INVESTIGATING THE PRESENCE OF THREATENED INSECTIVOROUS BATS ON COASTAL NSW SALTMARSH HABITAT

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ABSTRACT

The paper documents the presence of a number of species of insectivorous bats over saltmarshes in temperate Australia, including French Island and Quail Island, Victoria, Carama Inlet, Kooragang Island and South-West Rocks Creek, New South Wales. Bat activity, detected using an Anabat Recorder, was particularly high at Kooragang Island on the Hunter River. A detailed survey of insect diversity and abundance on Kooragang Island demonstrated a diverse range of insects corresponding to published data on the diet of bat species recorded. The study suggests that saltmarsh is likely to be an important source of insect prey for many bat species.

INTRODUCTION

Coastal saltmarshes are a widespread component of the coastal biosphere of Australia. However, prior to the middle of the 1990s, little research had been conducted on saltmarshes in Australia and information on their ecological contribution was lacking (Fairweather 1990). In recent years, saltmarshes have gained more attention from the public and scientific sectors alike, promoted by their decline from coastal areas. Photogrammetric surveys conducted over the past 50 years have revealed an alarming pattern of saltmarsh loss to both coastal housing development and mangrove transgression inland (Saintilan and Williams 1999). In almost all of the 27 estuaries studied in south-eastern Australia, losses of saltmarsh have been in the order of 20-50% since the late 1940s. The east and southeast bioregions now contain less than 354 square kilometres of the national total of 23,322 square kilometres (Zann 1997). Pressure to clear saltmarsh continues to increase, due to accelerating urban development, an ecological emphasis on mangrove rehabilitation, and controversy surrounding the contribution made by saltmarshes to the propagation of mosquitoes.

Saltmarshes are slowly being recognised as an important habitat that provides a number of ecological functions (Thomas and Connolly 2001, Valiela and Cole 2002), not the least of which is an intricate foodweb that provides links to other estuarine habitats (e.g. mangroves, mudflats, open water). Their position in the near-shore between the high tide mark and the sublittoral zone means they are only covered by tides infrequently and can support both aquatic and terrestrial fauna. Invertebrates such as spiders and various insects form a major component of the terrestrial fauna of saltmarshes (Hutchings and Recher 1974; Marsh 1982; Morrisey 1995). Insects in turn attract a variety of vertebrate fauna particularly birds. In addition, the insectivorous native water rat (*Hydromys chrysogaster*) is found on saltmarshes in Tasmania, eastern and southern Australia (Morrisey 1995). It follows, therefore that other insectivorous mammals such as bats might be found in association with saltmarshes to take advantage of potential food resources offered by saltmarshes. Although the composition of the insect populations of saltmarshes has not been studied in detail, the available information suggests a high insect abundance and diversity in saltmarshes (Hutchings and Recher 1974; Marsh 1982).

Research on saltmarshes in Australia as a whole is scant and no information is available on the possibility of bats using this abundant food source. Evidence from overseas, however suggests that insectivorous and carnivorous bats are more active in coastal marsh areas compared to nearby forested areas (Brosset *et al*. 1995). Bats exhibit a bimodal pattern of foraging activity being most active in the first hours after dark and three hours before dawn with a decline in the middle part of the night (Taylor and O'Neill 1988). These patterns reflect patterns of insect activity. The insectivorous bats thus appear to have adjusted their nightly activities to match those of their prey, thereby maximising foraging success and energy gains.

Bats are important contributors to Australia's mammal diversity and are ecologically diverse. Microchiropteran bats from several genera (e.g. *Mormopterus* spp., *Miniopterus* spp., *Nyctophilus* spp., *Scoteanax* spp., *Chalinolobus* spp., *Vespadelus* spp. and *Myotis* spp.) are insectivorous or carnivorous and have been recorded from surveys of estuarine areas. (Mills *et al*. 1994; Kutt 1997; Hoye 2002) Several species within these genera are listed as vulnerable under Schedule 2 of the NSW *Threatened Species Conservation Act* (1995) due primarily to ongoing habitat loss. At least eight species of threatened insectivorous bats are known to roost in forested areas adjacent to saltmarsh plains. As such they are likely to play key ecological roles as regulators of invertebrate populations and potential dispersal and pollination mechanisms within saltmarshes. However, the theory of a direct link to saltmarsh has not been tested.

Little is known about the habitat requirements of Australian bats and information is needed to make better-informed decisions when systems are disturbed, threatened or lost. This is particularly relevant if saltmarshes prove to be a major foraging habitat given its decline in coastal areas. The widespread practice of controlling populations of the saltmarsh mosquito, *Ochlerotatus vigilax*, by runnelling (Dale *et al*. 1993) may also impact on bat foraging if mosquitos prove to be an important component of their diet.

The primary aim of this study was to confirm the presence of microbats within various saltmarsh habitats in NSW and Victoria. Secondly, we sought to conduct a detailed survey of possible sources of insect prey in any area identified as important foraging habitat. While the demonstration of a direct link between bats and insects in saltmarsh was beyond the scope of this paper, we provide much-needed data on the presence of species which might prove to be of considerable ecological significance.

METHODOLOGY

Detecting bats in saltmarshes

An Anabat II sonar bat call detector was used to detect the presence of bats at selected sites in Victoria and NSW. Using the Anabat II sonar bat call detector is a standard technique for locating bats in various habitats during their peak activity time (Anderson and Miller 1977, Coles and Spencer 1996, De Oliveira 1996). Bat calls are species-specific so an assessment of what species are using the habitat can be made (Conole and Baverstock 1995, Herr and Klomp 1995).

The Anabat detector was deployed at six sites in Victoria and New South Wales between November 2001 and September 2002 (Figure 1). The sites were selected to encompass all of the temperate east-coast IMCRA Bioregions (Manning Shelf, Hawkesbury Shelf, Batemans Shelf and Twofold Shelf).

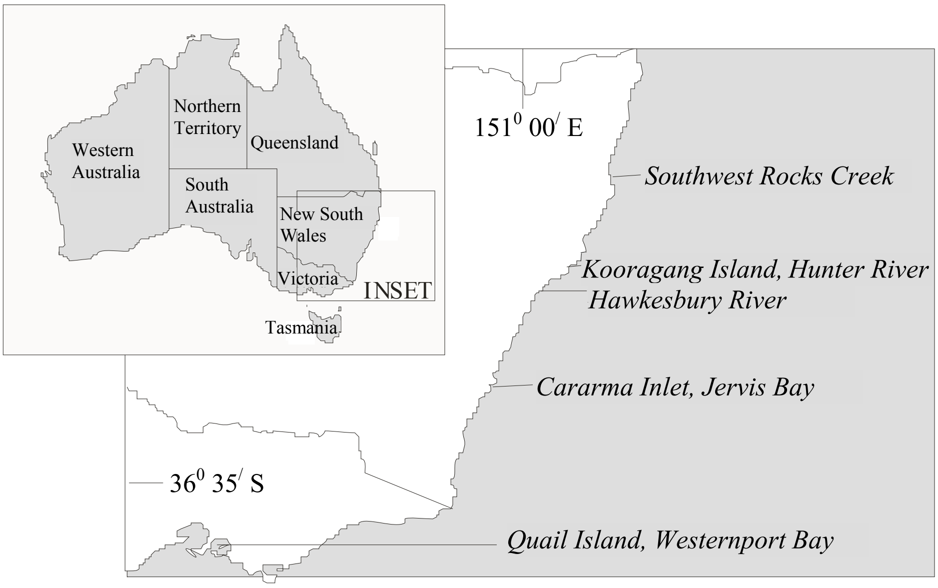


Figure 1: Location map.

Within Westernport Bay, Victoria, the detector was used within the saltmarsh plains of the French Island and Quail Island Nature Reserves, both considered relatively pristine reference sites in the Westernport Bay Mangrove and Saltmarsh monitoring program (Rogers *et al*. 2002). Both sites support a diverse saltmarsh community including *Halosarcia* sp., *Baumea, Samolus, Sarcocornia* and *Juncus*.

Cararma Inlet was chosen as a South-coast NSW site because of the presence of *Sclerostegia* sp. which gives a greater structural heterogeneity to the saltmarsh. The site is also conserved within a nature reserve.

Kooragang Island is a Ramsar site where saltmarsh rehabilitation is actively encouraged. Previous bat surveys by Hoye (2002) recorded bat activity within the mangroves of Kooragang Island. SW Rocks Creek near the Macleay River provides an example of a northern rivers saltmarsh plains dominated by *Sarcocornia quinqueflora* and *Sporobolus virginicus*.

The detector was placed within the saltmarsh habitat of each site and left to record over night. Tape recordings were analysed by Glen Hoye for the bat species recorded at each site.

Catching insects in saltmarshes

Insects were collected at two sites at Kooragang Island during the day. Insects were sampled using a sweep net with a nozzle on the end to attach a sample bag to gather insects from among the vegetation. The whole saltmarsh area was sampled by taking 10 random sweeps within 10 random plots within the saltmarsh. This gave 10 replicate, pooled samples for each saltmarsh area. The sites sampled at Kooragang Island had different successional histories. Site one is a wetland reserve while site two is a rehabilitated site, with a history of cattle trampling, which has been recovering for 8 years. Both site were dominated by Sarcocornia and had dense vegetation cover. Insects were swept into a mesh bag attached to the nozzle of the sweep net. Once the insects from 10 sweeps were in the mesh bag it was removed and securely tied before being placed in 70% alcohol.

In the laboratory samples were removed from the mesh bags and sorted on a tray under a magnifying light to remove all insects. Each sample was then placed under a stereo microscope and each insect placed into like types and counted. Each type of insect was identified as far as possible with the literature available. Individuals in this study were classified into their Order and Family.

RESULTS

Bats recorded over saltmarsh

The Anabat detectors recorded at least eight species of microchiropteran bats active over saltmarsh (Table 1; C=Confident identification; P=Probable; Po=Possible). Bats were recorded at every site with the

Table 1: Summary of bat species detected at six study sites in southeastern Australia. Bat species names are abbreviated according to the list below. Codes for confidence of identification of calls using Anabat II are: Confirmed (C); Possible (Po); Probable (P).

Location	Microchiropteran bat species								
	M. no	*M.* spp.	*C. go*	*C. mo*	*M. sc*	*V. da*	*V. re*	*V. vu*	Total passes
French Is., Victoria							P		1
Quail Is., Victoria						P			6
Southwest Rocks, NSW					C	Po			3
Big Bay, NSW									0
Kooragang Is., NSW	C			Po				P	56
Cararma Inlet, NSW		Po	Po						1

Species

M.no	*Mormopterus norfolkensis*	Eastern Freetail Bat*
*M.*spp.	*Mormopterus* sp. 1	Little Freetail Bat
C.go	*Chalinolobus gouldii*	Gould's Wattled Bat
C.mo	*Chalinolobus morio*	Chocolate Wattled Bat
M.sc	*Miniopterus schreibersii*	Large Bent-wing Bat*
V.da	*Vespadelus darlingtonii*	Large Forest Bat
V.re	*Vespadelus regulus*	Southern Forest Bat
V.vu	*Vespadelus vulturnus*	Little Forest Bat

* Listed as vulnerable under Schedule 2 of the NSW *Threatened Species Conservation Act* (1995)

Table 2: The arthropod fauna identified from the two sites (S1 and S2) at Kooragang Island.

Order	Family	No. of Species S1	No. of Species S2	Abundance S1	Abundance S2
Diptera (True Flies)	Muscidae (house/bush flies)	1	1	-	1
	Tachinidae (tachanid flies)	-	1	-	1
	Chironomidae (midges)	3	4	6	22
	Agromyzidae (leaf miner flies)	1	1	19	61
	Chloropidae (frit flies)	1	1	8	1
	Ephydridae (fruit/vinegar flies)	1	1	3	85
	Cecidomyidae (gall midges)	2	2	12	206
	Tabanidae (marsh flies)	2	2	2	3
	Syrphidae (hover flies)	1	-	1	-
	Unidentified	2	1	12	12
Total Dipteran species =16					
Hymenoptera (wasps, bees & ants)	Braconidae (braconid wasps)	-	1	-	1
	Chalcididae (chalcidoid wasps)	-	2	-	7
	Formicidae (ants)	-	2	-	52
	Unidentified	9	14	56	166
Total Hymenopteran species = 21					
Thysanoptera (Thrips)	Thripidae	1	1	6	7
Total Thysanopteran species =1					
Hemiptera (Bugs)	Lygaeidae (seed/chinch bugs)	2	2	129	109
	Miridae (dimpling bugs)	3	3	15	88
	Delphacidae (plant hoppers)	1	1	14	10
	Cicadellidae (leaf hoppers)	-	1	-	1
	Meenoplidae (plant hoppers)	1	1	2	1
	Aphididae (aphids)	1	-	10	-
	Unidentified	1	2	1	2
Total Hemipteran species =13					
Coleoptera (Beetles)	Melyridae (soft winged flower beetles)	-	1	-	1
	Curculionidae (weevils)	-	1	-	5
	Chrysomelidae (leaf beetles)	1	1	2	2
Total Coleopteran species =3					
Orthoptera (Grasshoppers & crickets)	Gryllidae (crickets)	-	1	-	1
	Tettigoniidae (katydids)	1	-	7	-
	Acrididae (locusts)	1	1	1	1
Total Orthopteran species =3					
Lepidoptera (Moths & Butterflies)	Lycaenidae (blues and coppers)	1	1	6	10
	Unidentified	1	1	3	2
Total Lepidopteran species =2					
Aranaea (Spiders)	Thomisidae (crab spiders)	-	1	-	5
	Salticidae (jumping spiders)	1	1	5	2
	Lycosidae (wolf spiders)	-	1	-	6
	Clubionidae (sac spiders)	1	1	101	94
	Unidentified	1	-	4	19
Total Aranaean species =7					
Acariformes (mites)	Hydrozetidae (aquatic mites)	1	1	384	34
Total Acariforme species =1					

exception of Big Bay, NSW. Kooragang Island, Hunter River revealed approximately 10 times the level of bat activity as any other site with 56 passes over the detector compared to 6 at Quail Island, 3 at Southwest Rocks and 1 at each of French Island and Cararma Inlet.

Insect fauna of saltmarsh

The saltmarshes sampled at Kooragang Island had an abundance of arthropod fauna. A total of 425 insects, mites and spiders were collected from site one while site two had nearly double the amount at 986. Table 2 gives the relative abundance of each Family of arthropods identified from each site containing saltmarsh.

The arthropod fauna of the saltmarshes studied was diverse with a total of 67 different species types in 8 orders identified. The total abundance of arthropods within each of the orders varied with site. However, it is evident that four orders always had the greatest abundances viz. Diptera, Hemiptera, Hymenoptera and Aranaea regardless of the numbers of families and species contained within each.

Hymenoptera were the most species rich Order with a total of 21 different species being identified followed closely by dipterans and hemipterans with 16 species and 13 species respectively. (Table 2).

The two sites at Kooragang were generally similar in their species composition of insects with the exception of Hymenoptera, which contained more species at site one than site two. Of the families identified the Chironomidae (midges) were the most species rich followed by Miridae (dimpling bugs) at both sites (Table 2). The greatest differences in total abundance of families were within the dipterans where site two had considerably more chironomids, Agromyzids, Ehydrids, Cecidomids than site one.

Figure 2 shows the mean abundance of individuals in each of the orders of insects, spiders and mites identified from each of the sites at Kooragang Island. Mean abundance of true flies (Diptera) was greatest at site one while wasps (Hymenoptera) were more abundant at site two. There was also a difference in the number of mites (Acariniformes) caught at each site with over 4 times as many at site one than at site two (Fig. 2). The remaining five insect orders (Hemiptera, Lepidoptera, Orthoptera, Coleoptera, Thysanoptera) and the spiders (Aranaea) were similar at the two sites in terms of mean abundance.

In terms of proportion of the catch (Fig 3), bugs (Hemiptera) were dominant at site one comprising 40% of the catch followed by spiders (26%). True flies (Diptera), comprising 40% of the catch, followed by wasps (Hymenoptera), with 23% of the catch, dominated site two. Bugs (Hemiptera) were also relatively abundant at site two with 21% of the catch. At both sites the thrips, beetles, moths and other orders only made up a relatively small proportion (<2%) of the catch.

DISCUSSION

The saltmarsh habitats investigated in this study contained an abundant and diverse arthropod community made up of spiders, mites and a variety of insects. The insect fauna was dominated by wasps, bugs and flies which is similar to a previous study conducted at Kooragang Island using a similar technique which found a dominance of flies and bugs (Clarke

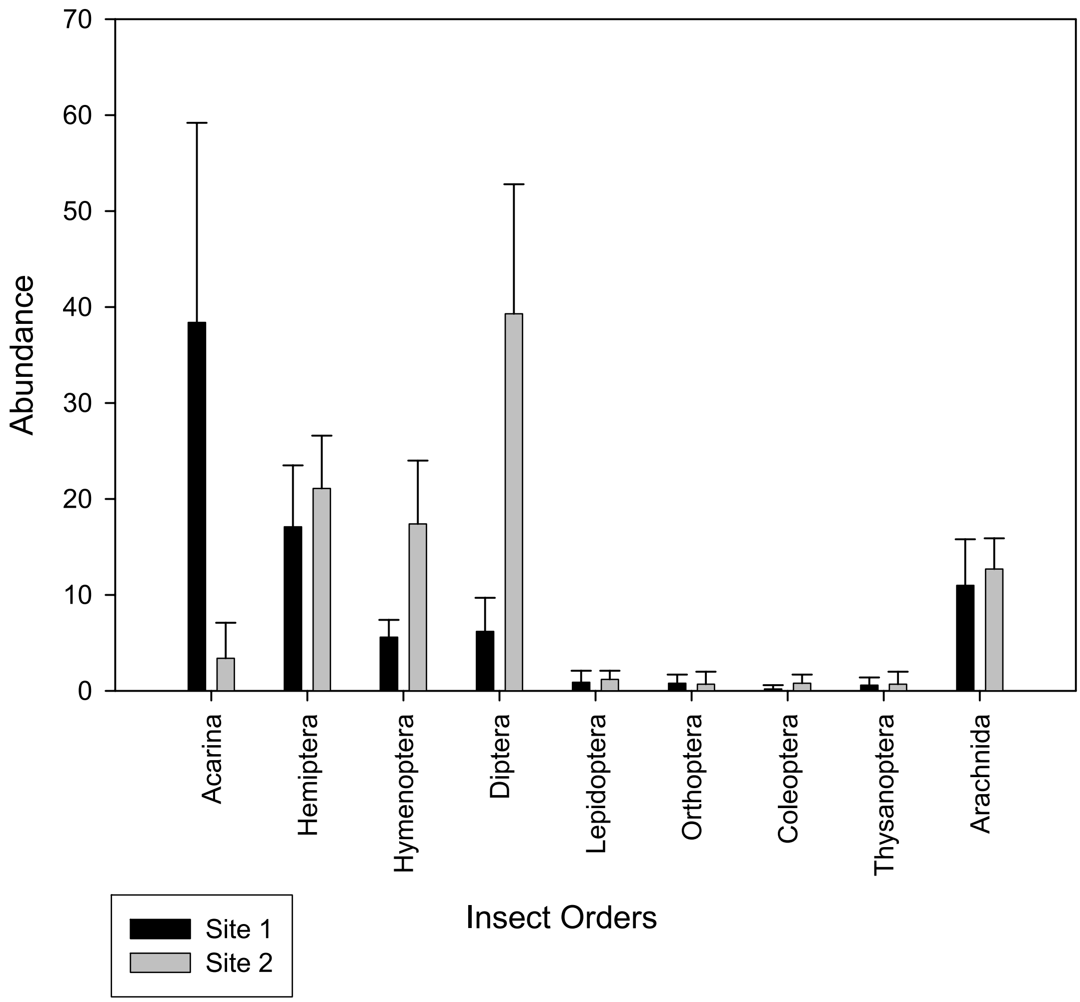


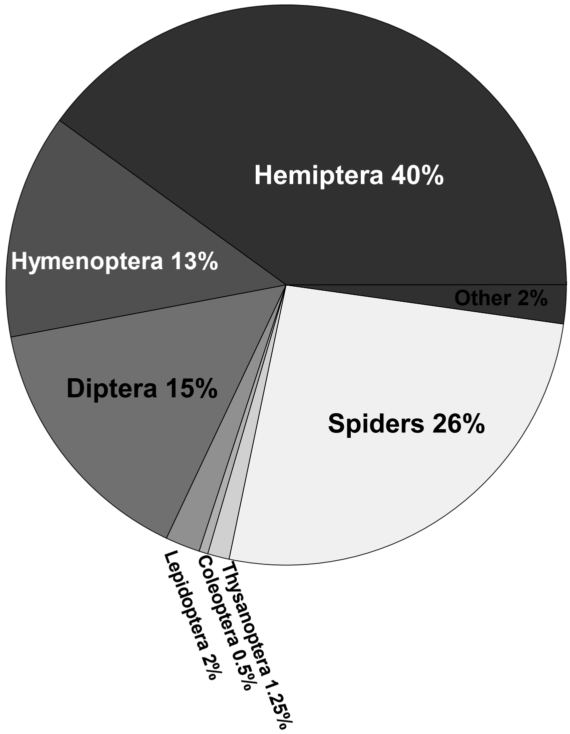
Figure 2: Mean abundance ± 1SD of individuals within each order of arthropod sampled at Site 1 and Site 2 at Kooragang Island.

and Miller 1983). This abundance and diversity of arthropod fauna appears to be a feature of saltmarshes and has been shown to be similar in a number of saltmarshes around NSW (Laegdsgaard unpublished data).

In addition to the diverse arthropod fauna, a number of bat species were detected in this pilot study, two of which are listed as vulnerable under Schedule 2 of the *Threatened Species Act* (1995). Of particular note was the intense bat activity recorded over the saltmarshes of Kooragang Island. Although only three bat species were recorded in this study, Hoye (2002) detected the presence of a further 10 species in the vicinity of saltmarsh on Kooragang Island. Three of these are listed under NSW legislation (Little Bent-wing Bat, *Miniopterus australis*, Large Bent-wing Bat, *M. schreibersii*, and Fishing Bat, *Myotis adversus*).

The insect populations described in this study were variable among sites with twice the abundance of arthropods at the second site compared to the first. Site 2 is a regenerating site, which may explain the larger quantity of insects caught there. In general diversity and abundance of organisms will be higher in a site undergoing succession than in

Kooragang Island 1



Kooragang Island 2

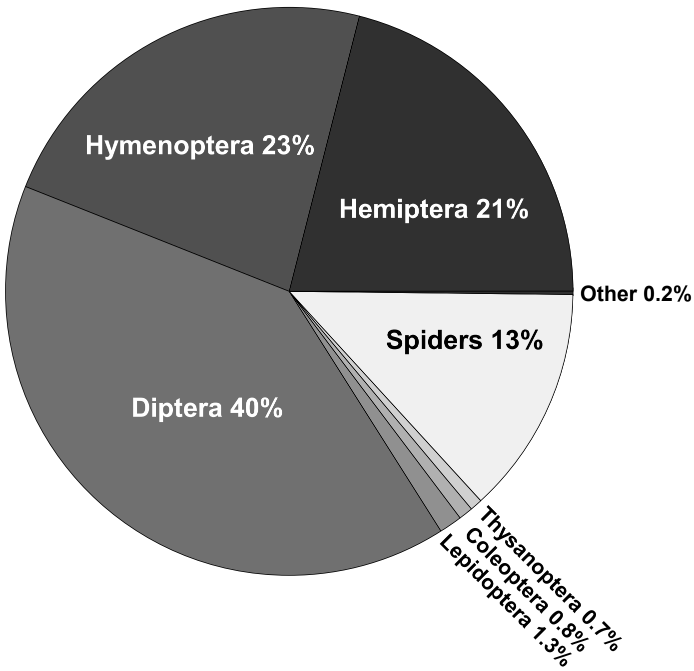


Figure 3: The proportion of each order of arthropod comprising the total catch at Kooragang Island Site 1 and Site 2.

a mature long established site (Verschoor and Krebs 1995). Kooragang Island has an abundance of disturbed and regenerating saltmarsh areas which are likely to provide an abundance of food resources. This may explain the high activity of bats that were recorded within this area.

This pilot investigation is the first attempt to record bat activity specifically over saltmarsh plains. The movements and activity detected may suggest that many of these bats are taking advantage of the abundance of aerial insects available. A large amount of energy is needed by bats to fly. Insects are energy rich food sources that provide bats with the energy they require. Winged and wingless ants, mosquitos, cockroaches, stoneflies, katydids, field crickets, moths, cicadas, leaf-hoppers, shield bugs, waterbugs, ground beetles, diving beetles, scarabs, click beetles, lacewings, termites, wasps, weevils, flies and caterpillars have all been recorded from scats and stomach contents of bats (Vestjens and Hall 1977).

The insect populations identified in this study are generally compatible with these data with representatives of the majority of these groups within the insect populations captured. Although, scant information is available of the diet of bat species, most bats feed opportunistically but the dominant food items targeted appear to be moths, wasps bugs and beetles (McKean and Hall 1964; Dwyer and Hamilton-Smith 1965; Green 1965; Ryan 1965; Vestjens and Hall 1977; Fullard *et al.* 1991; Menkhorst 1995). This corresponds to the dominant insect types described in this study.

Most of the Australian bats catch and eat their prey on the wing. Since they can remain airborne for hours at a time they can easily catch the high amount of food required to sustain flight. Individuals of some species of bats eat almost half their own body weight in insects each night (Churchill 1998). All insects captured were small but well within the range that bats can eat being small hunters. The insects collected in this study were done so during the day from within the saltmarsh vegetation. It is likely that many of these insects are roosting in the vegetation during the day and are active at night, however, further studies will need to be conducted to correlate the insect populations of the saltmarsh with the foraging patterns of bat species. Despite this, the diverse range of insects recorded and the correlation with bat diets is likely to indicate that this habitat is an important source of insect prey for many bat species.

Bats may even exhibit foraging activity during the day if prey is abundant and foraging gains outweigh those of predation risk. Eastern horseshoe bats in Queensland have been shown to forage during the day in search of specific food items such as butterflies, cicadas and dragonflies which are only active during the day (Pavey and Burwell 1998).

A particularly interesting discovery of this pilot is the presence of a rare and sparsely distributed bat species, the Eastern Freetail Bat (*Mormopterus norfolkensis*), flying (and possibly feeding) over saltmarsh on Kooragang Island. There is no information available on the diet or food preferences of the Eastern Freetail bat (Churchill 1998). However, the freetail bats are adapted well to movement on the ground and can capture prey by crawling among vegetation (Troughton 1965). This feature may make them very efficient within the saltmarsh habitat where many of the insects are found amongst the vegetation.

In addition to the Eastern Freetail Bat, the Chocolate Wattled Bat (*Chalinolobus morio*) and the Little Forest Bat (*Vespadelus vulturnus*) were also recorded at Kooragang Island. Chocolate wattle bats are opportunistic foragers and choice of prey tends to reflect the availability of aerial insects (Churchill 1998).

It is likely that insects are abundant on saltmarshes due to an abundance of food and shelter despite the presence of the occasional tidal inundation event. Davis and Gray (1966) found that shelter and food were more important to insect groups than tidal influence. The abundance of succulent plants and herbs within the saltmarsh plain provides ample food for plant juice feeders such as the bugs (Hemiptera) which were abundant. These in turn would provide food for other insects and spiders.

One species not detected in the survey that might also utilise saltmarshes is the fishing bat (*Myotis adversus*) which feeds on aquatic insects and small fish (Robson 1984; Law and Urquhart 2000). Saltmarshes offer many opportunities for the fishing bat in the presence of permanent and semi-permanent pools for their trawling activities. These pools have been investigated with respect to their fish fauna and been found to contain juveniles of several species along with blue-eyes, gobies and the introduced mosquito fish (Gibbs 1986; Davis 1988; Morton *et al*. 1988; Lincoln-Smith *et al*. 1994). These small fish varieties would be highly suitable prey items for the fishing bat.

The little forest bat (*Vespadelus vulturnus*) was another bat species that was active over the saltmarshes of Kooragang Island. This species has been observed to feed opportunistically on mosquitoes (Hoye 2002) and has been recorded previously in high numbers around Kooragang Island. The saltmarsh mosquito (*Ochlerotatus vigilax*) breeds in pools on marshes in warm temperate and tropical Australia and can in areas be quite numerous (Turner and Streever 1999). Although the results from this study did not indicate large mosquito populations, mosquito outbreaks are highly episodic (corresponding to spring tide and rainfall events), and large numbers have been collected in the past (Clarke and Miller 1983; Turner and Streever 1999). Encouraging the presence of the little forest bat at this site could form the basis of a biological control mechanism for mosquitoes. Bats are reliant on the availability of roost spots during the day and will remain in an area if roosts are plentiful. One way to augment the availability of roosts where they are lacking is to install roost boxes. This has been shown to be successful in eucalypt forests where the availability of hollows is lacking (Irvine and Bender 1995).

The vegetation structure of the extensive saltmarsh plains of Cararma Creek, Jervis Bay have been mapped in detail (Saintilan and Wilton 2001), and the saltmarsh plain and surrounding hinterland of both sites are relatively undisturbed. Here we detected a further two bat species active over saltmarsh, the Little Freetail Bat (*Mormopterus* sp. 1) and Gould’s Wattled Bat (*Chalinolobus gouldii*). Preliminary data on the insect populations at Cararma Creek also suggests an abundance of arthropod fauna at this site (Laegdsgaard unpublished data).

This study provides preliminary evidence that insectivorous bats are active over saltmarsh habitats in NSW and Victoria. In addition, there is an initial correlation with the insect populations of saltmarsh with what is known of the diet of bats identified. Because saltmarsh is itself under threat from sea-level rise and coastal development and no research has investigated the link between saltmarshes and endangered bats as their primary or adapted habitat, this project has identified an issue of major significance to endangered species management and coastal biodiversity and development. Further investigation is required to provide the direct link with saltmarshes and threatened bats in the form of observations of foraging, night insect populations and abundance and actual bat diet analysis. This research would provide guidance for the future successful management of saltmarshes as integral coastal ecosystems.

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