Dr. Volker Runkel
ecoObs GmbH

Automation in bat detectors and call identification

capabilities, current limitations and perspectives

III Spanish Bat Meeting
A Coruña, November 20th and 21st 2010

Setting the scene

- investigations of bat sonar systems
  - intensive research on acoustics and ecology (Griffin 1960, Pye 1973, Pye 1979, Ahlen 1981, Fenton 1981, Barclay 1982, Weid 1985, Fenton 1988, ...)
- bats are more easily accessible today
- since a few years increased interest: nature conservation and FFH/Natura2000 (EU)

Increased needs

- society, NGOs and government need reliable data for planning
- sampling locations/requests get more elaborate
  - long-term monitoring
  - sites like nacelles of wind turbines, motorway borders, ...
- nature consultants need tools for surveys that are
  - economical
  - automatic
  - fool-proof

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unbiased collection and objective analysis of activity data

Why automation?

- Large data sets in monitoring
- reproducible, comparable data
- improved surveys
  - multiple sampling sites at the same time
  - higher rate of sampling possible (not only a few nights)
- Economical: example based on batcorder

Manual detection / analyis				**Automatic detection/analysis**			
	Time	Basis	Sum		Time	Basis	Sum
Field work (16 nights á 8 hours)	128 hrs	45.- €	5760.- €	Deployment of 2 batcorders (16 x 2 hours)	32 hrs	45.- €	1440.- €
Analysis of 800 recordings (20/hr)	40 hrs	40.- €	1600.- €	Database import, analysis & control (2 hr / night)	32 hrs	40.- €	1280.- €
Overall			**7360.- €**	**Overall**			**2720.- €**

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Difference: 4640€

Levels of automation

- unattended recording of activity in the field
- automatic detection of calls
- automatic measurement extraction
- automatic species result per bat pass

Requirements for automated detection

- reliable and comparable data
  - **objective** triggering/detection
  - **omnidirectional** for all frequencies
  - known and **calibrated** sensitivity
  - devices must be identical in „behaviour“
  - **high quality** recordings for automated identification
  - **no insensitive interval**

(after Hayes 2000)

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(after Hayes 2000)

- the user wants
  - independent/long runtime
  - weather-proof / robust
  - low price

Current solutions for unattended recording

- div. simple solutions (*Horchboxen* etc.)
- Anabat SD2 (Titley)
- BATLOGGER (Switzerland)
- Songmeter (Wildlife Acoustics)
- Pettersson D500x
- ecoObs batcorder

Anabat SD2

- Specs
  - frequency-division and zero-crossing analysis

- Pros
  - very small data amounts
  - GSM data transfer (with GLM add-on)
  - long runtime
- Cons
  - not calibrated and highly directional microphone
  - high reduction of data, sound data is lost
  - call analysis ± manual

BATLOGGER

- Specs
  - Samplerate 312.5kHz, 16 bit
  - SDHC/SD memory card
- Pros
  - Built in GPS
  - small, good for hand-held usage
  - database available with automatic analysis
  - different trigger functions
- Cons
  - not calibrated
  - low sampling rate
  - low runtime (18 hrs.)
  - directional microphone

batlogger.ch

SM2Bat

- Specs
  - Samplerate 192 kHz (stereo), 384 kHz (mono), 16 bit
  - SDHC/SD memory cards
- Pros
  - high data storage (4 cards)
  - rel. cheap, robust
  - stereo
  - battery runtime 9 nights
- Cons
  - not calibrated
  - low sampling rate
  - handling not optimized
  - no special call trigger

www.wildlifeacoustics.com/
sm2_bats.php

Pettersson D500x

- Specs
  - Samplerate 300/500 kHz, 16 bit
  - CF memory cards
- Pros
  - high data storage (4 cards)
  - high quality recordings
- Cons
  - not calibrated
  - field installation difficult
  - directional microphone
  - no special call trigger

batsound.com/
psondet.html#D500Xseries

batcorder

- Specs
  - Samplerate 500 kHz, 16 bit
  - SDHC memory card

- Pros
  - calibrated
  - sensitive bat call trigger
  - rugged design
  - high quality recordings
  - runtime 7 to 9 nights
- Cons
  - expensive

Problems

- microphone
  - directionality and its setup
  - frequency response
- call quality
  - signal to noise ratio
  - echos
  - samplerate
- comparability of devices
- ease of use
  - installation in the field, in nacelles, ...
- runtime
  - battery, storage
- triggering of recordings
  - bushcrickets, ...

Perspectives

- sensitivity/microphone calibration
  - auto-calibration (for the batcorder)
- battery and storage technology
  - longer runtime while high quality recordings
- smaller size/weight of units
  - easier deployment
- decentralised sensors, central storage
- online (pre-)analysis


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So, tell me: Who is calling?

Acoustic identification of bats

- **listening to calls** through heterodyne, frequency division or time expansion systems
  - using frequencies and rhythm
  - highly subjective
  - but better integration possible
  - visual information in addition
- depending on many influences and **not feasible for monitoring**
  - influences like who is listening, how long can you hear the bat, number of bats and species calling
- not suited for long term monitoring or comparison of locations

Analysis of recordings

- computerized analysis
  - spectrum, sonagram, ...

- manual measurement of single calls
  - comparison with literature
  - own experience

- overview of parameters
  - many articles, http://www.batecho.eu

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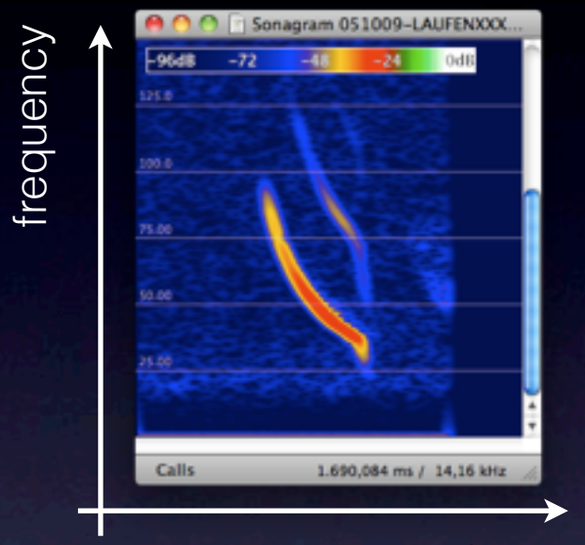

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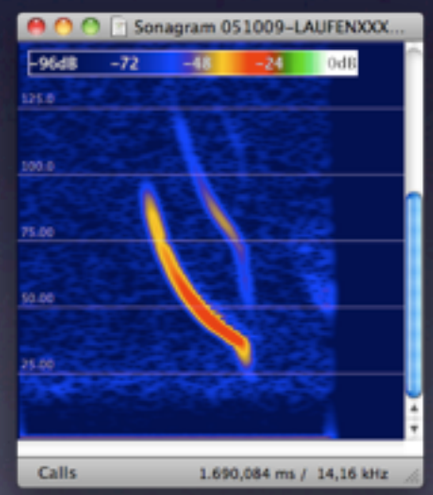

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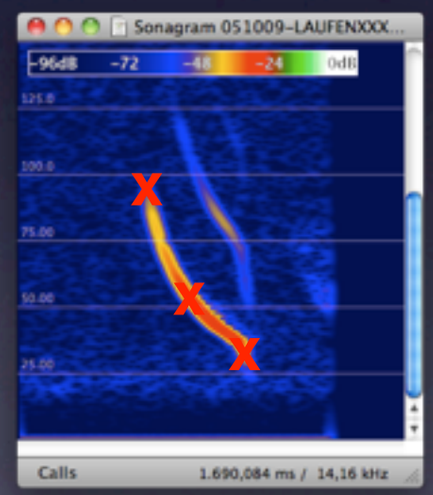

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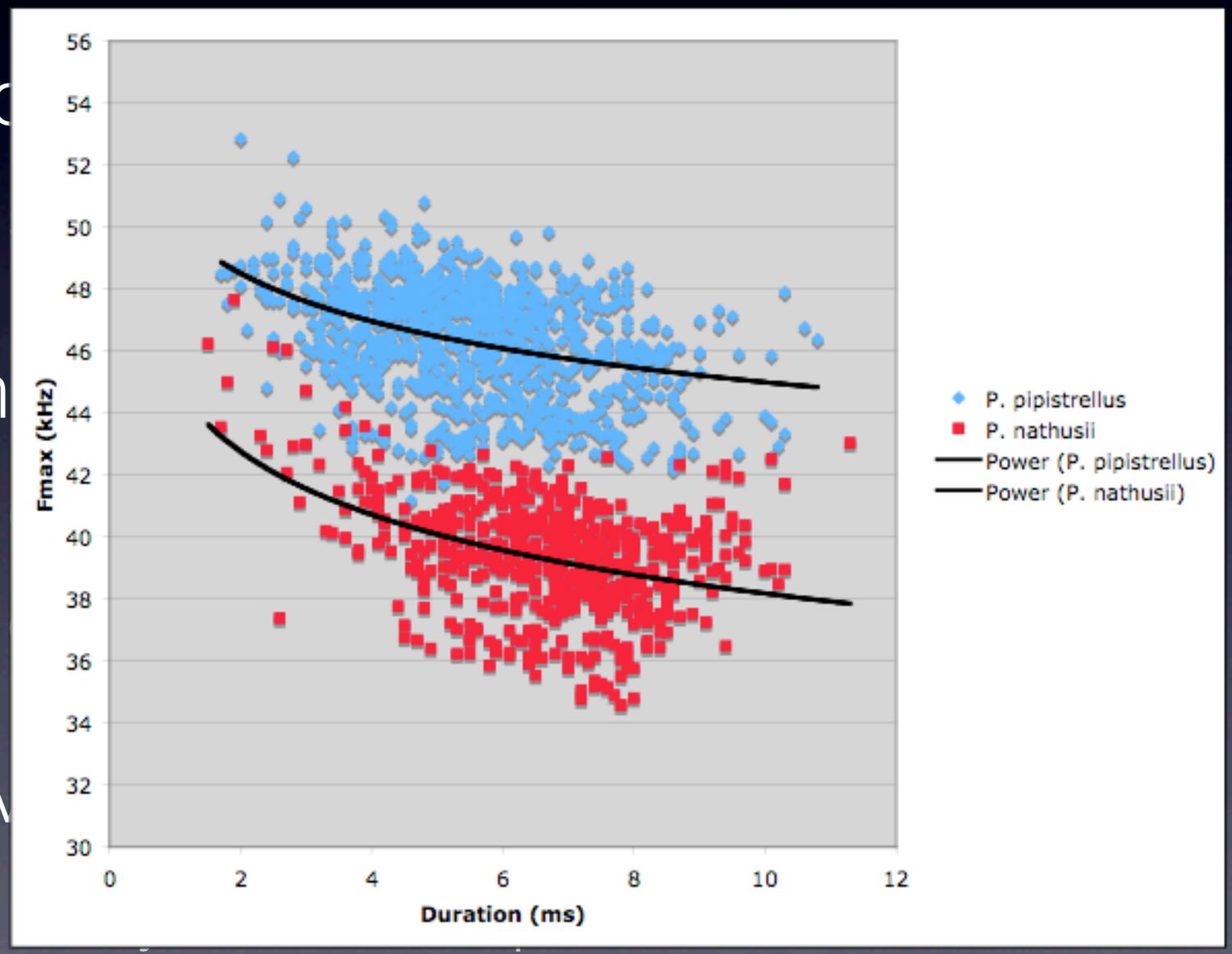

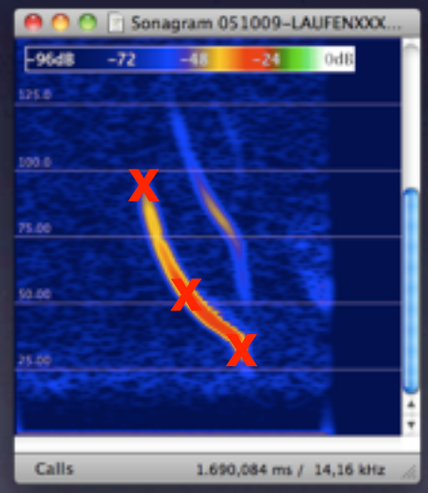

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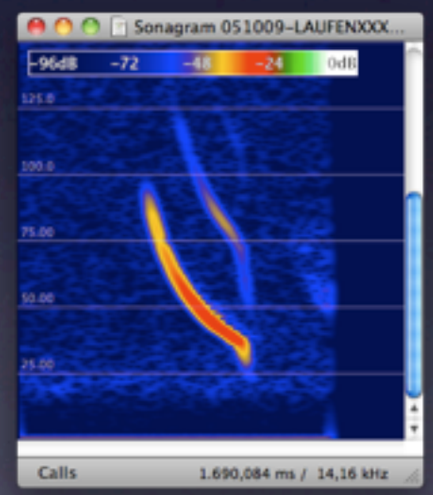

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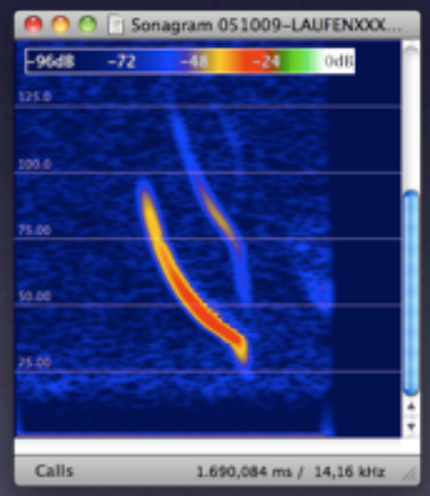
very time consuming
error-prone w/o statistical analysis
users w/o experience?



Automatic ID: Features

- Finding calls
  - **automatic extraction** of possible calls
- Call representation
  - **description of each call**: measurements, image, ...
- Species identification
  - comparison with **reference calls**
  - recognition of **outliers and other signals**
- Result extraction
  - None,one or many species per call sequence

Automatic ID: Problems

- Automated measuring and value extraction
  - quality of recordings, **echos**, **call fragments**, ...
  - speed/time for measuring
- Statistical analysis
  - different algorithms, **per call**, **per sequence**, weighting, ...
  - reference: **selection of calls**, social calls, outlier detection
  - also: **regional differences** (call variability)
- Extraction of results
  - **aggregation of results** per recording (multiple species)
  - number of species, order of species, ... **and all the *noise***

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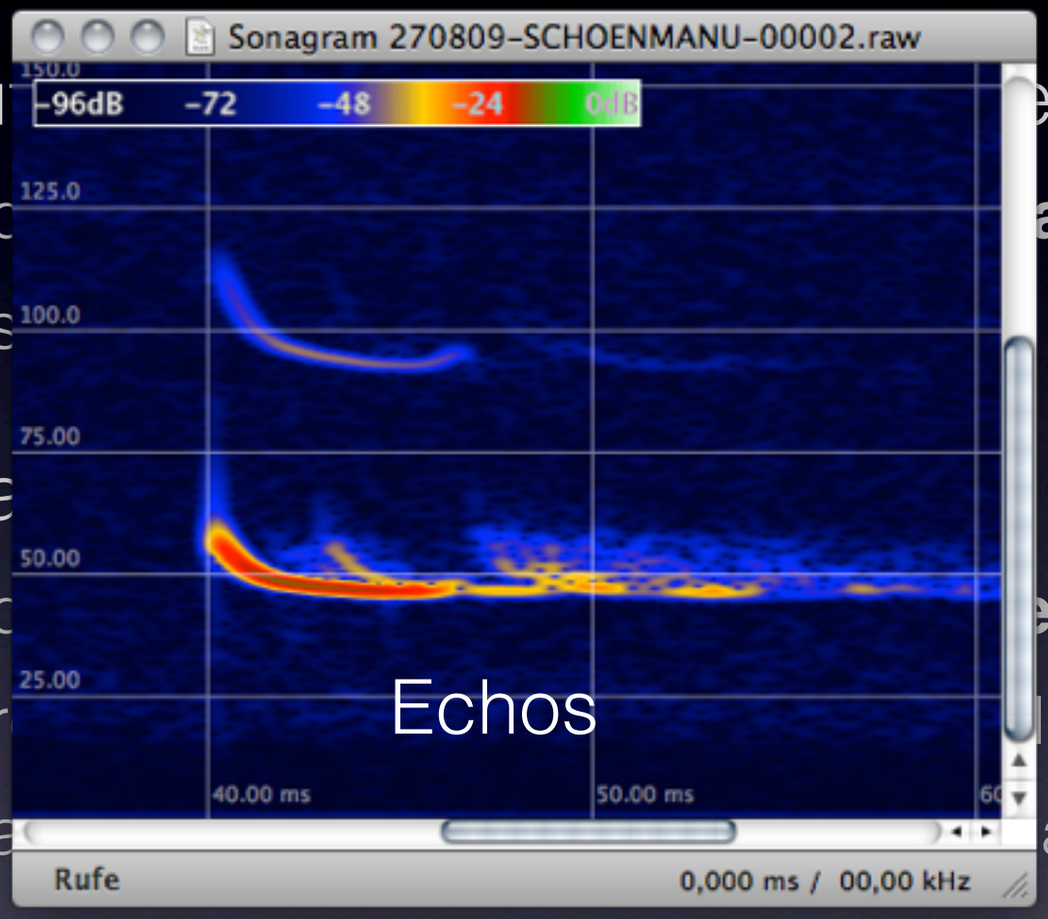
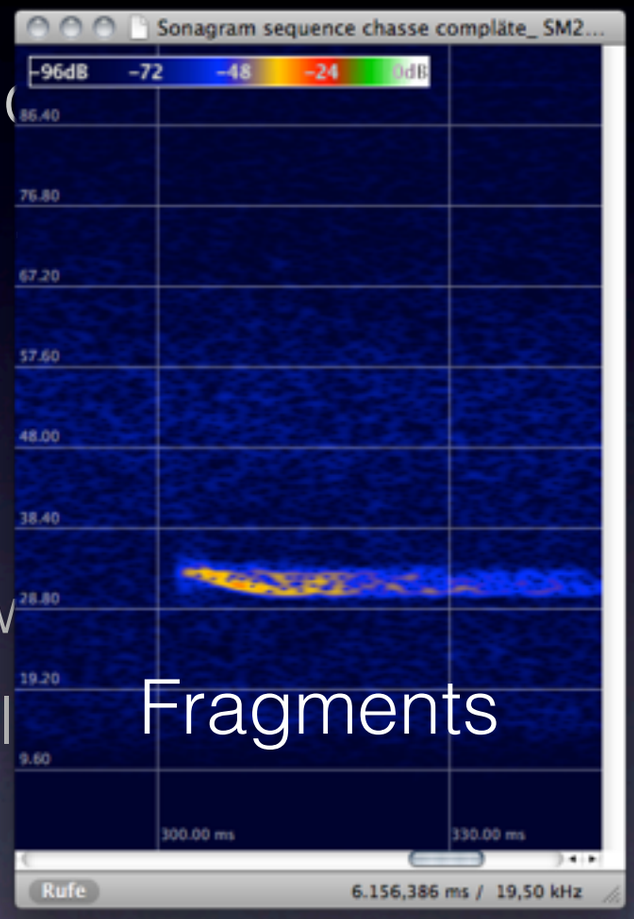


Echos



Fragments

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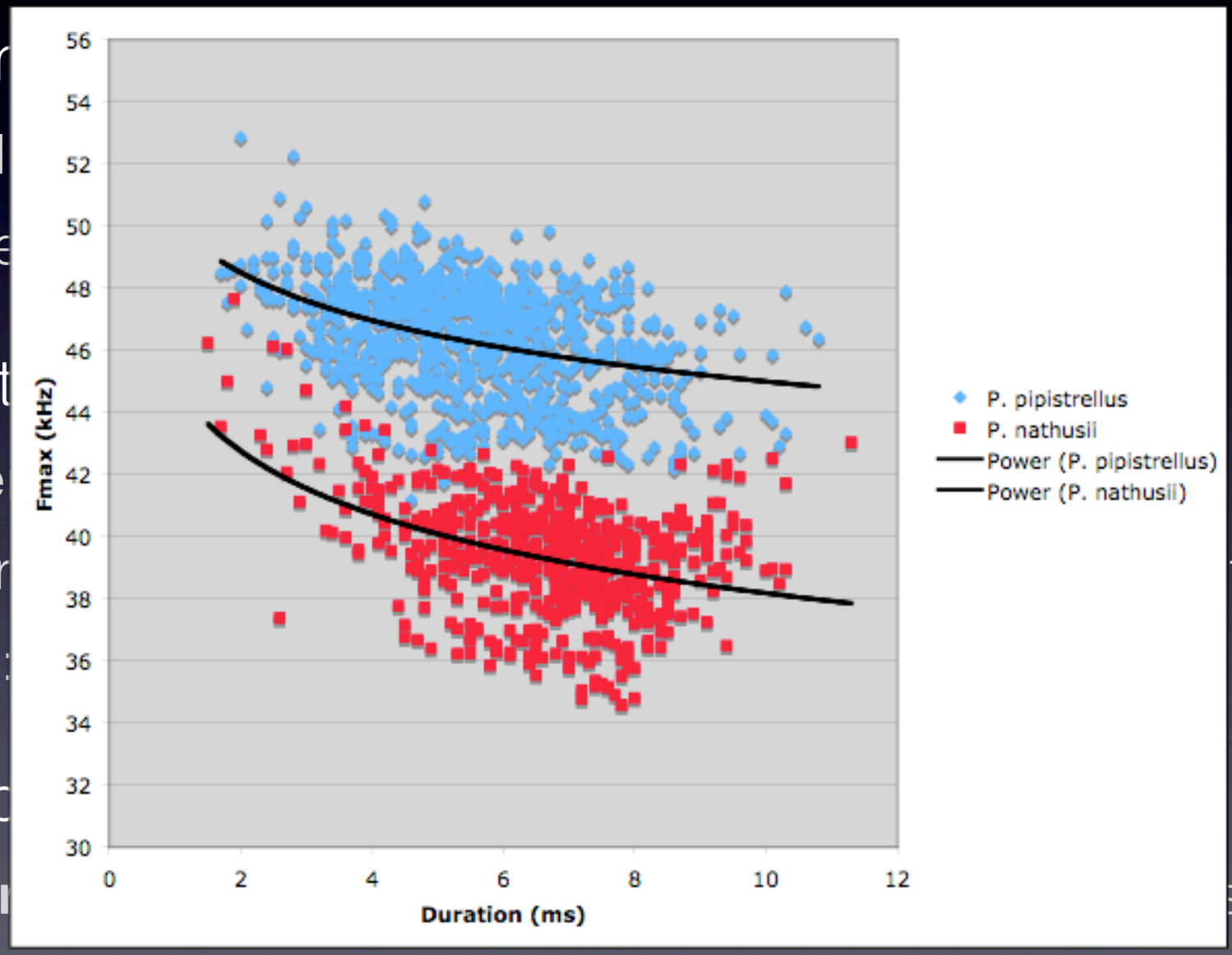

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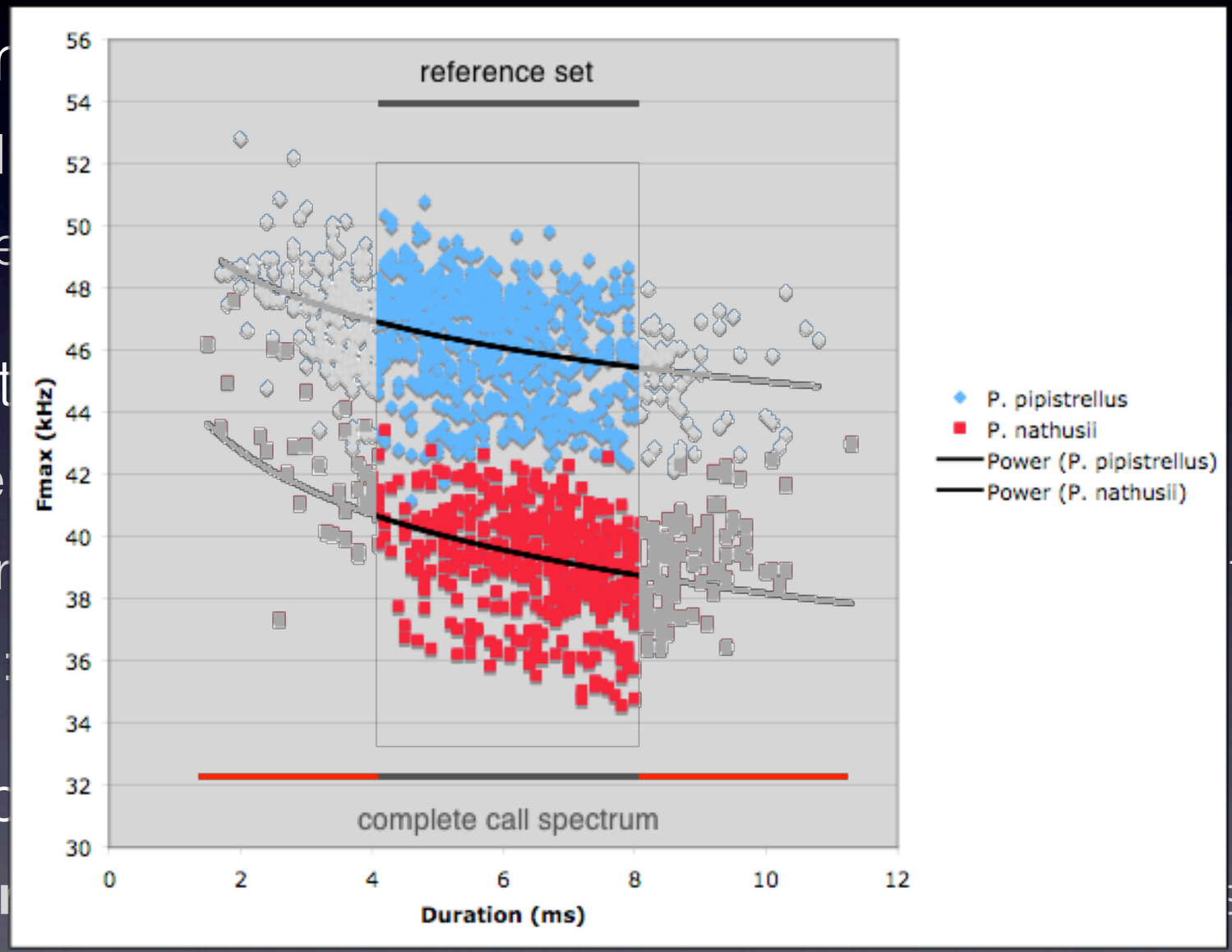

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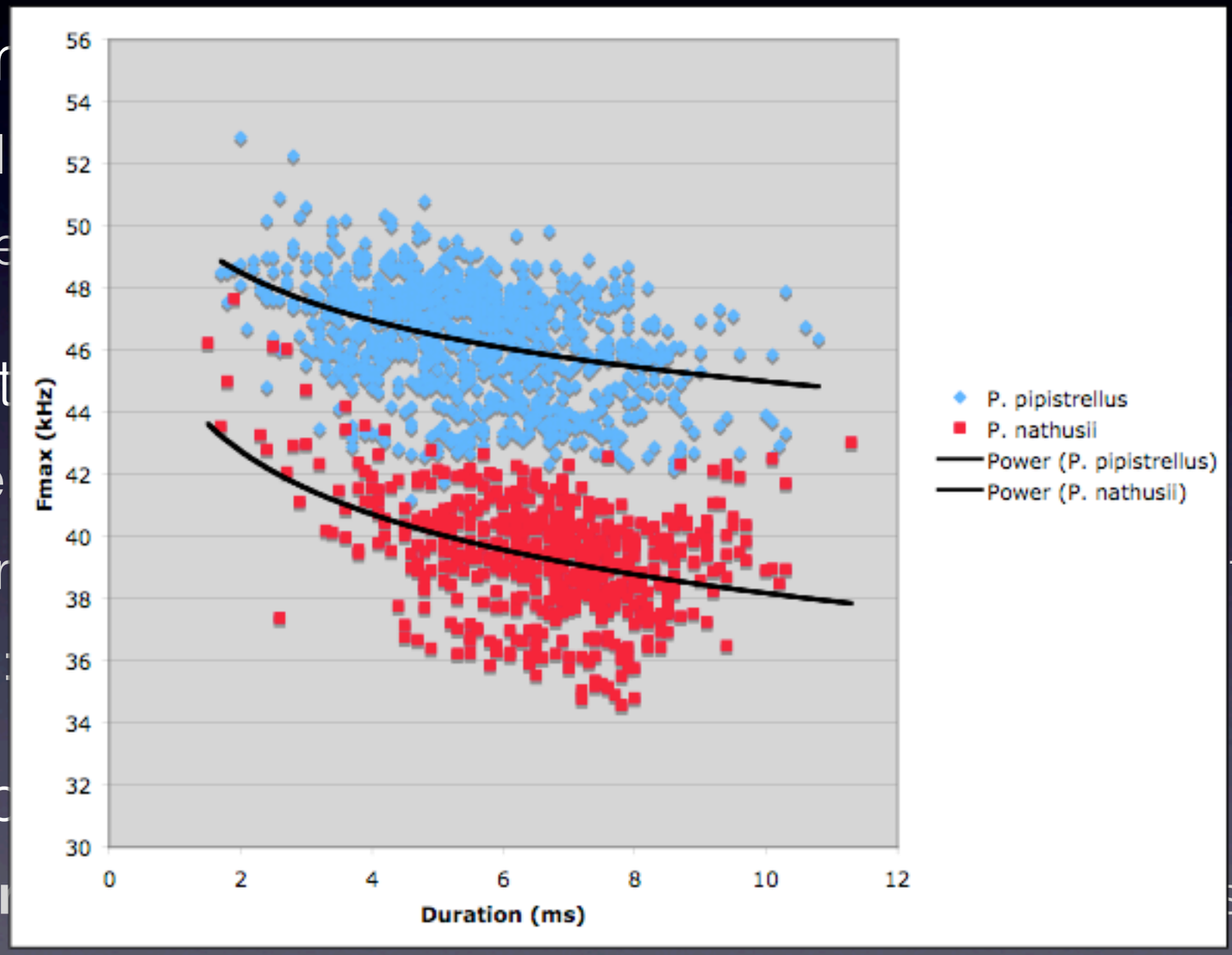

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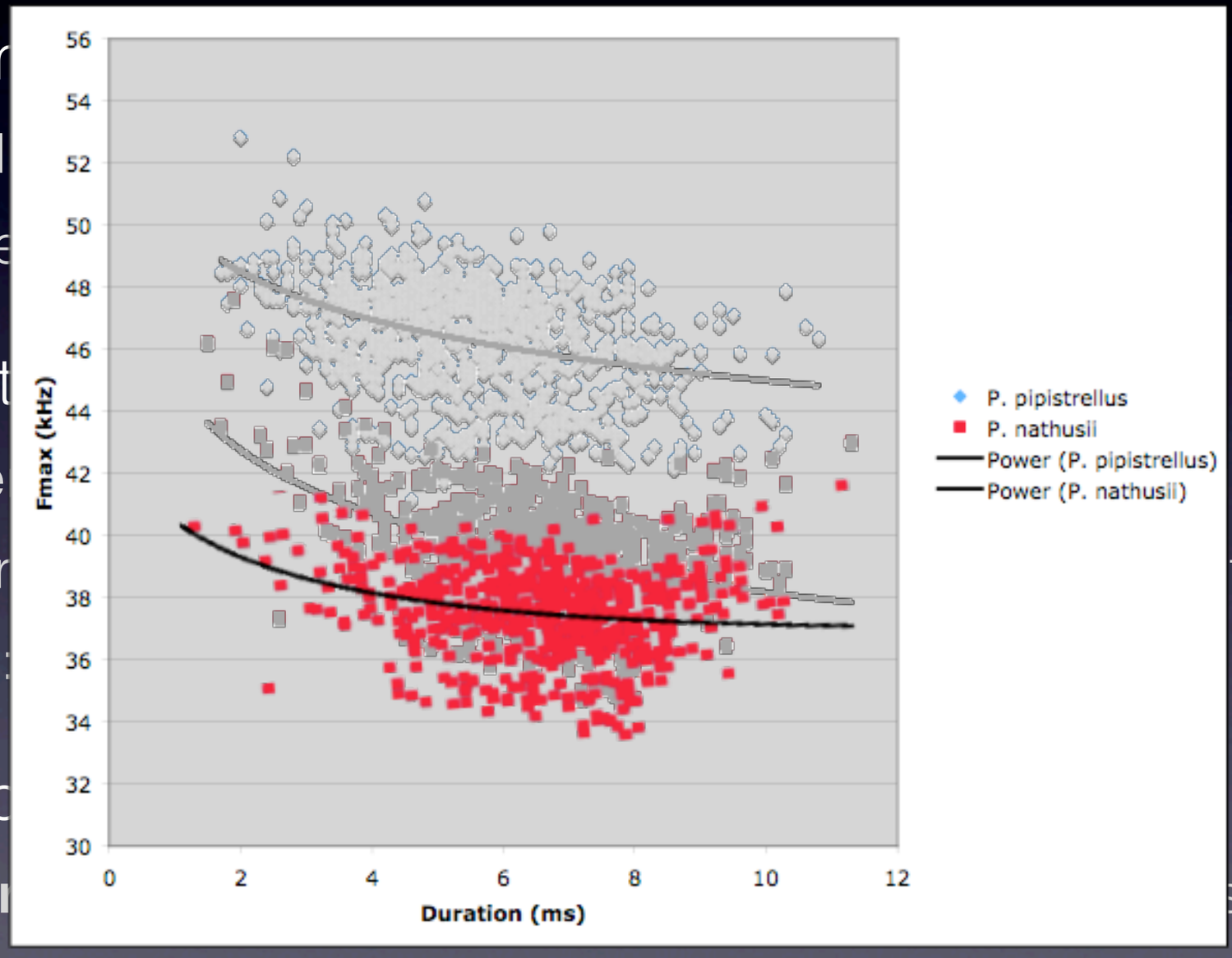

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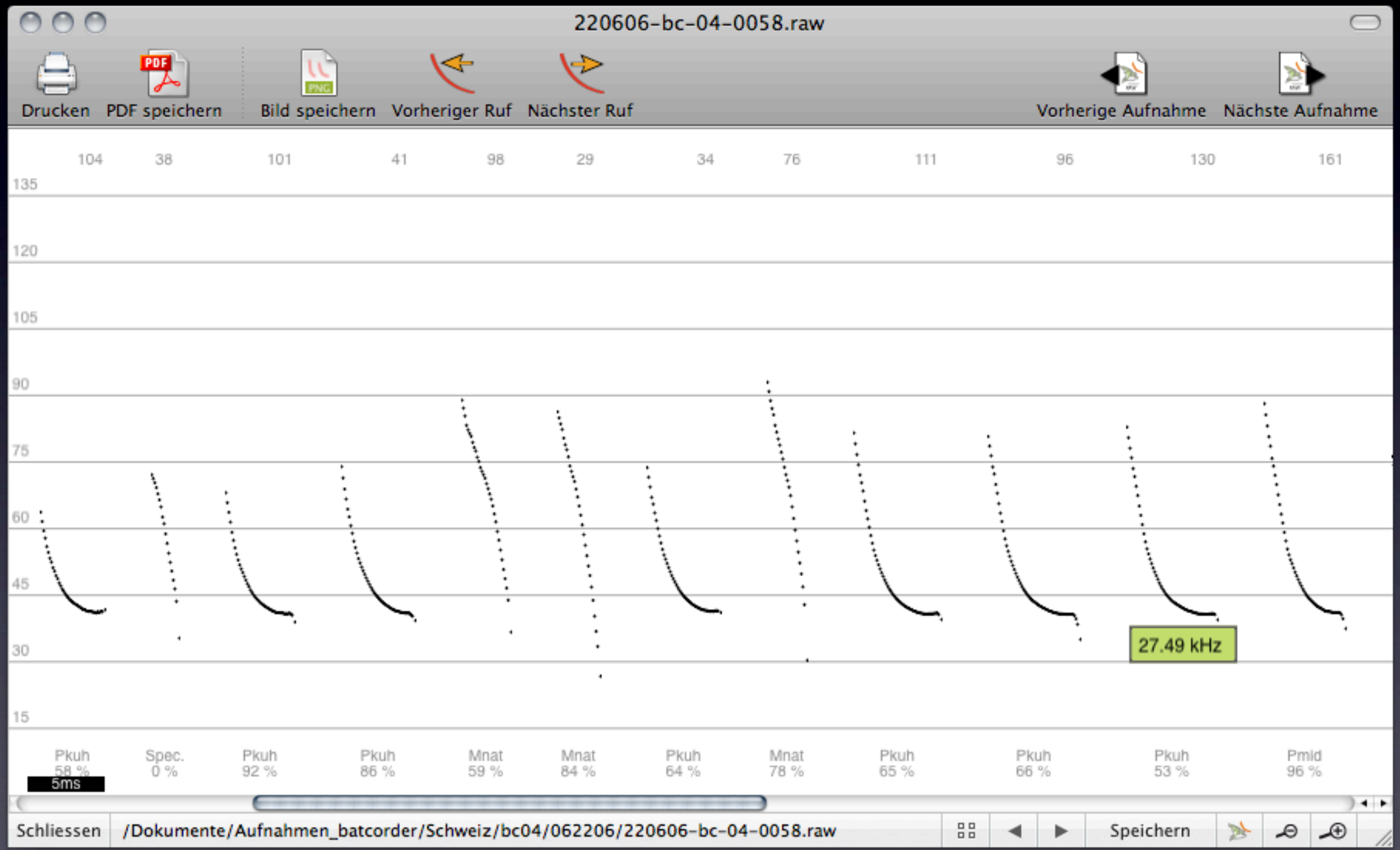

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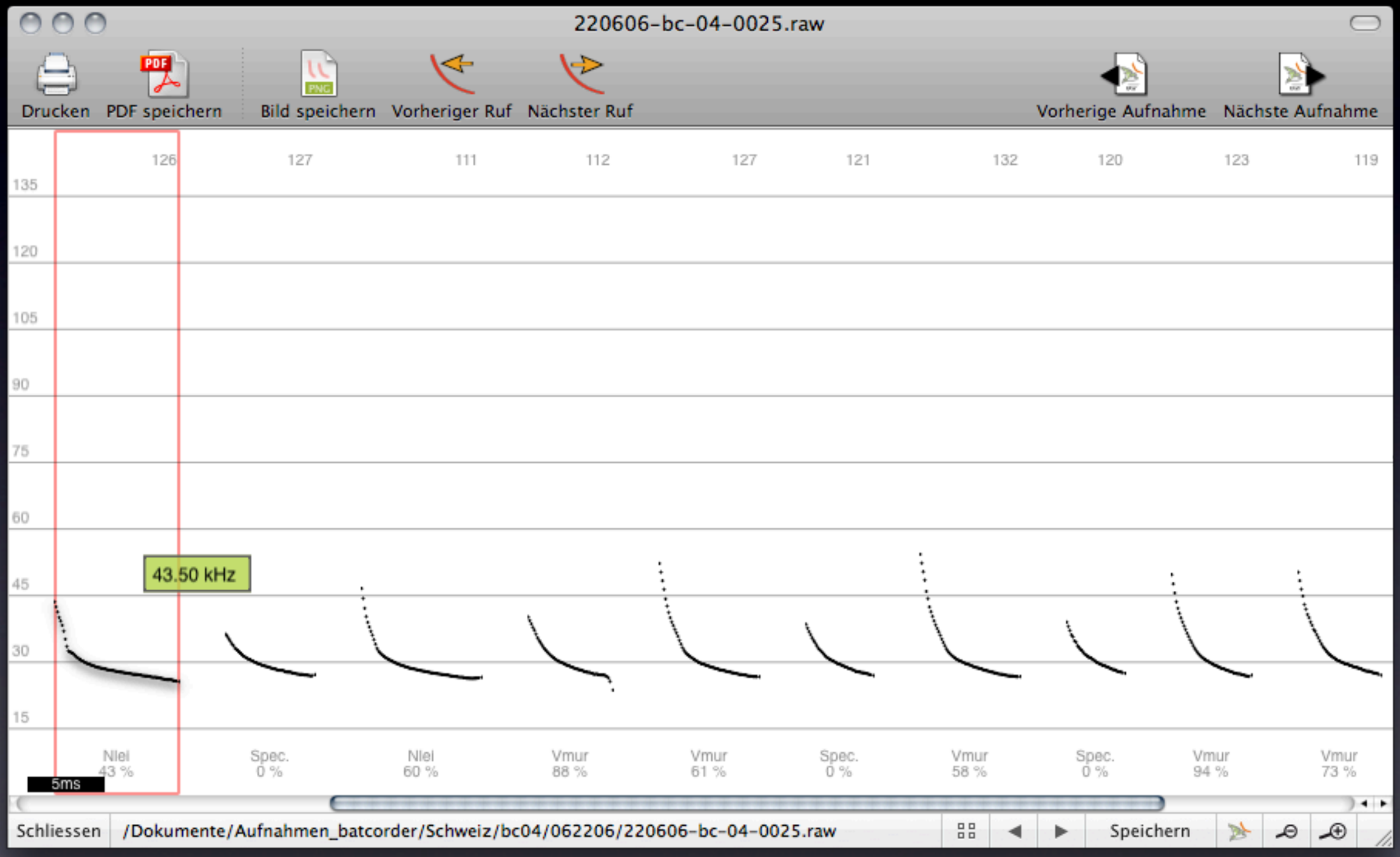
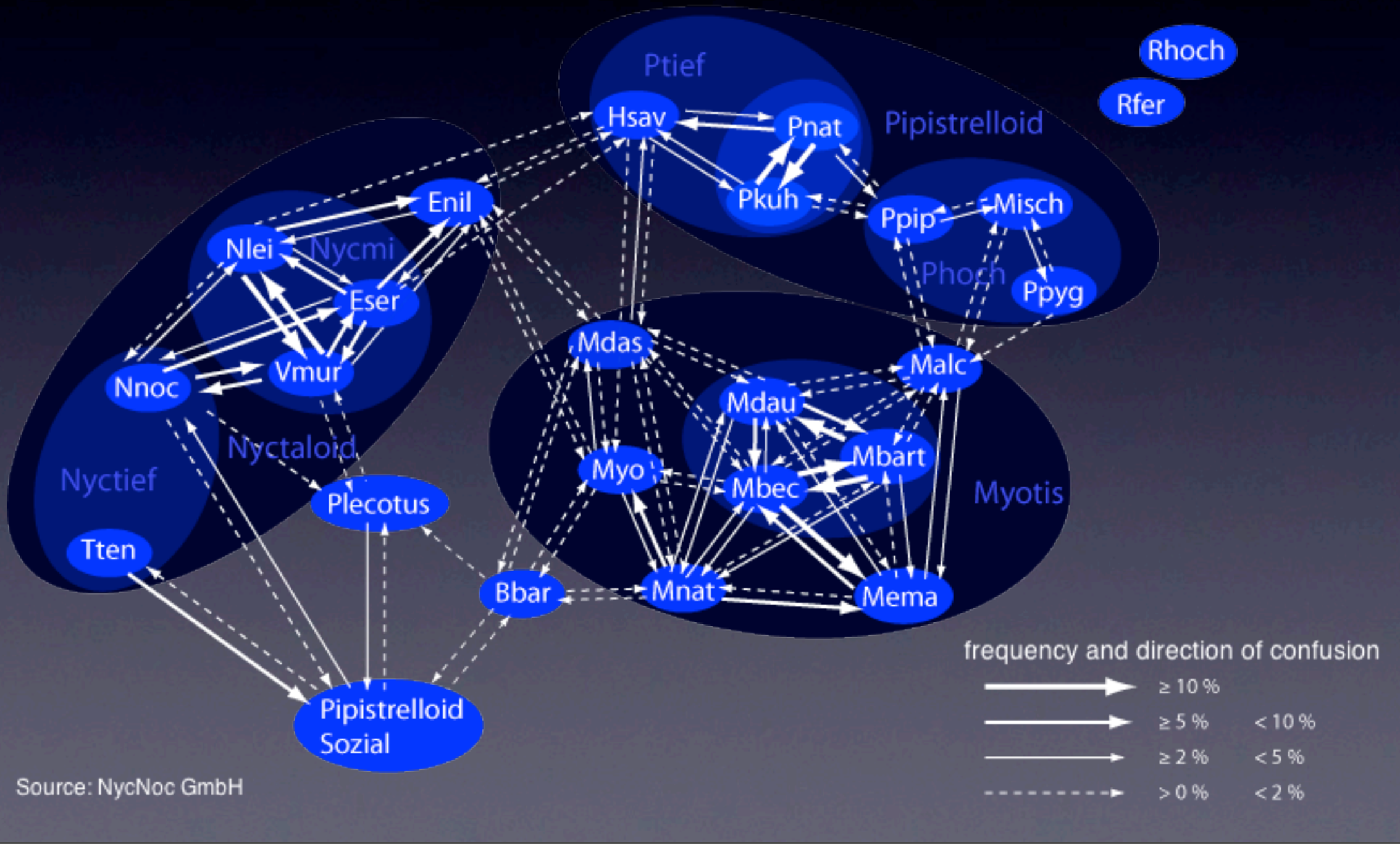


Analysis *noise*



Data interpretation and utilization

- Error rate leads to a certain amount of falsely identified species
  - that is how probabilities work
  - hierarchical procedure as in batIdent helpful in overlapping call repertoire
- Many recordings only identified on genus level / group level
  - same problem exists for manual analysis!
- A way to deal with this noise is necessary

Dealing with noise: human vs. machine

- Manual analysis
  - **context information** is used
    - we know species A was recorded 5 seconds ago and can use this information
    - Danger: circular conclusions
- Machine analysis
  - single calls, **not even context within recording** used
  - **each sequence independently**

How good are human experts?

- manual control not possible for larger data sets
  - we talk about 10.000 recordings or more
- Depends on call quality, recording situation and species
  - not necessarily better than automatic systems!

How good are human experts?

Table 1. Summary classification rates of bat recordings, assessed by using sensitivity (recordings correctly classified) and positive predictive power (PPP; predictions that were actually recordings of that species) for humans and artificial neural networks (ANNs).

		Humans			ANNs	
Taxon	*N**	Number of confusion species	Median percent sensitivity	Median percent PPP	Percent sensitivity	Percent PPP
Rhinolophus ferrumequinum	2	0	100 (100–100)	100 (100–100)	100	100
Rhinolophus hipposideros	2	0	100 (100–100)	100 (100–100)	100	100
Rhinolophus (to genus)	4	—	100 (100–100)	100 (100–100)	100	100
Myotis brandtii (Eversmann, 1845)	3	8	17 (0–33)	18 (0–33)	67†	22
Myotis mystacinus (Kuhl, 1817)	4	5	15 (0–25)	20 (0–32)	0	0
Myotis bechsteinii (Kuhl, 1817)	4	6	6 (0–25)	5 (0–39)	0	—‡
Myotis nattereri (Kuhl, 1817)	5	6	75 (45–95)	67 (50–89)	80	53
Myotis daubentonii	5	6	40 (20–60)	40 (25–45)	30	38
Myotis (to genus)	21	—	95 (86–100)	95 (92–100)	100	100
Pipistrellus pipistrellus	3	1	100 (100–100)	100 (100–100)	100	100
Pipistrellus pygmaeus	2	2	100 (100–100)	100 (100–100)	100	100
Pipistrellus (to genus)	5	—	100 (100–100)	100 (100–100)	100	100
Nyctalus leisleri	3	5	33 (0–67)	67 (0–100)	33	100
Nyctalus noctula	3	2	100 (100–100)	75 (75–100)	100	86
Nyctalus (to genus)	6	—	67 (67–83)	100 (80–100)	75	100
Eptesicus serotinus	4	7	50 (50–75)	67 (53–75)	88†	78†
Barbastella barbarstellus	2	5	0 (0–100)	0 (0–100)	50	50
Plecotus auritus (L., 1758)	3	6	67 (50–100)	55 (43–67)	83	63
Plecotus§ (to genus)	3	—	100 (67–100)	50 (40–65)	83	63

From: Human vs. machine: identification of bat species from their echolocation calls by humans and by artificial neural networks; N. Jennings, S. Parsons, and M.J.O. Pocock 2008

Available tools

- Omnibat (Ecocom, Sweden)
- BatScope (Martin Obrist, WSL)
- batIdent (ecoObs GmbH)
- Sonobat (USA)

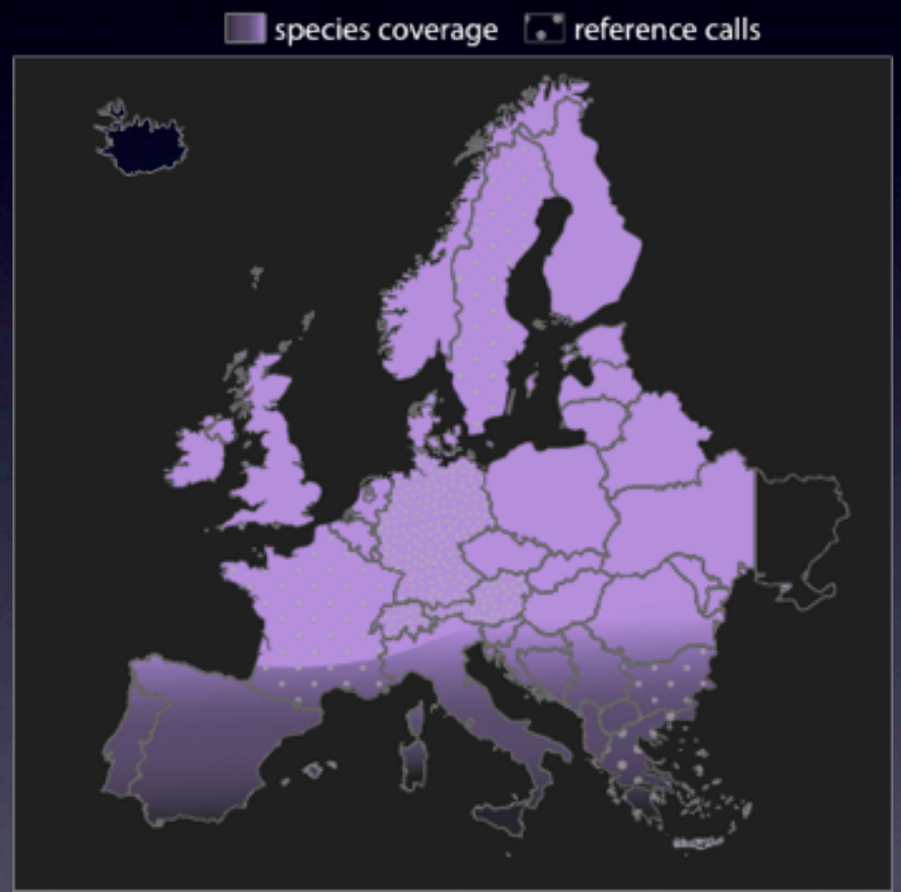
- available since 2010: http//www.omnibat.se
- works with all file formats
  - internally transformed to 10x time expanded format
- includes 10 species and 1 genus (*Myotis*): focused on northern species
  - *Nyctalus noctula, N. leisleri, V. murinus, E. nilssonii, E. serotinus, P. pygmaeus, P. pipistrellus, P. nathusii, Pl. auritus, B. barbastellus*
  - 5 new species planned for 2011 (extension for European species)
- ID process
  - uses image-based identification approach
  - 0.1 to 1 seconds calculation per recording
  - sequences for manual control are suggested
  - echos and non-bat-signals etc. are usually no problem

BatScope

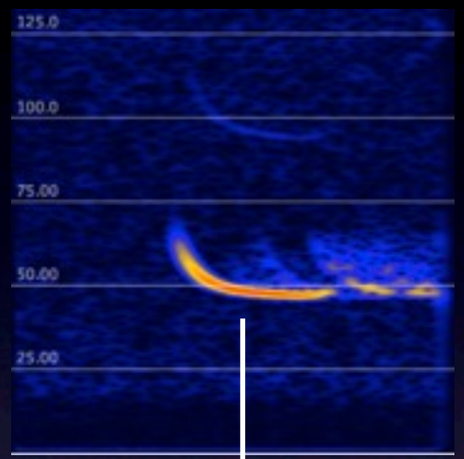
- Experience based on BATIT (since ~1995), avail since Nov. 2010
- Optimized for the BATLOGGER
- 24 species and genus *Plecotus*
  - all swiss species, w/o N. lasiopterus
- ID process
  - parameter extraction and different algorithms
  - image approach as backup
  - bushcricket recognition, basic outlier detection
  - manual control/interaction necessary when more than one species
  - regional species subsets planned
- http://www.wsl.ch/fe/biodiversitaet/produkte/batscope/index_DE

batIdent

- former bcDiscriminator (since 2006)
- needs measurement files
  - currently from bcAdmin or bcAnalyze
  - containing ~100 derived parameters
- 28 species (3 complexes), 11 groups
  - ~ 600 calls for training per species
- features
  - multi-step analysis (genus/groups/species)
  - randomForest for identification
  - robust outlier detection using support vector machines (svm)
  - optimized for batcorder recordings
  - ~0.3 seconds per recording



batIdent



Spec.

Bbar
Plecotus
Pipistrelloid
PipistrellusSoz
Myotis
Nyctaloid
Rhinolophus

Ptief
Phoch
Mmyo
Mdas
Mkm
Mnat
Malc
Mema
Nyctief
Nycmi
Enil
Rhoch
Rfer

Pmid
Hsav
Misch
Ppip
Ppyg
Mdau
Mbart
Mbec
Nnoc
Tten
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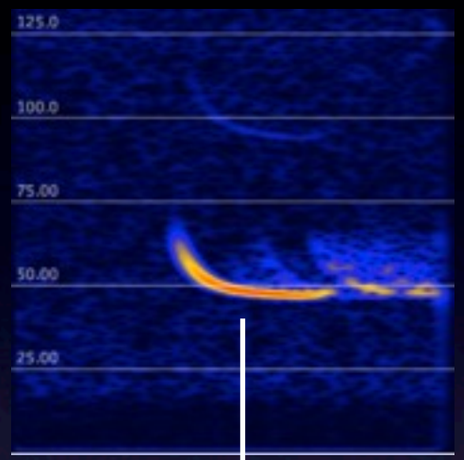
Nlei
Eser
Vmur
Rhip
Reur

Pnat
Pkuh

batIdent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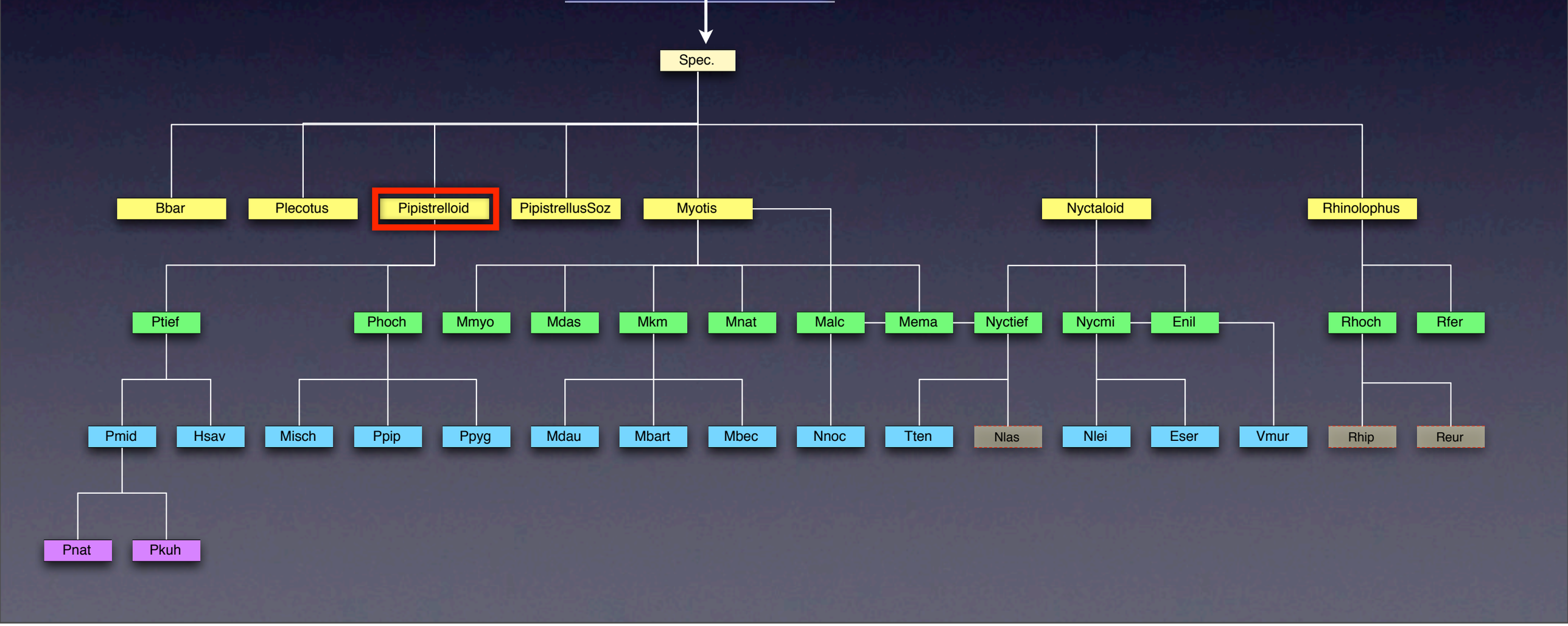
Spec.
Bbar
Plecotus
Pipistrelloid
PipistrellusSoz
Myotis
Nyctaloid
Rhinolophus
Ptief
Phoch
Mmyo
Mdas
Mkm
Mnat
Malc
Mema
Nyctief
Nycmi
Enil
Rhoch
Rfer
Pmid
Hsav
Misch
Ppip
Ppyg
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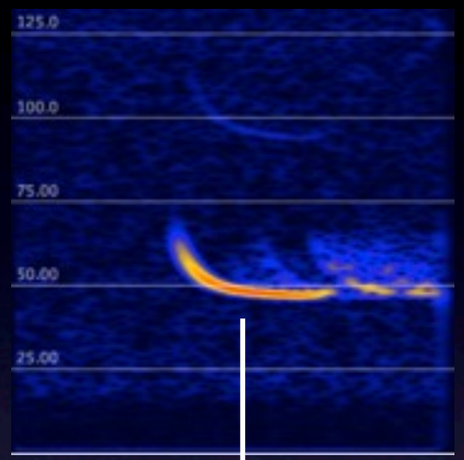
Reur
Pnat
Pkuh

batIdent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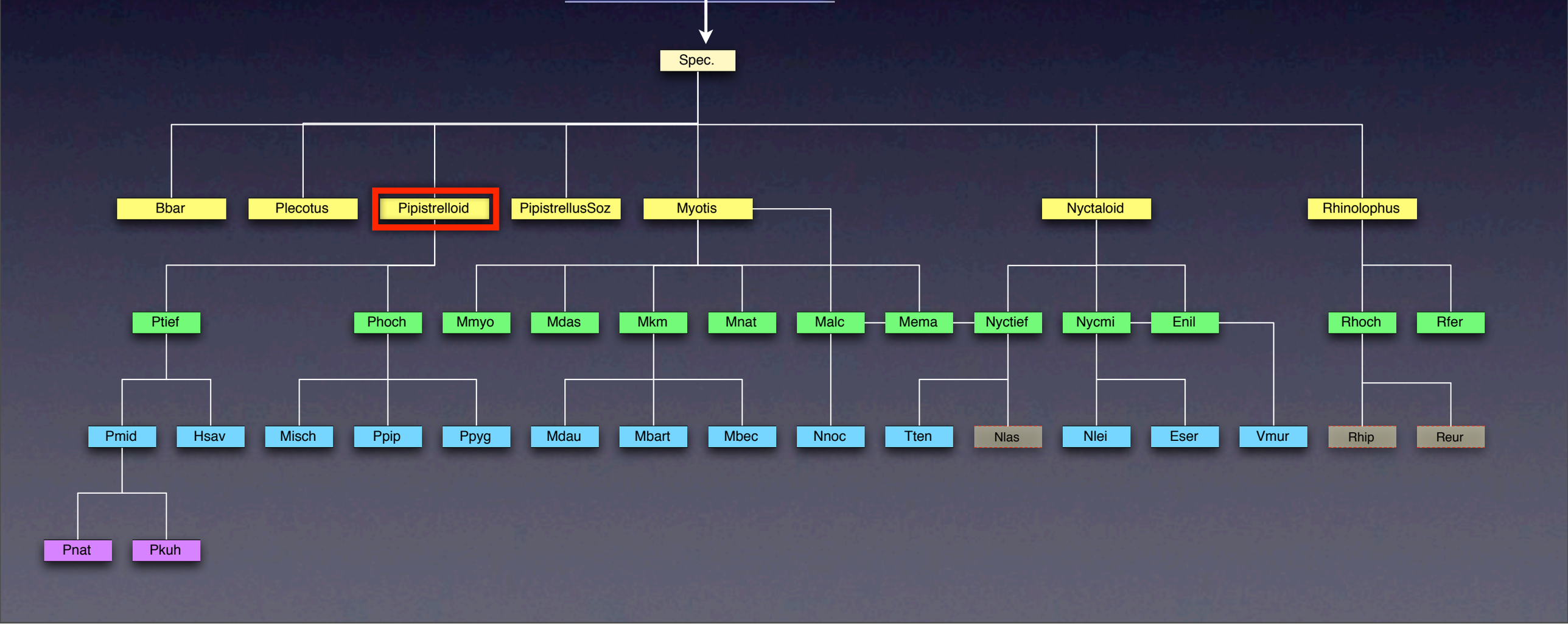
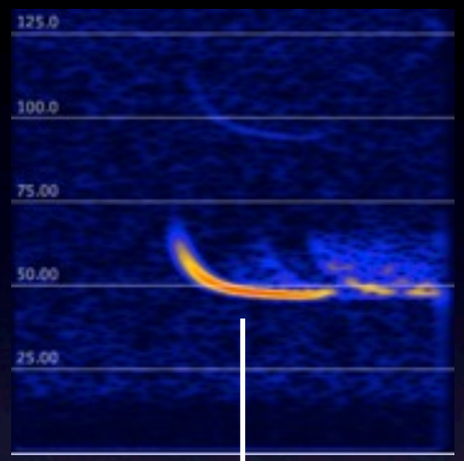
75.00
50.00
25.00


Spec.
Bbar
Plecotus
Pipistrelloid
PipistrellusSoz
Myotis
Nyctaloid
Rhinolophus
Ptief
Phoch
Mmyo
Mdas
Mkm
Mnat
Malc
Mema
Nyctief
Nycmi
Enil
Rhoch
Rfer
Pmid
Hsav
Misch
Ppip
Ppyg
Mdau
Mbart
Mbec
Nnoc
Tten
Nlas
Nlei
Eser
Vmur
Rhip
Reur
Pnat
Pkuh

batIdent



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Mbart
Mbec
Nnoc
Tten

Software comparison

- All applications are fast and allow manual control/insights -> no black box!
- Input files
  - Omnibat broadest
  - BatScope / batIdent limited
- Mature applications
  - BatScope and batIdent with both around 22 to 28 species/complexes
  - performance of around 85% to 95% with test calls
  - 60% to 90% with field recordings, still some exceptions
  - batIdent has broadest reference base (70000 signals)

What we've learned

- batcorder and our software is used since 2004
  - software used with other hardware as well
- tuning software to hardware improves quality
  - sensitivity and recording threshold
  - analysis threshold can be fixed accordingly
- references recorded with same hardware
  - frequency response
  - amplification/gain

Perspectives

- Regional species composition
  - taking species distribution into account
  - dangerous, but can improve performance
    - only reference calls from region
- Detection of "unknown" species
  - recognize calls as *unknown calls*
  - otherwise: high bio-diversity ;-)
- Most important: how to interpret the recorded data?

Summary

- Most species can be acoustically detected
- Automation
  - more economical data collection
  - necessary for comparisons of locations, habitat usage surveys and monitoring
- Automation in detection
  - multiple devices available
  - most suffer from problems still (directionality, calibration)
- Automation in identification
  - three tools available
  - BatScope and batIdent show very similar results
  - these two have reached the same level as human experts for a large number of species
  - Omnibat limited to Northern Europe at the moment
  - Coupling of hard- and software will give the best results

Thank you!