



# Automated acoustic observatories

## Scaling for the future

Ed Baker  
University of York



# What's the big goal?

Historically there are many.

- ▶ How many species are there?
- ▶ What are the distributions of these species?
- ▶ What do these species do?
  
- ▶ Can we accurately understand (model) an ecosystem?
- ▶ Can we do this for the entire biosphere?



Can we do everything?






Can we do everything?

No.





# How many species are there?

## **From an old sound recording to a new species in the genus *Horatosphaga* (Orthoptera: Tettigonioidae: Phaneropterinae: Acrometopini)**

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# What are the distributions of species?

Remarkably and immediately preceding this discovery, a large colony of **Tree Cricket** *Oecanthus pellucens* was also discovered at Dungeness in 2015. With at least 50 singing males and a similar number of females as well as nymphs this population may have a good chance of persisting (Walker, *loc. cit.*). This species had previously been recorded as singletons in Cambridge in 1996 and at Sittingbourne in Kent in 2005 (Beckmann & Sutton, 2015), and in 2010 the first breeding colony was reported from Jersey (David, 2013). In 2016, the Dungeness colony was again observed in August by David Walker, who estimated that over 100 singing males were present at the site (Sutton, 2016; Beckmann & Sutton, 2016).



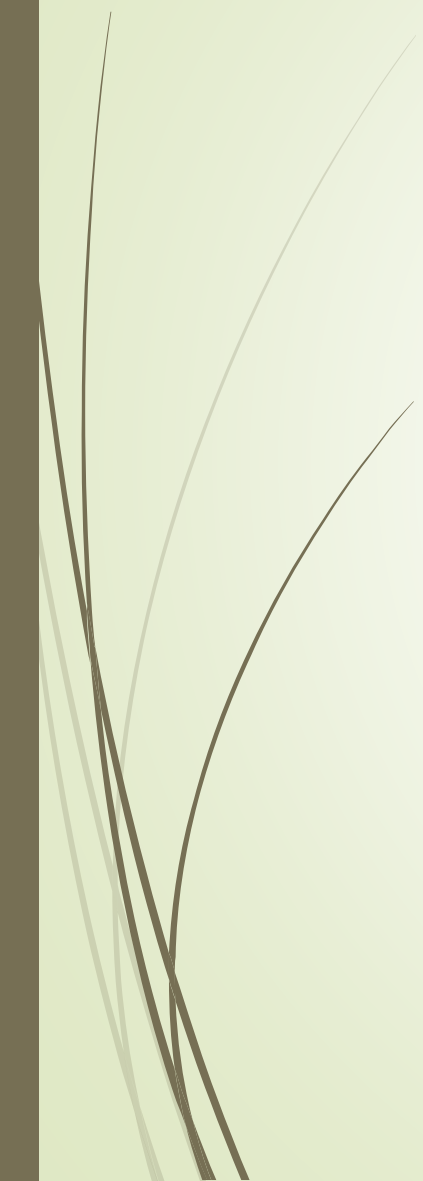
# What do these species do?

## Abstract

1. Sexual signals may be acquired or lost over evolutionary time, and are tempered in their exaggeration by natural selection.
2. In the Pacific field cricket, *Teleogryllus oceanicus*, a mutation (“flatwing”) causing loss of the sexual signal, the song, spread in <20 generations in two of three Hawaiian islands where the crickets have been introduced. Flatwing (as well as some normal-wing) males behave as satellites, moving towards and settling near calling males to intercept phonotactic females.



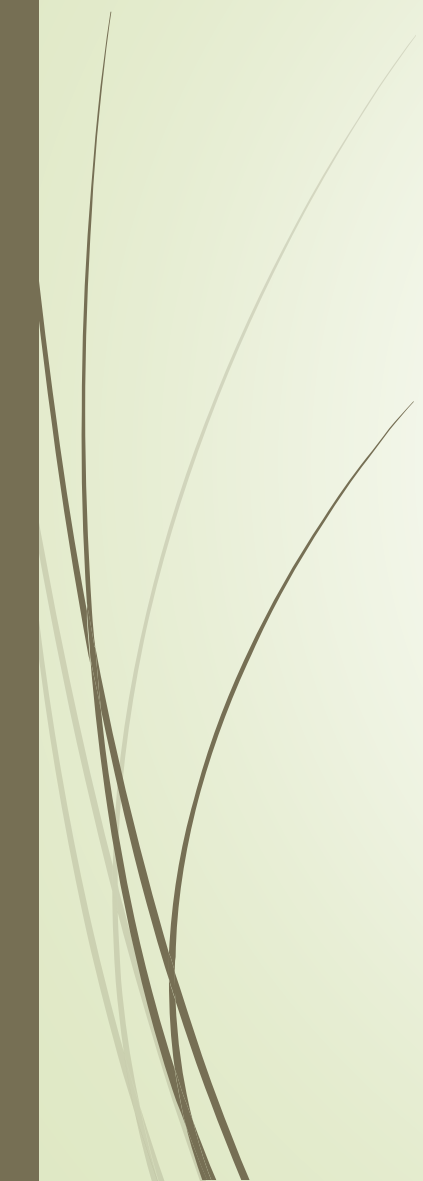
# The case for automation

- ▶ A desire to do more with the current resources
  - ▶ Our collective abilities are insufficient to fulfil the major goals for every species
- 



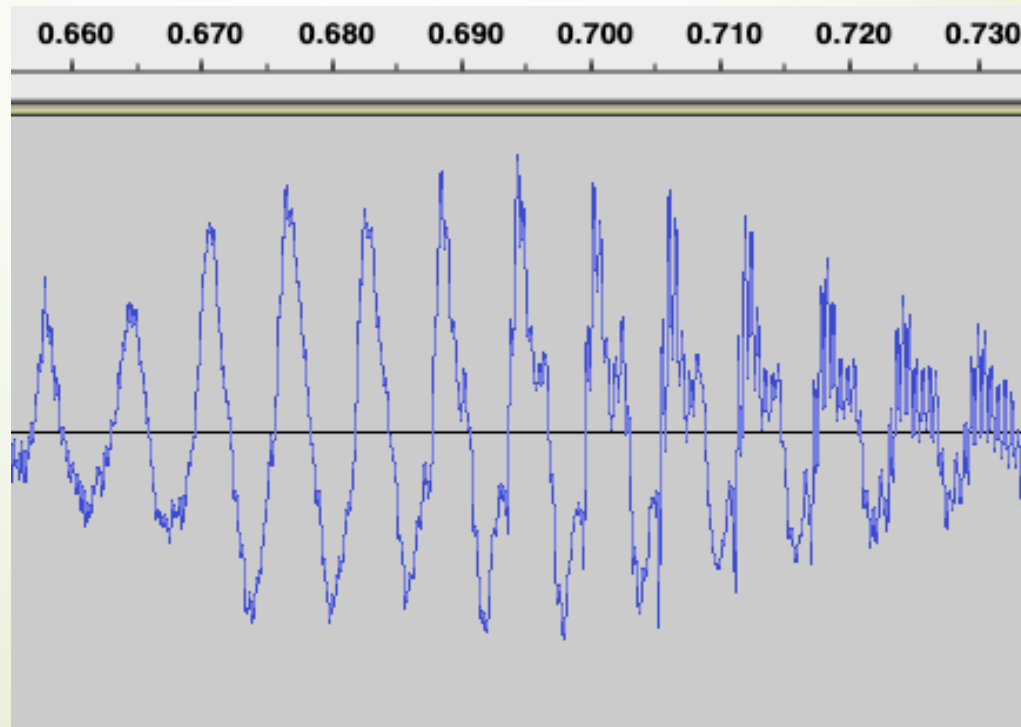


# The case for sound

- At it's most basic it is a 2-dimensional problem (amplitude varying with time)
- 

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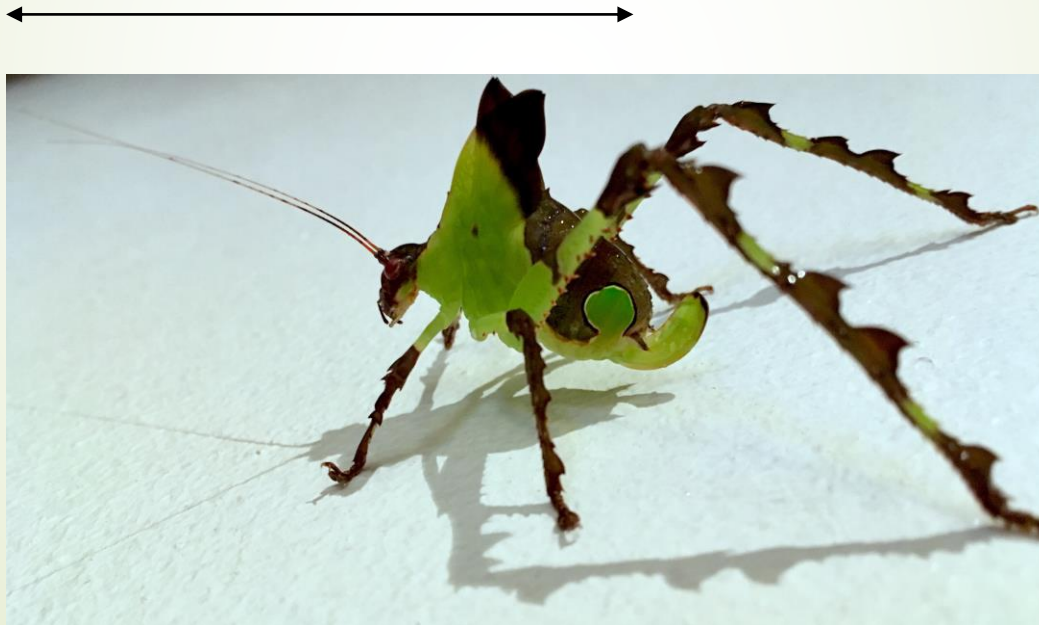
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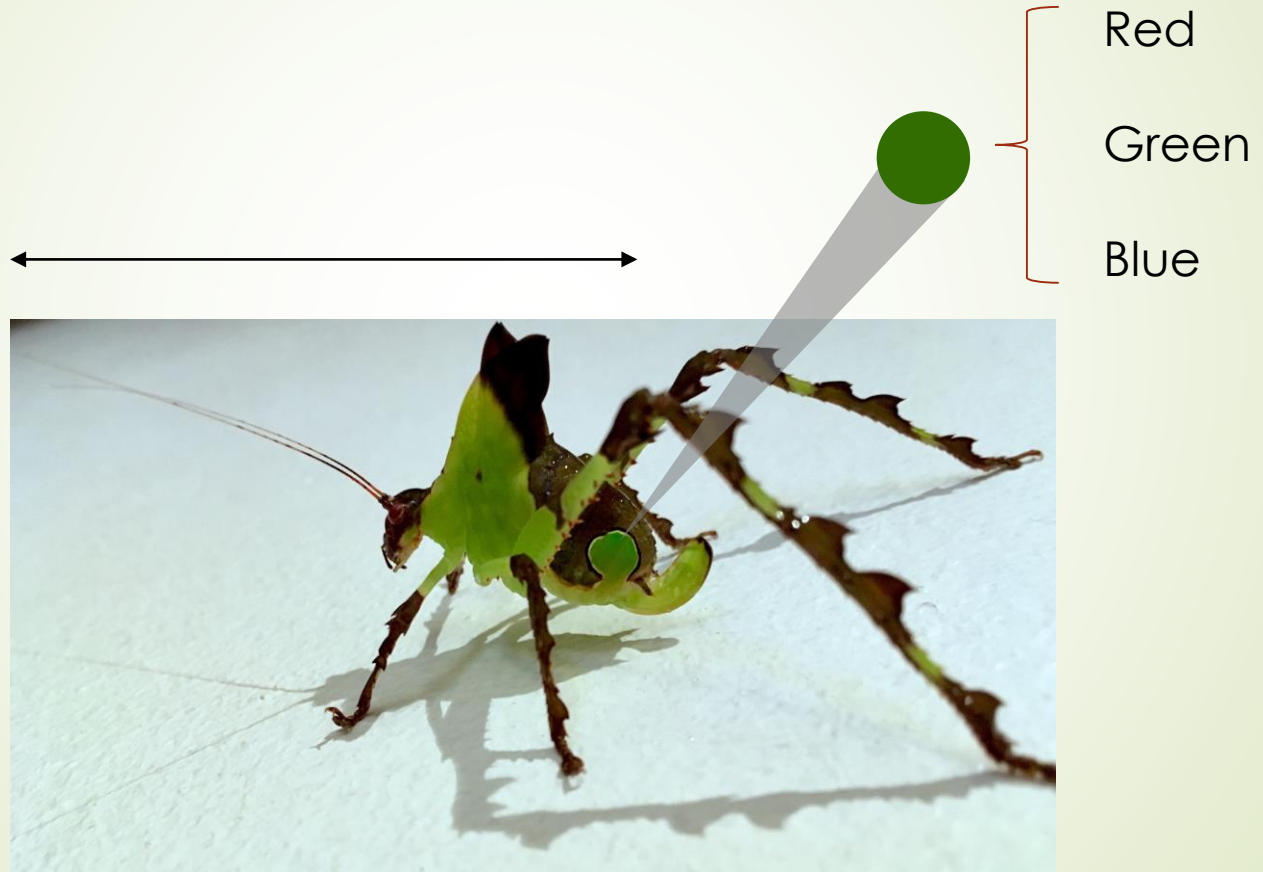
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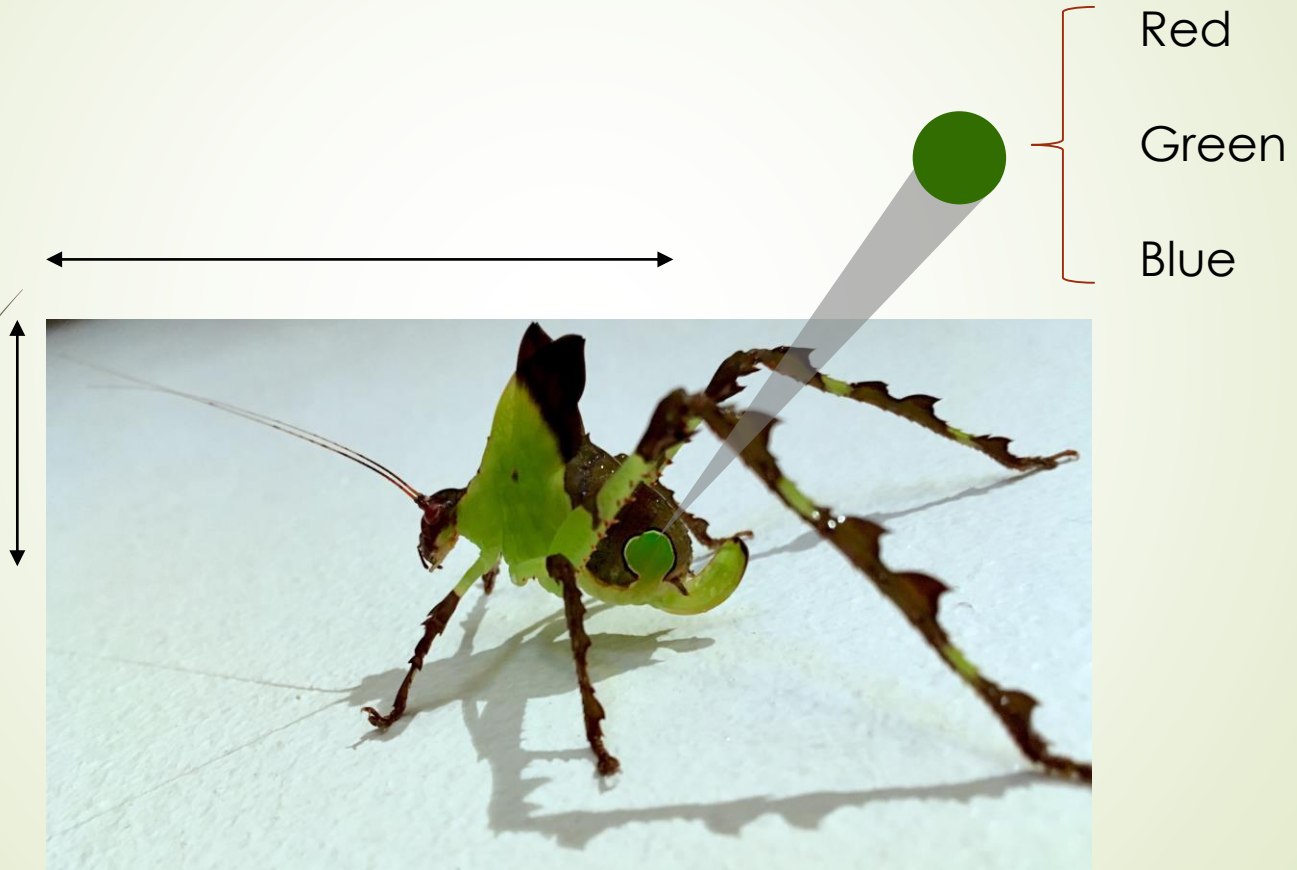
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5-dimensional





Why is this important?



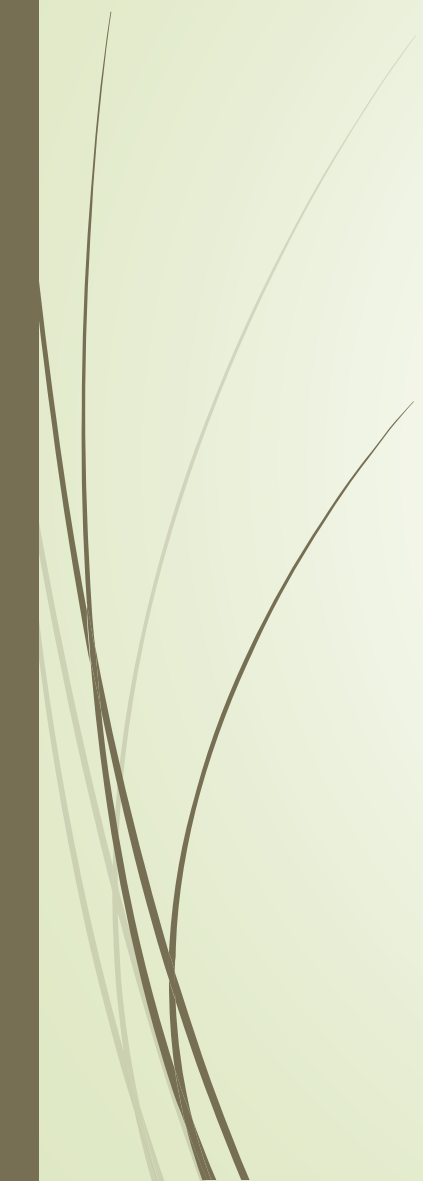


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- 



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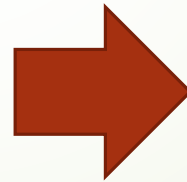
1990s

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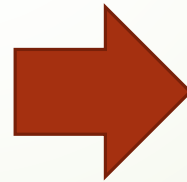
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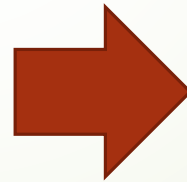
£2,000



£25

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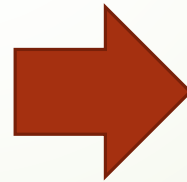
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8x cheaper

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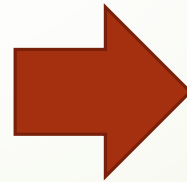


720x more calculations per second



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> 1,500x more RAM



# Correcting for inflation..

Increase in computational power per £: 57,600x

Using about 1/4000 of the energy



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**Disposable super computer than can be battery/solar powered.**



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Limited resource, pressure to partition





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- ▶ Frequency of calls



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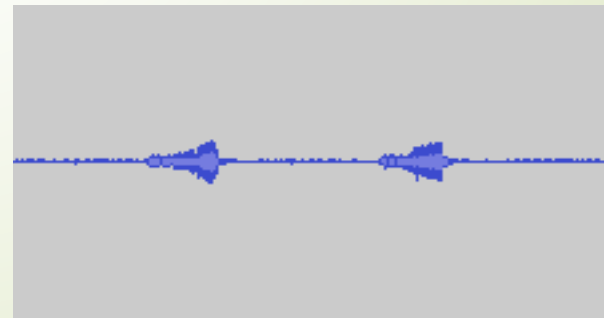
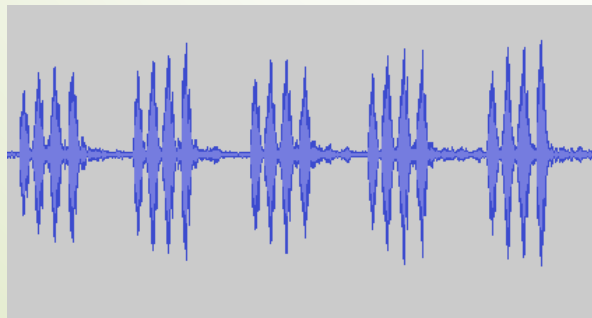
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- ▶ Frequency of calls
- ▶ Time of calls (time of year; time of day)

# The case for sound

Limited resource, pressure to partition

- Frequency of calls
- Time of calls (time of year; time of day)
- Structure of calls





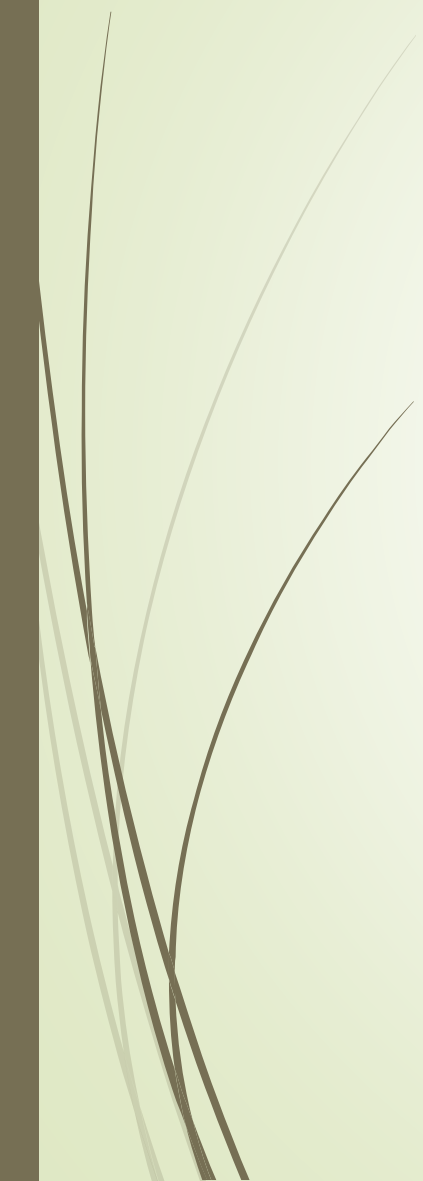


# The case for Orthoptera

- ▶ Tradition as model organisms (ALRC)
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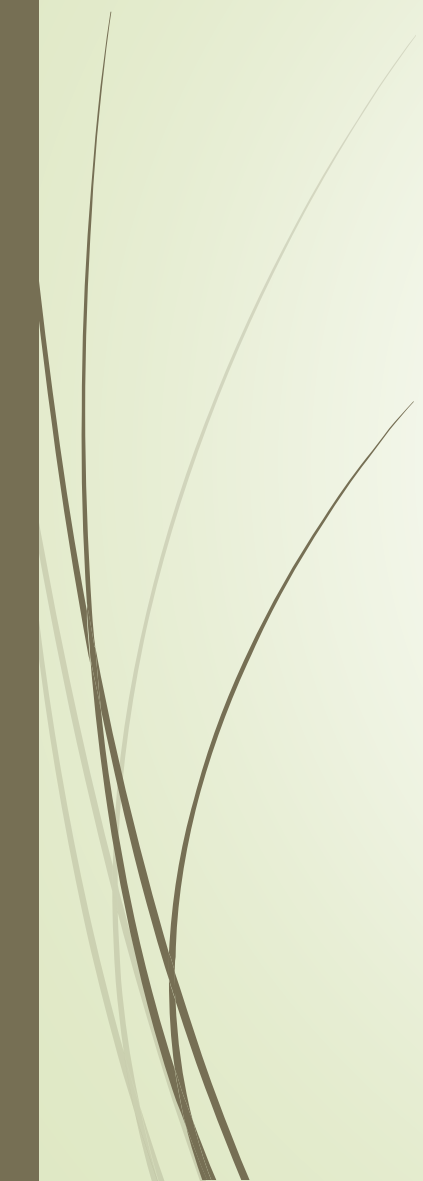


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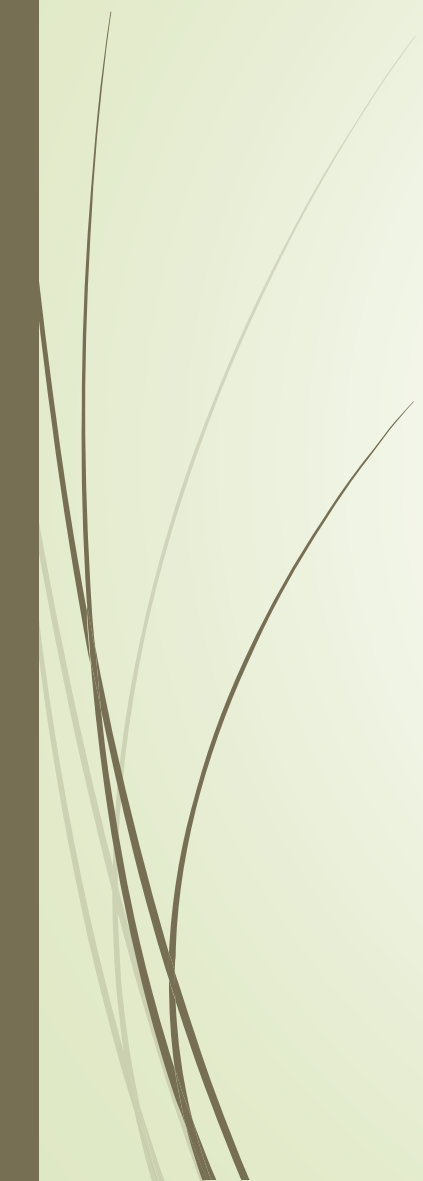


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# The case for Orthoptera

- Tradition as model organisms (ALRC)
- Song is stereotypical/neurologically controlled  
INATE not LEARNED
- Major cause of variation is temperature  
PREDICTABLE
- Calling song attracts mates



# What should we automate?

Start with what people can't do

- ▶ Can work in human-audible and ultrasound simultaneously



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Start with what people can't do

- ▶ Can work in human-audible and ultrasound simultaneously
- ▶ Can do 24/7 for a week without sleeping





# Major concerns

- Unaccountable
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How did the computer reach that conclusion?
- ▶ Error rate  
How do we know the computer is right? (False positive / false negative)



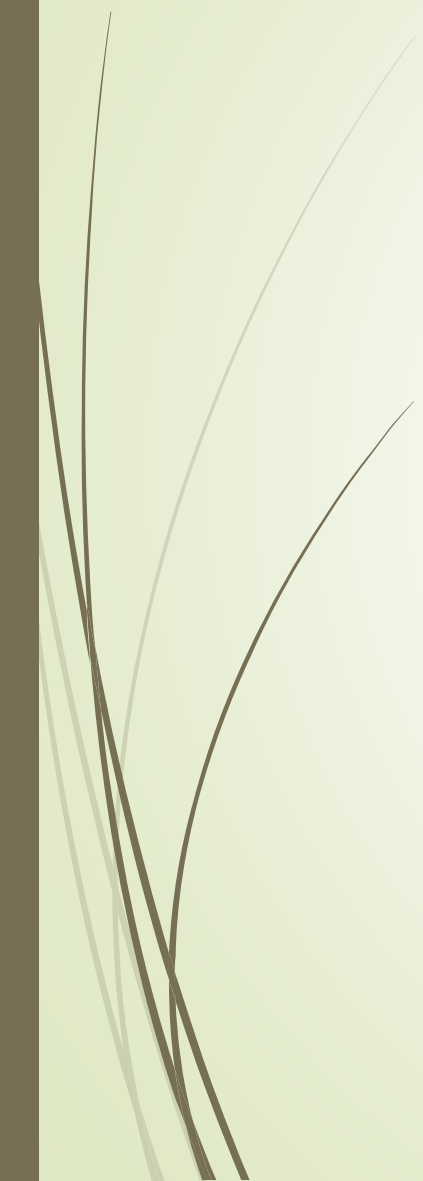

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How did the computer reach that conclusion?  
**If we choose how it makes a decision, we can make it explain how I got there**
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**We can test this and get reliable numbers**

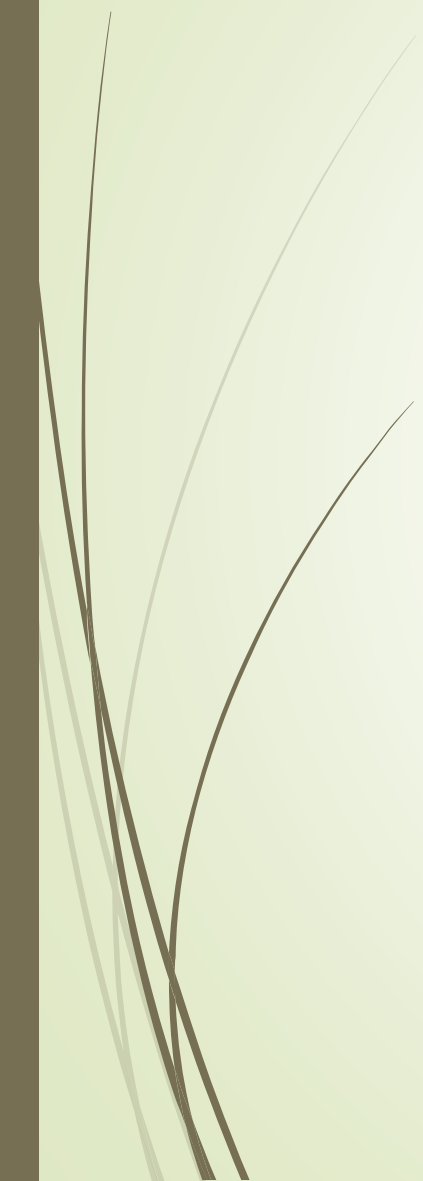



# What do people do?

- ▶ Unaccountable  
How did the computer reach that conclusion?  
**If we choose how it makes a decision, we can make it explain how I got there**  
**Cite the published key / collection used to make ID**
- ▶ Error rate  
How do we know the computer is right? (False positive / false negative)  
**We can test this and get reliable numbers**  
**Relies on every study depositing voucher specimens**



There are an awful lot of publications that don't link their results to voucher specimens, keys, sound recordings, or anything else



Automated systems can do this  
on their own



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How did the computer reach that conclusion?  
**If we choose how it makes a decision, we can make it explain how I got there**  
**Cite the published key / collection used to make ID**  
**Cite the algorithm and it's version used to make the ID**
- ▶ Error rate  
How do we know the computer is right? (False positive / false negative)  
**We can test this and get reliable numbers**  
**Relies on every study depositing voucher specimens**  
**Automatically submit sample sound files to a repository**



Current state







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- ▶ Systems are naïve
  - ▶ Not aware of the distribution/behavior/etc of the species they monitor
  - ▶ Only aware of a handful of species



Where do we go from here?







# Where do we go from here?

Make systems less naive





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- Account for species distribution and acoustic behaviour



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- Some work happening



# Where do we go from here?

Make systems less naïve

- ▶ Account for species distribution and acoustic behaviour

Figure out how to get a measure of abundance

- ▶ Some work happening

How do we deal with songs of unknown species?



# Automated Acoustic Observatories



Song Detection  
and Classification



# Automated Acoustic Observatories

Song Detection  
and Classification



Bats

Birds

Orthoptera

# Automated Acoustic Observatories





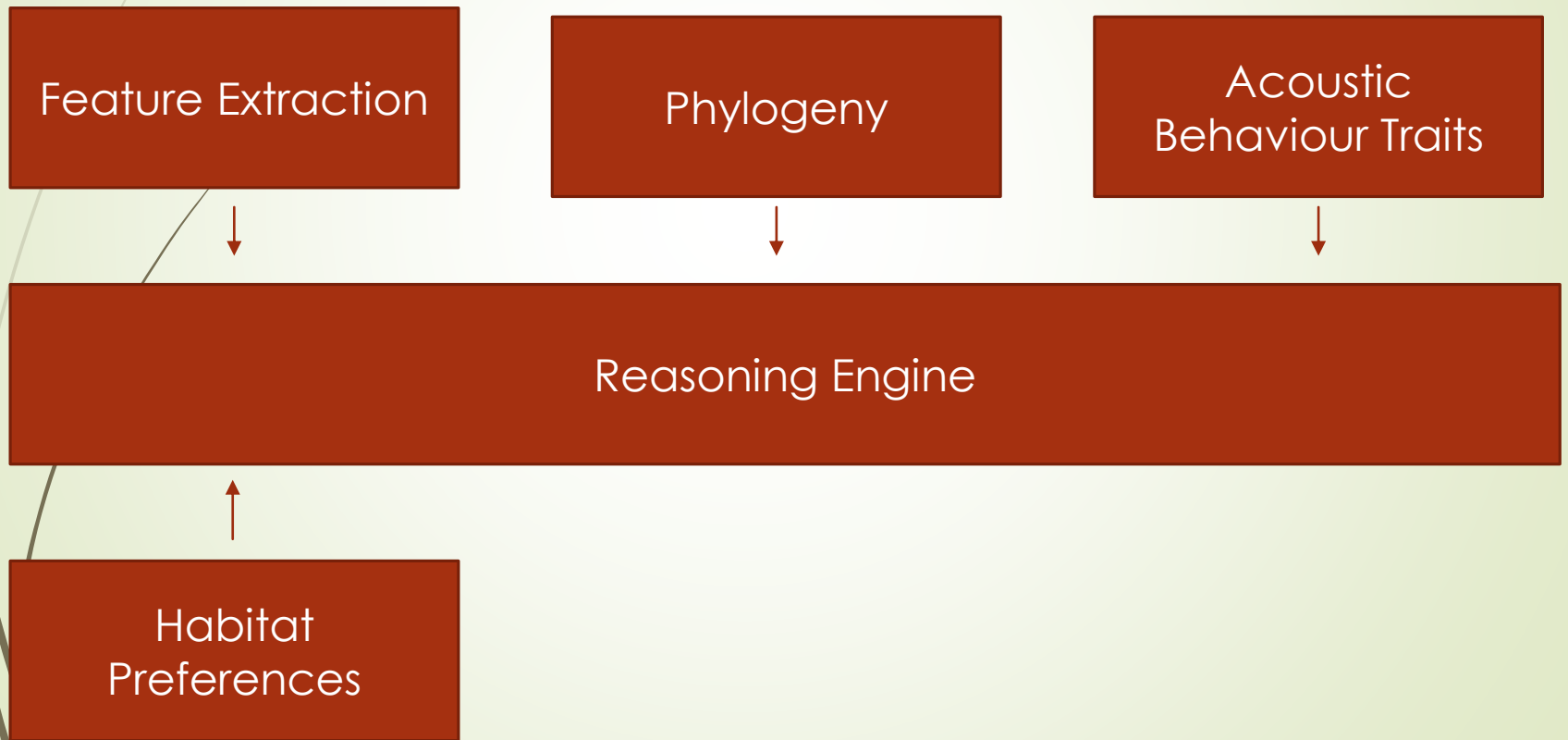
# Automated Acoustic Observatories

Feature Extraction

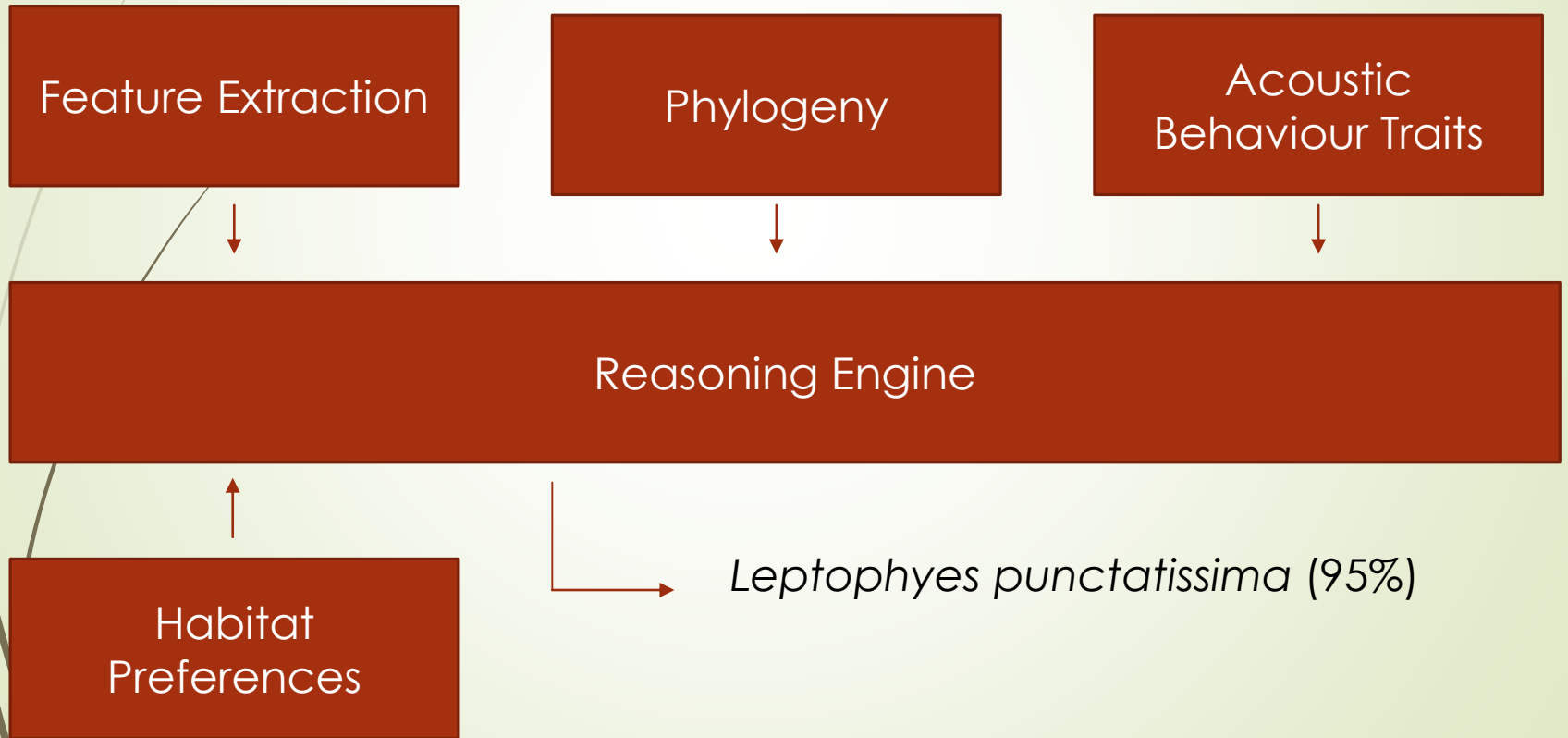


Reasoning Engine

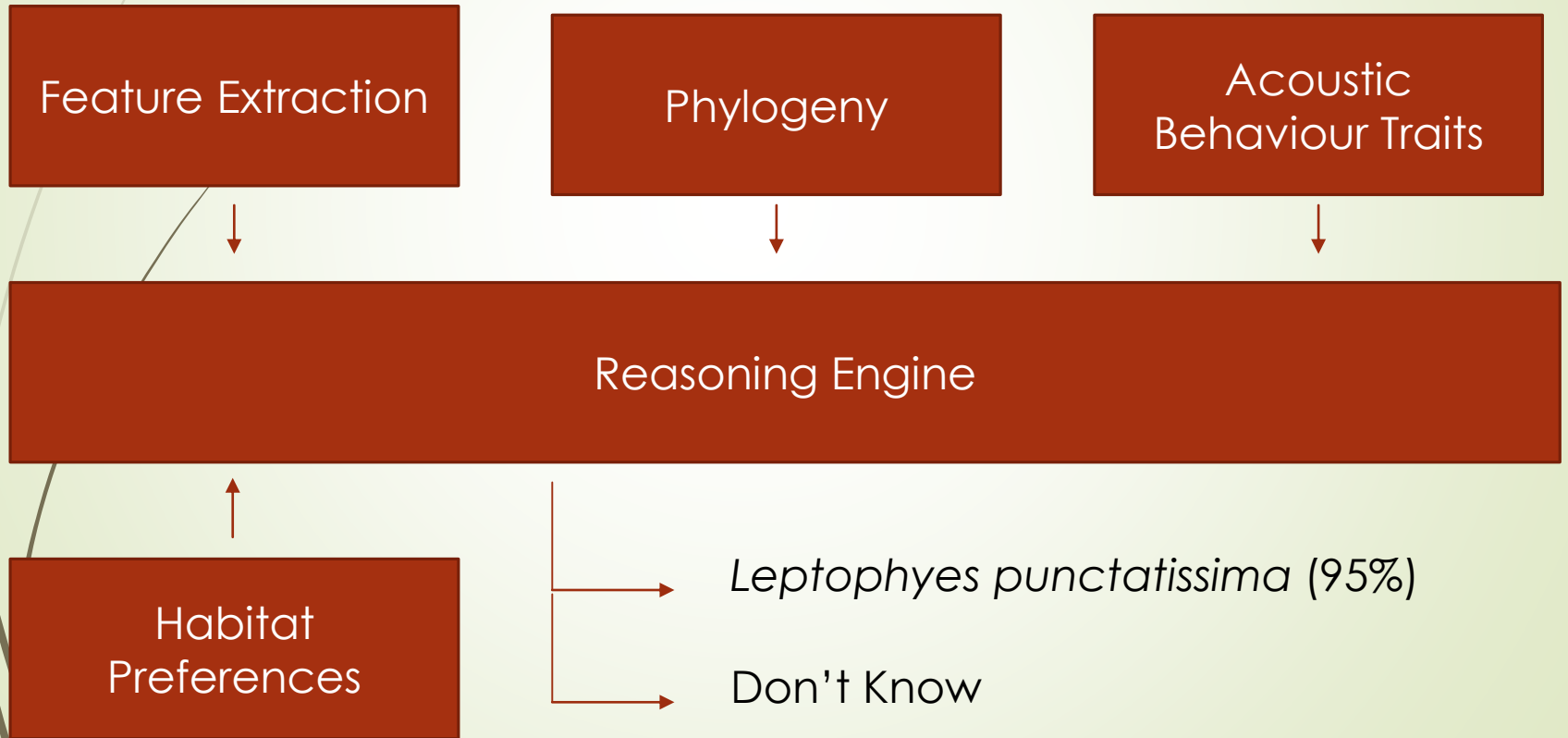
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