-89.
Rotundracythere gravepuncta (Hornibrook, 1952)* Morley and Hayward, 2012, Fig. 12n.
Rotundracythere* aff. *mytila (Hornibrook, 1952)+ This paper Fig. 3.
Saida truncula Hornibrook, 1952*, Figs 290-292.
Sclerochilus sp. a Swanson, 1979. Morley and Hayward, 2012, Fig. 12o.
***Sclerochilus* sp**. + This paper Fig. 3.
Scleroconcha aff. *sculpta* (Brady, 1898). Morley and Hayward, 2012, Fig. 13a.
Semicytherura arteria Swanson, 1979* Morley and Hayward, 2012, Fig. 13b.
Semicytherura* aff. *arteria Swanson, 1979* Morley and Hayward, 2012, Fig. 13c.
Semicytherura clausi (Brady, 1880)+
Semicytherura aff. *clausi* (Brady, 1880)* Morley and Hayward, 2014, Fig. 3.
Semicytherura costellata (Brady, 1880)* Morley and Hayward, 2014, Fig. 4.
Semicytherura hexagona (Hornibrook, 1952). Morley and Hayward, 2012, Fig. 13d.
Semicytherura sericava (Hornibrook, 1952)* Morley and Hayward, 2012, Fig. 13e.
Semicytherura sp. 3. Morley and Hayward, 2012, Fig. 13f.
Streptoleberis arcuata (Poulsen, 1962).
Swansonella novaezealandica (Hartmann, 1982). Morley and Hayward, 2012, Fig. 13g.
Swansonites aequa (Swanson, 1979)* Morley and Hayward, 2012, Fig. 13h.
Swansonites tumida (Swanson, 1979)* Morley and Hayward, 2012, Fig. 10n.
Tasmanocypris dietmarkeyseri (Hartmann, 1979)
Trachyleberis lytteltonensis Harding and Sylvester-Bradley, 1953. Morley and Hayward, 2012, Fig. 13i.
Trachyleberis aff. *militaris* (Brady, 1866)
Trachyleberis scabrocuneata (Brady, 1880). Morley and Hayward, 2012, Fig. 13l.
Trachyleberis zeacristata Hornibrook, 1952. Morley and Hayward, 2012, Fig. 13m.
***Trachyleberis* sp. 2**
Trachyleberididae*+ This paper Fig. 3.
Vargula ascensus Kornicker, 1979. Morley and Hayward, 2012, Fig. 13n.
Waiparacythereis joanae Swanson, 1969* Morley and Hayward, 2012, Fig. 13o.

Xestoleberis atra (Thomson, 1879)
Xestoleberis chilensis austrocontinentalis Hartmann, 1978+ This paper Fig. 3.
Xestoleberis olivacea Brady, 1898* Morley and Hayward, 2012, Fig. 14a.
Xestoleberis posidonicola Hartmann, 1979+
***Xestoleberis* sp. 2** Morley and Hayward, 2012* Morley and Hayward, 2012, Fig. 14b.
***Xestoleberis*? sp. 5** Morley and Hayward, 2012* Morley and Hayward, 2012, Fig. 14c.
***Xestoleberis*? sp. 6** Morley and Hayward, 2012* Morley and Hayward, 2012, Fig. 14d.
***Xestoleberis* sp. 8** Morley and Hayward, 2012* Morley and Hayward, 2012, Fig. 14e.
Xestoleberis* sp. 9 Morley and Hayward, 2014, Fig. 4.
Xestoleberis* sp. 11 Morley and Hayward, 2014, Fig. 4.
Xestoleberis* sp. 12 Morley and Hayward, 2014, Fig. 4.
***Xestoleberis* sp. 13**+ This paper Fig. 3.
***Xestoleberis* sp. 14**+ This paper Fig. 3.
Yassinicythere bassiounii (Hartmann, 1978)+ This paper Fig. 3.
Indet. gen. and sp. 1. Morley and Hayward, 2012, Fig. 14f.
Indet. gen. and sp. 3. Morley and Hayward, 2012, Fig. 14h.
Indet. gen. and sp. 4. This paper Fig. 3.

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