# Crossing Cook Strait: Possible human transportation and establishment of two New Zealand cicadas from North Island to South Island (*Kikihia scutellaris* and *K. ochrina*, Hemiptera: Cicadidae)

Kathy B. R. Hill[1], David C. Marshall and John R. Cooley

Ecology and Evolutionary Biology, University of Connecticut, 75 N. Eagleville Rd, Storrs, CT, 06269-U3043, USA. [1]E-mail: cicada900@yahoo.com.au

## Abstract

Two cicadas previously restricted to the North Island of New Zealand have recently been found on the South Island. The North Island bush species *Kikihia scutellaris* (Walker) first reported from around Picton, South Island, in 1966, is now found throughout much of Marlborough and the Marlborough Sounds, as far as Kenepuru Head to the north, Canvastown to the west, Grovetown to the south and Robin Hood Bay to the east. We also note a single older specimen collected in 1932 from Torrent Bay, Tasman Bay. Our new data suggest a substantially faster rate of spread than can be estimated for other cicada species, possibly because the preferred habitat of *K. scutellaris* is pre-existing and unoccupied by competitors. Three males of the second adventive species, the bush-edge green foliage cicada *Kikihia ochrina* (Walker), were found in one Christchurch street in February 2004. Its restricted distribution suggests that *K. ochrina* was transported within the past few years, possibly on one of the small garden trees and shrubs it frequents on the North Island. It remains to be seen whether this species will become established. Neither species is likely to pose economic or conservation concerns.

**Keywords:** cicada, dispersal, range expansion, recently established

## Introduction

All New Zealand cicadas belong to one tribe (Cicadettini), five genera and approximately 57 taxa (at least 42 species plus additional subspecies) (unpublished data). Cicadas arrived in New Zealand around 10 million years ago from two immigration events, and radiated into many different niches (Buckley *et al*. 2002, Arensburger *et al*. 2004a). Striking differences exist between North and South Island cicada faunas. In the North Island, ten out of 24 taxa inhabit the forest or forest edge, while on the South Island only two out of 39 taxa are found in the forest despite vast tracts of such habitat (Fleming 1975a, Dugdale and Fleming 1978, Fleming 1984). These faunistic differences may be the result of Pleistocene glaciation events that restricted bush and bush-inhabiting cicadas to the far north (Fleming 1975a, Fleming 1977, McGlone 1985, McGlone *et al*. 2001).

Cook Strait, separating North and South Islands, apparently acts as a barrier to cicada dispersal (Myers & Myers 1923, Fleming 1971, Fleming 1977). Only eight species from four of the five New Zealand genera have spread throughout both islands (Dugdale 1972, unpublished data), either by dispersal over water or during the ice ages when land bridges connected the islands (Fleming 1977). Molecular analyses (Buckley *et al*. 2001, unpublished data) demonstrate substantial genetic divergence between North and South Island populations of several of these species, and future taxonomic revisions (in addition to revisions we already propose for cicada taxa) may reduce the number of species found in common to both islands by subdividing several species. There are three unique taxa on offshore islands, one on each of the Chatham, Kermadec and Norfolk Island systems (Dugdale 1972), that all colonised from mainland New Zealand within the last 1.2 my (Arensburger *et al*. 2004b, unpublished data). *Kikihia muta longula* (Hudson) on the Chatham Islands may not be a good taxon (Fleming & Ordish 1966), and may have colonised so recently as to have been introduced via human transportation (unpublished data). There are no unique species found on Stewart Island, which is separated from the southern tip of the South Island by the 30km-wide Foveaux Strait. The cicada fauna there comprises the same four species from two genera that are present along the southern coast of the South Island (Dugdale 1972, Fleming 1975c). As with Cook Strait, Foveaux Strait was bridged by land during glacial periods (McGlone 1985).

Only one cicada species is currently believed to have crossed Cook Strait and become established during modern history. Fleming (1967) was the first to note the presence of the bush species *Kikihia scutellaris* (Walker) (Appendix, Figs. 1, 2) on the South Island, from specimens collected by A. D. McEwen in 1966 in Picton. *Kikihia scutellaris* is common in the coastal hills of Wellington in the *Melicytus*/*Pseudopanax*/*Metrosideros*-dominated bush, and Fleming (1975d) suggested that the species had been transported across Cook Strait from a North Island population via the interisland ferry. During the period 1967-1975, Fleming also found *K. scutellaris* at Shakespeare Bay, approximately 1km from the Picton ferry terminal (J. Dugdale pers. comm.). D. Lane (pers. comm.) heard *K. scutellaris* in 1967 in the valley on the south side of Picton. A single older South Island specimen, housed in the Museum of New Zealand Te Papa Tongarewa and collected by C. Lindsay on 29 Dec. 1932, in Torrent Bay, Tasman Bay, is reported here for the first time.

We present extensive new distribution records for *K. scutellaris* that suggest rapid recent dispersal. We then discuss the 2004 discovery of a second probable case of interisland human transport of cicadas from the North Island to the South Island, a record of the North Island bush-edge species *Kikihia ochrina* (Walker) (Appendix, Figs. 3, 4) in Christchurch.

# Materials and Methods

Records of *K. scutellaris* and *K. ochrina* were collected during extensive surveys of the South Island between December and March 2001-2005 as part of biogeographic and systematic studies of New Zealand Cicadidae. These surveys covered all South Island districts and all main and many minor roads, many surveyed on multiple occasions. The conspicuous species-specific songs of male cicadas allow us to detect even rare species while travelling under appropriate weather conditions.

For each sampling location, latitude and longitude were determined in degrees and decimal minutes using a Garmin GPS III and the Geodetic 1949 map datum. We gave each sampling location a unique seven-letter code of the form co.di.loc. (co = country, di = district code of Crosby *et al.* (1998), loc = unique mnemonic location code of three letters). We digitally-recorded some males (Sony WM-D6C DAT recorder or Marantz PMD 680 Flash Digital recorder, sampling at 48kHz) and collected the cicadas when possible. Recordings and specimens were compared with known vouchers to confirm species identity. Voucher specimens and a copy of all recordings are deposited at the Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand.

# Results

## *Kikihia scutellaris*

We found *Kikihia scutellaris* in 13 previously unknown South Island locations between January 2001 and February 2004: one in 2000/1, eight in 2001/2, three in 2002/3 and one in 2003/4. These localities range as far as Kenepuru Head to the north, Canvastown to the west, Grovetown to the south and Robin Hood Bay to the east (Fig. 5), at approximate distances of 9.0-32.5km from the Picton town centre (junction of High and Dublin Sts.); Picton being the location of the earliest north-eastern South Island records. Additionally, one area of especially high *K. scutellaris* density was found along approximately 31km of Kenepuru Road in December 2002. One male *K. scutellaris* was heard singing near the Picton ferry terminal on 10 Feb 2002. Differences in focus of collecting trips and weather variations during these years may be responsible for the different numbers of records collected in each summer.

The Kenepuru Road records are of special interest because we drove the entire length of that road from Linkwater to Titirangi Bay and back to Kenepuru Head over approximately 4 hours, listening for and noting all species present while paying special attention to *K. scutellaris*. Because we did not hear *K. scutellaris* north of Kenepuru Head, this locality may be a local northern range limit. However, it should also be noted that the road follows a higher elevation north of Kenepuru Head, and the bush becomes denser. We have made no attempt to record additional negative records because observations were made opportunistically.

***Kikihia scutellaris* detailed locality records** (Numbers following site codes are approximate straight-line-distances in km to Picton town centre.)**: MARLBOROUGH: NZ.MB.GRO (21)** Grovetown; 2.5km N. of Opawa River on SH1. 41º28.7S; 173º57.8E. 29 Jan 2002. Song heard. **NZ.MB.NPI (21)** 4.7km S. of Canvastown on Wakamarina Rd. 41º19.7S; 173º39.8E 19 Feb 2001. Song heard. **NZ.MB.PIN (32.5)** Pinedale Campground, 8.9km S. of Canvastown on Wakamarina Rd. 41º21.4S; 173º37.6E. 28 Jan 2002. 2 males collected, song recorded (Fig. 2). **NZ.MB.WAA (18)** 10.3km E. of SH6 on Kaituna-Tuamarina road. 41º26.5S; 173º54.5E. 28 Jan 2002. Song recorded. **NZ.MB.WHK (20.5)** 1km W. of Havelock Town Centre on SH6. 41º16.6S; 173º45.5E. 6 Feb 2002. 1 male collected. **MARLBOROUGH SOUNDS: NZ.SD.CUL (18.5)** Cullen's Point. 41º16.2S; 173º47.0E. 28 Jan 2002, 6 Feb 2002. Song recorded. **NZ.SD.KEN (17)** Kenepuru Head. 41º10.3S; 174º07.4E. 20 Dec 2002. Song heard. **NZ.SD.KJT (18)** Jct. of Kenepuru Rd. and rd. to Titirangi Bay, N. of Kenepuru Head. 41º09.7S; 174º07.3E. 20 Dec 2002. Song heard. **NZ.SD.MOR (11)** Queen Charlotte Drive, near Linkwater. 41º17.5S; 173º52.5E. 27 Jan 2002. Song heard. **NZ.SD.QCD (19.5)** Queen Charlotte Drive, S. of Havelock at Kaituna River. 41º 17.3S; 173º46.3E. 27 Feb 2004. 1 male collected. **NZ.SD.RBY (9)** Robin Hood Bay, SE of Picton. 41º21.4S; 174º04.6E. 10 Feb 2002. Song recorded**. NZ.SD.SBP (11)** approx 1km W. of Portage on Kenepuru Rd. 41º12.0S; 174º01.5E. 20 Dec 2002. Song heard. **NZ.SD.TAP (28)** SH6 at Wakamarina River bridge, near Canvastown. 41º17.5S; 173º40.1E. 6 Feb 2002 song heard. Additionally, almost continuous *K. scutellaris* calls were heard along 31km of Kenepuru Rd from 8.5km N. of Queen Charlotte Drive to Kenepuru Head on 20 Dec 2002.


**Fig. 1.** *Kikihia scutellaris* male.

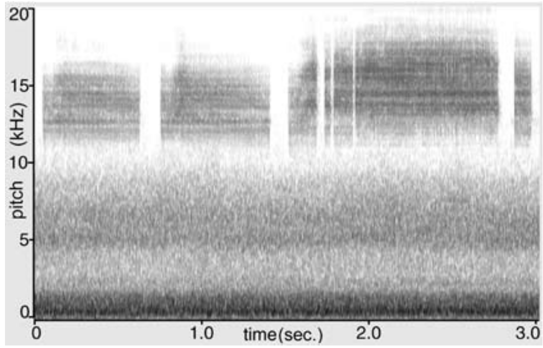


**Fig. 2.** Sonogram of a typical calling phrase of *Kikihia scutellaris* (track FL.02.NZ.SD.PIN. T01). Note all *K. scutellaris* sound is between 11 and 20kHz; 4-9kHz is primarily *Amphipsalta zelandica*; 0-2kHz is random background noise.


**Fig. 3.** *Kikihia ochrina* male on *Pittosporum* sp.

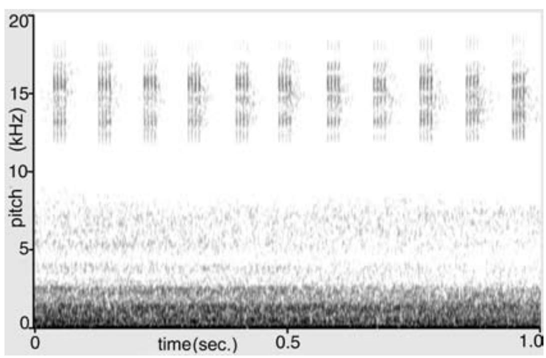


**Fig. 4.** Sonogram of 1.0 seconds of typical song of *Kikihia ochrina* (track DAT.04.NZ.MC.OCH. T1). Note all *K. ochrina* sound is between 11 and 18kHz; the rest is *Amphipsalta zelandica* and traffic noise.

### *Kikihia ochrina*

At 4pm on 17 Feb 2004, during a mostly sunny period, three male *K. ochrina* were heard singing from the crowns of two mature, exotic ash trees planted between the sidewalk and street in front of 308 Memorial Ave., Christchurch. We recorded the males singing and captured a single male specimen. We walked around the area at that same time and heard no other males calling within a few hundred meters. We returned one week later in the morning, but no *K. ochrina* were calling although other species of cicada were singing in the area. Further attempts to repeat the observation were prevented due to bad weather. In February 2005 we returned to this same location. No *K. ochrina* were heard singing.

***Kikihia ochrina* locality detail: MID CANTERBURY: NZ.MC.OCH.** Crowns of two mature, exotic ash trees on the sidewalk in front of 308 Memorial Ave, 1.6km SE of the junction with Russley Rd in Christchurch. 43°30.254S; 172°33.895E. 17 Feb 2004. 1 male collected, 3 males total heard/recorded (Fig. 4).

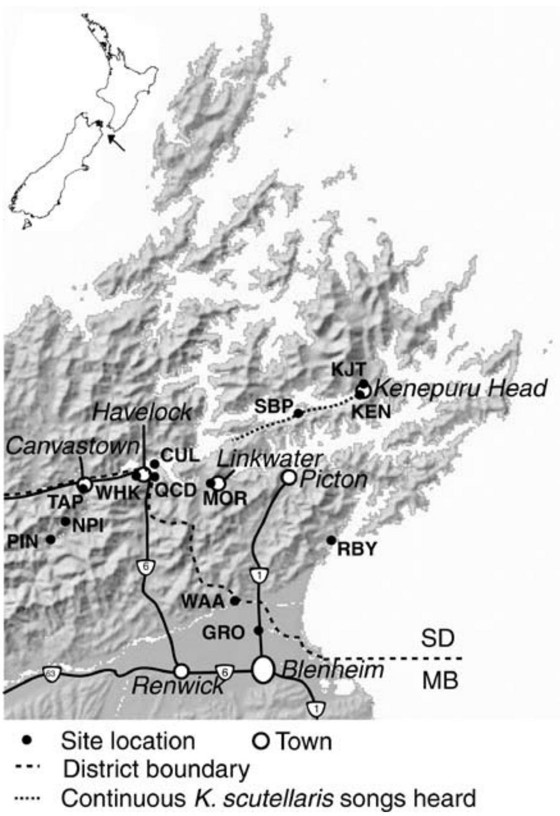


**Fig. 5.** Distribution map of South Island *Kikihia scutellaris* records (2001-2004, C. Simon research group); abbreviated location codes (LOC only, see methods) are given for figure clarity. District boundary between Marlborough (MB) and Marlborough Sounds (SD) follows Crosby *et al.* 1998. New Zealand map at top left indicates, with arrow, the area shown in detail. Digital elevation map from GeographX, New Zealand.

## Discussion

The two North Island cicada species that have been recently found on the South Island have different dispersal histories. While *K. scutellaris* appears to have spread from Picton throughout much of northern Marlborough and the Marlborough Sounds, *K. ochrina* has been heard only in a single location in the South Island. See Appendix for species identification and natural history information.

### *Cicada dispersal*

Although many a dismayed collector has watched a cicada streak away into the distance, cicadas generally do not move very far. Studies by Fleming and Scott (1970) and Cumber (1952) on *Kikihia muta* (Fabr.) males collected from flax bushes (*Phormium* sp.) and nearby rough pasture suggested a correlation between the sizes of adults and nymphs captured on the different flora, perhaps as a result of low dispersal. Nymphs of eastern North American periodical cicadas (*Magicicada* spp.) move little underground (see references within Karban 1981). Adult *Magicicada* of both sexes are attracted to male chorusing centres (Alexander and Moore 1958), and Karban (1981) found that some marked cicadas (especially mated females) moved more than 50m. Additionally, there are several published observations of adult *Magicicada* seen flying farther than 300m (Williams & Simon 1995 and references within). However, Karban (1981) found that the chorusing centres remained stable throughout an emergence and were the most heavily oviposited areas, suggesting that most mated females do not disperse far. Unpublished data on New Zealand cicadas suggest that at least two species complexes have populations only tens of kilometres apart with highly distinctive mitochondrial DNA, which is evidence of low dispersal.

Most evidence for rapid dispersal in cicadas comes from examples in which species invade open niches. Comparisons of the current range of 17-year *Magicicada* with estimates of the northern extent of deciduous forest at the North American Last Glacial Maximum (LGM), 18,000ya (Webb *et al*. 1993), suggest a postglacial range expansion northward of up to 900km. Over a maximum of 18,000 years, or approximately 1000 generations for 17-year *Magicicada* species, this would require northward dispersal of 0.9km per generation. Of course, the cicadas may have moved much faster than that – the deciduous forest habitat reached its modern extent only about 8,000 years after the LGM (Webb 1981). *Kikihia muta* and *K. angusta* (Walker), which inhabit lowland grasses and tussocks, respectively, are found throughout their habitats despite the fact that the New Zealand grasslands have been greatly expanded by burning and agriculture since humans arrived no earlier than 1200 years ago (Fleming 1975a, McGlone 2001). Phylogeographic studies can identify areas that have been subject to such rapid invasions. For instance, nearly identical mitochondrial DNA haplotypes are found in *K. muta* on the East Coast of the South Island extending approximately 600km from Opihi Bay to the Waitaki River (unpublished data). This could indicate spread of approximately 1.5km/generation for a three year life-cycle (Cumber 1952).

Most cicadas have multiple year life-cycles (Myers 1929b, Karban 1986, Moulds 1990), raising the possibility that surveys of adults could underestimate cicada species ranges, because in any given year all individuals might be subterranean juveniles. Such exact periodicity is rare, and most cicadas occur every year in any one location. However, proto-periodicity (absence or rarity in some years) could occur in new populations that have not been established long enough for life-cycle flexibility to fill in all of the years. If *K. scutellaris* and *K. ochrina* populations emerge only once every few years in newly colonised locations, then the reports of these species may not accurately represent the initial colonisation or extent of spread. Proto-periodicity could explain why *K. scutellaris* appeared to be limited to the Picton area for as long as ten years after its initial discovery, and why *K. ochrina* was only discovered in 2004.

The predators of cicadas are typically generalists such as birds and spiders (Cumber 1952, Kay 1980) so predation pressures should be comparable on the North and South Islands. Additionally, mymarid wasps that parasitise cicada eggs and the "vegetable cicada" fungus, *Cordyceps sinclairii* (Berk) that attacks nymphs (Cunningham 1921, Kay 1980)) especially *K. scutellaris* nymphs (Fleming 1975b, Fleming 1975d), are found on both islands. Female cicadas lay 200 to 600 eggs (Marlatt 1907, Moulds 1990), so there is a great capacity to increase in number if competition, predation and parasitism are low.

## *Kikihia scutellaris introduction and dispersal hypotheses*

Prior to the data presented here, only a few localised records around Picton were known for *Kikihia scutellaris* in the South Island. A single, previously unreported female *K. scutellaris* was collected in 1932 from Torrent Bay, Tasman Bay. No further records of this species known to us have been found near this area, and it is approximately 67km from the closest record described in this paper. We have not visited this exact locality so we cannot comment on the current presence or absence of *K. scutellaris* at Torrent Bay; however we have surveyed nearby areas without finding this species. Given the number of localities recorded here as probable dispersal from Picton (discussed further below), it is difficult to understand why *K. scutellaris*, if present in Torrent Bay in 1932, has not spread through seemingly reasonable habitat. We assume that the Torrent Bay introduction did not lead to establishment and we do not discuss this record further.

Fleming (1975d) believed that *K. scutellaris* was probably transported across Cook Strait on the ferry from Wellington, where it is a common cicada around houses near native forest. C. Fleming and co-workers found that *Kikihia scutellaris* of both sexes were attracted to lights at night (J. Dugdale pers. comm.), and there are several labelled as such in the Museum of New Zealand Te Papa Tongarewa. Lights at the harbour and around the ferries are not too far from forested areas, and this suggests a simple way of getting trapped aboard. At a private residence in the Miramar Heights district we have two personal observations and many anecdotal reports of *K. scutellaris* adults brought into the home on laundry – suggesting a second possible means of transportation! Because the known host species of *K. scutellaris*, mahoe, is common on both the North and South Islands and is not a common ornamental species, it is unlikely this plant would be shipped between islands and thus facilitate the transport of nymphs or eggs. Although *K. scutellaris* is a comparatively long-winged species (Fig. 1), the association of this colonisation event with the Picton ferry terminal, rather than with parts of the Marlborough Sounds closer to the North Island, argues for human transportation rather than unaided dispersal. We have yet to conduct molecular analyses that might determine the North Island source population.

New records from 2001-2004 (34-37 years after the first Picton records) indicate that *K. scutellaris* has now spread significantly (Fig. 5), as far as 32.5 km (NZ.MB.PIN site) from Picton. The dispersal of this species seems extremely rapid. If *K. scutellaris* was introduced to Picton around the mid 1960s then dispersal has occurred at a rate of almost 1km per year. Because most cicadas require multiple years to develop (the similarly sized *K. muta* takes 3-4 years; Cumber 1952), the per-generation dispersal rate is likely higher, perhaps 3km/generation or more. Although this is higher than the 0.9-1.5km/generation dispersal rates roughly estimated for 17-year *Magicicada* spp. and *K. muta* (above), the *K. scutellaris* case may be different in one key respect: *Magicicada* spp. and *K. muta* may have been limited by the dispersal rates of their host plants; *K. scutellaris* is not limited this way as it is moving into pre-existing habitat, and its niche appears to be empty of other similar-sized cicada species in the South Island. Thus, freed from adult and nymphal competition, this species may be capable of rapid range expansion on the South Island.

Our estimate for the dispersal rate of *K. scutellaris* depends on the assumption that the species was restricted to the Picton area in the mid-1960s. This assumption is here based on the fact that C. Fleming, J. Dugdale and others conducted extensive work on cicadas in the northern South Island at that time. Had *K. scutellaris* been more widely distributed during the 1960s, even in a proto-periodical condition (discussed above), it seems unlikely that multiple records would have been discovered for Picton while none were made for nearby localities such as Linkwater and Havelock, where Dugdale and Fleming spent considerable time. If the current South Island range of *K. scutellaris* has been established in just 35-40 years, and if the species continues dispersing at its current rapid rate, then in 100 years time it will have reached nearly as far as Takaka, St Arnaud and Kaikoura. The dryness of southern Marlborough may inhibit dispersal to the south, so spread to Kaikoura may be possible only through an indirect route.

## *Kikihia ochrina* introduction and dispersal hypotheses

With its single, spot occurrence in Christchurch, *K. ochrina* seems likely to have been recently introduced, almost certainly by way of human transport from its range in the North Island. As with *K. scutellaris*, a single mated female could have been transported live and escaped to oviposit on a nearby tree. Alternatively, *K. ochrina* might have been introduced via vegetation containing eggs or cicada nymphs that were moved from the North Island; such commerce in plants between the North and South Islands is common at times (B. Edwards pers. comm.). Such transportation via the host has been reported for other cicadas; Chilcote and Stehr (1984) described a case of *Magicicada* nymphs transported in root balls, and Fleming (1973, 1975d) published an account of two specimens of the northern North Island subspecies *Kikihia cutora cutora* that emerged in a Wellington greenhouse from a potted plant moved from Auckland. Given the numbers of plants that are moved around, to some degree it seems surprising that the transportation of cicadas is apparently not more common. Perhaps cicadas do get transported this way with some regularity, but the few that survive to become adults usually go unnoticed and do not successfully reproduce. Like most of the New Zealand cicadas the life-cycle of *K. ochrina* is unknown, but they presumably develop over several years, so a plant harbouring nymphs or eggs (see Appendix for host range) could have been moved into the area well prior to the appearance of the adults. Further observations will have to be made over several years to determine if the adults observed in 2004 successfully reproduced.

If *K. ochrina* does become established in Christchurch it may not be able to move westward out of the city, as Christchurch is fairly well isolated by the drier Canterbury Plains. This species may, however, be able to colonise the wetter parts of Banks Peninsula, although the absence of *K. subalpina* (common in Christchurch) from that area may indicate some presently unknown barrier to cicada dispersal to, or survival on, the Peninsula.

### *Threats to current ecosystems from invading cicada species*

The addition of an extra *Kikihia* species or two into the South Island should pose little threat to current ecosystems or commercial enterprises. *Kikihia scutellaris* and *K. ochrina* are similar to other South Island *Kikihia* species, and they have never been observed to reach the high densities of known pest cicadas.

Most cicadas do little damage to their habitat. All cicadas lay eggs in slits cut in the bark, stem or leaf of a plant by the female's strong ovipositor. The large New Zealand *Amphipsalta zelandica* (Boisduval) is sometimes a nuisance to orchardists, foresters, and gardeners, as the scarred branches may weaken and snap off or allow access for disease organisms (Ranger 1945, Lloyd 1949, Kay 1980), but no such effects from any of the smaller species have been documented. The feeding of large numbers of adults on plants is usually not severe (Kay 1980) and the feeding of nymphs on the roots of plants appears to detrimentally affect plant growth or vigour only under enormous population densities (Hamilton 1961, Moulds 1990) that would almost certainly never be achieved with *K. scutellaris* or *K. ochrina*.

Competition or hybridisation with other cicada species, however, has the potential to compromise the South Island cicada fauna. Many *Kikihia* species are recently derived (Arensburger *et al*. 2004b, unpublished data) and there are several examples of interspecific hybridisation (Fleming & Dugdale unpublished correspondence[1], unpublished data) that demonstrate a lack of pre- and post-mating barriers. Incompletely differentiated songs and occasional novel situations that circumvent the usual pair-forming behaviours (unpublished observations) can lead to such hybridisations. However, the songs of *K. scutellaris* and *K. ochrina* are so distinct from other South Island cicadas that such mistakes seem highly unlikely, and both species are unlikely to come into direct contact with many individuals of other species. Neither of these species has been observed to form interspecific hybrids with other species on the North Island. The distinct ecology and singing station of *K. scutellaris* (see Appendix) should only isolate it further from other South Island cicadas. *Kikihia ochrina* could compete with *K. subalpina* for singing station and oviposition sites (it is thought that both of these species are generalists on a range of hosts); however both species usually occur in low densities.

## Acknowledgements

The authors would like to thank John Dugdale (Landcare Research, Nelson) for information on the distribution of *K. scutellaris* on the South Island when it was first discovered; Phil Servid (Museum of New Zealand Te Papa Tongarewa) for searching the museum collection for specimens of *K. scutellaris*; Bob Edwards (Editor, Commercial Horticulture magazine) for information on interisland trtansport of NZ plants; and David Lane for information on *K. scutellaris* aural records. Chris Simon provided comments on a draft version of the manuscript. The Department of Conservation granted collection permits for localities within National Parks. Funding for the fieldwork contributing to this paper was supplied by the Royal Society of New Zealand Marsden Fund and NSF DEB 00-89946 to Chris Simon. For further information, pictures and songs of New Zealand and worldwide cicadas visit the Cicada Central website, currently hosted by the Ecology and Evolutionary Biology (EEB) department of the University of Connecticut. http://collections2.eeb.uconn.edu/collections/cicadacentral/

[1] Archives of the New Zealand Arthropod Collection, Mount Albert, Auckland, New Zealand

## References


Alexander R.D., Moore T.E. 1958. Studies on the acoustical behavior of seventeen-year cicadas. *Ohio Journal of Science 58:* 107-127.

Arensburger P., Buckley T.R., Simon C., Moulds M., Holsinger K.E. 2004a. Biogeography and phylogeny of the New Zealand Cicada Genera (Hemiptera: Cicadidae) based on nuclear and mitochondrial DNA data. *Journal of Biogeography 31:* 557-569.

Arensburger P., Simon C., Holsinger K. 2004b. Evolution and Phylogeny of the New Zealand cicada genus *Kikihia* Dugdale (Homoptera: Auchenorrhyncha: Cicadidae) with special reference to the origin of the Kermadec and Norfolk Islands' species. *Journal of Biogeography 31:* 1769-1783.

Buckley T.R., Simon C., Chambers G.K. 2001. Phylogeography of the New Zealand cicada *Maoricicada campbelli* based on mitochondrial DNA sequences: ancient clades associated with Cenozoic environmental change. *Evolution 55:* 1395-1407.

Buckley T.R., Arensburger P., Simon C., Chambers G.K. 2002. Combined Data, Bayesian Phylogenetics, and the Origin of the New Zealand Cicada Genera. *Systematic Biology 51:* 4-18.

Chilcote C.A., Stehr F.W. 1984. A new record for *Magicicada septendecim* in Michigan (Homoptera: Cicadidae). *The Great Lakes Entomologist 17:* 53-54.

Crosby T.K., Dugdale J.S., Watt J.C. 1998. Area codes for recording specimen localities in the New Zealand subregion. *New Zealand Journal of Zoology 25:* 175-183.

Cumber R.A. 1952. Notes on the biology of *Melampsalta cruentata* Fabricius (Hemiptera-Homoptera: Cicadidae), with special references to the nymphal stages. *Transactions of the Royal Entomological Society of London 103:* 219-237. [Note that *M. cruentata* is used in error for *K. muta*.]

Cunningham G.H. 1921. The genus *Cordyceps* in New Zealand. With special entomological notes on the hosts, by J.G. Myers. *Transactions and Proceedings of the New Zealand Institute 53:* 372-382.

Dugdale J.S. 1972. Genera of New Zealand Cicadidae (Homoptera). *New Zealand Journal of Science 14:* 856-882.

Dugdale J.S., Fleming C.A. 1978. New Zealand cicadas of the genus *Maoricicada* (Homoptera: Tibicinidae). *New Zealand Journal of Zoology 5:* 295-340.

Fleming C.A. 1967. Notes on the distribution of New Zealand cicadas. *New Zealand Entomologist 3:*16-17.

Fleming C.A. 1971. A new species of cicada from rock fans in southern Wellington, with a review of three species with similar songs and habitat. *New Zealand Journal of Science 14:* 443-479.

Fleming C.A. 1973. The Kermadec Islands cicada and its relatives (Hemiptera: Homoptera). *New Zealand Journal of Science 16:* 315-332.

Fleming C.A. 1975a. Adaptive radiation in New Zealand cicadas. *Proceedings of the American Philosophical Society 119:* 298-306.

Fleming C.A. 1975b. Cicadas (1). *New Zealand's Nature Heritage 4:* 1568-1572.

Fleming C.A. 1975c. Cicadas (2). *New Zealand's Nature Heritage 4:* 1591-1595.

Fleming C.A. 1975d. New Zealand cicadas. *Nature (Naturalists Club Notes- Correspondance School, Department of Education):* 11-26.

Fleming C.A. 1977. The history of life in New Zealand forests. *New Zealand Journal of Forestry 22:* 249-62.

Fleming C.A. 1984. The cicada genus *Kikihia* Dugdale (Hemiptera, Homoptera). Part 1. The New Zealand green foliage cicadas. *National Museum of New Zealand Records 2:*191-206.

Fleming C.A., Ordish R.G. 1966. Type specimens of G. V. Hudson's taxa of New Zealand cicadas (Genus *Melampsalta*: Hemiptera Homoptera). *Records of the Dominion Museum 5:* 195-200.

Fleming C.A., Scott G.H. 1970. Size differences in cicadas from different plant communities. *New Zealand Entomologist 4:* 38-42.

Hamilton D.W. 1961. Periodical cicadas, *Magicicada* spp., as pests in apple orchards. *Proceedings of the Indiana Academy of Science 71:* 116-121.

Hudson GV. 1950. *Fragments of New Zealand entomology*. Ferguson and Osborn Ltd, Wellington, New Zealand.

Karban R. 1981. Flight and dispersal of periodical cicadas. *Oecologia 49:* 385-390.

Karban R. 1986. Prolonged devolopment in cicadas. In: *Evolution of Insect life cycles* (eds

F. Taylor & R. Karban). pp 222-235. Springer-Verlag, New York, U.S.A.

Kay M.K. 1980. Forest and Timber Insects in New Zealand. Large cicadas. *Forest Research Institute, New Zealand Forest Service 44:* 1-4.

Lloyd RC. 1949. Cicada damage in an indigenous forest. *New Zealand Journal of Forestry 6:* 64-65.

Marlatt C.L. 1907. The periodical cicada. *Bulletin of the United States Department of Agriculture, Bureau of Entomology 71:* 1-181.

McGlone M.S. 1985. Plant biogeography and the late Cenozoic history of New Zealand. *New Zealand Journal of Botany 23:* 723-749.

McGlone M.S. 2001. The origin of the indigenous grasslands of the southeastern South Island in relation to pre-human woody ecosystems. *New Zealand Journal of Ecology 25:* 1-15.

McGlone M.S., Duncan R.P., Heenan P.B. 2001. Endemism, species selection and the origin and distribution of the vascular plant flora of New Zealand. *Journal of Biogeography 28:* 199-216.

Moulds M.S. 1990. *Australian Cicadas*. New South Wales University Press, Kensington, Australia.

Myers I., Myers J.G. 1923. The sound organs and songs of New Zealand Cicadidae. *Australasian Association for the Advancement of Science 16:* 420-430.

Myers J.G. 1929a. The taxonomy, phylogeny and distribution of New Zealand cicadas (Homoptera). *Transactions of the Entomological Society of London 77:* 29-60.

Myers J.G. 1929b. *Insect singers*: *a natural history of the cicadas*. George Routledge and Sons Limited, London, U.K.

Ranger F.J. 1945. Cicada damage to exotic shade bearers. *New Zealand Journal of Forestry 5:* 153.

Salmon J.T. 1980. *The native trees of New Zealand*. Reed, Wellington, New Zealand.

Webb T. III, Bartlein P.J., Harrison S.P., Anderson K.H. 1993. Vegetation, lake levels and climate in eastern North America for the past 18,000 years. In: *Global Climates since the last glacial maximum* (eds H.E. Wright Jr., J.E. Kutxbach, T. Webb III, W.F. Ruddiman, F.A. Street-Perrott & P.J. Bartlein). pp. 415-467. University of Minnesota Press, Minneapolis, MN, U.S.A.

Williams K.S., Simon C. 1995. The ecology, behaviour, and evolution of periodical cicadas. *Annual Review of Entomology 40:* 269-295.

# Appendix

## Species identification and natural history

### *Kikihia scutellaris*

*Kikihia scutellaris* is known as a shade singer from its unusual habit of often singing within the bush, rather than in the sunlit tops of trees and shrubs (Myers 1929a, Fleming 1975b, Fleming 1984). It can be attracted to bright lights on warm nights. Found throughout the North Island from sea level to over 1000m, *K. scutellaris* inhabits open woods and is usually associated with mahoe/whiteywood (*Melicytus ramiflorus* Forster & Forster)-dominated forest (Fleming 1975b, Fleming 1975d). Mahoe is common in both North and South Island forests and scrublands (Salmon 1980), which suggests that *K. scutellaris* might spread far into bush and/ or bush-edge areas of the South Island. *Kikihia scutellaris* is relatively small, with a body length of approximately 16mm in males and 19mm in females. Its song pitch is relatively high, ranging from about 11-20kHz, with most of the energy at 13-17kHz (Fig. 2). The complex song, which sounds somewhat sad (Hudson 1950, Fleming 1975b), can be translated phonetically as phrases of "duuuu duuuu dee-di-deeeeeee--dit", with more or fewer "duuuus" per phrase. *Kikihia scutellaris* is distinguishable from other South Island species by its long wings relative to the body and by its olive-green and black colouration (Fig. 1). Radiating through the black markings on the dorsal mesothorax are fine, dendritic copper lines. The intersegmental membranes of the abdomen are a bright turquoise blue and the ventral side of the abdomen is pale with a thick black medial line. *Kikihia scutellaris* has been recorded from October to May, with individuals most common from December to March (personal observations).

### *Kikihia ochrina*

*Kikihia ochrina* inhabits the bush edge throughout the North Island and is common in residential areas. It most often ranges from sea level to 400m (Fleming 1984) and rarely over 1000m (personal observations). *Kikihia ochrina* usually sings from plants such as *Hebe*, *Coprosma*, *Melicytus*, *Myoporum* and *Pseudopanax* (Fleming 1984), often from leaves rather than stems (Fig. 3). The high-pitched repetitive ticks of the song range from 13-18kHz and are produced at about 11/sec. (Fig. 4). *Kikihia ochrina* is the brightest green of all of the New Zealand cicadas (a small fraction are yellow/gold), a colouration that affords excellent camouflage for a cicada perched on a sunlit leaf. It is distinguishable from other South Island species by its uniform bright green body, broken only by a little black colour around the ocelli and two thin black sickle shapes on the mesothorax (Fig. 4). Average body length is 17.9mm in males and 21mm in females (Fleming 1984). *Kikihia ochrina* has been noted from early October (personal observations) to late July, but it is most common March to April (Fleming 1984).