Terrestrial invertebrates from the salt marshes of the Avon-Heathcote Estuary/Ihutai and Pegasus Bay

R Macfarlane, August 2012

Edited by Denise Ford, 20 June, 2014

Produced for the Avon Heathcote Estuary Ihutai Trust

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Contents

1 Executive Summary

This report was commissioned to investigate terrestrial invertebrate fauna (insects, spiders and mites) of tidal and estuary margin vegetation of the Avon-Heathcote Estuary/Ihutai and Pegasus Bay, Canterbury.

Invertebrates were collected from two main sites. Within each site two areas were sampled.

- Avon Heathcote Estuary/Ihutai
    - Bridge Street
    - Tunnel Road
- Ashley River
    - Ashley River mouth
    - Saltwater Creek

Three main vegetation types where sampled:

- Saltmarsh Ribbonwood (*Plagianthus divaricatus*)
- Jointed Rush (Oioi) (*Apodasmia similis*)
- Saltmarsh meadow, consisting mainly of glasswort (*Sarcocornia quinquiflora*), bucks horn plantain (*Plantago coronopus*) and remuremu (*Sellieria radicans*)

Invertebrates were collected by the following sampling methods:

- Beating of vegetation
- Sweeping with nets
- Pan traps

Modified pan traps were developed to overcome the difficulties of collecting in tidal habitats.

Saltmarsh Ribbonwood (*Plagianthus divaricatus*)
Saltmarsh ribbonwood has six to ten regular species of insect herbivores.

- Leaf and shoot feeders include species of the leafhopper *Arawa* sp. and the small mining weevil *Peristoreus durus*. Two moth species *Pseudocoremia laetiflora* and *Stigmella aegialeia* identified as leaf feeders of saltmarsh ribbonwood by Paviour-Smith (1956) were not identified in this survey.
- The seed provides food for the caterpillars of moths: an undescribed species of *Anisoplaca* (Gelechiidae) and a species of *Meterana* (Noctuidae). The mirid bug *Halormus velifer* sucks the developing seed leading to premature shrivelling and blackening. Our survey record of *H. velifer* nymphs extends the known seasonal activity of this species.
- Several generalist feeding species of scale insects were found on saltmarsh ribbonwood. The soft brown scale *Coccus hesperidum* is a new host record for this plant.
- The flowers of the saltmarsh ribbonwood attracted at least one if not three thrip species to feed on the pollen and nectar. A small general flower-visiting beetle *Dasytes* sp. was also present.
- The main species collected from the litter layer was the bark lice *Philotarsopsis guttatus*, this was the only species with nymphs among the saltmarsh ribbonwood. *P guttatus*, possibly breed among the litter and lichen. Other litter dwelling species included a few mildew beetles (Cortacariidae) and a limited number of fungus gnats (Diptera).
- The parasite guild was found to have a little known and possibly undescribed species. The leafhopper *Arawa* sp. revealed to be a definite host of *Elenchus maoricus* (Elenchidae).

Large numbers of a Mymaridae species (family of chalcid wasps) were collected from the saltmarsh ribbonwood; this may mean that they parasitise *Arawa* or the small weevil *Peristoreus durus*.

Jointed rush (Oioi) (*Apodasmia similis*)

- A new moth herbivore of the genus *Megacraspedus* was recorded from the jointed rush. It is possible that this is an undescribed introduced species that also feeds on *Juncus* species.
- The scale *Poliaspoides leptocarpi*, originally described from Christchurch was recorded in this survey. Little is known about this species distribution nationally.
- Adults and nymphs of the Miridae, *Josemiris corvalhoi,* were abundant indicating the reliance that this insect has on jointed rush.
- No species were found that could be determined as litter dwellers.

Saltmarsh meadow and Sea rush (*Juncus maritimus*)

- The bug *Anchodelphus olearus* (Delphacidae) was a characteristic herbivore among the wet saltmarsh meadow near Tunnel Road. This bug represents a previously unknown species host of *Elenchus maoricus* or possibly an undescribed species of *Elenchus*.
- The drier saltmarsh meadow and/or sea rush, which is above the normal tides, provides suitable habitat for nymphs of the root mealy bug *Balanococuss* sp.

- Overall this survey of tidal and estuary margin vegetation revealed new insect herbivores and a new parasite link (Delphacidaie a new host of Strepsiptera).
- Sampling during plant and seed growth clearly showed on which part of the plant the herbivores feed.
- The importance of tactical collecting from an adjacent habitat (saltmarsh meadow) was shown. It demonstrated that the main fauna did come from the saltmarsh ribbonwood and jointed rush.
- Saltmarsh ribbonwood had more invertebrate diversity than the jointed rush.
- A diverse fauna derives nourishment from the litter layer
- At times, there is a considerable influx of transient or casual visitors e.g. midges and muscid flies that breed within the adjacent estuary. The importance of transient adult insects using shrubland for shelter and rest, therefore providing predators with an increased prey was an unexpected finding.
- Modified pan traps used in this survey were more efficient and reliable than traditional methods for collecting invertebrates from dense, stiff divaricating shrubs and low vegetation.
- Identification guidance for characteristic species and specimen curation has been provided (Appendix 1). A photo gallery of invertebrates recorded along with their feeding sites and/or damage gives basic information on the species that make the estuarine habitat their home.

2 Introduction

Estuarine habitats are often partly saline and often tidal. Along the New Zealand coastline, they form limited narrow areas of habitat that act like islands separated by sand dunes or rocky areas. These coastal fringes tend to be placed under considerable recreational, fishing and tourist pressure. Waterways can be adversely affected by an increase in nitrogen from sewage and/or fertilizers from intensive agriculture. These pressures can lead to modification of the plant dune and saltmarsh meadow habitats. The Impacts of these pressures from an insect, mite and spider perspective are poorly understood.

In central Canterbury, there are three estuarine habitats to the north and within 30 km of the largest, the Avon-Heathcote Estuary/Ihutai. These estuarine areas with salt enriched islands experience natural changes to river mouth flow (Ashley River) or previous induced changes (Waimakariri River, Brooklands Lagoon) or periodic salt water enrichment (Ashdown flats). This series of broadly similar habitats are rather isolated from each other from the perspective of small flying insects. Isolation of habitat impacts on the dispersal of those species in guilds that rely on food chain herbivores.

Saltmarsh ribbonwood (*Plagianthus divaricatus*) marks a division between tidal rush fields which maybe interspersed with saltmarsh meadow. This shrub forms a moderate initial barrier physical barrier, along a significant part of the Avon-Heathcote Estuary/Ihutai, from incoming waves that may arise from storm surges or tsunami. The rush dominant tidal fields are mainly made up of the endemic jointed rush (oioi) *Apodasmia similis* (Restionaceae); sea rush *Juncus maritimus* (Juncaceae), an Australian variety, and in some places the adventive three square rush *Schoenplectus validus/pungens* (Cyperaceae). Rush species are an important component of estuarine habitat for arthropods. Saltmarsh meadow consists mainly of glasswort (*Sarcocornia quinquiflora*), bucks horn plantain (*Plantago coronopus*) and remuremu (*Sellieria radicans*).

2.1 Estuarine Entomology

In New Zealand, little has been recorded of insect, mite and spider diversity in temperate estuarine margins. Less is known about the relationships within these habitats; herbivory predation, parasitism, and those species in the litter and carrion. Two general surveys of Brooklands Lagoon and the Avon-Heathcote Estuary (Macfarlane & Clark, 2008) and the Otago Peninsula (Paviour-Smith, 1956; Patrick, 1995) provide most of the scanty information available on a national basis. Paviour-Smith (1956) sampled insects, mites and crustacean primarily from core samples along transects. A lack of precision with identification restricted the information available from the distinct plant communities that Paviour-Smith (1956) sampled.

Other studies of similar habitat include a survey of moths by Patrick (1995) from saltmarsh meadows and shrubs at Aramoana (Otago Peninsula) over a 10-year period. The coastal margin survey of Curtis (2011) used Malaise traps and pan traps to compare the insect fauna adjacent to smaller estuarine and beach areas near Gisborne, Okains Bay Banks Peninsula and several Chatham Island sites. The results of this work is not yet available.

2.1.1 Salt-marsh or seashore ribbonwood shrubland *Plagianthus divaricatus*

The first recorded species associated with saltmarsh ribbonwood was the endemic shield bug *Oncacontias vittatus* (Acanthosomatidae), collected by Myers (1926). The revision of 115 species of New Zealand Miridae species (largest family of true bugs) by Eyles & Schuh (2003) recorded *Halormus velifer*, the predatory *Rhomna scotti* and *Sejanus albisignatus*. This revision allowed for the identification of adults and nymphs from these species previously found on saltmarsh ribbonwood in the Avon-Heathcote Estuary/Ihutai (Eyles, 2006).

Of the 61 species of fungus weevils (Anthribidae), only one species *Hoherius meinertzhageni* has been collected in numbers from the three native Malvaceae trees and shrubs, of which saltmarsh ribbonwood is one. The fungal spores and higher plant tissue from these three species have been found in the hindgut of adult *H meinertzhageni*. The soft native scale *Aphenochiton inconspicuous*, which has a range of host plants, and the cosmopolitan black soft scale *Saissetia oleae* (Coccidae) have both been recorded on saltmarsh ribbonwood (Hodgson & Henderson, 2000)

The Macfarlane & Clark (2008) study revealed surprising diversity amongst species within the saltmarsh ribbonwood, including the presence of many parasitic hosts. The exceptional diversity in spiders (20 species) raises several questions about the possible predator diversity in divaricating shrubs.

2.1.2 Jointed rush (oioi) *Apodasmia similis*

Little has been recorded about the insects feeding on jointed rush other than the description of the scale *Poliaspoides leptocarpi* in 1915 from New Brighton (Hodgson & Henderson, 2000). *Josemiris carvalhoi* (Miridae) has been collected from the same site. Eyles (1996, 2005), described this species along with providing photos and biological information. Patrick (1995) noted this endemic rush as a food plant for an undescribed species of moth, *Megacraspedus* (Gelechiidae). The part of the plant that this moth species feeds on is unknown.

2.1.3 Sea rush *Juncus maritimus*

Up to 1960, there were no recorded insect herbivores on sea rush (Dale & Maddison, 1982). A limited number of species have now been found, a number of herbivores (mealy bugs, trips) and possibility Chalcoidea, a family of parasitic wasps (Macfarlane & Clark, 2008). Patrick (1995) found that sea rush hosted the moth species *Elachista gerasmia* (Elachistidae) and *Glyphipterix iocheaera* (Glyphipterigidae). Eyles (1975) collected the slender straw-coloured *Trigonotylus doddi* from the intertidal zone at Rabbit Island near Nelson, on grasses near the shore. This indicates that the host of this bug is not the maritime rush but a grass species. The mealy bug *Balanococcus nelsonensis* (Pseudococcidae) has been described from *Juncus maritimus* and *J. gregiflorus* Cox (1987).

2.2 Aims of this study

- To determine the diversity and heritage significance of insects by guilds.
- To determine which part of the plant the herbivore feeds on and to illustrate feeding damage on estuary margin saltmarsh ribbonwood and tidal jointed rush.
- To investigate the insect and parasite host relationships, notably the little known parasite order Strepsiptera with Hemiptera hosts.
- To record major variation in seasonal activity for the main insect species and relate this to the plant stage of development wherever possible.
- To illustrate estuarine insects and mites to aid future studies by students and scientists and monitoring by environmental agencies. Awareness of this almost unknown fauna from a restricted area of vulnerable habitat is required to foster appreciation and at least some recognition. Canterbury, a major population centre with two universities. It is fortunate to have available a suite of habitats with temperate vegetation, as opposed to mangrove

vegetation.
- To develop and test ways to improve pan trap performance.
- To assess reasons why divaricating shrubs can support a relatively diverse predator fauna, including spiders.

3 Methods

3.1 Sampling and survey issues

The combination of plant simplicity and specialist habitat conditions within the saltmarsh habitat might be expected to limit diversity of terrestrial invertebrate species. Littoral animals among this suite of plant communities have consistent challenges from salinity and regular tidal flows. Early terrestrial invertebrate surveys of estuarine habitat failed to precisely identify the fauna of these plant communities. Sampling in tidal areas by Paviour-Smith (1956) by using core sampling found immature insects were a dominant part of the species collected. Since the 1950s, considerable progress has been made with both mite and spider identification (Sirvid et al., 2010) and insect orders e.g. flies and parasitic wasps (Macfarlane et al., 2010). The Canterbury survey of 2008 (Macfarlane & Clark, 2008), based on an extensive summer survey mainly with pan traps, revealed a large community of species. Diversity within the saltmarsh habitat makes identification and quantification between plant communities difficult. Insect, spider and mite identification is still a challenge despite the apparent simplistic nature of their habitat.

Estuarine-lagoon insects were collected from two coastal estuaries: the Avon- Heathcote/Ihutai and Ashley River-Saltwater Creek. The northern end of the Avon-Heathcote/Ihutai estuary (Bridge Street) is 23 km south of the Ashley Lagoon site. The 4.5 km long Brooklands Lagoon is halfway between these two estuaries. Thus, habitat isolation is considerable for specialist insect species dispersing from the tidal and estuary margins of these sites.

3.2 Sites

Four sites were chosen to survey invertebrate communities in tidal and estuary margins. The two main sites being the Avon Heathcote Estuary/Ihutai up-stream from the Bridge Street bridge and the mouth of the Ashley River. Two saltmarsh meadows were also chosen; the north-eastern end of Tunnel Road close to the south bank of the Heathcote River and Saltwater Creek on the north-eastern side of State Highway One bridge (Table 1).

Table 1: The four survey sites chosen for this survey

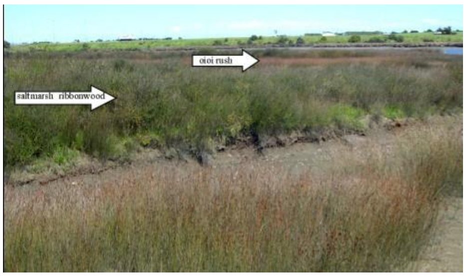
Site	Latitude	Longitude
Bridge Street	43 31.6 S	172 43 E
Ashley River Mouth	43 17.68 S	172 43 E
NE end of Tunnel Road	43 33.31 S	172 41.6 E
NE side of Highway 1 bridge Saltwater Creek	43 15.88 S	172.42.2 E

3.2.1 Avon Heathcote Estuary/Ihutai

Bridge Street: An area of the estuary at Bridge Street area was chosen as the main initial site to investigate herbivores and their parasites within the tidal zone (Figure 1). Jointed rush at this site is of a large area and has a relatively stable insect fauna. The distance from adjacent vegetation, such as sea rush and pine trees will limit the number of vagrant insects collected.

Estuary margins within this site have areas of adjacent vegetation such as broom, wattle and kanuka (*Kunzea ericoides*). This vegetation is a source of transient/causal species such as the broom seed bruchid beetle, Psyllidae species and other mirids. Vagrant species from adjacent vegetation may mask the true insect diversity within the margin and tidal zones of this estuary.

Collection samples can be contaminated by vagrant insects when using less specific sampling techniques such as light trapping. Light trapping attracts insects from a wide area, therefore bringing in insects that do not normally live or breed in the habitat being sampled. The effort put into providing quantitative data for the survey, the lack of a second good low set light trap and placing more pressure on the few national Lepidoptera specialists for identification of moths was the reason, why light traps were not used in this survey.



- (a) View South West across river to Bexley Reserve

(b) View West with to Avon River from bridge

(c) Bridge Street north shore tidal channel

(d) Bexley western jointed wire rush site looking NE

Figure 1: Avon River/Ōtākaro Bridge Street site with patches of salt marsh ribbonwood and jointed rush

Tunnel Road: The second site on the Avon-Heathcote Estuary/Ihutai was at the northeast end of Tunnel Road close to the south bank of the Heathcote River. This site is the largest (on average 8 m wide and 30 m long) and purist area of saltmarsh meadow known to the author that regularly remains moist within the Avon-Heathcote Estuary/Ihutai. The site is a mixture of glasswort, remuremu and a little plantain. Adjacent to the site is the tall brown native grass *Puccinellia stricta*. At the upper end of the site is a mixture of sea rush and saltmarsh meadow species (Figure 2).

Figure 2: Tunnel road East side tidal vegetation, Mt Pleasant in the background. Green saltmarsh meadow, brown sea rush and yellow Puccinellia stricta grass on the south side

3.2.2 Ashley River Mouth-Saltwater Creek

Ashley River Mouth: The main site at the Ashley River mouth was on the north side, north-west of macrocarpa trees and near the end of a tidal estuary branch. All collections were made from the saltmarsh ribbonwood just south of the posts (Figure 3a) and beside the saltmarsh meadow (Figure 4). To the seaward side an extensive area of original saltmarsh ribbonwood is on a perched bench, therefore is not kept moist by high tides. The main adjacent vegetation is grass with a corridor of dry saltmarsh meadow approximately 2-3 m wide and 40 m long. The only conspicuous area of jointed rush on the north side of the Ashley River mouth was a small area (approximately 8 m sq.) southeast of the foot bridge (Figure 3a).

The saltmarsh meadow strip has a limited amount of remuremu, the main plant hosts are glasswort and bucks horn plantain. By 20 January the remuremu had little flower left. Near this saltmarsh meadow, at the southern end of the corridor there was an appreciable amount of Batchelor's button flowering. This flower resource possibly accounted for the single catch of *Leioproctus fulvescens*, which specialises in Asteraceae flowers.

Saltwater Creek: The Saltwater Creek area is regularly submerged by the tide. The area surveyed consists of oioi, jointed rush (*Apodasmia similis*)

a) Raupo berm footbridge & jointed rush patch (about 12-16 m^2

b) Collection site of saltmarsh ribbonwood starts by fence post & main saltmarsh

Figure 3: Ashley River mouth North bank: tidal waterway edge and mixed dry herb-shrubfield

Figure 4: Saltmarsh meadow corridor entrance beside saltmarsh ribbonwood. Corridor SE end of largest saltmarsh meadow. Note vehicle tracks

3.3 Site variation for each vegetation type - shrubland, rush, saltmarsh meadow

The Bridge Street site has both saltmarsh ribbonwood and jointed rush within the tidal estuary (Figures 1a, 1c). Saltmarsh ribbon is also on the areas fringed by the high tide (Figure 1d).

The saltmarsh ribbonwood at the Bridge Street site differs from the Ashley River site (Figures 3a, 3b) in several ways. The habitat sampled at Bridge Street has a regular tidal flow of semi-saline water. The saltmarsh ribbonwood, degraded saltmarsh meadow and tall grass at the Ashley River site (Figures 5a, 5b) are non-tidal. Therefore the Bridge Street site was consistently moister then the Ashley River site. The Ashley River site had a more extensive and probably consistently older area of saltmarsh ribbonwood than the Bridge Street site. The saltmarsh ribbonwood at the Ashley River site was surrounded by long dry grass or short degraded plantain dominant saltmarsh meadow. By February, the grass and degraded saltmarsh meadow vegetation had browned off.

The Tunnel Road site had moist saltmarsh meadow that was regularly sub-merged by the tide.

In January, this area was lush and green with remuremu in flower. The jointed rush at Saltwater Creek is also tidal.

The two saltmarsh meadows (Tunnel road and Saltwater Creek) can experience extremes in salinity. The Tunnel road saltmarsh is affected by periodic heavy rain with fresh water runoff from the flats via a ditch. Hence, salinity will be low for brief periods. Conversely the extensive salt marsh meadow at the Ashley River mouth reserve is wet slightly by king tides. Infrequently it can be covered by river water at high tide during floods. Overall, the salinity of the Ashley River mouth saltmarsh meadow is relatively constant being moderate to high.

(a) General view West and inland (b) 2-3 m wide dry saltmarsh meadow corridor

Figure 5: Ashley River mouth main sampling area

3.4 Collection Methods

Sampling techniques in previous studies of estuarine areas have included traditional methods such as sweep netting, beating (shrubs), and the collection and rearing of pupae. These techniques are labour intensive and are open to collector bias. Pan traps are a less labour intensive method from which quantitative comparisons between adjacent habitats can be made. Comparisons between habitats are important to clarify the habitat use and range of a variety of insects as demonstrated in surveys of the Styx Mill Conservation Reserve (Macfarlane & Scott, 2007) and the New Brighton sand dunes (Macfarlane, 2005). Two other common sampling methods: Malaise traps and light traps not were used in this survey. Malaise traps are a labour effective way of collecting insects but like light trapping samples insects from a large area. Hence, there is less certainty regarding the insects' habitat. The shear breath of the survey plus no funding for or arrangements to identify adult moths, made these two methods not viable for this survey

Consistent, regular wetness caused by tides combined with the flatness of the salt marsh meadows limits the value of sweep netting. Traditional sweep nets must sweep above the vegetation or get wet. Catches from pan traps used in the traditional method, placed on the ground, suffer disturbance from wind and birds such as the pukeko. These issues severely comprise the reliability of individual traps and replications. Conversely, the stiffness and rigidity of the divaricating shrub, saltmarsh ribbonwood only allows for surface sampling.

An alternative sampling method that is effective for both labour saving and insect sampling within the shrubland and tidal vegetation habitats is required. Paviour-Smith (1956) used cores and modified flat-sided sweep nets to counter difficult collecting from low wet tidal vegetation. To overcome the same difficulties we developed a modified pan trap. These modifications included dowling under two sides of the trap for the divaricating shrubland and the trap on platform for the salt marsh meadows (Figure 6).

Comparisons were made to determine the most effective sampling method on saltmarsh ribbonwood, especially for herbivores associated with parasites (e.g. Strepsiptera) and predators (e.g. Spilongona flies). This stiff divaricating shrub in the past has mainly been sampled by sweep netting.

Insects, spiders and mites were gathered by beating, sweeping, pan trapping and some direct examination of oioi rush stems and saltmarsh ribbonwood seeds. The modified pan traps were not used until near the end of the sampling regime (Appendix 2).

(a) Pan trap on platform

(b) Pan Trap with dowling support

Figure 6: Modified Pan Traps

3.5 Sampling

The two main estuarine sites were sampled from spring to summer to determine how consistently herbivores and their parasites would be found (their fidelity to the plant habitat) Table Two lists the sites, sampling type and dates. An initial survey in 2008 started too late to cover flowering and the growth of saltmarsh ribbonwood seedpods (Macfarlane & Clark, 2008).

Table 2: Sites sampled showing collection dates and methods. (*=Dusk sampling)

Bridge Street	Beating, Pan Traps Beating, Sweeping Beating, Sweeping Beating, Sweeping, Pan Traps Sweeping Sweeping Beating, Sweeping	Sep 19th 2009 Sep 30th 2009 Nov 2nd 2009 Nov 3rd 2009 Nov 15th 2009 Dec 4th 2009 Dec 9th 2009
Tunnel Road	Beating, Sweeping, Pan traps	Jan 2nd 2010
Ashley River mouth	Beating, Sweeping Beating, Sweeping Beating, Sweeping Pan Traps (6) Beating, Sweeping Beating, Sweeping Pan Traps (8)	Sep 2008 Oct 19 2009 15 Nov 2009 15-19th Nov 2009 Feb 9th 2009 Feb 18th 2009 20-25th Jan 2010
Saltwater Creek	Beating, Sweeping	Jan 25th 2010

3.5.1 Bridge Street

Insects and mites were collected from jointed rush at the Bridge Street site on the 19th and 30th of September, and the 2nd of November (east and west sides). (Figures 1c, 1d). On the 30th of September the larger area of jointed rush on the western Bexley side upstream from the bridge was swept. Fresh jointed rush was collected for caterpillars that were being reared in canisters. About 10 stems were checked for scale insects in the nodes below the seed head. On 15 November dusk sampling was carried out in an attempt to collect adult moths from the jointed rush.

3.5.2 Tunnel Road salt marsh

Sampling at this site consisted of platform pan traps, eight traps were placed in the saltmarsh habitat.

3.5.3 Ashley River mouth

At the main site, six pan traps were placed in the saltmarsh ribbonwood canopy from 15-19 November 2009. A further eight pan traps were deployed (20-22 January 2010) in ribbonwood within the adjacent saltmarsh meadow. At the Ashley river site a small patch of jointed rush was swept at a raupo berm (Figure 3a).

3.5.4 Saltwater Creek

A large patch of jointed rush was beaten at this site on January 25th 2010.

4 Results and Discussion

Between September 30th 2009 and February the 9th 2010 over 10,200 insect specimens were collected along with over 1,000 mites and 244 spiders (Table 3). The majority of the specimens collected were from Bridge Street and the North bank of the Ashley River sites (Appendix 2). Herbivores were the most consistent guild collected over the different habitats and made up 42% of the total number of specimens (Table 4). In this study, there was a high catch of transient midge species caught in the open saltmarsh meadows. Surges of insect biomass can arrive from the adjacent estuaries. Predators that are in the estuary at low tide may also move into the upper part of the rushes for shelter at high tide and possibly night time.

Table 3: Overall composition of arthropods by guild and habitat, number of individuals collected

Guild	Salt marsh ribbonwood	Tidal meadow & sea rush	Jointed rush	Total
Transients	394	5059	44	5441
Herbivores	1558	533	410	3057
Parasites	626	227	10	823
Litter and unknown	143	212	109	465
Insect predators	112	284	3	408
Carrion/dung	1	106	0	107
Spiders	260	32	13	244
Total	3094	6453	589	10,515

The saltmarsh meadows had a comparatively good catch of herbivore specimens considering it was only sampled three times compared to 21 for saltmarsh ribbonwood and nine times for jointed rush. Nectar in the saltmarsh meadow flowers and the presence of prey species (small flies such as midges, and *Rhegmoclemina* sp.) would account for the good catches of predators and parasites from the two saltmarsh meadows.

Table 4: Overall percentage composition of arthropods by guild and habitat

Guild	Salt Marsh ribbonwood	Tidal meadow & sea rush	Jointed rush	Mean per habitat
Transients	12.7	78.3	7.5	32.8
Herbivores	50.4	8.3	69.6	42.8
Parasites	20.2	3.5	1.7	8.5
Litter and unknown	4.6	3.3	18.5	8.8
Insect predators	3.6	4.4	0.5	2.8
Carrion/dung	0.003	1.6	0	0.5
Spiders	8.4	0.5	2.2	3.7

Between 160 and 250 insect species and at least 25 spider species (Table 5) and at a very minimum 10 mite species were recognised in this survey. Species for the five different types of vegetation is recorded in Appendix 2. The diversity of spiders and parasites is approximate because of identification issues encountered with such an intensive survey. For these two groups identification was largely based on body pattern and colour, leg length and shape.

Table 5: Number of Insect and spider species by guild and habitat

Guild	Salt Marsh ribbonwood	Tidal meadow & sea rush	Jointed rush	Sea rush	Total
Transients	23	7	7	7	44
Herbivores	23	24	8	6	59
Parasites	23	33	5	1	62
Litter and unknown	21	10	4	2	37
Insect predators	11	17	1	5	34
Carrion/dung	1	6	0	1	8
Spiders	20	2	3	1	26
Insect & spider total	122	99	26	23	270
Crustacea-crabs etc.	0	2	0	0	

4.1 Invertebrates from salt marsh ribbonwood *Plagianthus divaricatus* (Malvaceae)

4.1.1 Pollination and flower visitors

Few pollinating insects were seen visiting the flowers through the day. Two general flower-visiting insects were collected; a single female *Lasioglossum sordidum* (a native bee species) and a single blue *Dasytes* (Melyridae) beetle. The small Dasyhelea (Ceratopogonidae) midges may visit the flowers but were not observed. *Lasioglossum* (bee) species collected from pan traps during flowering probably visit the flowers to some extent. The low number of diurnal visitors suggests there is limited nectar available from the flowers of the saltmarsh ribbonwood. Night time observation is required to sight possible pollination by flies or moths. The sweet fragrance of the flowers may guide insects to the plant for pollination. The most abundant insect (37 adults, 40 nymphs) found during flowering was a brown thrip (Thripidae) with paler yellow nymphs (Figure 7a). At least 3-4 species were present with about two species consistently collected (Appendix 2).

Thrips were almost exclusively collected by beating into a fine net when the saltmarsh ribbonwood was in flower. The ability of thrips to transfer pollen is probably quite limited; each individual is small and can only carry a few pollen grains on the outside of the body. Collection of thrips declined when there was only seed or leaf on the plants.

Tubulifera thrips collected from the jointed rush were quite distinct in appearance from the dominant thrip species among the saltmarsh ribbonwood. The Tubulifera thrips have a brown notum on dark adults and a tube at the tip of their abdomen, their nymphs are red (Figure 7b).

(b) Tubilfera from jointed rush (nymps red)

(a) Thripidae from saltmarsh ribbonwood

Figure 7: Thrips collected from saltmarsh ribbonwood and jointed rush.

4.1.2 Herbivores

A: Foliage and stems: Populations of the leafhopper of the genus *Arawa*, were low in spring when the saltmarsh ribbonwood was in flower. Numbers of small and medium sized nymphs from this species increased considerably as flowering finished (Appendix 2). In November, the greyish medium sized nymphs of *Arawa* sp. were the main invertebrate herbivore by biomass. Three adult males were collected from beating, but sweeping produced a rather better ratio of adults to nymphs 27 % (23 leafhoppers) compared to 13.6% (25 leafhoppers). The lower rate of adult collection was expected, some adults managed to escape from the beating before the container lid or net was closed.

The saltmarsh ribbonwood herbivores (looper caterpillar, *Arawa* leafhoppers) collected on the 2nd November were left alive along with the spiders for 3 days. By this time most of the *Arawa* leafhoppers had died. It was hoped that by keeping them alive male Strepsiptera would emerge from any affected leaf hoppers. No Strepsiptera males emerged, however this is a possible means of collecting these parasites if spiders can be removed.

Other species collected in spring included; the adults of the leaf-feeding weevil, *Peristoreus durus*, a few small weevil larvae, probably *Peristoreus durus* and small numbers of bagworm moth caterpillars assumed to be *Mallobathra homalopa* (Psychidae).

The extraction of the invertebrate fauna from beating or sweep samples generally took 2-4 hours, with a carefully examination for larvae within the leaves. Leaves were quite often chewed and the undersides of some were silvery. A few of these apparently damaged leaves were opened up with a pin, but no small caterpillars were found.

At Bridge Street, beating of a row of saltmarsh ribbonwood along a muddy waterway margin, yielded parasitised individuals of the soft brown scale insect *Coccus hesperidum*. This minor pest species has a wide host range (Hodgson & Henderson, 2000). On 9 October, a visual inspection was made of the saltmarsh ribbonwood for scale and damage to the leaves as well as to check for progress in seedpod formation. In addition to *C. hesperidum*, an undescribed *Leucopsis* species is also known from saltmarsh ribbonwood (Henderson pers. comm.). The presence and abundance of scale insects is not easily determined; immature scale insects are not easily swept or beaten off host plants. Myers (1926) collected *Oncacontias vittatus* from saltmarsh ribbonwood; this is certainly a casual association. We did not collect this species and there are no other records from this habitat (Lariviere, 1992). From this, we conclude *O. vittatus* does not breed on saltmarsh ribbonwood.

Overall, very few aphids were collected at the Ashley River or Bridge Street sites, especially in the pan traps. Less than half the aphids collected were winged females. These aphids were not identified. We suspect the aphids had originated from adjacent vegetation. We would expect to see a greater number of aphids if they were breeding on the saltmarsh ribbonwood shrub. An endemic species of aphid has been previously described from lowland ribbonwood *Plagianthus betulinus*.

B: Seed feeders: With the onset of seed development in October and November, the relative numbers of some of the main insect herbivores on the saltmarsh ribbonwood changed. A visual inspection of the leaves, pods and other debris swept and beaten from the saltmarsh ribbonwood revelled holes in old seeds. On 2 November and again on 3 November one fresh hole was seen at the base of a green pod, but not always within the calyx as shown in Figure 8a. A few green seedpods had been chewed with a more open hole and caterpillars of *Anisoplaca* (Gelechiidae) were found within the developing seed (Figure 8b).

Anisoplaca sp. caterpillars from an early instar were found within the seed or loose among the beaten insects, for at least 64 days - 30 September to 4 December (Appendix 2). These greyish-bodied caterpillars with rather obscure brown spots and a black head capsule are readily distinguished from the eventually larger *Meterana* species (Noctuidae) that was also found. *Meterana* caterpillars have a yellow body and head with conspicuous dark brown spotting especially the larger caterpillars (Figure 9). *Meterana* was seen to be active for at least 142 days between September 30th and February 18th. This is a new record for this host plant association.

Orange mirid nymphs began to be collected from the Bridge Street site at this stage in the season. Eyles (Paraparamu) identified these from photographs as *Halormus velifer* (Appendix 1). The holotype was collected from near Bridge Street in 1998. Adults were recorded from 8th December to March 3rd (Eyles & Schuh, 2003), but nymphs were not recorded. Our survey record of *H. velifer* nymphs from this area extends the known seasonal activity of this species. We suspect *H. velifer* feed largely on developing seed, partly because it is not present on the plant until developing seeds are present. This indication of feeding on developing by *H. velifer* matches that of other Miridae species, for example those species that feed on Lucerne seeds.

Damage to seeds from the three insect species that feed on them can easily be distinguished; *Anisoplaca* caterpillars live within the seed and have a narrow entry/exit hole, *Meterana* chew the seed from the outside making a shallow open bowl, the mirid bug *H. velifer* sucks the developing seed leading to premature shrivelling and blackening. Sucking insects such as *Arawa* species and possibly thrips may damage small pods.

a) Three quarter grown geen seed pod with *Anisoplaca* sp. hole arrowed.

b) *Anisoplaca* sp. caterpillar in seed, note black head capsule

Figure 8: Feeding damage on the saltwater ribbonwood seed by *Anisoplaca* sp.

Figure 9: *Meterana* sp.: larger mature caterpillar on the left and medium instar on the right.

4.1.3 Parasites

The parasite guild has some little known and possibly several undescribed species from three insect families. The five individuals of *C. hesperidum* collected from the saltmarsh ribbon were parasitised by a grey-bodied chalcid pupa (small parasitic wasp). Pan trapping 11 days earlier from nearby saltmarsh ribbonwood revealed adult *Encarsia* sp.. Two adults were also collected from sweeping in the area. It is suspected that these dark *Encarsia* sp. may be *E. citrina*, largely because the soft brown scale C*. hesperidum* is a known host of *E. citrina* (Noyes & Valentine, 1989).

A possible parasite of other scales namely a yellow Aphelinidae parasite was present at both Bridge Street and the Ashley River site. This latest sampling also highlighted the presence of two Mymaridae species, which are normally egg parasites. They may parasitise the eggs of the *Arawa* sp. or the small weevil *Peristoreus durus*. The smaller species averaged over six per pan trap day. Even the larger waisted species and the yellow Aphelinidae exceeded 0.6 per pan trap day in mid-November at the Ashley River site.

The Ashley River mouth site also identified the parasitism of *Arawa* leafhoppers by the parasitiod *Elenchus maoricus* (Elenchidae). From October 19th to at least February 18th, there were *E. maoricus* larvae or pupae within adult and large nymphs of *Arawa* sp.. The first parasitised nymph had been affected by two males of *E. maoricus*, one of which had emerged.

This indicates males of E. maoricus should be in flight in October. The host is reputed to die within a few days of emergence of the male Strepsiptera (Hassan, 1939; CSIRO (Division of Entomology), 1991). Male *E. maoricus* in larger *Arawa* hosts often protruded on the abdomen upper side and were reasonably conspicuous. These male pupae were black when dissected and so was the only adult male collected (Appendix 1). Females protrude little from the abdomen underside.

Parasitism of the *Arawa* species in the saltmarsh ribbonwood was patchy. It increased sharply from October to November; this is common for many parasites if the host has more than one generation per year. Of the 81 susceptible adults and last instar nymphs 23 % were parasitised, compared to 61.5% from 49 hosts collected in February 2008 (Macfarlane & Clark, 2008; CSIRO (Division of Entomology), 1991). It is possible collections from nearly the same area the previous autumn reduced the parasite populations.

The Bridge Street site revealed no parasitism by *E. maoricus* in the 87 adults and last nymphal stages of *Arawa* collected in spring. No *E. maoricus* were found in *Arawa* at the Tunnel Road site in January 2010, but an adult male was collected. Clearly, the more recently reinforced population of saltmarsh ribbonwood shrubland in the Avon-Heathcote Estuary/Ihutai had less *E. maoricus* among the *Arawa* species that at the Ashley River site. A reason for this difference may be the presence of *Arawa variegata*, a grassland species of leafhopper, at the Ashley River site. *Arawa variegata* is known to be parasitised at a low level by an undetermined species of Strepsiptera, possibly *E. maoricus*. The availability of the host, *Arawa variegata*, will reinforce the population of *E. maoricus* at the Ashley River site.

If *E. maoricus* affects both *Arawa* species and *Anchodelphax olenus* from the salt marsh meadow, then either host can readily spread the flightless female parasite across isolated corridors of either saltmarsh ribbonwood or patches of salt marsh meadow in estuaries and lagoons.

Cowley (1984) described *Coriophagus casui* (Halictophagidae) as having a cream to pale brown abdomen and golden brown body from *Novothymbris vagans* (Cicadellidae) and *Notogryps ithoma* (Delphacidae). Thus, un-emerged *Coriophagus casui* within the host are likely to be distinctly brown compared to the black of those with Elenchus species.

Figure 10: Main booklice species, adults and nymphs. Left *Ectopsocus briggsi*, right *Philotarsopsis guttata*

4.1.4 Predators

A modest number of spiders were collected from the saltmarsh ribbonwood during this survey. Beating was one of the most effective means of collection. A few specimens were collected in the pan traps, including male spiders. The populations and diversity of spiders was appreciably less in spring than in summer. A small speckled cobweb spider was the most numerous species. Four green crab spiders (Thomisidae) were only collected at the Ashley River site in January 2009 and 2010. Few jumping spiders (Salticidae) where collected from the saltmarsh ribbonwood compared to the summer sampling in 2008.

4.1.5 Fungal and consumers of decaying leaf and other litter

The pale yellowish-brown book lice *Philotarsopsis guttata* and its nymphs were the main species collected from the litter (Figure 10). The record of *P. guttata* nymphs in the saltmarsh ribbonwood makes it certain that this species is a genuine inhabitant of this vegetation.

Five other species of booklice collected from the saltmarsh ribbonwood were represented by only 1-4 specimens. One of these species *Ectopsocus briggsi* (Appendix 2) was the main species collected from *Cassinia* shrubland at Kaiapoi Lakes it also occurs in lowland gardens (Crosby, 1968).

The bagmoth *Mallobathra homalopa* is known to inhabit saltmarsh ribbonwood but our survey did not confirm this. The collection methods used in this survey are not suitable to detect or identify specialist moths such as the litter feeding *Tinea mochlota*, or the lichen feeding *Phaesaces aprocrypta*.

Other litter feeding species included a few mildew beetles (Cortacariidae). These beetles were not consistently collected from the saltmarsh ribbonwood indicating they are mostly active at ground level. Regular exposure to tidal water would preclude them from breeding in this habitat. Most were collected from adjacent grassland, where they can feature prominently (Macfarlane & Scott, 2007).

A few adults and on one occasion six apparent Nematocera fly larvae were collected from litter. Larvae with a conspicuous head capsules were too large to be the larvae of the common Nematocera (*Dasyhelea* sp. Orthocladine midges) collected from the saltmarsh ribbonwood. The size of the larvae corresponds to the Keroplatidae family of fungus gnats (includes the predatory glow-worm larvae) or the fewer less common crane fly adults. The fungus gnat fauna found was limited (*Anomalomyia* sp. and perhaps a few *Mycetophila* sp.) and possibly one Keroplatidae. These flies breed on fungi among the litter at the base of the saltmarsh ribbonwood, if fungi and fly larvae can tolerate higher salinity. Mycetophilidae prefer woodland to grassland (Macfarlane & Scott, 2007), some species are conspicuous in hind sand dunes (Macfarlane & Scott, 2007). The invertebrate fauna among the root zone remains to be examined.

4.1.6 Associated transient species

The most consistent species collected over the survey sites were Diptera (flies), these species were considered transients. The saltmarsh ribbonwood provides shelter from the wind and a place to rest near to where the females may lay eggs. The flies are possibly less obvious to predatory insects and spiders, within the saltmarsh ribbonwood. The adult flies clearly do not feed within the saltmarsh ribbonwood. During flowering in spring, they may take marginal advantage of nectar or pollen to provide a dietary supplement for an early generation.

Several species of midge (Chironomidae) and one main species of the 'biting midge' *Dasyhelea* sp. (Appendix 2), where identified from the saltmarsh ribbonwood habitat. The midges almost certainly originate from the adjacent waterway and margins as these are areas of habitat for their larvae.

The adults of a smaller fly were identified as a species of *Dasyhelea* sp.. The identification of this fly was largely based on contrasting pale yellow and black markings on the thorax and pale haltere knobs. This species may be an undescribed native species or possibly an accidental introduced species (Appendix 1). *Dasyhelea* is a large worldwide genus (Borkent, 2012) of which the true diversity in Australia is not well documented, even less than that of New Zealand and the Pacific islands (Debenham, 1989).

Beating of the saltmarsh ribbonwood revealed a considerable number of males of the fly *Spilogona limpida* (Hutton) at the Ashley River site in summer but not spring. A much lower ratio of females was collected in pan traps within the saltmarsh ribbonwood upper canopy. Males in the saltmarsh ribbonwood canopy will be seeking resting females for mating. Females lay their eggs in areas within or at the margins of the estuary, the likely habitat of the fly larvae's prey. Females of *S. limpida* may take advantage of the, at time, considerable resources of midges, book lice nymphs and other smaller insects rather than the *Arawa* species that live and shelter in the saltmarsh ribbonwood.

Malloch (1924) distinguished *S. limpida* from the common *S. pennata*, which is of similar appearance (size and colouring). Harrison however did not recognise *S. limpida* in his partly completed revision of New Zealand Muscidae. Hence, information on the distribution of *S. limpida* is meagre. It is found mainly in the lowlands of both the Eastern South Island and Steward Island. Fortunately, the male is distinctive (Appendix 1) amongst the diverse *Spilogona/Millerina* complex (Macfarlane et al., 2010). A few specimens of a second smaller species with black legs were also collected from the saltmarsh ribbonwood (*Chryosotus/Diaphorus*). However, the *Spilogona/Millerina* are active within the saltmarsh ribbonwood unlike *Chryosotus/Diaphorus* which are active in the open short saltmarsh meadow or grass (Appendix 1).

4.2 Invertebrates from Jointed Rush (Oioi) *Apodasmia similis*

In this habitat sweeping of the rush fields for insects, spider and mites was found to more effective than beating. The denseness of the rush masses allowed the trial of the pan traps with dowling. They could be placed among the dry upper parts of the plants to collect parasitic and nocturnal invertebrates.

Herbivores: Caterpillars of an undescribed species of the moth, genus *Megacraspedus* (Gelechiidae) were collected from the jointed rush at Bridge Street. They were beaten from rush upstream from Bridge Street (east side) on the 19th of September 2009 and were still present by the 4th of December 2009. These small brown caterpillars with a beige strip (Figure 11a) were collected from the same site in September 2008, but were not counted. On the 30 September 2009, over 100 caterpillars were collected from 6-10 sweeps of the seed and flowers of the jointed rush, on the west side (Bexley Wetland).

On the 15th of November, at the Ashley River site five caterpillars of the same species were collected from the small patch of jointed rush near the bridge at the raupo berm. On the 25th of January 2010, at Saltwater Creek the remaining jointed rush seed had holes but no caterpillars (Figure 11b). This infers that the caterpillars had developed in pupae or moths. This species has not been formally collected from Brooklands Lagoon, information gathered as above can provides clues to the presence of this species. The caterpillars of the species were consistently present even in small patches of jointed rush providing there were seeds and/or flowers. Evening sweeping when the tide is out during summer months through until autumn is required for collection of the adults. It remains unresolved if this species of *Megacraspedus* is the same as an undescribed species found feeding on *Juncus*. Should they be the same species, it may be an accidentally introduced species associated with sea rush.

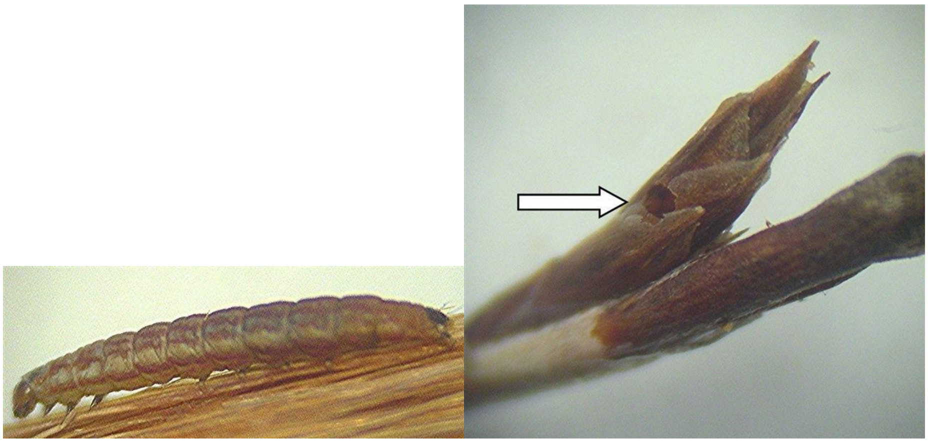
In the North Island adults of a small undescribed species of *Megacraspedus* (Gelechiidae) have been collected from jointed rush at dusk. These were collected in the months of December and January (Hoare pers. comm., Landcare Research, Auckland). An undescribed species of *Megacraspedus* has also been collected from rush habitat at Travis Wetland, Christchurch.

At Bridge Street, the other common insect herbivore on these rushes was the scale insect *Poliaspoides leptocarpi*. The few fully developed white males were readily detected as they were partly exposed (Appendix 1). Peeling of the outer upper part of the nodes of a few stems revealed one and up to at least three brown females (Appendix 1). This scale insect species has not been sampled from this site since 1916. It has only recently been found in the Auckland area (Henderson pers. comm.). The raupo berm at the Ashley River site was not checked for this scale species. Other sites in the Avon Heathcote Estuary/Ihutai and Saltwater Creek estuaries have yet to be checked thoroughly for this probable host specific scale. Considerable populations can be overlooked because of the need to dissect the nodes to reveal the females.

In November, 20 to 30 sweeps of the jointed rush gathered only the greenish nymphs of *Josemiris carvalhoi* (Appendix 1, 2). However, by the beginning of December, adults were present and the nymphs were less readily collected. Seasonal activity for adults ranges from December to April (Eyles, 1996, 2005). This record of nymphs is significant, it indicates jointed rush is a habitat where the species breeds, but also extends the known season of activity by a month earlier. Eyles (1996) commented that the overall diet of *J. carvalhoi* remains to be fully resolved. Other species are known to feed on insect eggs in stems, the immobile scales and even mites. The numbers of *J. carvalhoi* adults collected and mounted in the main insect collections are low. There is a lack of nymphs (Eyles, 1996, 2005) from which to verify the habitat association of this species.

Thrips (Figure 7b) were present in reasonable numbers early in the season (Appendix 2). The most favourable time for them to feed is when pollen or developing seeds are available on the jointed rush and sea rush. No thrips were collected from the west side with a larger more open net, while on the same day a muslin type net collected an appreciable amount of these thrips (Appendix 2). The nymphal thrips (no wings) were red, unlike the brown or yellow nymphs on the saltmarsh ribbonwood.

Five light bluish adult beetles of the Melyridae family were collected from the west site at Bridge Street on November 2. These general flower visitors and the undetermined Dermestidae (carpet) beetle could well feed on the pollen in the jointed rush flowers.



a) *Megacraspedus* caterpillar

b) Round feeding hole in shoot of oioi rush

Figure 11: *Megacraspedus* caterpillar and damage to jointed rush

4.2.1 Litter

Only one individual of each of the two species *Ectopsocus briggsi* and *Peropsis maoricus* were collected from the jointed rush litter. The exotic *E. briggsi* occurs in lowland gardens (Crosby, 1968) and inland shrubland (Derriak et al., 2001). Periodic tidal water at the base of the rushes is almost certainly unfavourable for many species. Paviour-Smith (1956) does list limited numbers of unidentified book lice from saltmarsh meadow.

4.2.2 Predators

There was a change in the main invertebrate fauna at dusk compared to what was sampled in the daytime (Appendix 2). A mass of blackish Sminthuridae springtails were swept from both sides of the Avon River at the Bridge Street site on November 15th, they were not counted. Spiders are associated with these springtails. Few spiders were collected from the jointed rush during the day, no individuals were found of an undescribed *Scorporius* species previously collected by Macfarlane & Clark (2008). A concentration of casual visitors to the rushes in low light and high tide may provide prey for unknown estuarine predators such as *Scorporius* and *Cryptostigmata* mites. At least five mite species were easily distinguished from the jointed rush; few of the predatory red-legged *Microtrombilium* species were present.

4.2.3 Parasites

No distinct association of parasites and hosts was revealed in the jointed rush. Scelionids (parasitic wasps) may have a host in this habitat; this is likely to be the eggs of sucking bugs and caterpillars. A later seasonal or more extensive collection of scales and herbivore eggs is required to reveal parasitic links among the rushes. Attempts to rear parasites from the *Megacraspedus* caterpillars collected from the jointed rush were unsuccessful.

4.2.4 Associated transient species

Sweeping at dusk gathered hundreds of blackish springtails (Sminthuridae); these animals may need the shelter of the jointed rush to keep dry and protected during the night or at high tide. Daytime sampling focused on low tide, therefore we did not observe if springtails used the jointed rush at high tide. This species may feed on the stems of the rush, litter at the base of the rush or possibly fungi.

The main casual associate among the jointed rush were Orthocladinae midges, but at times

Chironmindae midges were more important in terms of biomass. Relatively few Dasyhelea 'biting' midges were collected from the jointed rush compared to the saltmarsh ribbonwood. Adults of all these species have no piercing sucking mouthparts and the larvae inhabit fresh to semi-saline water. This complex of flies was more numerous in the diurnally dry and stiffer salt-marsh ribbonwood. We concluded that the jointed rush was used as shelter or resting sites for midges and biting midges.

Other incidental herbivore associates collected from the jointed rush where collected as single specimens from Bridge Street. These include two Hemiptera (true bugs): a winged (alate) aphid and a *Trioza* (Hemiptera) male, a Sciaridae fly and the long grass inhabiting longhorn grasshopper *Conocephalus* sp. A single specimen of the fly *Gaurax flavoapicalis* was collected; this species is associated with bird dung (Macfarlane & Scott, 2007) or carrion of insects (Macfarlane et al., 1999, 2010) and possibly molluscs (shellfish). A single undetermined Corticaridae was similar if not the same as the main species found associated with saltmarsh ribbonwood. It may feed on fungi in the litter in nearby trees or the in saltmarsh shrubland. The sole Anthribidae (fungus weevil) collected, which normally feed on fungal material in dead twigs and branches (Holloway, 1982), was not identified. Three black broom bruchids *Bruchidius villosus*, which feed on broom seed, were also collected.

On two occasions, a small number of *Arawa* nymphs were swept from the jointed rush at Bridge Street. These nymphs are definitely incidental associates of the jointed rush probably originating from the adjacent saltmarsh ribbonwood. The nymphs could be dispersing for short distances to search for new hosts or temporarily resting in the jointed rush. It was noted that young saltmarsh ribbonwood was establishing amongst the jointed rush.

4.3 Context sampling of saltmarsh meadow: mainly glasswort *Sarcocornia quinquiflora*, bucks horn plantain *Plantago coronopus* and remuremu *Sellieria radicans* and grass

4.3.1 Pollination

When in flower the remuremu may attract a range of visitors partly for the pollen. The sighting of a lone bumblebee worker suggests that the nectar secretion from this plant is limited. High salinity could possibly inhabit nectar secretion. Any available nectar will be valued in January to March, because the surrounding grass-dominated area does not provide any energy or liquid resources.

The saltmarsh meadow strip at the Ashley River site had a limited amount of remuremu, the main plant hosts are glasswort and bucks horn plantain. By the 20th of January the remuremu had little flower left. Near this saltmarsh meadow at the southern end, there was appreciable amount of Batchelor's button flowering. This flower possibly accounted for the single catch of *Leioproctus fulvescens*, which specialises in Asteraceae flowers.

4.3.2 Herbivores

The small plant hopper (Delphacidae) which appears to be the endemic species *Anchodelphax olenus* (Appendix 1) was the main herbivore present at the Tunnel Road site. It was only a minor species in the drier salt marsh meadow at the Ashley River site. This species has been previously recorded from January to April on the Three Kings Islands, Auckland, Otaki, Levin and Wellington. It is found in association with *Lepidium*, *Muechlenbeckia* and convolvulus. (Fennah, 1966). An unidentified delphacid has been collected from the hind dune at New Brighton (Macfarlane, 2005). Of the 81 *A. olenus* adults collected at the Tunnel Road site only

5% had full-length wings. The presence of full-length wings allows the plant hopper to disperse more readily between the small and isolated patches of salt marsh meadow along the Canterbury coast from Ashworth flats to Lake Ellesmere.

On the degraded plantain dominant, drier and smaller salt marsh meadow at the Ashley River site the main herbivore present was a considerably larger plant hopper, which appears to be *Oliarius oppositus*, the most common species of Cixiidae. It is found in a large range of grasslands (Lariviere, 1999). This species may have come from the adjacent long grass and uses the short saltmarsh meadow as a corridor.

At both the Ashley River site saltmarsh meadow and the Tunnel Road site, a light-brown geometrid moth was a conspicuous insect. An abundant unidentified geometrid species was also collected near Dunedin (Paviour-Smith 1956). The main species of caterpillar collected from the Dunedin survey (Paviour-Smith, 1956) was the little known *Scoparia tetracycla* (Meyrick), which has Christchurch as the type locality. This species was illustrated by Hudson but not formerly described (Dugdale, 1988).

The small black field cricket *Bobilla* species was readily seen at the Ashley River saltmarsh meadow but was not collected at the Tunnel Road site. Two factors may explain this contrast. Firstly, the Tunnel Road saltmarsh meadow is consistently wet, while the Ashley River site is dry. The Ashley River site resembles sand dune habitat (Macfarlane, 2005) and the dry low savannah like grasslands at McLean's island (Macfarlane et al., 1999). Secondly, the dry long grass at the Ashley site may be a more favourable food source than the native salt grass *Puccinella stricta* at Tunnel Road. Paviour-Smith (1956) noted the field cricket from grassy meadows with an inferred preference for grass rather than saltmarsh meadow.

Sea rush was not sampled adequately to determine herbivore relationships. It does seem to host some Thripidae species and quite possibly the Diptera, *Hydrellia enderbii*.

4.3.3 Parasites

The plant hopper *Anchodelphax olenus* was found to be parasitised by *Elenchus maoricus* or perhaps and undescribed species of *Elenchus*. This is the first example of *A. olenus* hosting an *Elenchus* species. Other *Elenchus* species are known to parasitise Delphacidae (Kathirithamby, 1989). Worldwide there are no known Delphacidae hosts for the other species of Strepsiptera known in New Zealand.

4.3.4 Litter

Species of blowfly were a major component of the biomass of pan trap catches at the Ashley River mouth site. The European *Calliphora vacina*, the black Muscidae *Hydrotea rostrata* and the litter/compost and general feeding *Muscina stabulans* were present. This site was adjacent to a sheep and cropping farm, which may explain presence of these introduced species, none of these flies were collected at the Tunnel Road site.

Interestingly an undescribed native species of Diptera Rhegmoclemina (Scatopsidae: Nematocera) (Appendix 2) was consistently caught at both the Tunnel Road site and the Ashley River site. Ian Andrew (unpublished) had noted an undescribed species of Scatopsidae from the Manawatu River estuary. I identified another native species of Scatopsidae from the Tasman braided riverbed survey (Anderson report in prep). Paviour-Smith (1956) noted numerous Nematocera larvae from November to May in saltmarsh meadow near Dunedin. Scatopsidae was not listed or recognised from the Dunedin survey. Scatopsidae is illustrated in Appendix 1.

The drier saltmarsh meadow and/or sea rush, which is above normal tide, seems to provide a suitable habitat for nymphs of the root mealy bugs *Balanococcus* sp. An undescribed *Rhegmoclemina* (Scatopsidae), may also inhabit this drier ground. Larvae/nymphs of this small sized ground fauna may provide food for the little known fly *Spilogona limpida* (Muscidae) and other fly species such as *Diaphorus/Chrysotus* and *Parentia*. Insects from these drier sites also provide hosts for at least seven species of parasitic wasps in the families: Scenlionidae (at least three species), Diapriidae (*Spilomicrus* sp), Eulophidae and a wingless Encyrtidae.

No beetles were collected in the very restricted sampling of saltmarsh meadow. In an examination of the splash zone near Auckland Kuschel (1990) did record 14 or 15 rove beetle species and a restricted number of weevils.

4.4 Modified Pan Traps

The use of modified pan traps proved successful. Dowling on the side of the traps helped to stiffen the traps sides making them more stable within the saltmarsh ribbonwood. By making the pan traps more rigid they tilted less easily and over a day lost little, if any, fluid. However, sometimes during removal the dowling caught in the shrub making the removal of all the catch awkward. The platform traps worked better than expected in the moist sandy salt marsh meadows. They were easy to both insert and remove using a crowbar. The use of pan traps on platforms will allow tidal vegetation to be sampled between tides. Traps set near the upper limit of the tide may well be able to operate over more than a single tide. Traps on a platform are less likely to tip with the wind, and be interfered with by birds or people. They remain though to be tested in more challenging related habitats, such as the drier higher saltmarsh meadow and other parts of estuary-lagoon habitats where installation maybe more difficult.

It seems likely that the basic easily made short platform traps, applied in our survey, would be a novel adaptation for sampling low tidal vegetation. Much work has been done on the modification of pan traps to increase trap catches. In North America more complex and bulky alternative means of sampling, termed fallout traps, have been used in intertidal habitat to supplement core sampling and pitfall traps (Heatwole, 2004; Davis & Gray, 1966). More complex pan traps on platforms have been used for shrub vegetation to sample pollinator visitors (Tuell & Isaacs, 2009). Colouration of traps has also been tested for preferred colours for syrpid, thrip and bee visitors (Chen et al., 2004; Campbell & Hanula, 2007).

4.5 Habitat invertebrate diversity, seasonal change and heritage values

4.5.1 Saltmarsh ribbonwood

Saltmarsh ribbonwood has a considerable diversity of herbivores. Many of the scale insects known from this shrub are generalist species with a wide host range. There seems to be strong seasonal patterns for some of the herbivores associated with this shrub. Notably the flower visiting thrips and to a lesser extent, the seed feeding bug and caterpillar fauna.

Thrips were only common during flowering and without formal identification *Thrips obscuratus* might be the primary species present. Efforts to gain biological knowledge on this native species, since the revision of Terebantia (Mound & Walker, 1982), have focused on horticultural plants (Macfarlane et al., 2010). Consequently, the range of native host plants for this species is unclear (Mound & Walker, 1982).

The main bug (Hemiptera) species present throughout the spring and summer was the leafhopper *Arawa* sp. The numbers of small and medium nymphs of this species peaked in spring, from which we inferred they feed on young shoots other than seed. As the soft and juicy green seed begin to mature later in spring the populations of seed feeders decline. The suspected seed feeding specialist mirid *Halormus velifer* was only active in late spring. However, the main species of scale insects that feed on saltmarsh ribbonwood remains obscure. The few specimens collected were dead after being parasitized or chewed by other insects, such as book lice or caterpillars. The survey failed to verify the presence of some moth and bug species reputed to feed on the saltmarsh ribbonwood.

The parasite fauna associated with the saltmarsh ribbonwood herbivores remain rather tenuous apart from *Elenchus*, which affect *Arawa* leafhoppers. It seems almost certain the male *Elenchus* is active from spring, about the time the saltmarsh ribbonwood is in flower. We base this assumption on the presence of one emerged male from an *Arawa* nymph, and limited information regarding other Strepsiptera species which states the host dies soon after emergence of the adult parasite (CSIRO (Division of Entomology), 1991). The seasonal duration of *Elenchus* remains to be verified. It was disappointing that no adult *Elenchus* were collected from where the majority of *Arawa* hosts were parasitised.

No Dryinidae (Hemiptera) were collected in the 2008/2009 survey, they parasitise leafhoppers (Macfarlane et al., 2010) and have been collected from marram grass at the New Brighton dunes (Macfarlane, 2005). It seems that the estuarine margin and tidal vegetation does not suit their host leafhoppers.

Saltmarsh ribbonwood seems to support limited spider diversity in the early part of the summer season with an increase as the season progresses. The increase correlates with the onset of increasing numbers of smaller and less mobile prey such as leafhopper nymphs, thrips and booklice. A sixth reason for the high spider density, five reasons are previously listed in Macfarlane & Clark (2008), is the increase of insects at high tide. At high tide an influx of insects such as midges shelter in the saltmarsh ribbonwood and dry long vegetation.

4.5.2 Jointed rush (oioi)

The overall insect and mite fauna of the jointed rush is less complex than the saltmarsh ribbonwood. It has its own distinct set of insects and mite herbivores along with their own poorly understood set of parasites and predators. The use of this habitat by casual visitors such as estuarine flies remains to be clarified. Casual visitors may use this habitat for shelter at night and when the tide is in, or to prey on smaller animal such as mites and scale insects.

4.5.3 Saltmarsh meadow

The saltmarsh meadow is a challenging habitat to sample. Much of the vegetation, apart from the top of the rushes, remains wet for most of time between tides. The surface of the meadows tends to be flat so the typical sweep net is of limited value. Basic unmodified pan traps can float away in high tides. Paviour-Smith (1956) focused on core samples and visual records for large animals because of these restrictions. The use of modified pan traps in our study allowed us to readily collect some of the dominant bug (Hemiptera) herbivores, some parasitised by Strepsiptera.

5 Identification guidance for characteristic species and specimen curation

The main text includes photographs of insect herbivores with their feeding sites or damage as well as litter inhabitants. Further photographs of predators, parasites, casual and transient associates are in the gallery (Appendix 1). These photos allow readers to appreciate just what an interesting and attractive array of insects and spiders make the estuarine habitat their home. This basic information can be used by those with responsibility or an interest in our heritage, and for overall habitat evaluation and conservation.

The gallery photos provide a general impression of some distinctive species and guidance about identification issues at a species level. The gallery also includes information on the vegetation types from where the species were collected. Providing a habitus guide on insect and spider species is important to aid further studies, surveys or monitoring in Canterbury and north to the southern limit of subtropical mangrove vegetation.

The paucity of entomologists that can accurately identify to genera and species level even with the backing of a suitable collection is a limitation. In addition, the literature for some of the more diverse families is too often inadequate to either go beyond genera identification or recognise undescribed species. This gallery should allow for an easier and better follow on investigation or monitoring of the insects, spiders and mites by others including less experienced entomologists. The photos and descriptions in the gallery can allow for an in- formal reference to taxa to proceed before they have been formally described. Formal descriptions are needed for several taxa from these estuarine habitats.

Given this diversity, photographs are presented for a selection of flies, the main bugs and caterpillars, all the booklice, the sole Strepsiptera species and a few parasites, beetles and a selection of spiders in the separate gallery (Appendix 1). Two numerically dominant species from saltmarsh meadow are illustrated, because the identification of *Anchodelphax olenus* has yet to be verified by a suitable Hemiptera specialist and the New Zealand revision of Delphacidae (Fennah 1966). These comparative photographs include the various guilds as well as some of the most prominent casual associates e.g. midges of the families Chironomidae and Dasyhelea. Larvae of these flies or can live among the moist tidal mud and within waterways (Macfarlane et al. 2010, Appendix 1).

Macfarlane & Clark (2008) illustrated several herbivore species from saltmarsh ribbnwood e.g. the small brown weevil *Peristoreus durus*, the saltmarsh ribbonwood greyish speckled leaf hopper *Arawa* species as well as species of beetles (two species), parasitic wasps (two species), flies (two species), bagworm moth) and one of the least known native bees *Leioproctus keehua* that specialises in coastal areas. The unidentified *Spilogona* sp. we now suspect was probably *Spilogona pennata* or possibly *S. limpida*. At that stage suitable specialists had yet to identify the weevil and leafhopper.

Specimens of caterpillars were sent to Dugdale and the main bugs to Lariviere and Henderson for identification and some additional duplicate specimens to be kept in the NZAC collection. A reasonable proportion of the remainder of the specimens were lodged in the Lincoln University collection, but only a modest selection was mounted on pins.

6 Delphacidaie, a new New Zealand Strepsiptera host record

This survey provides a critical evaluation of some possible additional hosts and habitats for *E. maoricus* or possibly an undescribed *Elenchus* species. Given the new family host and habitat record revealed in our survey for New Zealand, perhaps a few more specimens of undescribed Strepsiptera exist in our insect collections. Gourlay (1954) recorded *Arawa variegata* (syn *Deltocephalus montanus* see (Knight, 1975)) as a host without clearly stating this was based on rearing this parasite from the host. The original *E. maoricus* male was collected from Stephen Island at 300-600 ft. among tussock grassland (Gourlay, 1953). At best, it is very unlikely to have flown up from any Delphacidae at the seashore among salt marsh meadow. The mainly rocky Stephen Island shores probably have no salt marsh meadow. The Strepsiptera from *Arawa* species might yet be an undescribed species of Halictophagidae, despite the literature record by Gourlay of *Arawa variegata* as a host for *E. maoricus*. On a world basis, *Halictophagus* is the main genus recorded from elsewhere in the world from Cicadellidae hosts with only a few records of Elenchidae from Asia, (Kathirithamby, 1989; Macfarlane et al., 2010). For Elenchidae, Delphacidae are the main known hosts.

Subsequently as a result of the current survey, the little known parasite *Elenchus maoricus* (Strepsiptera) was found in saltmarsh shrubland and possibly saltmarsh meadow on different hosts (Macfarlane et al., 2010). *E. maoricus* had initially been collected from upland and lowland pasture grasses (Macfarlane et al., 2010). It was disappointing that no male Strepsiptera were collected from within the saltmarsh ribbonwood canopy given the favourable level of parasitism combined with the use of pan traps.

Records of duration of immature (nymphs, caterpillars, puparium) for *Elenchus* feeding stages provided new biology including host information and any changes in levels of parasitism. The flightless immature insects provide stronger evidence of a plant being a true host than adults, but tend to be more difficult to find. This was done for both saltmarsh ribbonwood and jointed rush.

7 Recommendations

Further collections from the full spectrum of estuary margins, tidal vegetation, wood and algal wrack would improve our understanding of the difference in a basic food resource for predators. For example long-legged flies such as *Parentia* and *Scorporuis*, and Muscidae *Spilogona.* Potential invertebrate food resources include insect eggs, scales and the smaller but more mobile mites

The use of Malaise traps and light traps would allow the collection of moths and other night-time species. Malaise traps improve the likelihood of collecting adult moths and parasitic Diptera. However, the openness of the survey sites to the public means that there is a high risk of interference and possible vandalism. The habitat is also a factor when using Malaise traps. The saltmarsh ribbonwood is too dense to place the tent-like Malaise trap over it; therefore, it would need to be placed on the grass beside the plants. Hence, any catch will have a slight to moderate bias towards catching insects and spiders from the grass rather than the targeted saltmarsh ribbonwood. Finally, to achieve a reasonably comprehensive sampling, sorting and counting from flowering onwards will require a considerable input of time.

Light traps at ground level or on platforms on the saltmarsh ribbonwood or among the jointed rush and sea rush in early summer and dusk or night sweeping should help reveal the adult moths of the caterpillars collected in this survey. This will ultimately allow for species identification of the moth herbivores revealed in our survey. Light traps, however do not discriminate catches because the light attracts insects from at least 10 m, even when it is set at ground level in open areas.

Illustration of estuarine insects and mites will aid future studies by students or scientist guardians or monitoring by environmental agencies. Awareness of this almost unknown fauna from a restricted area of vulnerable habitat needs to begin to be appreciated and then at least partly readily recognised. Canterbury is fortunate to have this available suite of habitats with temperate as opposed to mangrove vegetation near to a major population centre backed by universities. There is a need to develop and test ways to improve pan trap performance.

Better stability of pan traps is required to retain captured insects including countering trap spillage due to wind and birds (includes pukeko feeding on collected insects). Greater penetration of dense habitats (e.g. divaricating shrublands) is required than what is now achieved by beating or sweeping. Sampling performance among often wet tidal rush and meadow vegetation also needs to be improved. Disturbance by curious or malicious people needs to be minimised. Sampling within the shrubland at ground level and insect identification is needed to clarify which species are truly associated with favourable parts of the ground zone or are just transient species.

Unresolved issues, which might suit a student study, are to examine plant host ranges of the 'spotted' *Megacraspedus*, that could include sea rush *Juncus maratimus*. Resolve what parasites are truly associated with this habitat and their herbivore hosts.

8 Conclusion

This and the earlier Macfarlane & Clark (2008) survey, provide basic information on terrestrial invertebrates within the estuarine habitats of Pegasus Bay. This resource is aimed at conservation management of this precious and often underappreciated part of our natural and educational heritage. The surveys make a considerable impact towards filling the almost complete void of our knowledge of insects, spiders and mites in estuary and lagoon habitats along the mid Canterbury coastline.

There is still a considerable national gap in our understanding of the natural heritage value of this suite of temperate estuarine vegetation with its associated fauna. Therefore, the combined results of our surveys need to be made available via formal publication and the web. The habitat is different to the subtropical mangrove estuarine habitat and beach, where for instance (Kuschel, 1990) tabulated species from either open beach or beach and grass.

A further investigation is desirable, with the backing of suitable specialist investigators. The ability to focus and identify spiders, Coleoptera (beetles), Hymenoptera, Lepidoptera (moths and butterflies), thrips and perhaps Hemiptera (bugs) will improve on the information gathered in this survey (Appendices 1 and 2). A complete assessment of insect diversity on Canterbury and New Zealand coastlines is required to understand fully the communities within the habitats sampled in this report. For the saltmarsh ribbonwood the flowers, litter zone and moth caterpillars present in the seed require attention. The impact of tides in changing fauna present in the upper zones of rush vegetation requires more investigation. Determination of seed feeding fauna, and the moth species that feeds on jointed rush remain to be determined. As does the interrelation- ships between some of these insects and mites.

It is desirable to achieve some extension of this survey for several tidal margin and regularly tidal habitats. This would ensure these temperate habitats have been reasonably comprehensively covered for characteristic insect and mite species, any icon species, species diversity and food web relationships. The less studied habitats in Canterbury include saltmarsh meadow, sea rush and drier salinity enriched storm vegetation (plantain/Glasswort). A comprehensive study would allow an adequate summary to be written for this littoral fauna. This would compare differences between insects and mites in tidal zones as opposed to tidal margin. A clearer understanding is required of the plant habitats utilized by the fauna of these communities. This basic work build on a sound scientific base can be available for conservation planting and monitoring for pollution.

Overall, considerable progress has been made in this study to the finding of new terrestrial invertebrate herbivore records and clarifying on which part of the plant the herbivore feeds. This was largely achieved by recording seasonal changes in herbivore populations and dominance of the immature stage (nymphs, caterpillars) in relation to the adults, from the onset of flowering through to the presence of only dry brown seed.

The authors have been pleased to make progress towards understanding the uniqueness of the terrestrial invertebrates inhabiting the estuarine habitat in central Canterbury.

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