Auchenorrhyncha PEET Workshop

9-11 March 2007

Cicadoidea Part I: Overview of Phylogeny

A. Overview of Taxonomy of Cicadoidea (Max Moulds and Kathy Hill)

B. Molecular Phylogeny of Cicadettini (Vanderpool, Marshall, Hill, Moulds, Simon)

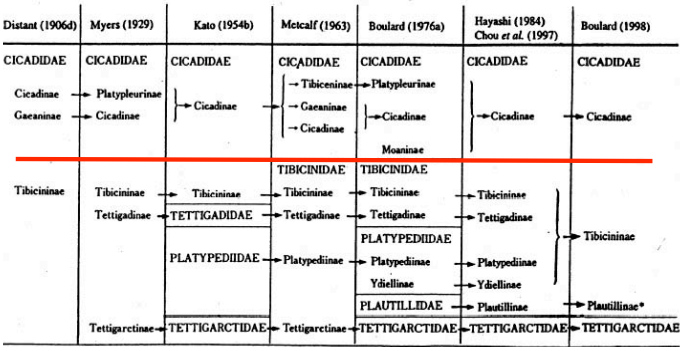
Acknowledgments

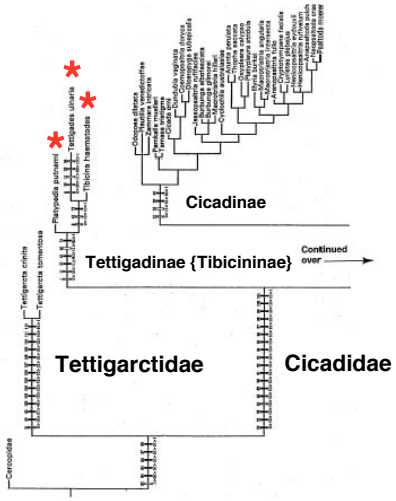
World collectors/collaborators: Yves Basset, Michel Boulard, Thomas Buckley, Jian-Hong Chen, Jason Cryan, Chris Dietrich, John Dugdale, Hans Duffels, David Emery, Matja Gogala, Geert Goemans/Lois O'Brien, Stephane Puissant, Tomi Trilar, Allen Sanborn, Jerome Sueur, Martin Villet, Matt Whiles, Julie Urban

Simon Lab people contributing (not including co-authors): Peter Arensburger, John Cooley, Michael Cordiero

Support: The US National Science Foundation, The NZ Marsden Fund, The National Geographic Society, The Fulbright Foundation, The University of Connecticut, and Victoria University of Wellington.

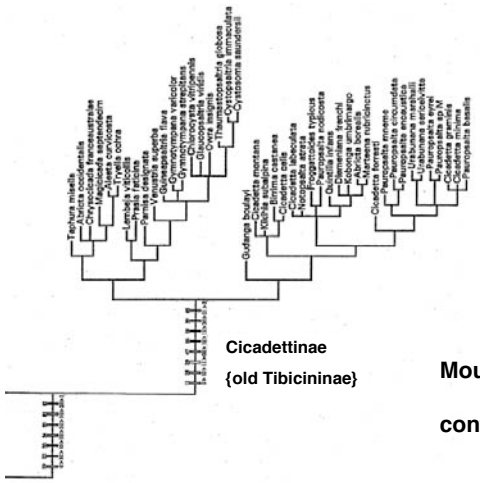
Moulds 2005, Fig 1. Historical family (caps) and subfamily concepts Timbal covers vs. none





Moulds 2005

Basal nodes and character transformations shown are the same for all 161 MP trees.



Moulds 2005

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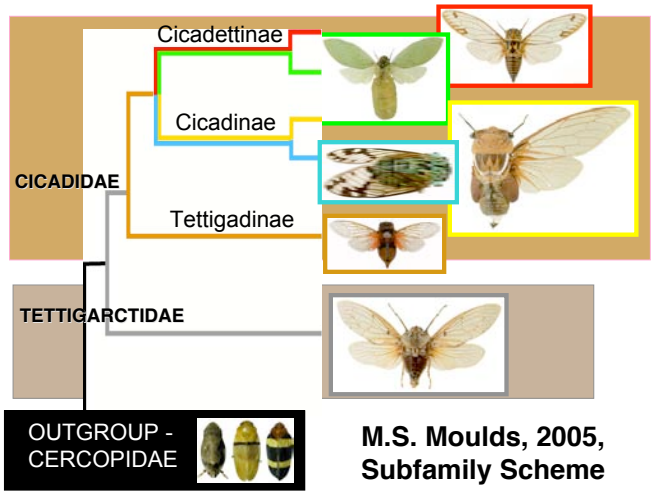


M.S. Moulds, 2005, Subfamily Scheme

TETTIGARCTIDAE

www.ento.csiro.au/aicn/images/cain1154.jpg

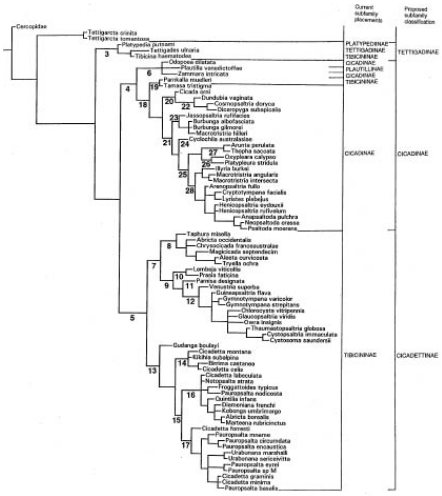
Tettigarcta crinita Photo: Moulds 1990

G.R. Brown, NSW Agricultu

Family Cicadidae

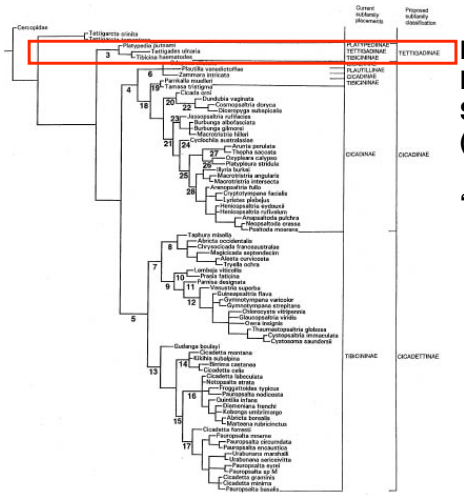
- Estimated 3000 spp. worldwide
- All temperate continents
- Mesozoic origins

Tibicen linnei, K. Hill, Delaware



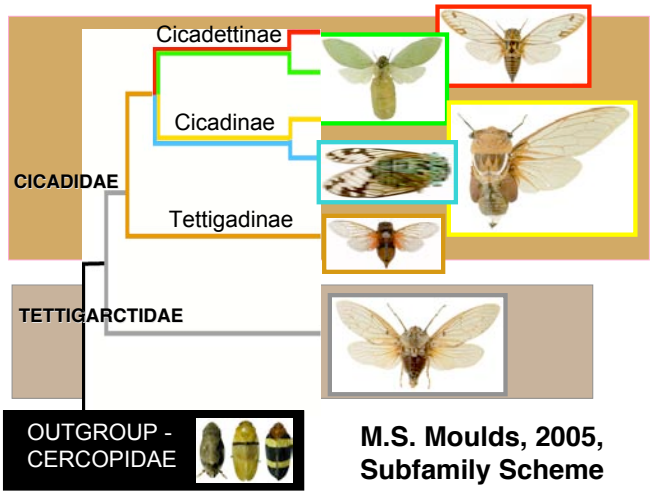
Moulds' 2005, New Cicada Subfamilies (Fig 53)

Strict consensus Max Parsimony , 112 morph chars (5 nymphal chars)



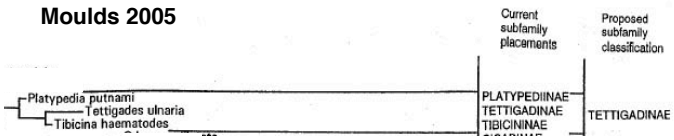
Moulds' 2005 New Cicada Subfamilies (Fig 53)

"Tettigadinae"



M.S. Moulds, 2005, Subfamily Scheme

Moulds 2005



http://www.naturewatch.ca/
Okanagana ornata

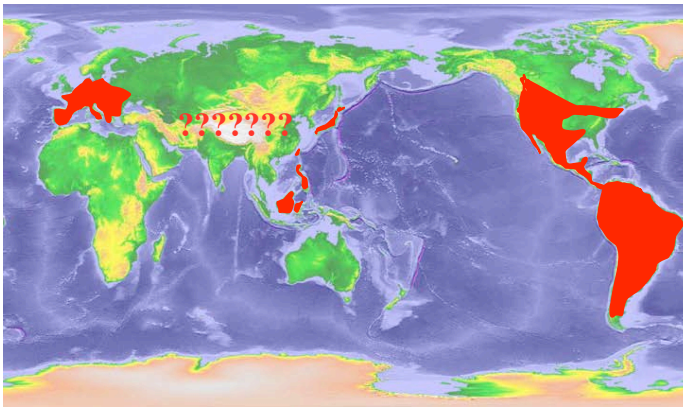
Okanagana rimosa
http://www.lesinsectesduquebec.com

Tettigadinae

K. Hill & D. Marshall

Okanagana hesperia

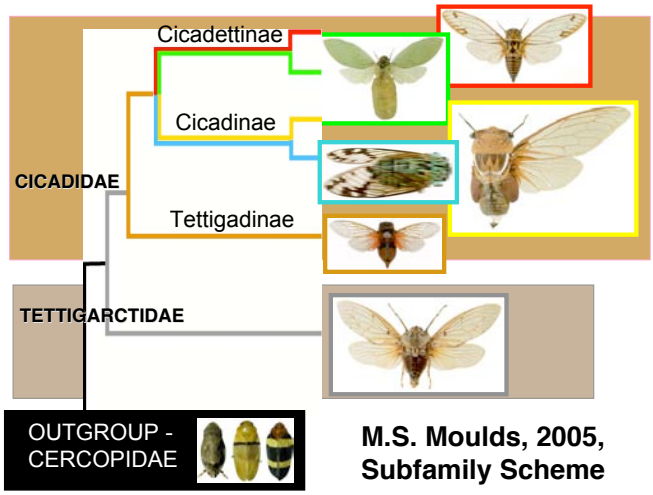
Worldwide Tettigadinae distribution



Approximately 200? extant species

Moulds' 2005 New Cicada Subfamilies (Fig 53)

Cicadinae



M.S. Moulds, 2005, Subfamily Scheme

Cicadinae

Zammara

Tacua

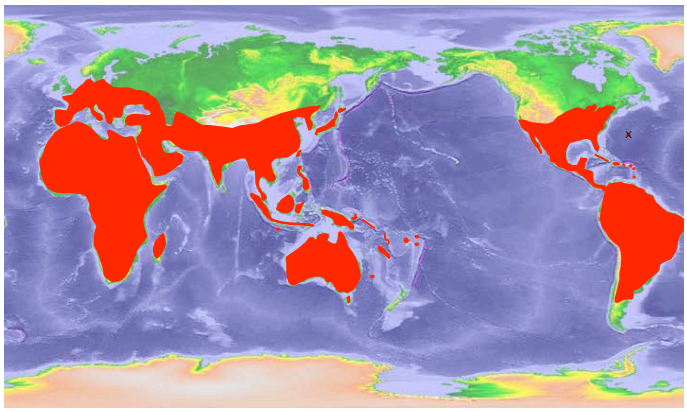
Cyclochila

Tibicen

Thopha

Platypleurini, Ugada limbata, Ghana
Pinned from alcohol, photo K. Hill

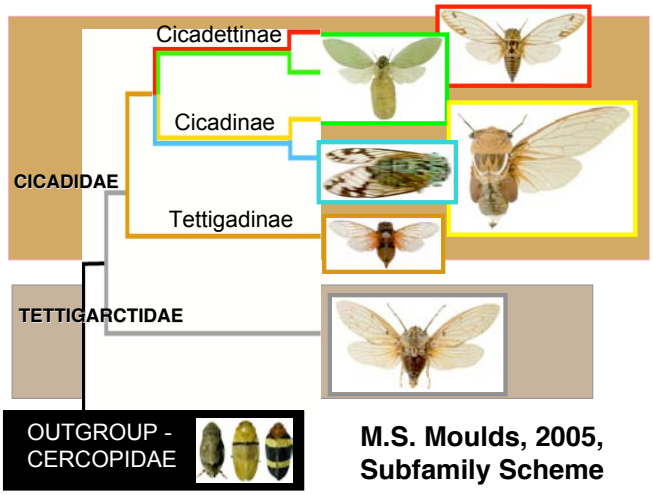
Worldwide Cicadinae distribution



Perhaps 1000 extant species

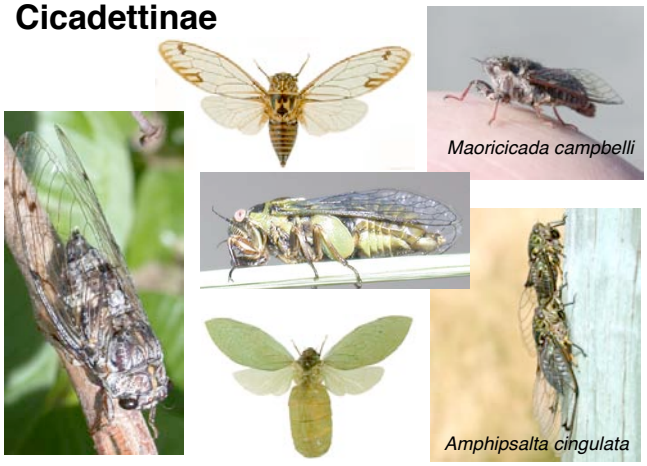
Moulds' 2005 New Cicada Subfamilies (Fig 53)

Cicadettinae formerly Tibicininae (part)

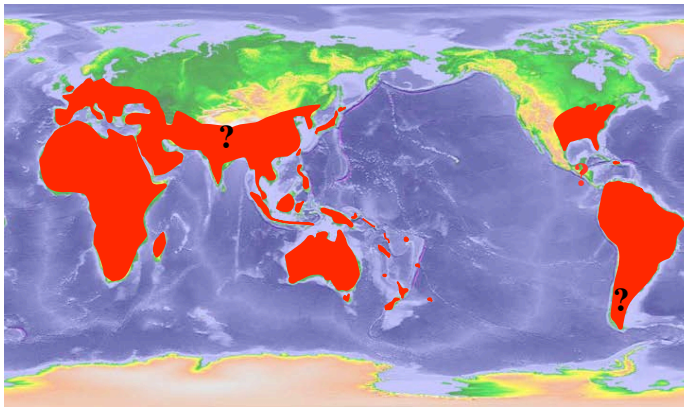


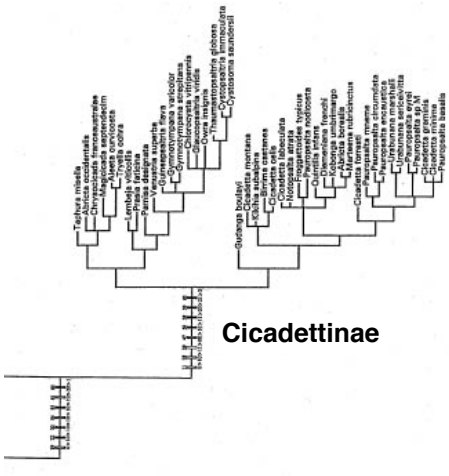
M.S. Moulds, 2005, Subfamily Scheme

Cicadettinae



Worldwide Cicadettinae distribution





Cicada Tribes Not Well-Defined

Moulds 2005, Fig 53

Cicadettinae

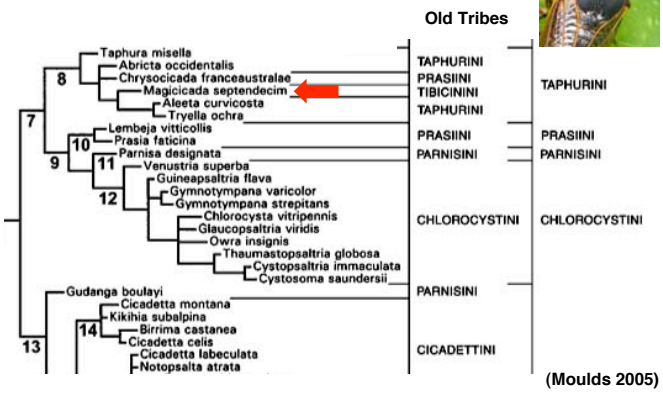
Sister tribes of Cicadettini

Tribe Cicadettini

Sister Tribes of Cicadettini

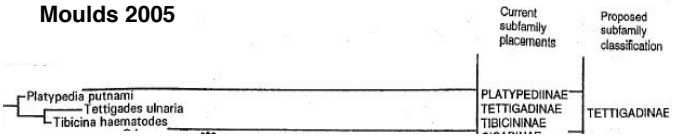
Chlorocystini **Parnisini** **Prasiini** **Taphurini**	Moulds (2005) unnamed monophyletic group (Chlorocystini Parnisini, Prasiini, Taphurini). *Magicicada* moved to Taphurini
Carinetini* **Dazini** **Hemidictyini*** **Huechysini** **Lamotialnini** **Tettigomyiini** **Ydiellini***	Moulds (pers. com.) These other Cicadettinae tribes may fall within the above monophyletic group but unknown. Huechysini probably fall within the Cicadettini. *Tribes with highly divergent attributes e.g., Carinetini, Hemidictyini and Ydiellini probably require resolution with DNA.

Magicicada now in Tribe Taphurini (also suggested by Maxine Heath)



(Moulds 2005)

Moulds 2005

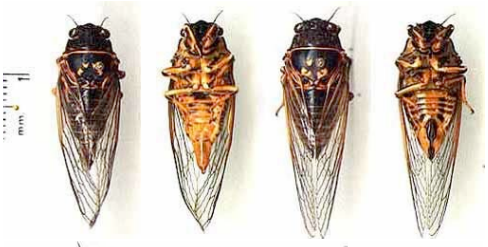


Magicicada **formerly placed with** ***Tibicina*** **and** ***Okanagana***

Okanagana

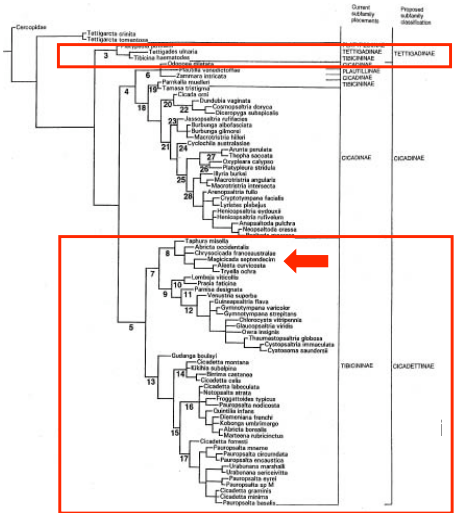
Magicicada

Okanagana rimosa



Magicicada septendecim

http://hydrodictyon.eeb.uconn.edu/projects/cicada/sp_pages/NA_species/



Magicicada **relationships previously unknown, now Taphurini**

Marobduus gillioni, Ghana

Ydiellini [related to Taphurini?]

Carineta sp., Peru

Molecular Phylogeny of Cicadettini

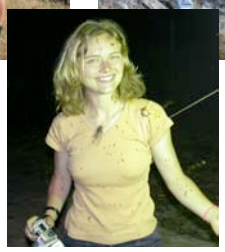
Dan Vanderpool[1], David Marshall[1], Kathy Hill[1], Max Moulds[2], & Chris Simon[1,3]

University of Connecticut
The Australian Museum
Victoria University of Wellington

Dan Vanderpool

Max Moulds

Dave Marshall



Kathy Hill

Tribe Cicadettini

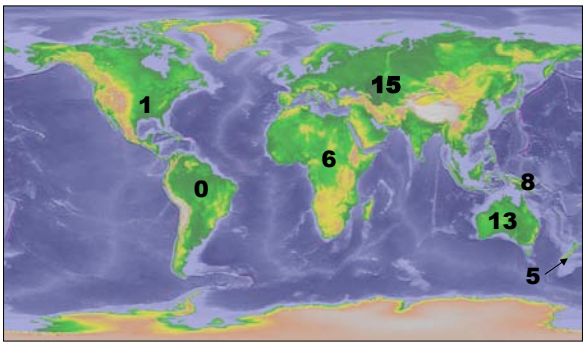
- **Estimated 1000 spp. worldwide**
- **1/3rd of world cicada diversity**
- **500+ Australia**
- **All temperate continents except South America**
- **Many species undescribed...**

Tribe Cicadettini

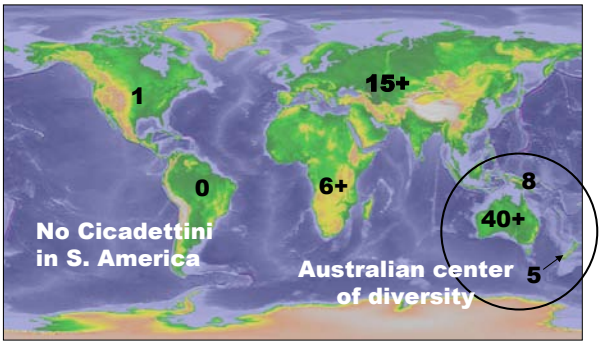
- **Very small to medium-sized**
- **Songs usually high-pitched and complex**
- **Rare in tropics**
- **Prefer bush edge, shrub/scrub, and grass habitats**
- **"Duetting" pairs**

Males can be attracted by imitating female species specific wing flick.

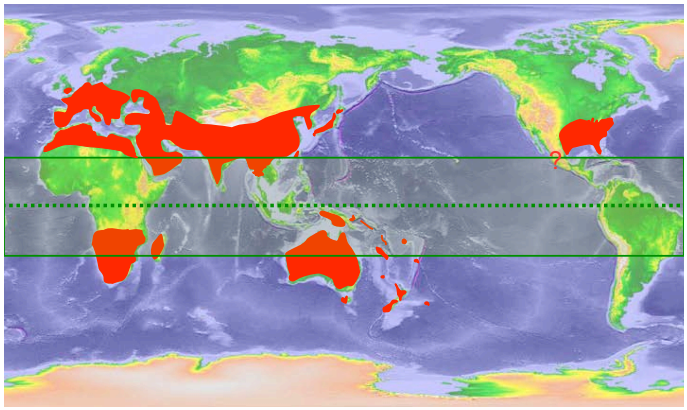
Worldwide Distribution of Described Cicadettini Genera



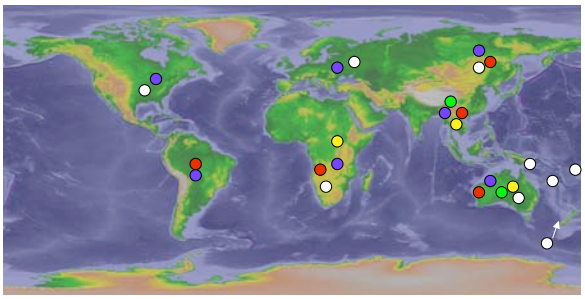
Worldwide Distribution of Described Cicadettini Genera



....a worldwide tribe, but poorly represented in the tropics



Sister Groups of Cicadettini: Parnisini, Taphurini, Chlorocystini, & Prasiini



Phylogenetic Questions

Is the tribe Cicadettini monophyletic?

Is the tribe composed of well-defined sub-clades?

Did they originate in Australasia, & spread to other continents?

Did Cicadettini radiate in concert with the aridification of Australia?

Are Cicadettini post-Gondwanan?

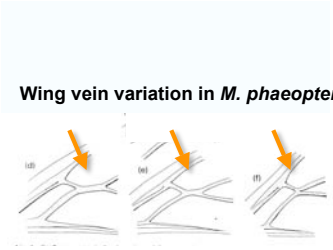
Taxon sampling

- 129 Cicadettini species
- 10 outgroup taxa (3 Chlorocystini, 6 Taphurini)...more to come.
- Cicadinae outgroup (*Tamasa*)
- All continents
- Emphasis on distinctive forms, earlier branching lineages (e.g., type species of all genera).

Cicadetta n. sp. "Escarpment Tick-tock" (Cicadettini)

Tryella willsi (Taphurini)

Tribe Cicadettini



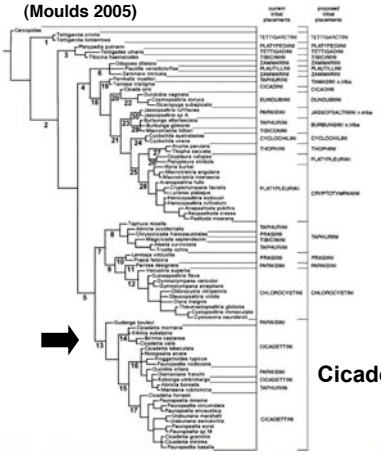
Wing vein variation in *M. phaeoptera*

Dugdale & Fleming 1979, Fig. 4

Moulds: New tribal definition based on 4 derived characters; more taxa

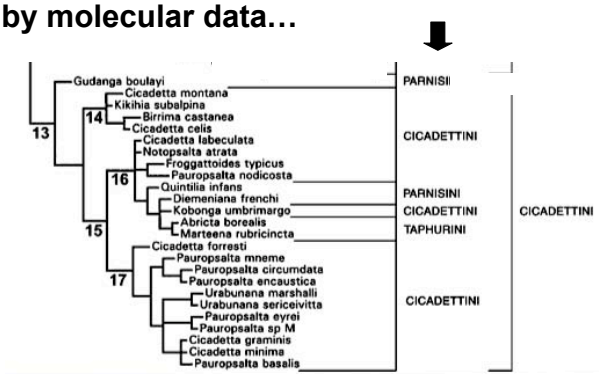
Testing the monophyly of the new tribal definition

(Moulds 2005)



Cicadettini

Former Tribes of Genera transferred to Cicadettini by Moulds 2005 supported by molecular data…



Genetic Dataset

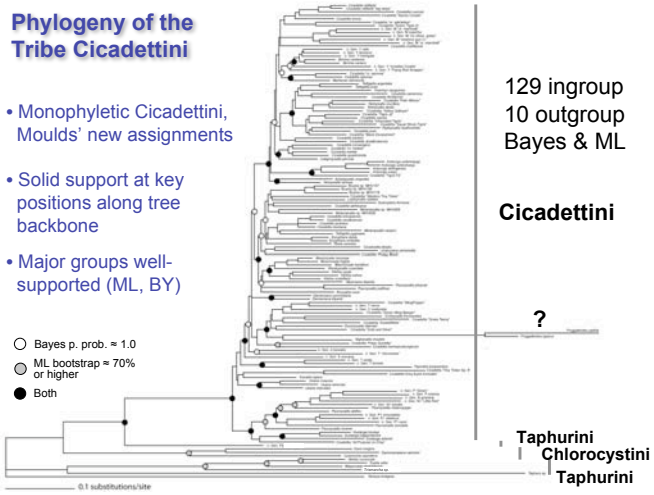
- ca. 1500 bp mtDNA cytochrome oxidase I and II
- ca. 3000 bp nuclear EF-1α, introns and exons (Some nuclear data still missing)
- All data aligned by eye, gaps treated as missing data.
- Combined data analyses only (this talk)

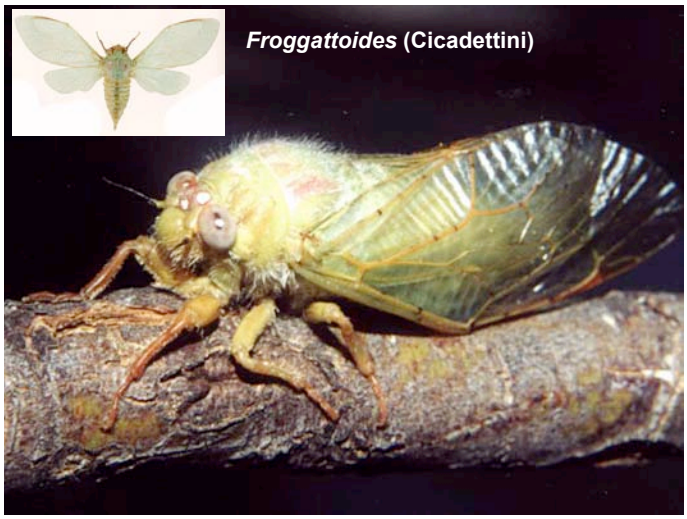
Phylogenetic Methods

- Maximum-Likelihood (superior branch length estimation; Marshall Simon Buckley 2006, Syst. Biol.)
  - Garli v0.95 (Genetic Algorithm, D. Zwickl), single partition mtDNA+nuclear, GTR + 8 category gamma
  - RAxML v2.2.1 (A. Stamatakis, SFIT), two partitions, separate model parameters, GTR+CAT, 25 rates.
- Bayesian (80-taxon dataset only – DV)
  - MrBayes 3.0b4, complex six-partition model, separate parameters, GTR+gamma

Phylogeny of the Tribe Cicadettini

- Monophyletic Cicadettini, Moulds' new assignments
- Solid support at key positions along tree backbone
- Major groups well-supported (ML, BY)



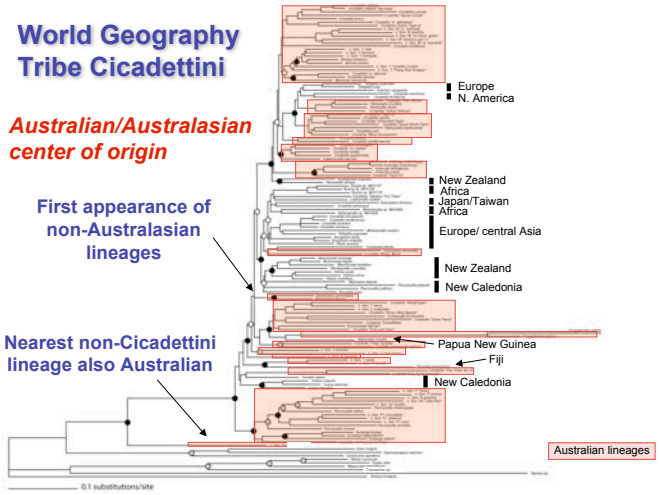


World Geography Tribe Cicadettini

Australian/Australasian center of origin

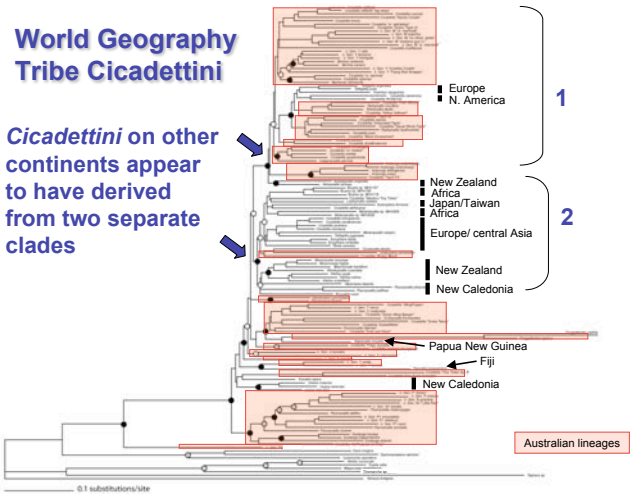
First appearance of non-Australasian lineages

Nearest non-Cicadettini lineage also Australian

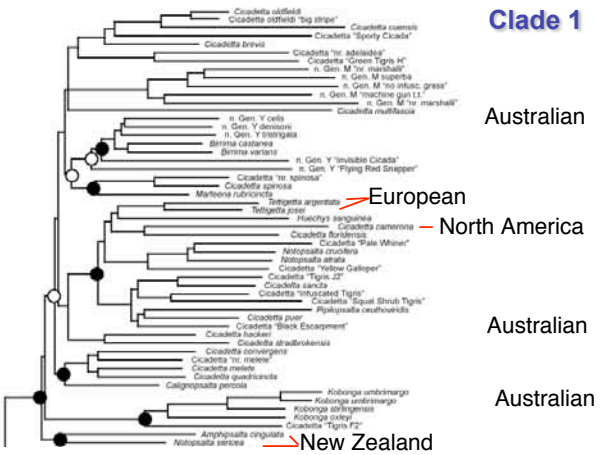


World Geography Tribe Cicadettini

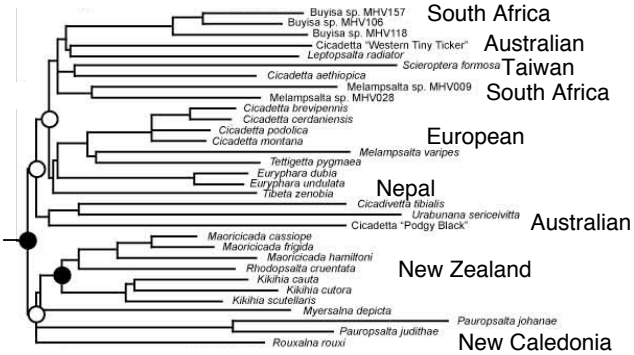
***Cicadettini* on other continents appear to have derived from two separate clades**



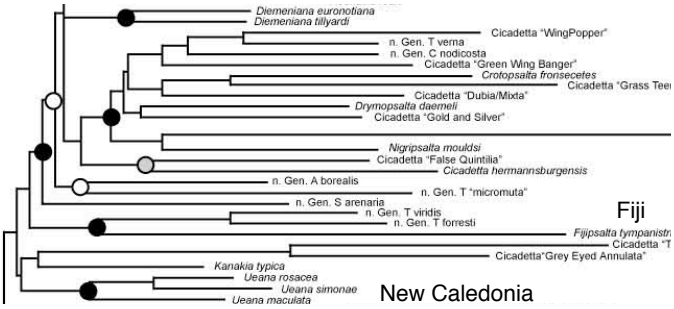
Clade 1



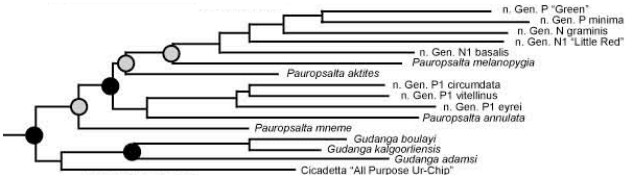
Clade 2



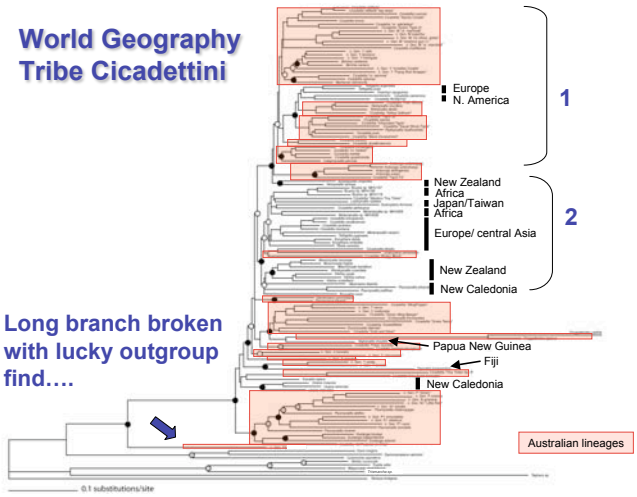
Mostly Australian Paraphyletic Mess



Australian Pauropsalta and relatives



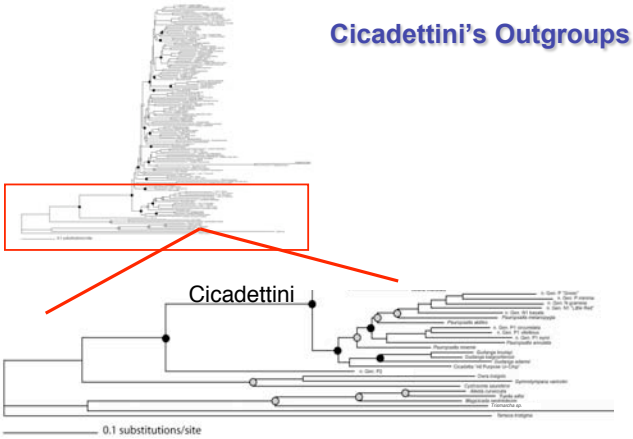
World Geography Tribe Cicadettini



Long branch broken with lucky outgroup find….

Breaking long branches, literally….

Cicadettini's Outgroups



Molecular Dating – Methods

- **Bayesian relaxed-clock, MULTIDIVTIME (Thorne et al. 1998)**
- **Tree from partitioned ML (RAxML) analysis, with smaller, representative taxon sample.**
- **Diffuse priors (stdev = mean)**
- **Fossil and Geological calibrations**

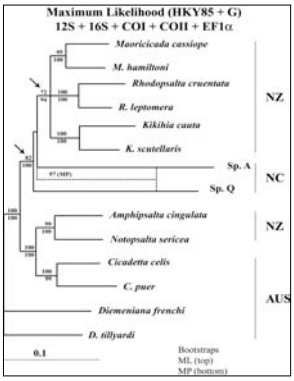
Molecular Dating – 2 Calibrations

Age of large New Zealand cicada radiation (KMR)

- NZ/NC ancestor 7-14 Ma molecular clock and local geological calibrations (Norfolk Island emergence; Arensburger et al. 2004)

Age of *Paracicadetta* fossil lineage (France)

- European presence in late Oligocene (ca. 24 my) (Boulard and Nel 1990)

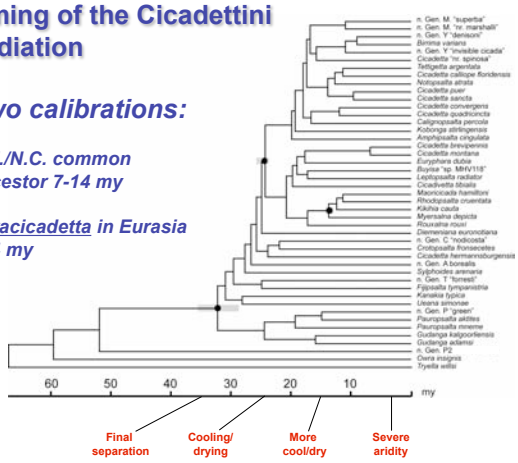


Timing of the Cicadettini Radiation

Two calibrations:

N.Z./N.C. common ancestor 7-14 my

Paracicadetta in Eurasia >24 my



In Summary

- Out of Australia hypothesis strongly suggested
- If true, Cicadettini have colonized the remaining temperate continents during two separate invasions from Australia.
- Diversification began after breakup of Gondwana, probably Oligocene or Miocene.
- Most species have formed during and after the Miocene-era aridification of Australia and other southern continents.
- Narrow tropical "waist" of Central America may help explain absence of tribe from S. America.

Future Work

- Better outgroup sampling and additional fossil calibrations (e.g., Prasiini)
- Biogeographic reconstructions to test the "Out of Australia" Hypothesis
- In-depth phylogenetic analysis of widespread, speciose Australian genera

The End