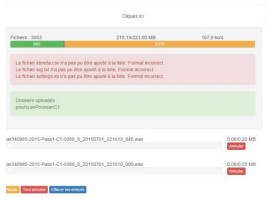
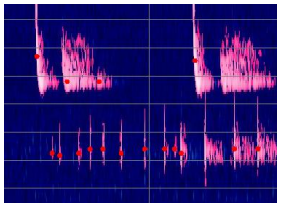
CASPA 2019

Session 1 : Participation

VIGIE-CHIRO : UN SUIVI ACOUSTIQUE STANDARDISÉ DE LA BIODIVERSITÉ TERRESTRE

YVES BAS





Vigie-Chiro : un suivi acoustique standardisé de la biodiversité terrestre

Vigie-Chiro
Suivi des chauves-souris

SON
Suivi des orthoptères nocturnes

MUSEUM NATIONAL D'HISTOIRE NATURELLE

BTO

CESCO
Centre d'Écologie et des Sciences de la Conservation

Centre d'Écologie Fonctionnelle & Evolutive

cnrs
dépasser les frontières

Yves Bas, *Christian Kerbiriou, Isabelle Le Viol, Stuart Newson, Kevin Barré, Grégoire Loïs, Jean-François Julien*

VIGIENATURE
Un réseau de citoyens qui fait avancer la science

MUSÉUM
NATIONAL D'HISTOIRE NATURELLE

Naturalistes

STOC

STERF
Suivi Temporel des Rhopalocères de France

SHOC
SUIVI HIVERNAL DES OISEAUX COMMUNS

SON
Suivi des orthoptères nocturnes

Vigie-Chiro
Suivi des chauves-souris

Steli
Suivi Temporel des Libellules

vigie-flore

Grand public

Observatoire des PAPILLONS Jardins

OPÉRATION Escargots

OBSERVATOIRE DES BOURDONS

SPIPOLL

Oiseaux des jardins

sauvages de ma rue

BIRDLAB

Gestionnaires, acteurs

PROPAGE
Protocole Papillons Gestionnaires

OBSERVATOIRE AGRICOLE BIODIVERSITÉ

Vigie-Chiro
Suivi des chauves-souris

VIGIENATURE École

Vigie-Chiro

1) Introduction aux chiroptères (chauves-souris) et leur étude par l'acoustique
2) Les protocoles standardisés et participatifs
3) L'activité acoustique comme mesure d'abondance relative
4) L'identification automatique
5) La gestion des erreurs et la qualification des données

Vigie-Chiro

1) Introduction aux chiroptères (chauves-souris) et leur étude par l'acoustique
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Order Chiroptera (= bats)

The only mammals performing active flight

- Chiroptères~ “Main ailée”
- > 1000 species in the world, 35 in France
- Mostly insect-eating in Europe, 3 species occasionnaly fishing, and 1 hunting small birds on migration.
- More diverse ecology in the tropics: foraging fruits, nectars, amphibians, other bats, etc
- Echolocation is essential for most species, for orientation and prey detection. No terrestrial equivalent. Roughly equivalent to cetacean echolocation (but much more diverse)
- Exceptionnal longevity for their size (41 years and 7 g)
- Ecosystem services: pest control, pollination, seed dispersal…

3 main field methods

1) Day Roost search

- 3 main roost types: tree, buildings, cavities
- Time-consuming, especially if search is systematic...

Diplomacy…

…and safety issues!

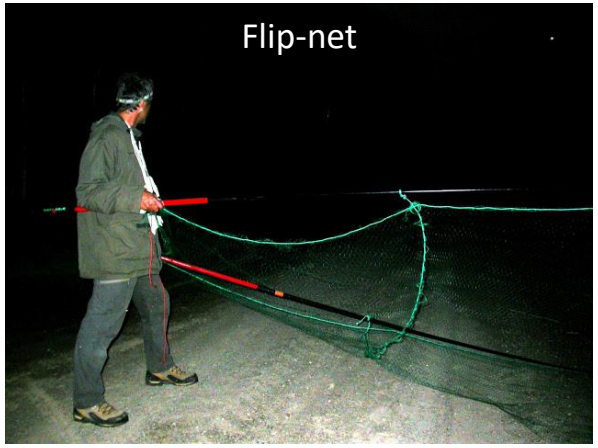
3 main field methods


Pose de filet japonais

2) Capture

- With mist-nets, over water, at roost entrance or on busy flight corridors
- Low efficiency compared to birds
- Other techniques:
  - Harp-trap
  - Flip-net

Permit necessary
Long apprenticeship


Flip-net

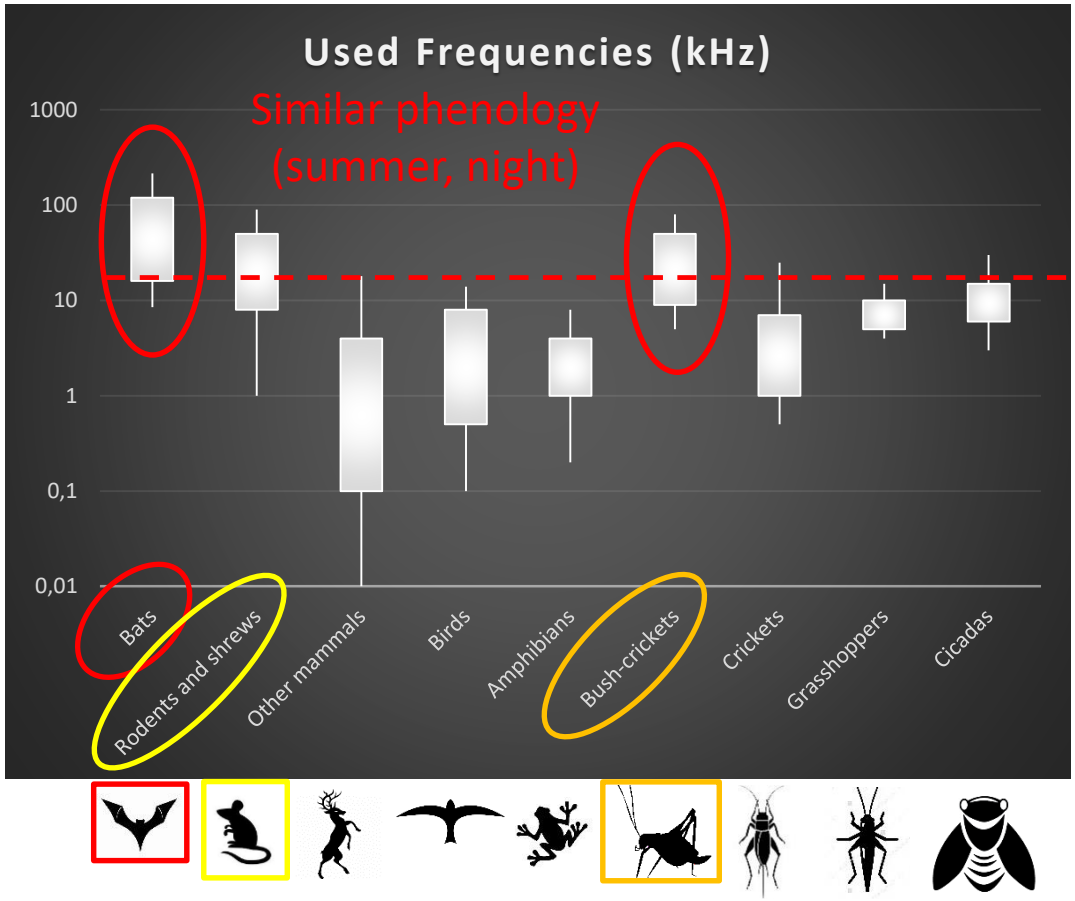
Harp-trap

Bat survey: the sound approach

1) Introduction to bats and their study
2) Acoustic field methods
3) Sampling strategies
4) Monitoring protocols
5) Acoustic activity as a measure of relative abundance
6) Automatic identification: why and how?
7) How to deal with errors?
8) Acoustic localisation and bat flight path reconstruction

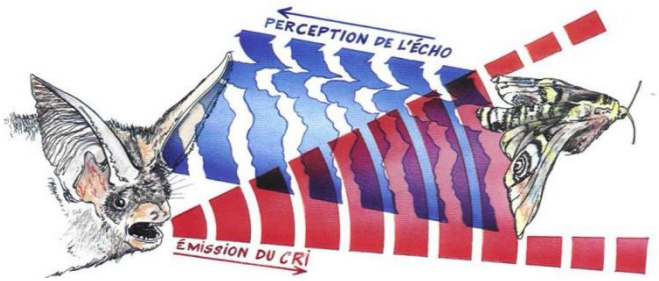
3) Acoustics

Main acoustically active groups (long range)



Inaudible

or

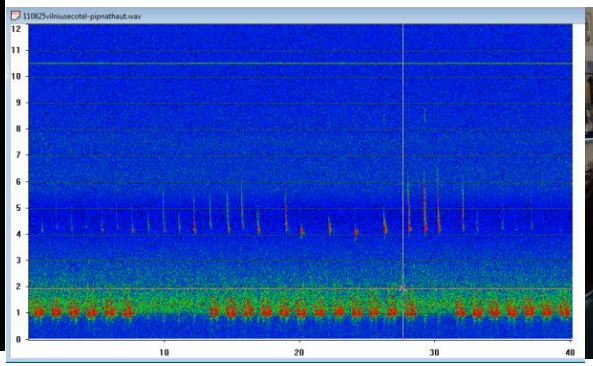


3 main field methods

3) Acoustics

• Detectability: bats emit calls continuously during flight
➢ 1 call every 1-3 wingbeats (= 2-15 calls/sec)
➢ To detect preys, obstacles, water, other individuals, etc
• Limits: most of these calls are beyond ear limits > specific detectors or recorders
• 2 types of id process: (1) by ear in the field or (2) a posteriori spectrogram analysis

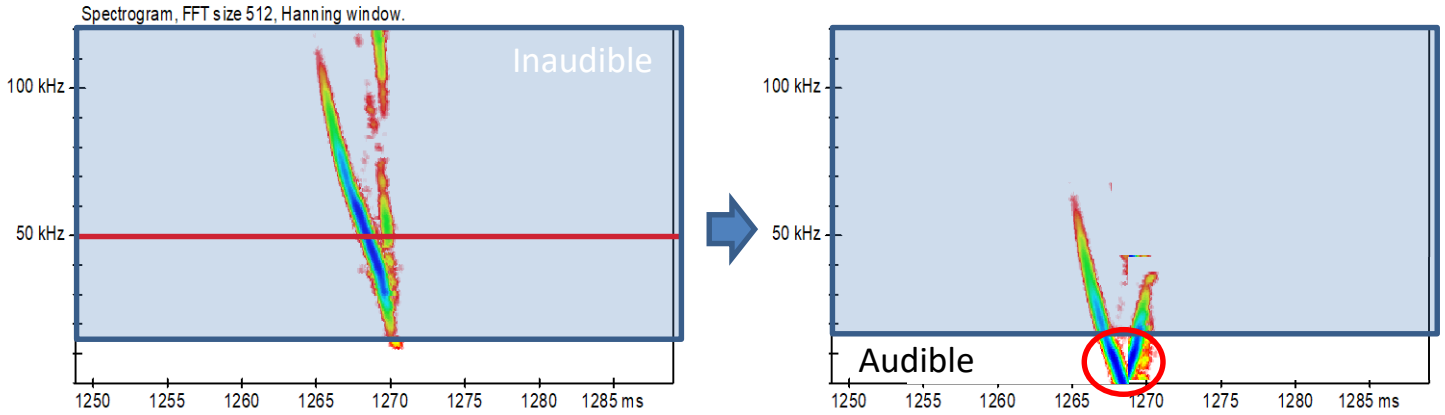
2000s



Bat identification: the sound approach

1990s: active detection

- Hearing ultrasounds > 3 techniques:
  - ➢ Frequency division: no limit in time and frequency but low taxonomic resolution (poor information)
  - ➢ Heterodyne: shifting frequencies according to a certain threshold



Bat identification: the sound approach

2000s: active detection

• Hearing ultrasounds > 3 techniques:

➢ Frequency division: no limit in time and frequency but low taxonomic resolution (poor information)

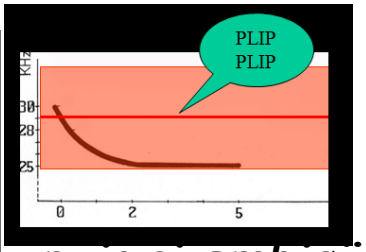
➢ Heterodyne: shifting frequencies according to a certain threshold - Moderate taxonomic resolution

➢ Time Expansion: sound is recorded during a limited time (0.1-10s) then played back 10x slower to make frequency 10x lower. Limit: sampling time < 10%

Bat identification: the sound approach

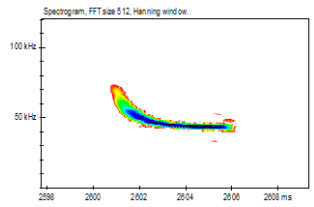
1990s: active detection

La méthode “Barataud” (traditionnelle en France) :



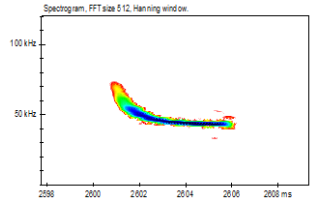
Ecoute en Hétérodyne sur le terrain

puis si ambigüité…



Ecoute en Expansion de temps sur le terrain et/ou sur ordinateur

puis si ambigüité…



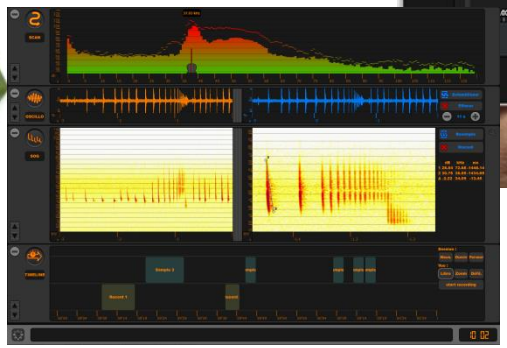
Determination sur critères visuels (mesures)

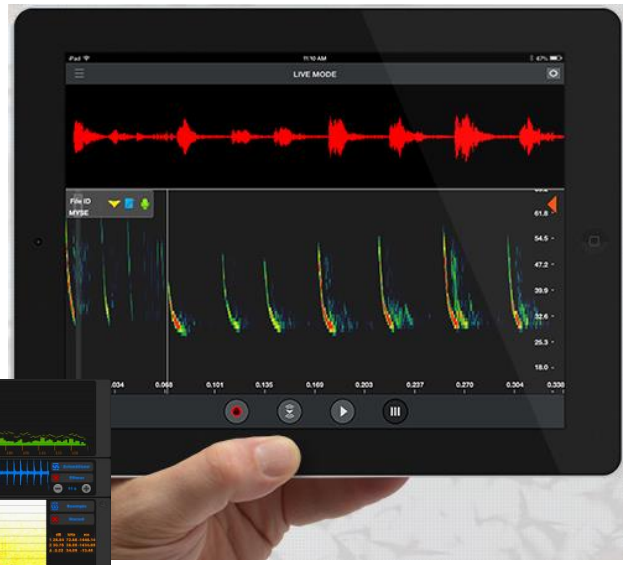
Bat identification: the sound approach

2010s: active detection

Revolution around 2010 : direct high frequency recording affordable!

- **Spectrogram analysis in the field!**





Bat identification: the sound approach

2010s - a new method: passive detection

Revolution around 2010 : direct high frequency recording affordable!

- **Autonomous long duration recordings!!**

• Features:

- Automatic trigger
- Need for fast spectrogram analysis (new id methods)
- Unattended!

Bat identification: the sound approach

2010s - a new method: passive detection

• Features:

- ➢ Automatic trigger
- ➢ Need for fast spectrogram analysis (new id methods)
- ➢ Unattended!

• Advantages :

- ➢ Sampling compounded (more sites, longer sampling)

Disadvantages :

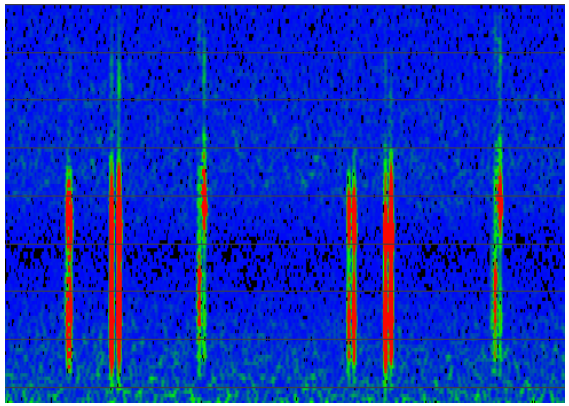
- A posteriori analysis is time-consuming
- Constant need for automation (softwares)

Bat identification: the sound approach

2010s - a new method: passive detection

• Automatic trigger principles:

- ➢ Recording is triggered on signal-to-noise ratio
- ➢ Sensitive but false positives due to other "noise" (bush-crickets, rain, wind, etc) – 85 % on average
- ➢ Need for smarter post-processing



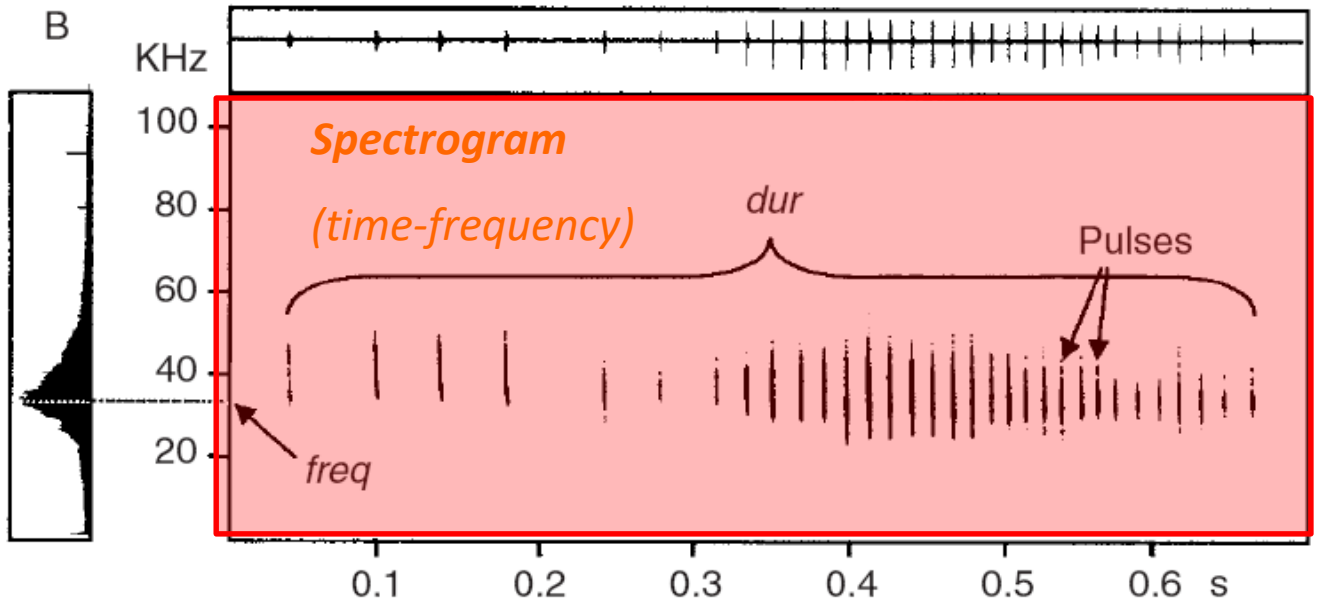
Bat identification: the sound approach

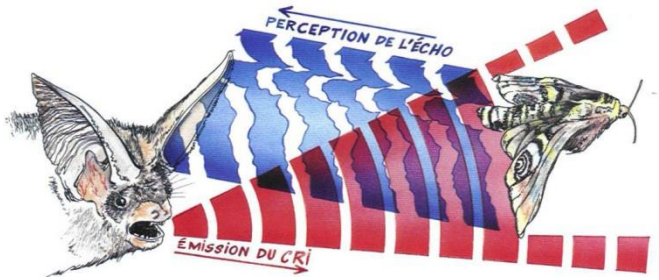
Sound visualisation

Oscillogram (time-amplitude)

Power spectrum

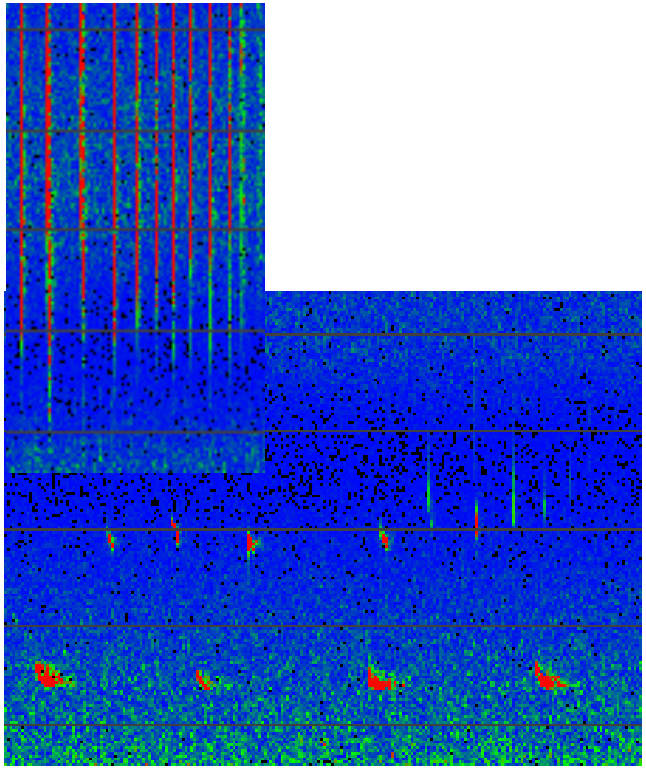
(frequency-amplitude)



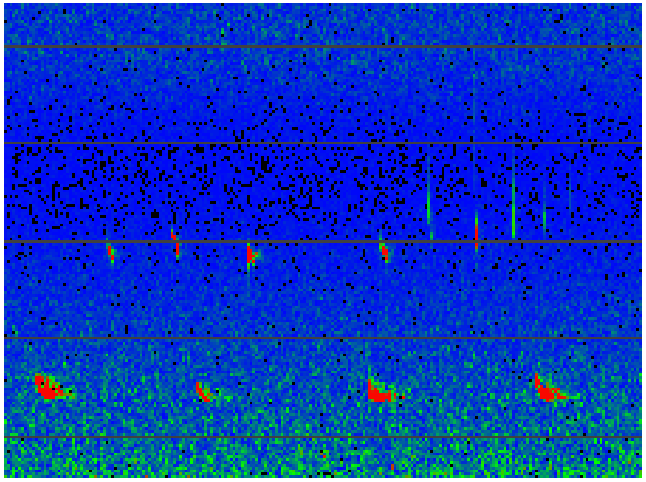


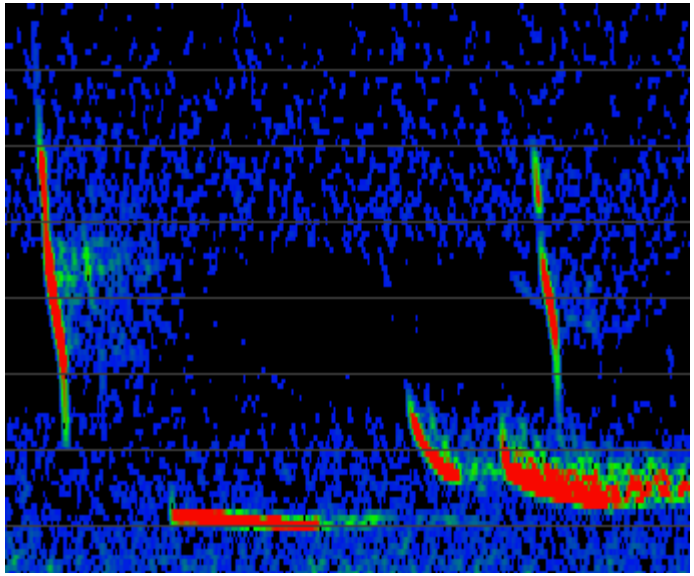
Bat identification: the sound approach

Ecology and echolocation



- **Rythm:**
  - 1 call every 1-3 wingbeats = **2-15 calls/sec**
  - **15 calls / seconde =** 15 “frames” per seconde, smooth ☺ but detection radius limited to 10 m ☹
    - Gleaning or hawking of small abundant preys
  - **2 calls / seconde = “**stroboscopic” ☹ but detection radius of 80 m ☺
    - Large species foraging less abundant preys in open areas



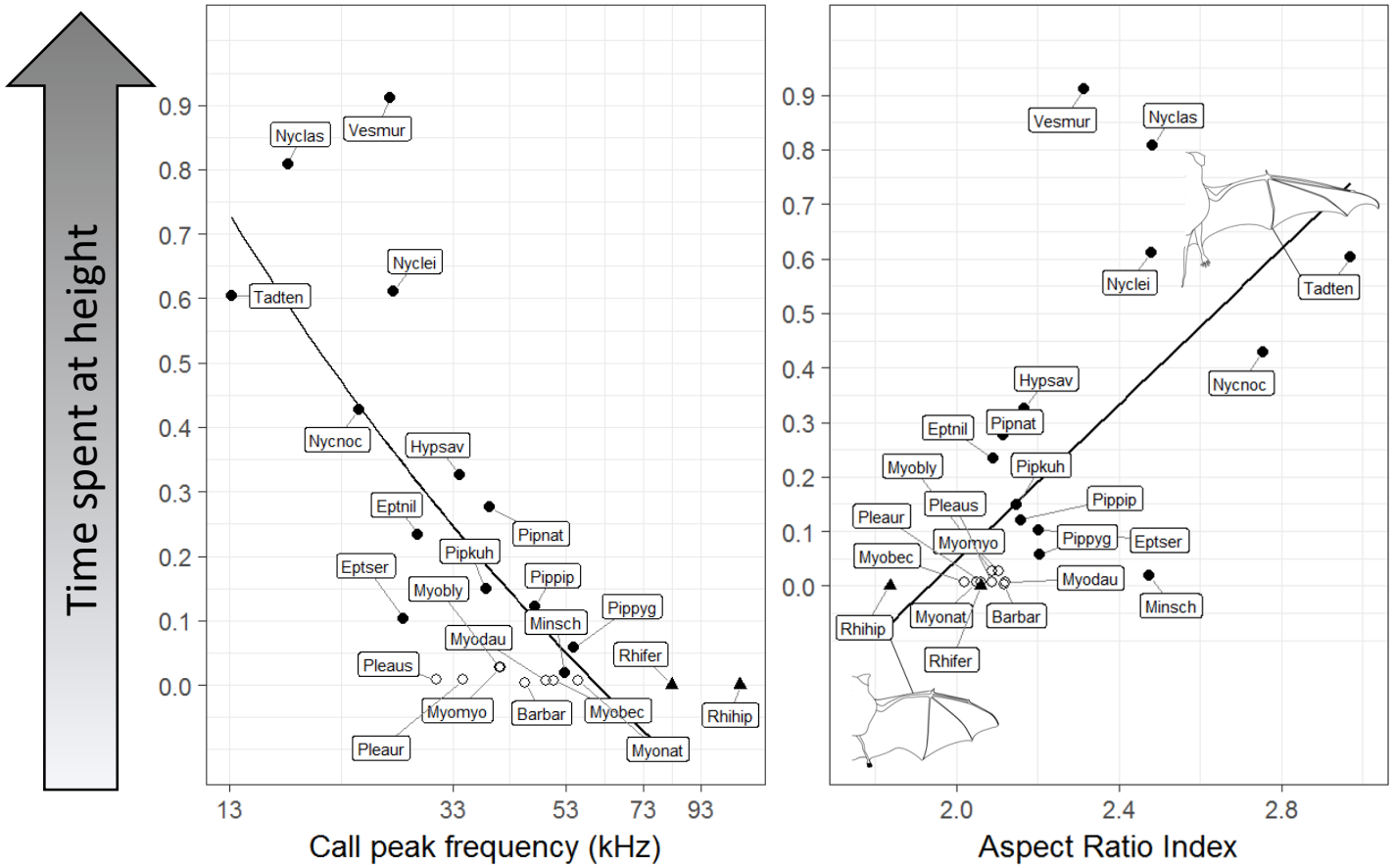


Bat identification: the sound approach

Ecology and echolocation

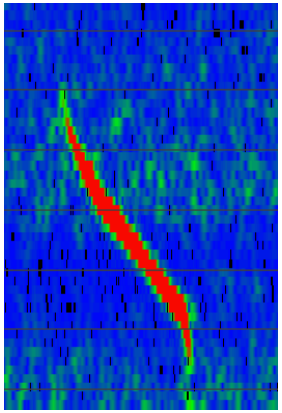
- **Frequency:**
  - The higher the frequency, the smaller preys will return an echo (ex : small diptera or moth) ☺, but stronger attenuation: small detection radius ☹
    - Example : Soprano Pipistrelle, specialized on mosquitoes
  - Inversely, low frequency echolocation will detect only large preys (specialisation) but will have larger detection radius
    - Example : Free-tailed bats fly high to detect preys in large volumes.

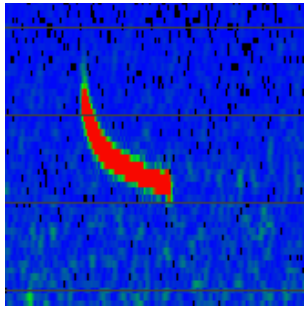
Bats: a unique sensory-motor system

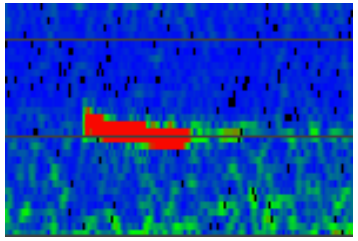


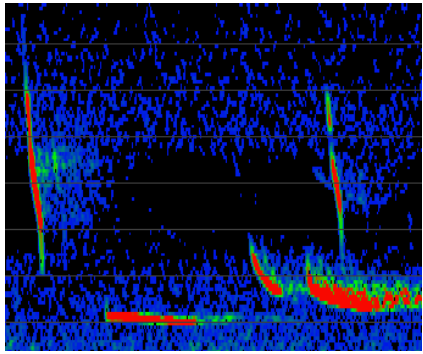
- Bat traits co-evolved with species niche

Roemer et al. submitted









Bat identification: the sound approach

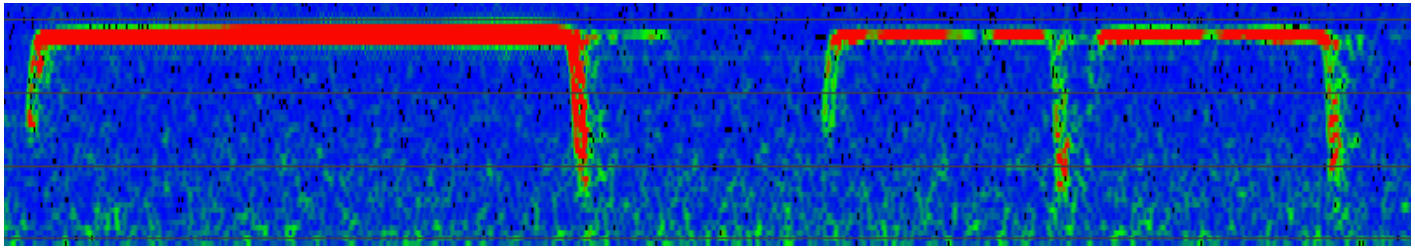
Ecology and echolocation

- **Frequency modulation:**
  - Large bandwidth:
    - Accurate range resolution (=distance to prey)
    - Able to detect preys on vegetation (= gleaning)
    - Long-eared bats and Myotis in Europe
    - Disadvantage : small detection radius ☹
  - Inversely, open area hawkers tend to concentrate most energy in a narrow bandwidth
    - Advantage: maximise detection radius ☺
    - Increase modulation in approach phase
    - Pipistrelles, Serotines, Noctules, etc

Bat identification: the sound approach

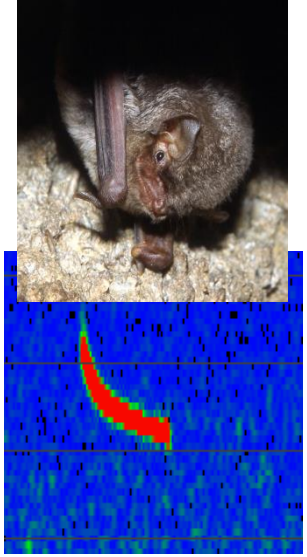
The doppler technique: Horseshoe bats

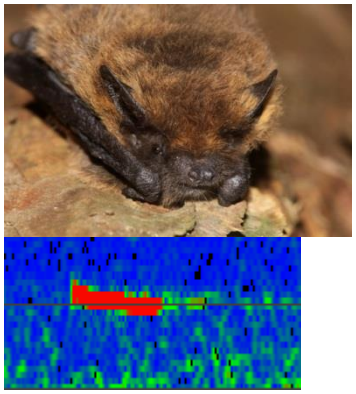
- **Drastically different techniques:**
  - Long constant frequency calls to exploit Doppler shifts information:
    - Able to detect moving preys, even in cluttered environment
    - Able to forage from a branch
    - Anticipating prey movements (moth)
  - Angular resolution thanks to constant ear movements



Bat identification: the sound approach

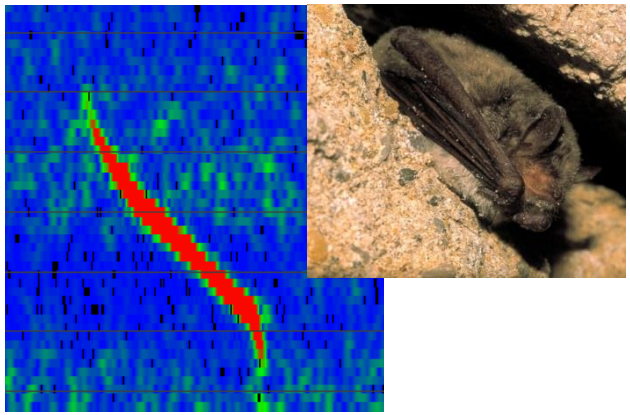
European acoustic types





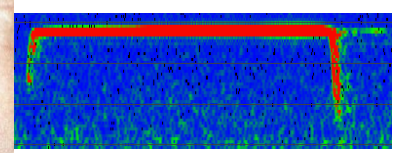
High flight (largest group)

Myotis (large bandwidth)

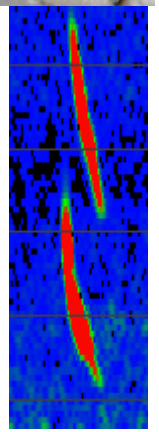


Barbastelle Bat

Horseshoe bats



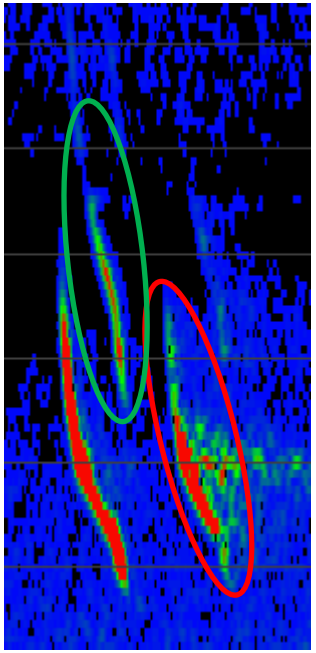
Long-eared bats



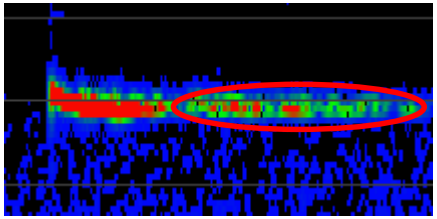
Bat identification: the sound approach

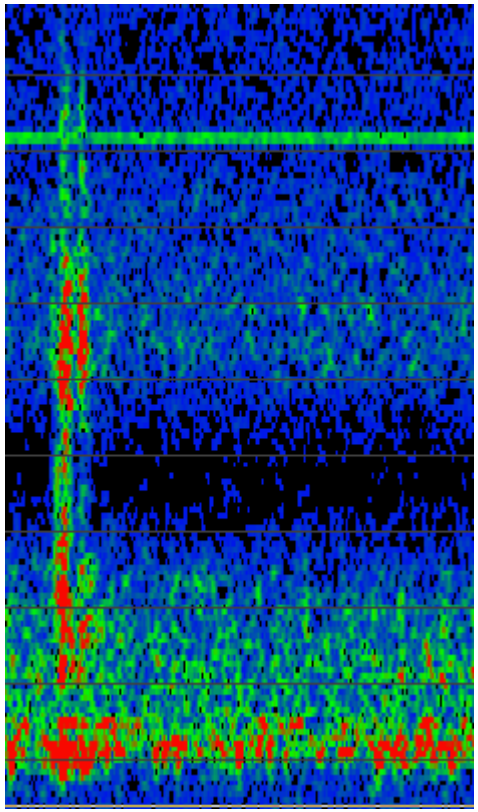
Some traps in spectrogram analysis

Harmonics (frequency x2, x3, …)



Echoes

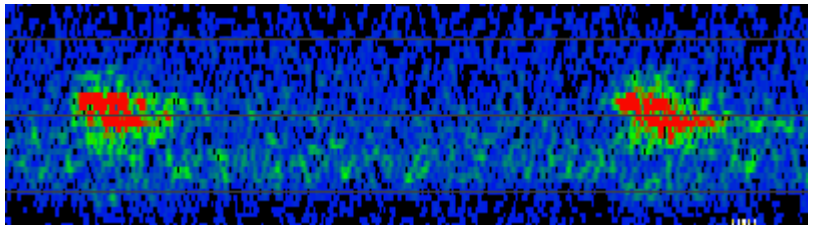


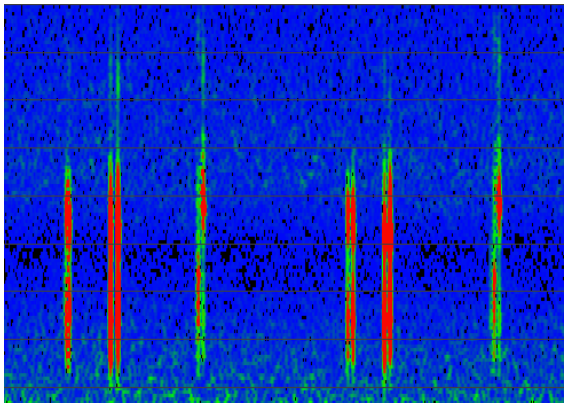


Bat identification: the sound approach

Some traps in spectrogram analysis

- **Recognizing non bat ultrasounds**
  - Usually non pure tones
  - Irregular rythms
  - Usually extremely short (wind, rain, bush-crickets)
  - Or very long (metallic sounds, electronical parasites, birds, rodents, …)



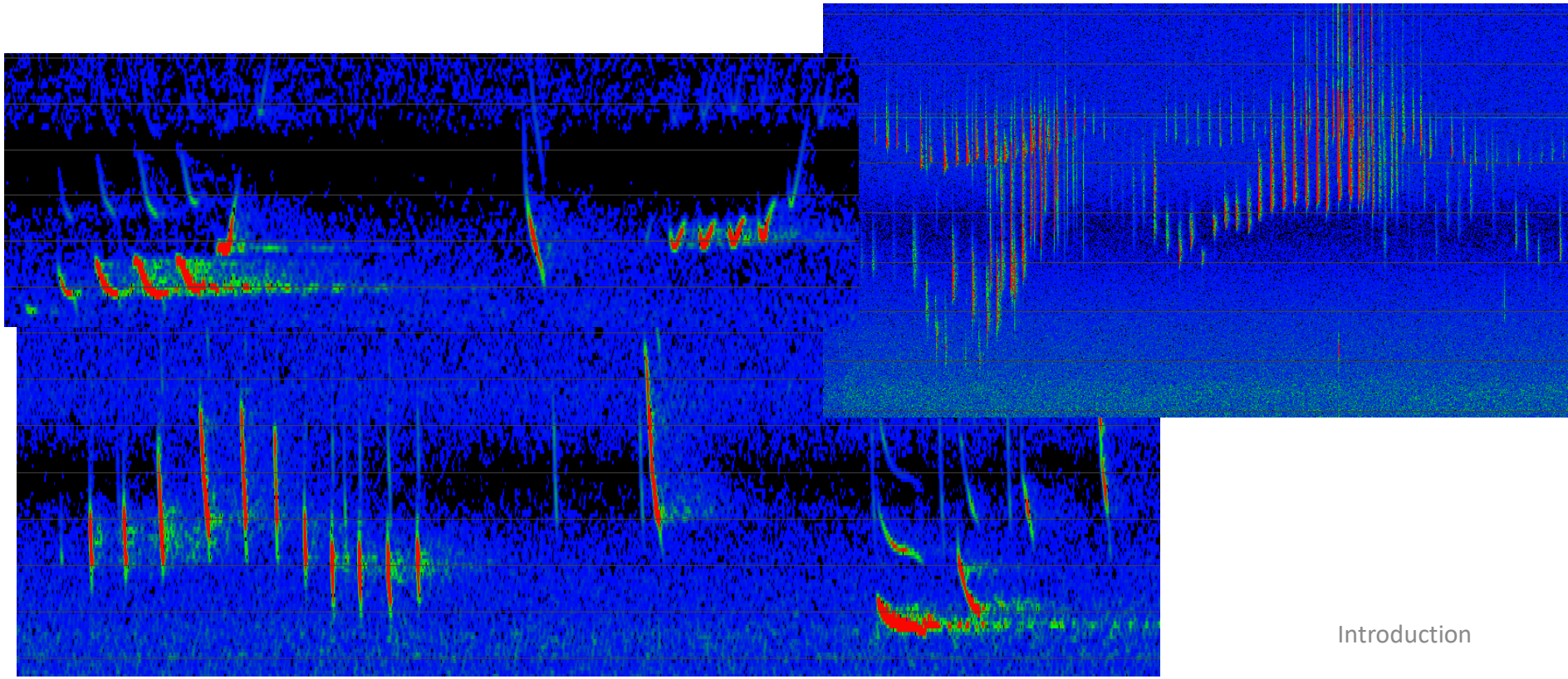


Bat identification: the sound approach

Lack of knowledge to be identified in many cases

Some traps in spectrogram analysis

- **Recognising social calls**
  - ➢ Chaotic frequency shifts
  - ➢ Structurally more complex

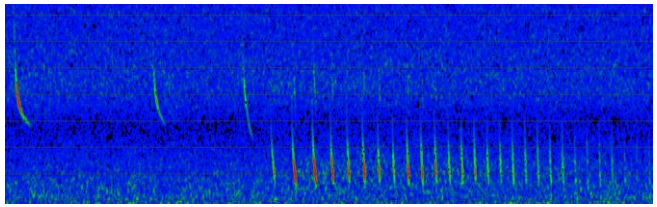


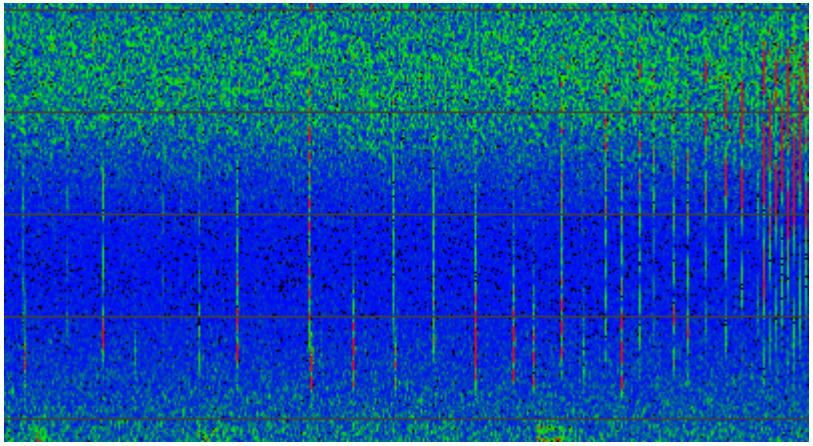
Bat identification: the sound approach

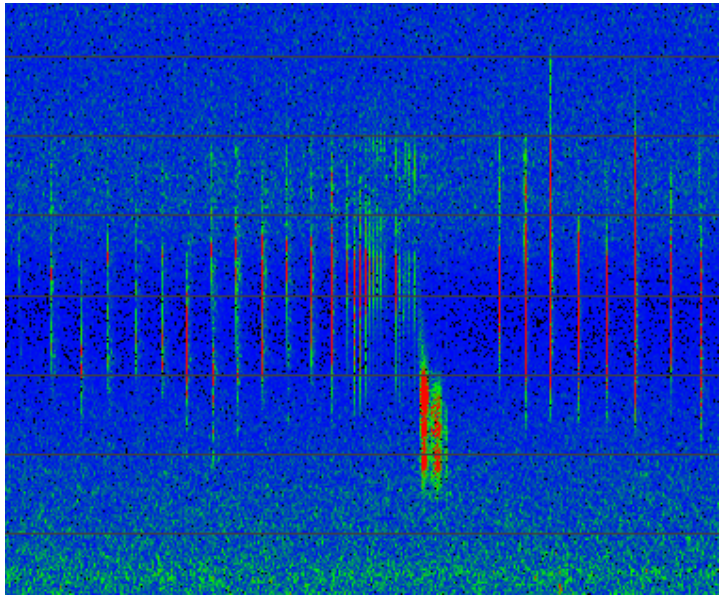
Some traps in spectrogram analysis

• **Recognising « buzzes »**

= progressive acceleration until inter-pulse intervals < 10 ms : Typical of prey capture sequences, but also when drinking, landing, etc.





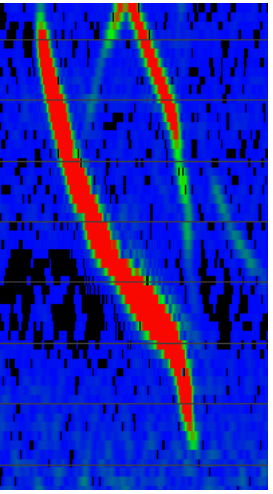


Bat identification: the sound approach

Some traps in spectrogram analysis

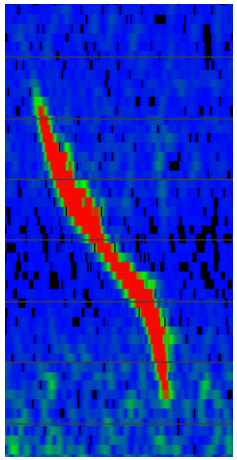
• **Strong and heterogeneous environmental attenuation**

Exemple of the very same call recorde by 4 microphones



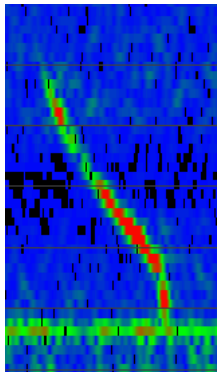
EF = 22 kHz
BW = 73 kHz
Dur= 5.7 ms
FME = 45 kHz

Distance = 6 m
Angle = 5°



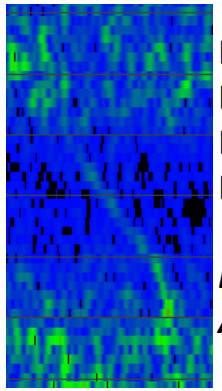
EF = 23 kHz
BW = 53 kHz
Dur= 5.0 ms
FME = 58 kHz

Distance = 9 m
Angle = 60°



EF = 28 kHz
BW = 41 kHz
Dur= 4.5 ms
FME = 42 kHz

Distance = 8 m
Angle = 170°



EF = 30 kHz
BW = 26 kHz
Dur= 3.2 ms
FME = 38 kHz

Distance = 10 m
Angle = 120°

Increasing distance and angle

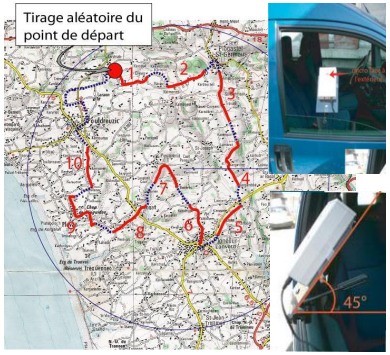
Vigie-Chiro

1) Introduction aux chiroptères (chauves-souris) et leur étude par l'acoustique
2) Les protocoles standardisés et participatifs
3) L'activité acoustique comme mesure d'abondance relative
4) L'identification automatique
5) La gestion des erreurs et la qualification des données

Bat acoustic monitoring: principles

- <u>Standardized recordings</u> (=repeatable measurement)
  - Same locations
  - Same periods
  - Same detectability
    - Trigger sensitivity
    - Microphone type
- <u>Different methods depending on public and material</u>

Walk transects



Car transects

Whole-night recordings

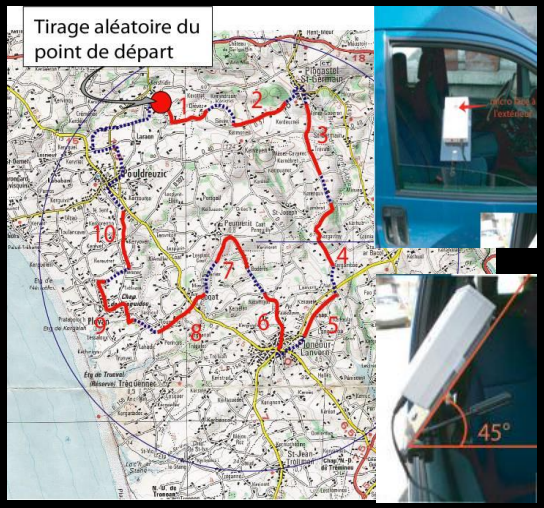
Vigie-Chiro: 3 different data collection protocols

Starting 2006

NEW 2014

Car transects

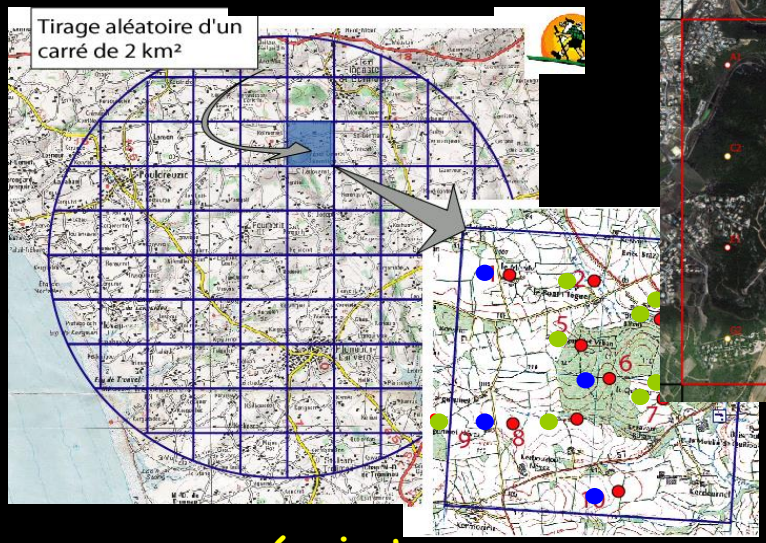
10 x 2 km / 25 km/h



Following iBat international scheme

Point counts

10 points / 2x2 km squares



6 minutes recording

Stations

1 - 10 points / carrés 2x2 km

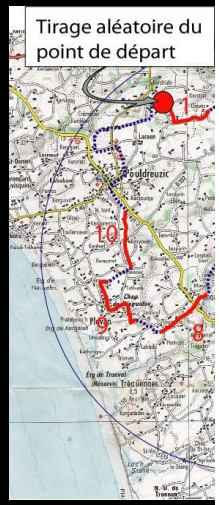
Whole night recordings

What is the relative contribution of each protocols to monitor bats and bush-crickets?
Is there some complementarity?

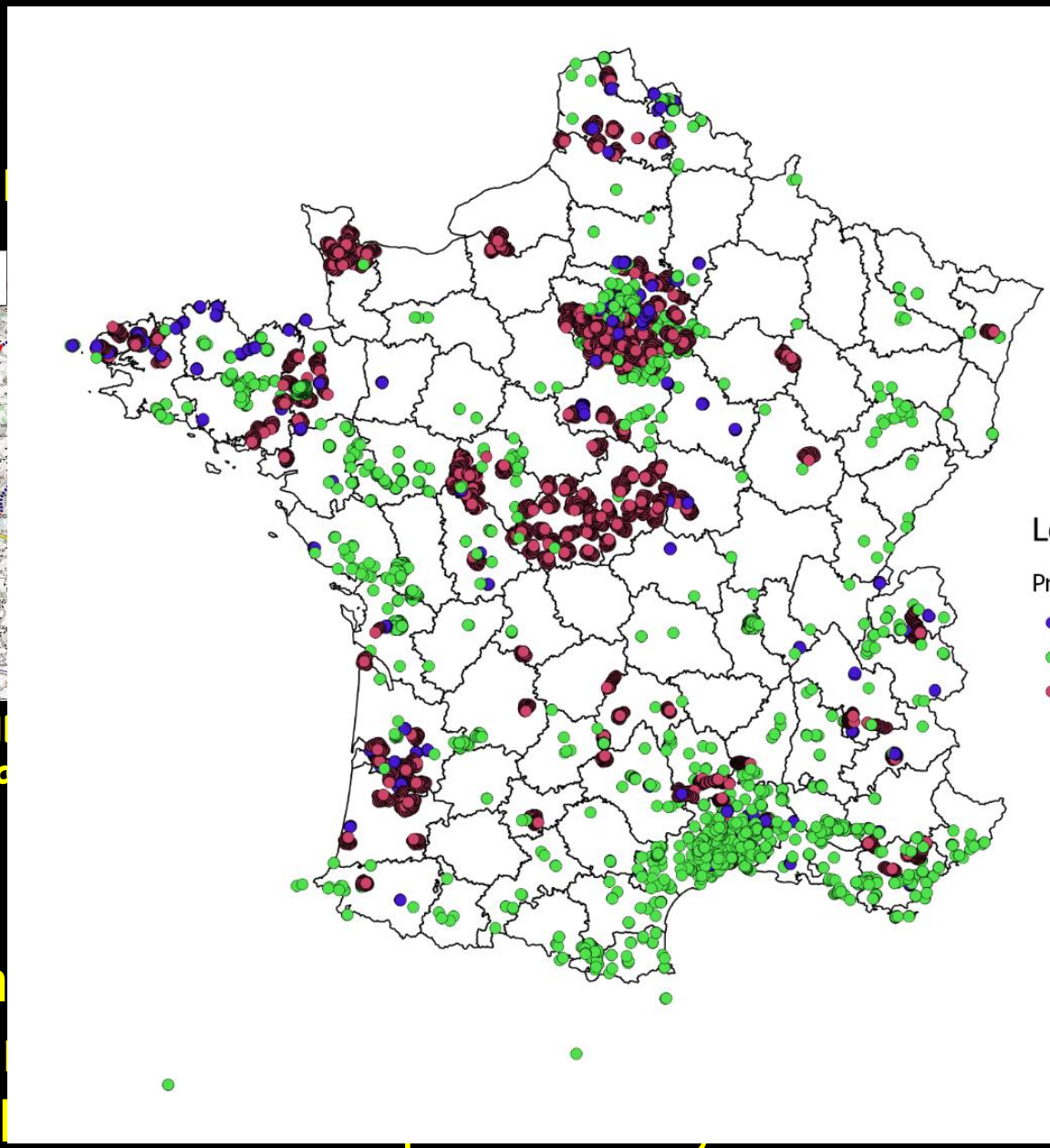
Vigie-Chiro: 3 different data collection protocols

Car

10 x 2



Foll
interna



tions

points
2x2 km

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Monitoring protocols comparison

Testing trend detection power:

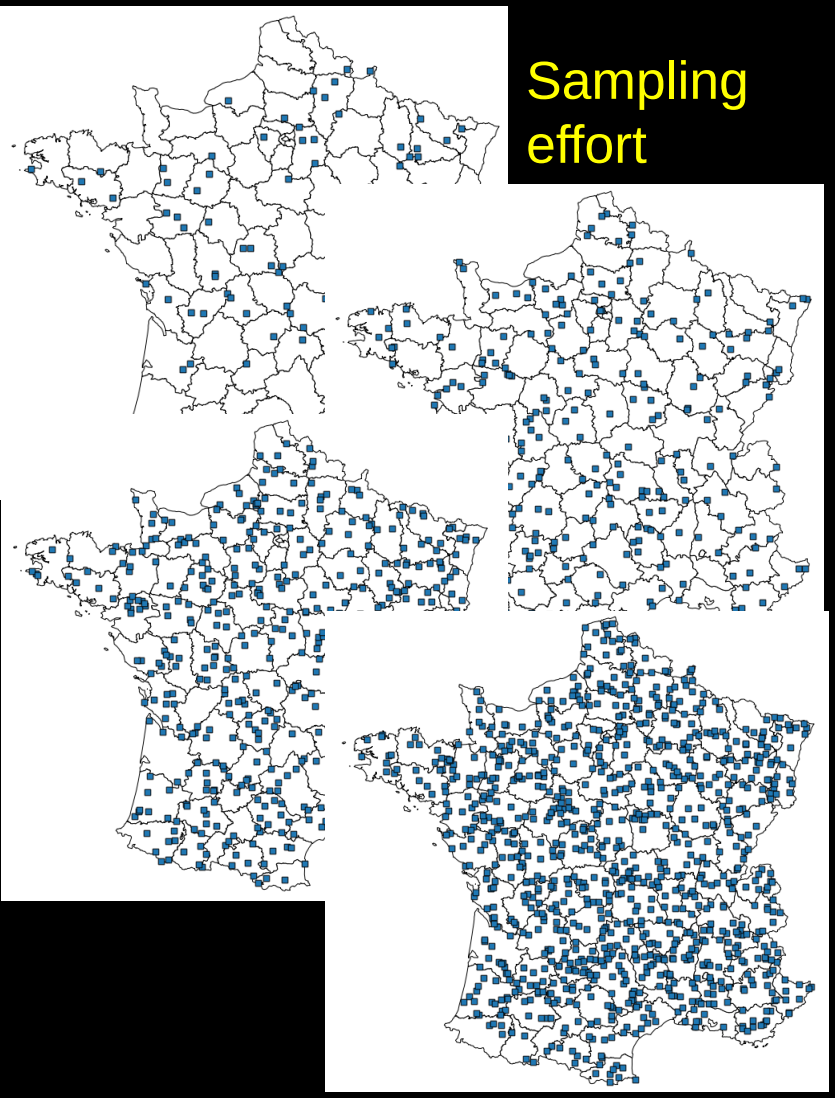
Scenarios:	**Car transects**	**Point counts**	**Stations**
Pessimistic	50	300	100
Current	100	1000	250
Optimistic	400	3000	1000

Simulations fed with Vigie-Chiro data input:

- Average measured activity (*corrected by latitude/longitude*)
- Spatial variability (*among sites variance*)
- Temporal variability (*among same-year visits variance*)

Monitoring protocols comparison

Testing trend detection power:



Sampling effort

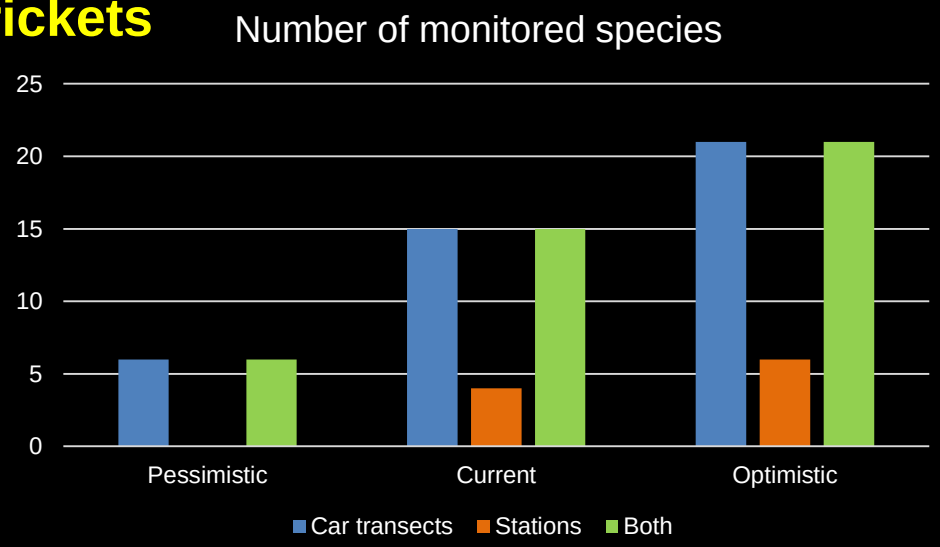
Simulations:

- 11 successive years sampling
-Negative binomial distributions (both spatially and temporally)
-**30% decreasing trends** (= smallest decreasing trends that could justify listing VU (IUCN))
-2 nights recorded / year / points or transects
-500 data sets for n points
-GLM: Bat passes ~ Time + Site

=> Target: getting significant effect of time (z-test, $p < 0.05$) on > 50% simulated datasets

Monitoring protocols comparison

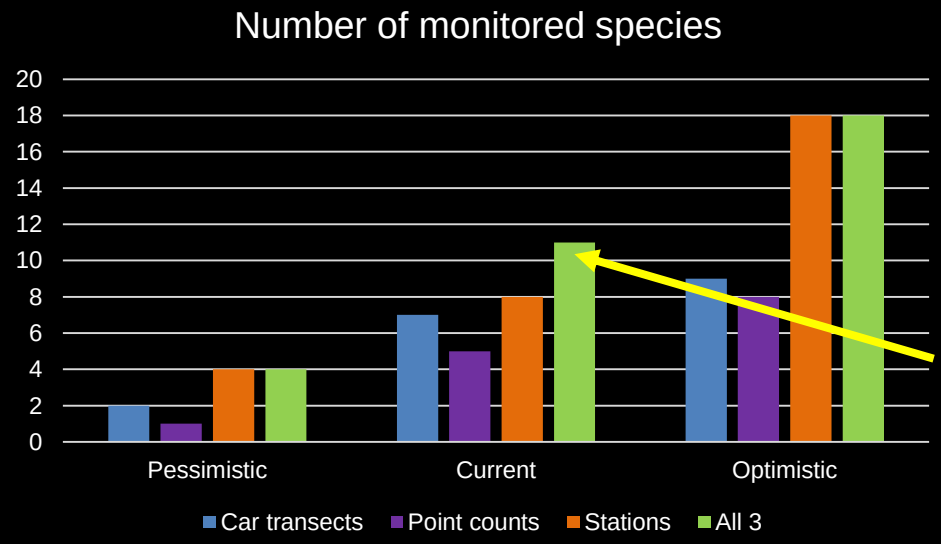
Bush-crickets



Car transects more efficient (immobility of singing individuals)

…but representativity bias (road edges) to be control by other protocols

Bats



Stations protocol has great potential to increase number of monitored species

…but good complementarity of the 2 other schemes

Monitoring protocols comparison

Bats under current scenario

Species monitored	Car transects	Point counts	Stations
Barbastella barbastellus	O	O	X
Eptesicus serotinus	X	O	O
Miniopterus schreibersii	O	O	X
Myotis daubentonii	O	X	X
Nyctalus leisleri	X	X	O
Nyctalus noctula	X	O	O
Pipistrellus kuhlii	X	X	X
Pipistrellus nathusii	X	X	X
Pipistrellus pipistrellus	X	X	X
Pipistrellus pygmaeus	X	O	X
Plecotus spp.	O	O	X

Monitoring protocols comparison

Bats under current scenario

Species monitored	Car transects	Point counts	Stations
Barbastella barbastellus	O	O	X
Eptesicus serotinus	X	O	O
Miniopterus schreibersii	O	O	X
Myotis daubentonii	O	X	X
Nyctalus leisleri	X	X	O
Nyctalus noctula	X	O	O
Pipistrellus kuhlii	X	X	X
Pipistrellus nathusii	X	X	X
Pipistrellus pipistrellus	X	X	X
Pipistrellus pygmaeus	X	O	X
Plecotus spp.	O	O	X

Large, detectable, crepuscular species are best monitored by car transects

Monitoring protocols comparison

Bats under current scenario

Species monitored	Car transects	Point counts	Stations
Barbastella barbastellus	O	O	X
Eptesicus serotinus	X	O	O
Miniopterus schreibersii	O	O	X
Myotis daubentonii	O	X	X
Nyctalus leisleri	X	X	O
Nyctalus noctula	X	O	O
Pipistrellus kuhlii	X	X	X
Pipistrellus nathusii	X	X	X
Pipistrellus pipistrellus	X	X	X
Pipistrellus pygmaeus	X	O	X
Plecotus spp.	O	O	X

Species with constant late night activity are best monitored by stationary recordings

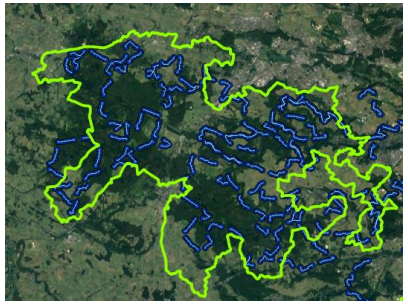
Vigie-Chiro

1) Introduction aux chiroptères (chauves-souris) et leur étude par l'acoustique
2) Les protocoles standardisés et participatifs
3) L'activité acoustique comme mesure d'abondance relative
4) L'identification automatique
5) La gestion des erreurs et la qualification des données

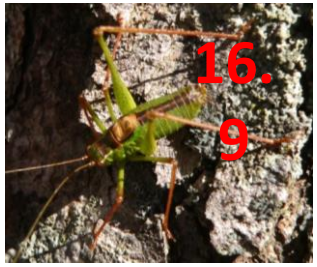
Rencontres scientifiques 2016

Acoustic activity as a measure of relative abundance

Interpreting data locally



Nb of call sequences / 20 km transect

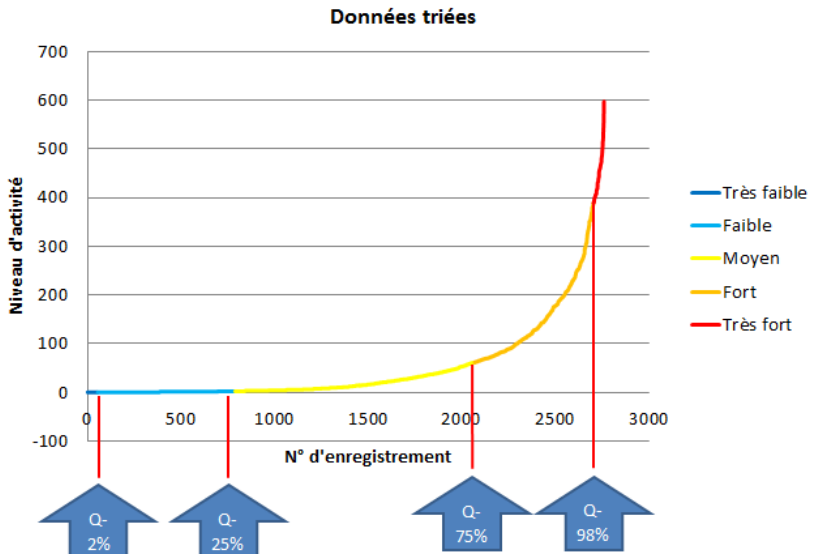


Parc naturel régional Haute Vallée de Chevreuse

Raw data quite uninformative

Benchmarking activity

→ Simple principle, powerful tool (cf. Haquart 2013)



Déclinable *(avec suffisamment de données)* :

- Par région
- Par habitats
- Par saisons
- Par types de Behaviour (buzz, social/swarming…)
- Etc

Benchmarking activity

→ En pratique, c'est une grille de lecture :

Référentiels d'activité des protocoles Vigie-Chiro

Les valeurs données dans le tableau ci-dessous sont des nombres de contacts cumulés sur l'ensemble du circuit routier ou sur l'ensemble du carré pédestre ou encore sur une nuit complète en point fixe, selon le protocole. Elles permettent d'interpréter objectivement l'activité mesurée sur vos sites :

- Si vous mesurez une activité supérieure à la valeur **Q98%**, c'est que vous avez obtenu une activité **très forte**, particulièrement notable pour l'espèce
- Si vous mesurez une activité supérieure à la valeur **Q75%**, c'est que vous avez obtenu une activité **forte**, révélant l'interêt de la zone pour l'espèce
- Si vous mesurez une activité supérieure à la valeur **Q25%**, c'est que vous avez obtenu une activité **modérée**, donc dans la norme nationale
- Si vous mesurez une activité inférieure à la valeur **Q25%**, vous pouvez considérer l'activité comme **faible** pour l'espèce

	Protocole Routier			Protocole Pédestre			Protocole Point Fixe		
Espece	Q25%	Q75%	Q98%	Q25%	Q75%	Q98%	Q25%	Q75%	Q98%
Barbastella barbastellus	1	2	7	1	7	10	1	15	406
Eptesicus serotinus	1	7	18	1	4	22	2	9	69
Hypsugo savii	3	13	23				3	14	65
Miniopterus schreibersii							2	6	26
Myotis bechsteinii							1	4	9
Myotis daubentonii	1	3	11	2	10	92	1	6	264
Myotis emarginatus							1	3	33
Myotis blyhtii/myotis							1	2	3
Myotis mystacinus							2	6	100
Myotis cf. naterreri	1	2	4	1	5	8	1	4	77
Nyctalus leisleri	2	7	18	2	7	42	2	14	185
Nyctalus noctula	2	7	18	1	8	25	3	11	174
Pipistrellus kuhlii	2	9	33	3	20	71	17	191	1182
Pipistrellus nathusii	1	10	36	1	4	44	2	13	45
Pipistrellus pipistrellus	35	95	163	13	59	119	24	236	1400

http://vigienature.mnhn.fr/page/des-referentiels-pour-interpreter-vos-donnees

Benchmarking activity

→ Exemple (1/2) :

Participation du 2 sept. 2016 20:03:00 effectuée par Yohan Douveneau

Search:

Nom français	Nom scientifique	Risque d'erreur (%)	Nb Validations	Effort de validation	Nb de Contacts par Nuit	Niveau d'Activite
Pipistrelle commune	Pipistrellus pipistrellus	1	26	FORT	949	FORTE
Serotine commune	Eptesicus serotinus	1	6	FORT	63	FORTE
Pipistrelle de Kuhl	Pipistrellus kuhlii	1	8	FORT	42	MODEREE
Noctule commune	Nyctalus noctula	1	1	SUFFISANT	38	FORTE
Noctule de Leisler	Nyctalus leisleri	1	2	FORT	26	FORTE
Oreillard gris	Plecotus austriacus	1	2	FORT	21	FORTE

Benchmarking activity

→ Exemple (2/2), consecutive nights:

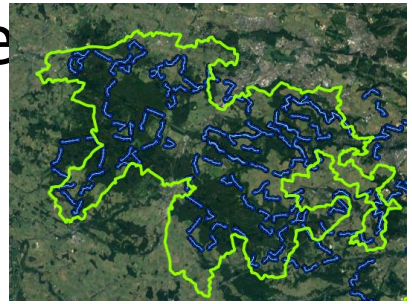
Participation du 11 juil. 2016 21:00:00 effectuée par Fédération des réserves naturelles catalane

Vigiechiro - Point Fixe-660437

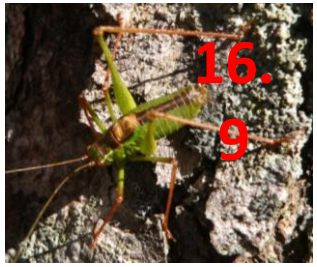
Code	Groupe	Nom français	Nom scientifique	Risque d'erreur (%)	TriGroupe	11	12	13	14	15	16	17
Barbar	Chauve-souris	Barbastelle d'Europe	Barbastella barbastellus	1	3	9	5	1	1	6	8	6
Eptser	Chauve-souris	Serotine commune	Eptesicus serotinus	1	3	16	12	41	28	35	41	29
Hypsav	Chauve-souris	Vespere de Savi	Hypsugo savii	1	3	295	124	22	16	106	65	85
Minsch	Chauve-souris	Minioptere	Miniopterus schreibersii	1	3	3	6	8	5	5	2	1
Myocap	Chauve-souris	Murin de Capaccini	Myotis capaccinii	77	3	0	0	1	0	0	0	0
Myodau	Chauve-souris	Murin de Daubenton	Myotis daubentonii	84	3	1	1	0	0	1	0	1
Myoema	Chauve-souris	Murin a oreilles echancrees	Myotis emarginatus	1	3	7	4	0	0	1	0	0

Acoustic activity as a measure of relative abundance

Interpreting data locally



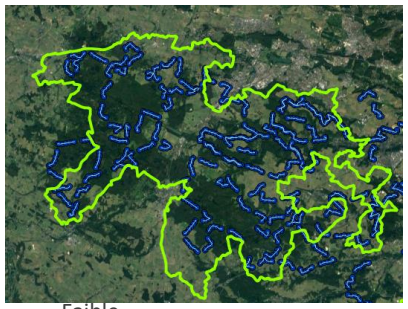
Nb of call sequences / 20 km transect



Parc naturel régional Haute Vallée de Chevreuse

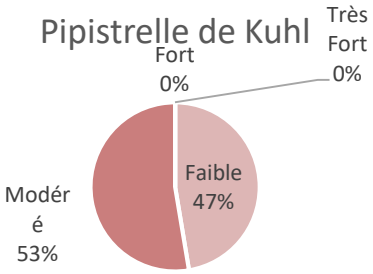
Acoustic activity as a measure of relative abundance

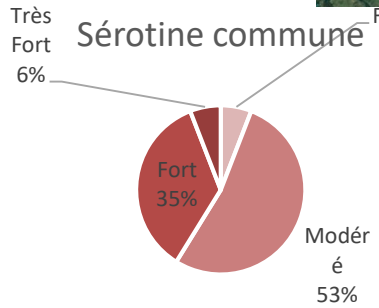
Exemple :

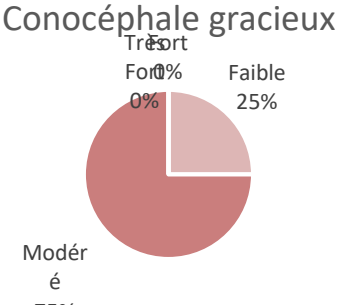


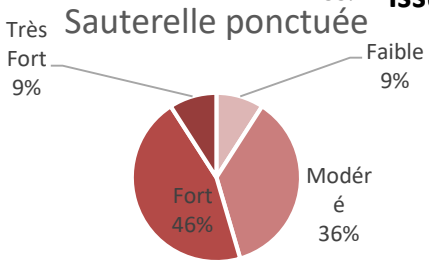
2 espèces dont l'activité est toujours faible à modéré :

Quantile distribution on a whole site









Strong activity over-represented
> Strong responsibility (potential conservation issue)

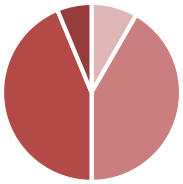
Rencontres scientifiques 2016

Acoustic activity as a measure of relative abundance

Robust method: applicable to rare species (little data necessary)

RNCFS Caroux-Espinouse

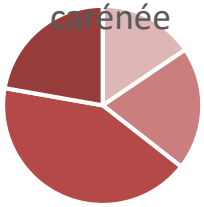
Barbastelle



Oreillard gris

Parc naturel régional du Marais poitevin

Ephippigère carénée

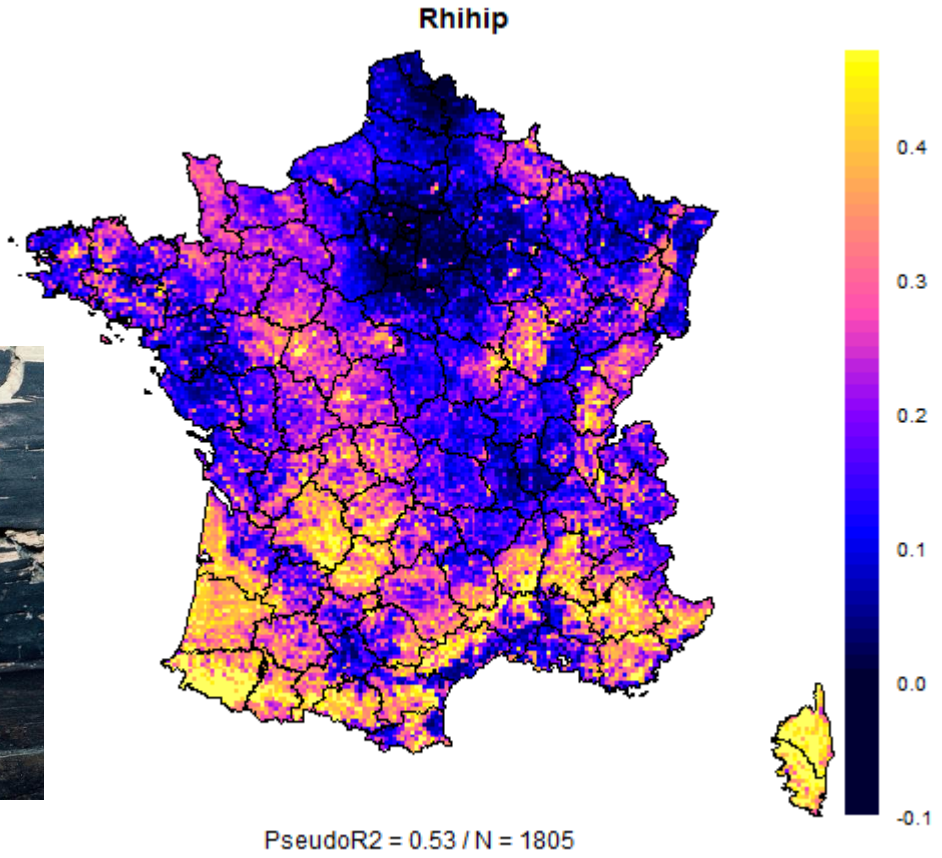


Parc national de Port-Cros

Using acoustic activity to map species relative abundance

Identifying stronghold populations

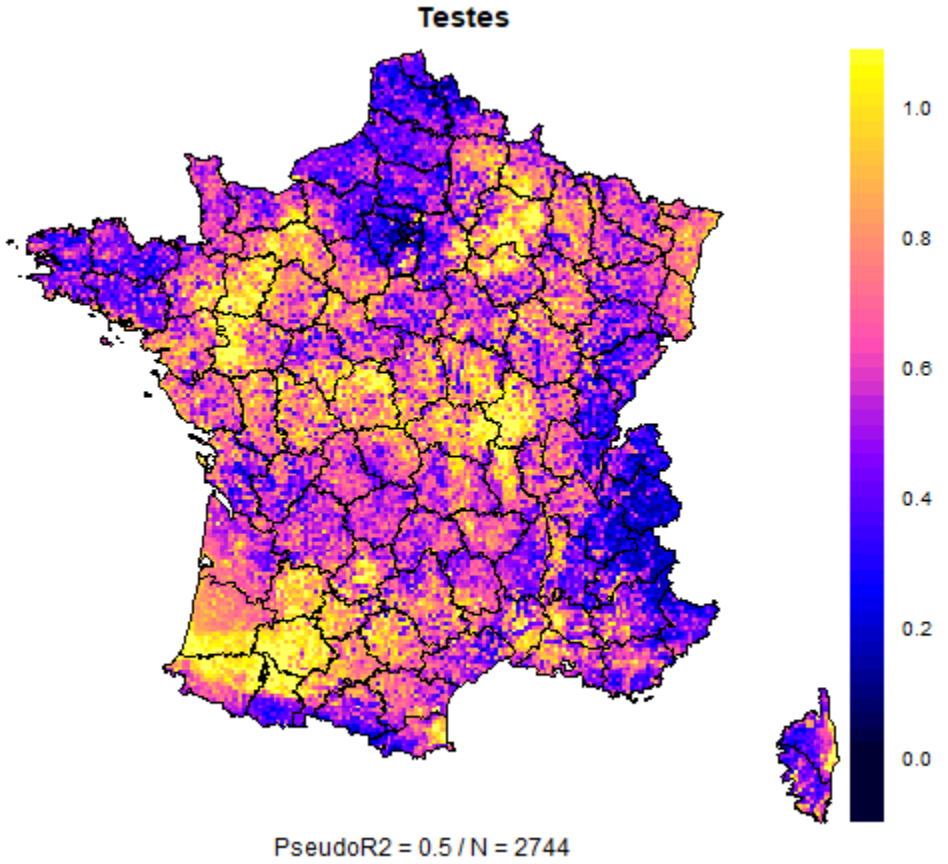
Lesser
Horseshoe Bat



Using acoustic activity to map species relative abundance

Identifying stronghold populations

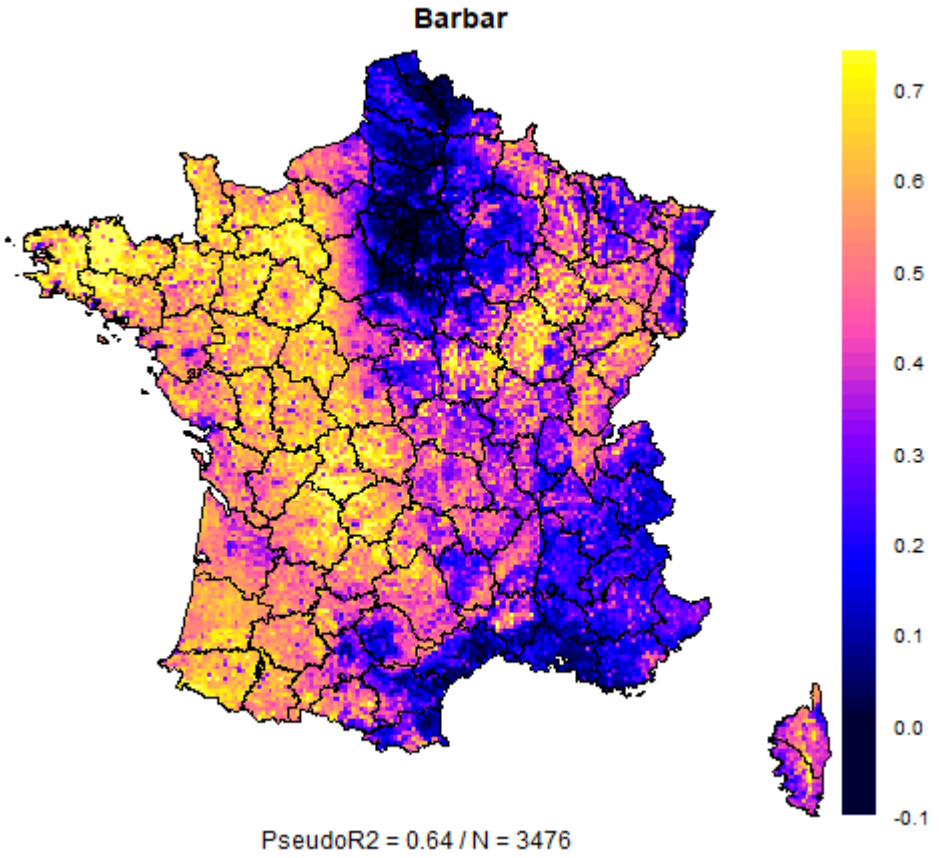
Slender Bush-Cricket



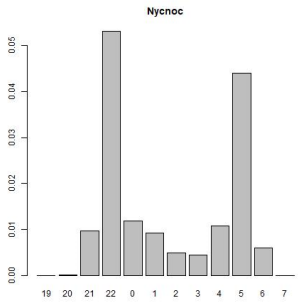
Using acoustic activity to map species relative abundance

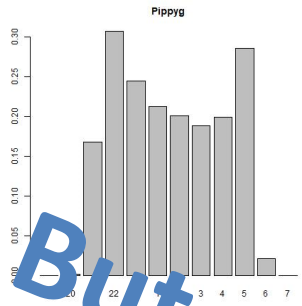
Identifying stronghold populations

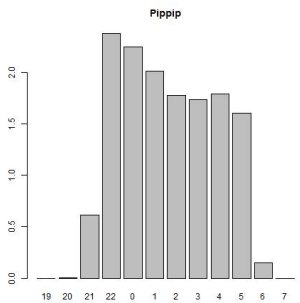
Barbastelle
Bat

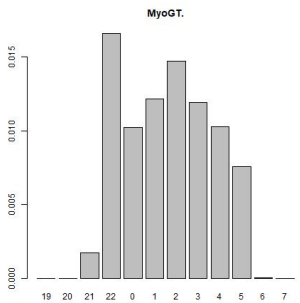


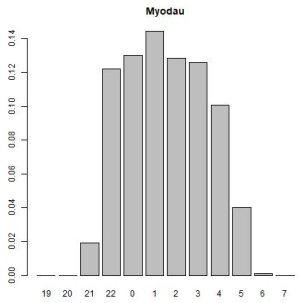
Rencontres scientifiques





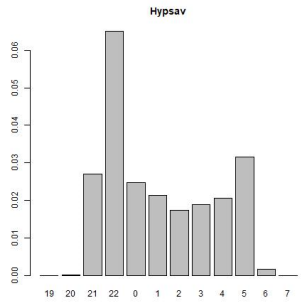


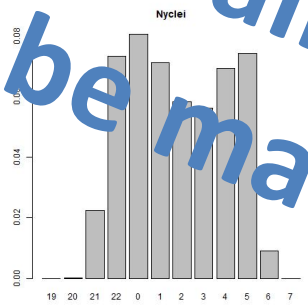


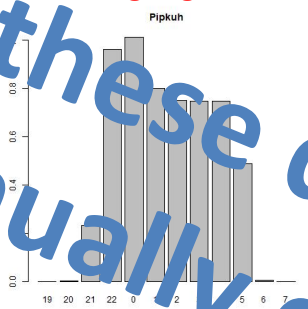


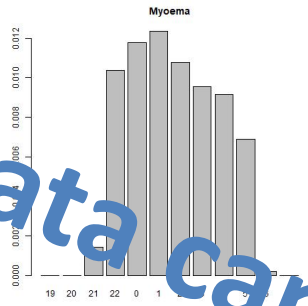
Benchmarking night-time activity

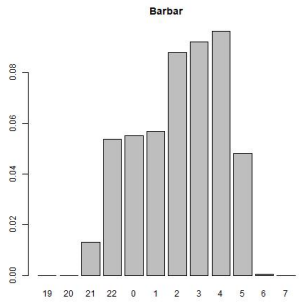
But all these data can't be manually checked

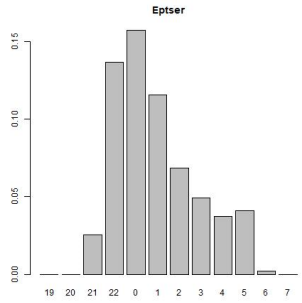


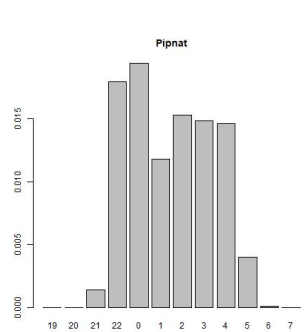


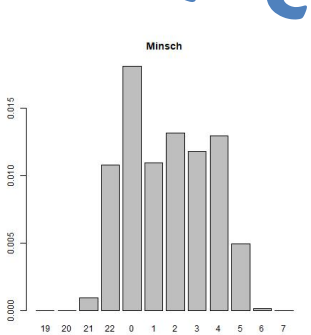


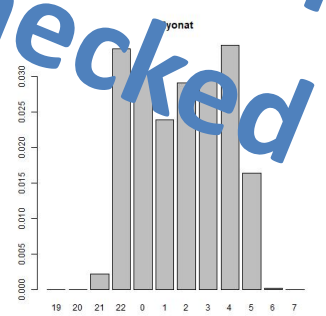


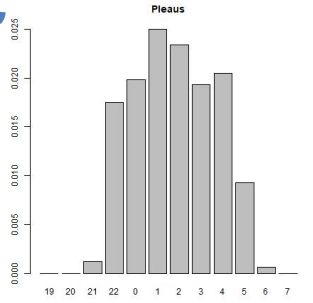










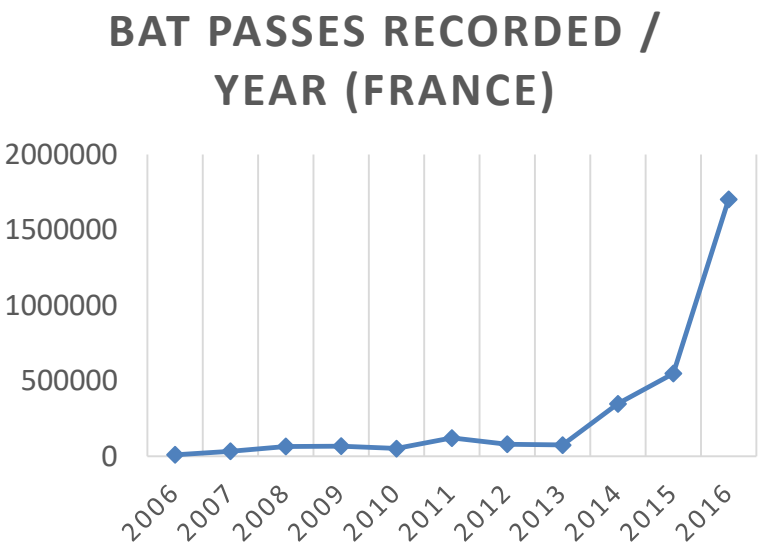


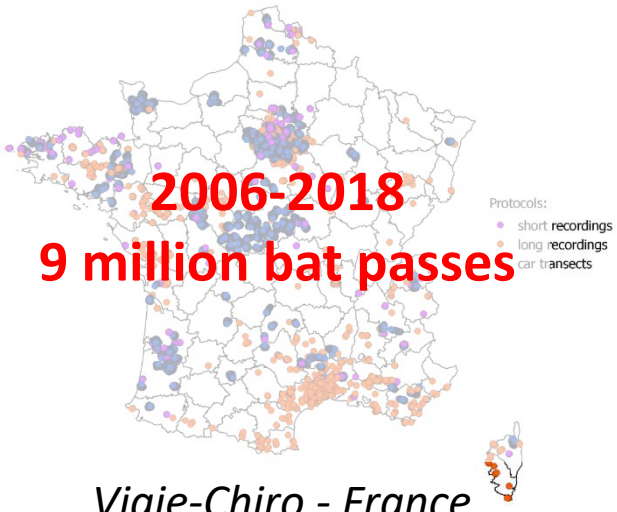
Vigie-Chiro

1) Introduction aux chiroptères (chauves-souris) et leur étude par l'acoustique
2) Les protocoles standardisés et participatifs
3) L'activité acoustique comme mesure d'abondance relative
4) L'identification automatique
5) La gestion des erreurs et la qualification des données

Why using automatic id?

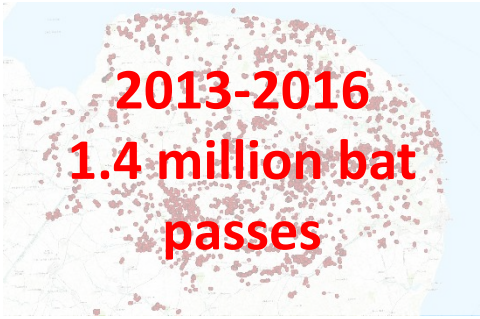
- Reduced costs => exponential data increase

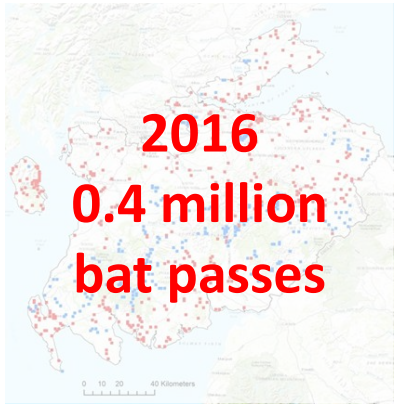




Vigie-Chiro - France

Norfolk BS (UK)





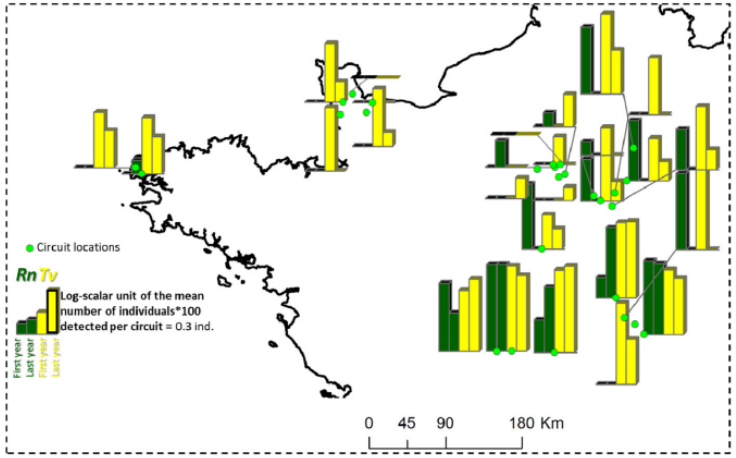
South Scotland BS (UK)

- Complete manual checking impossible…

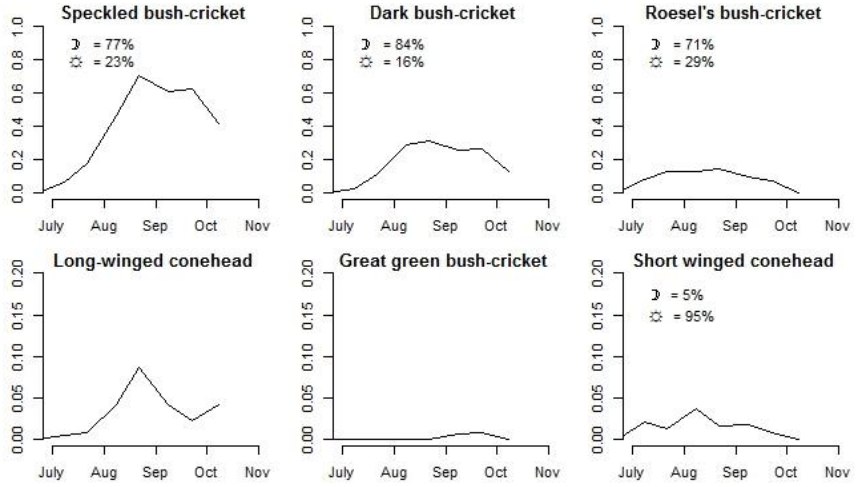
There is just no other way than auto id!

Why using automatic id?

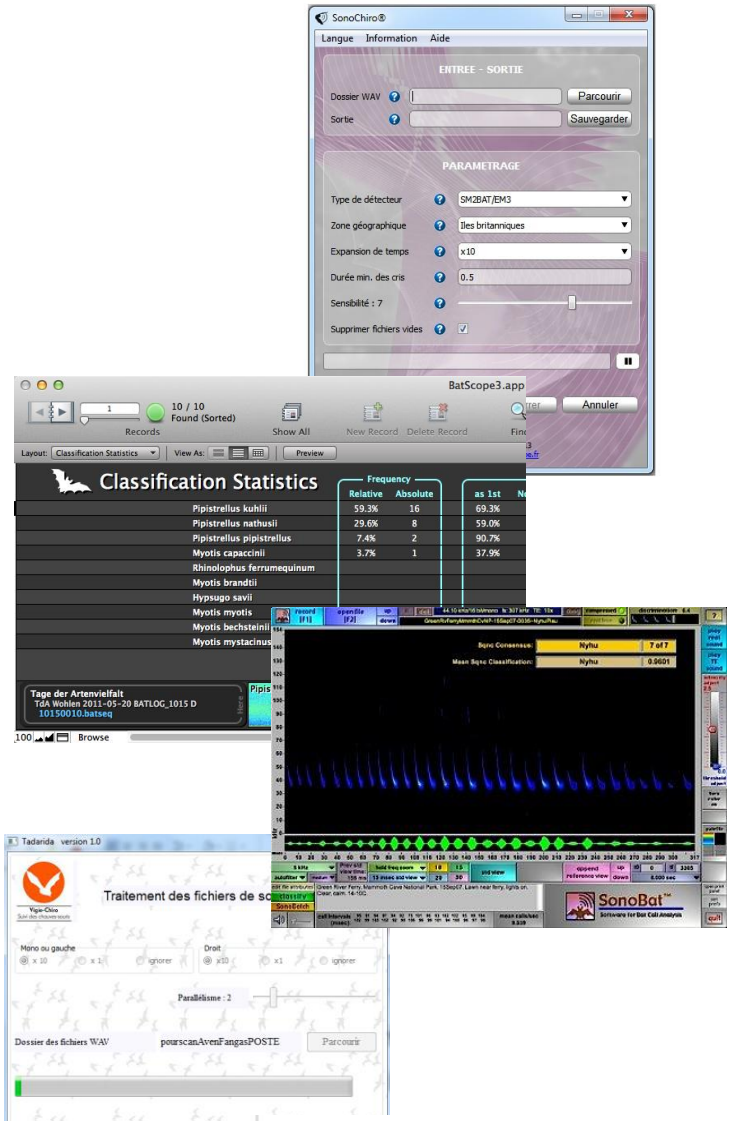
- Other less known good reasons:
  1) Manual checking error rate is decreasing over time! but biasing trends estimates… Solution: machines can easily re-analyse historic data and control observer bias
  2) You can get very good data on non-targeted taxa such as bush-crickets: spatial and temporal patterns, trends!!



Jeliazkov et al. (2016) GECCO



Newson et al. (2017) MEE



Auto id developments

Appeared recently (2012)

- **Fast development in Europe**

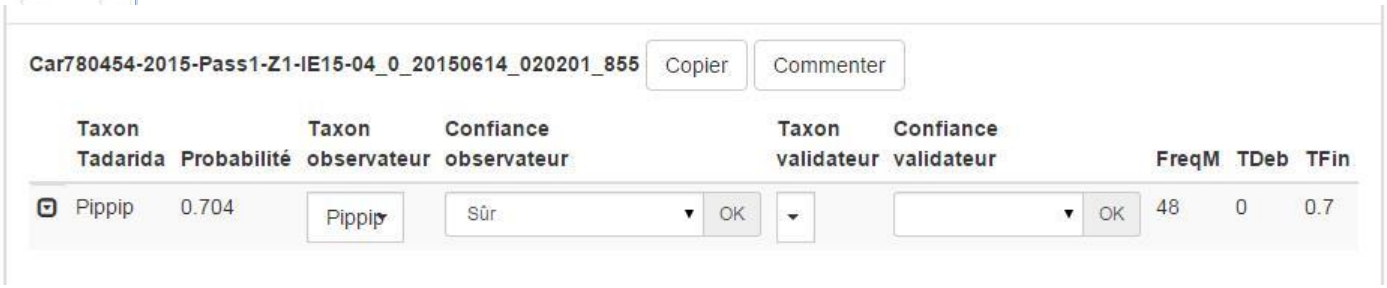
➢7 softwares en Europe, 4 in North America, 3 in Latin America, 1 in South Africa, etc

➢ Efficiency depends:

- On size of soundreference database
- Recorder type
- The number of species covered (10-114)

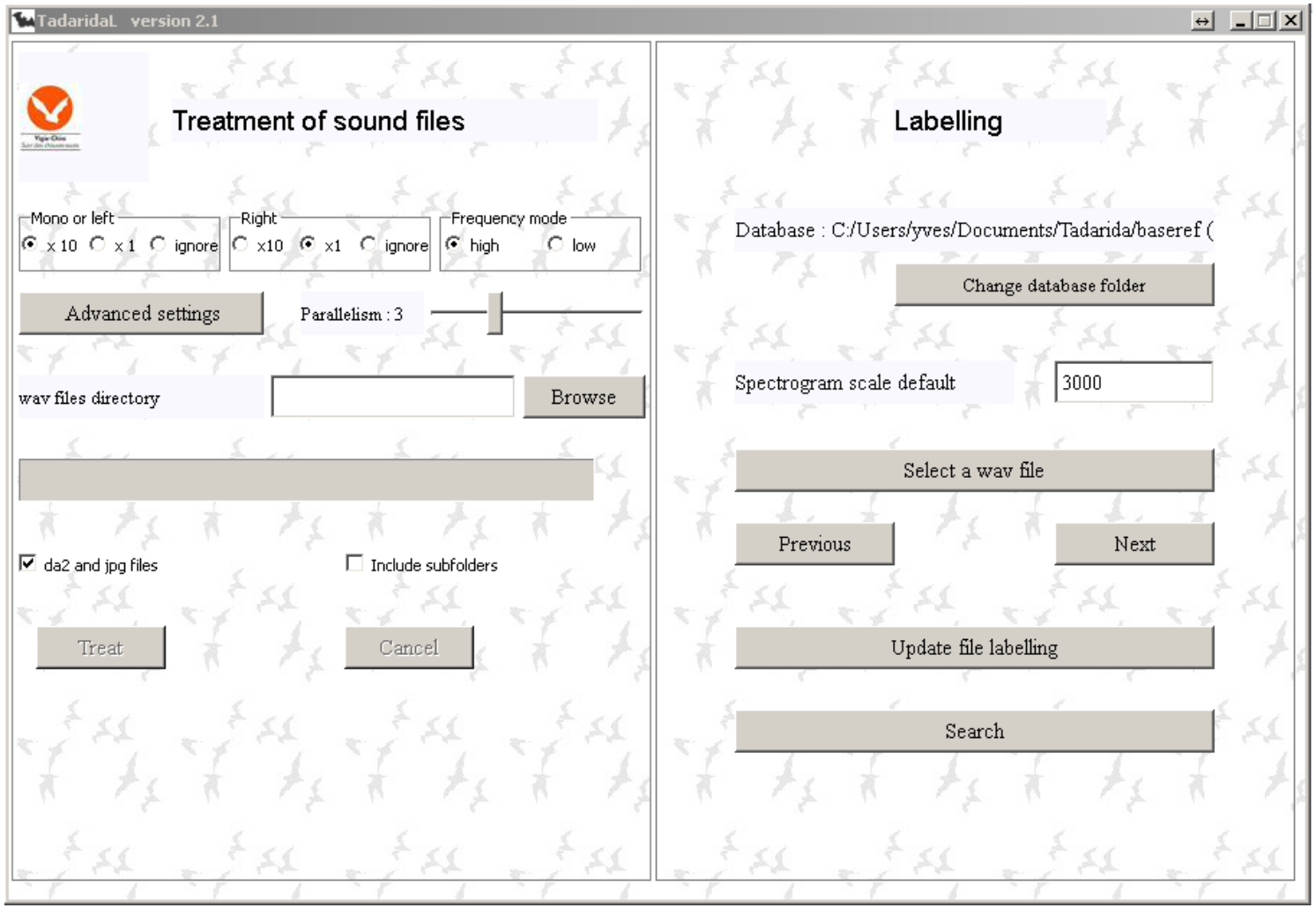
- Principle: **software propose an** identification with a confidence score, **the user validate a sample**…

➢Time gain depends on objectives of analysis



How using auto id?

- The example of Tadarida open software



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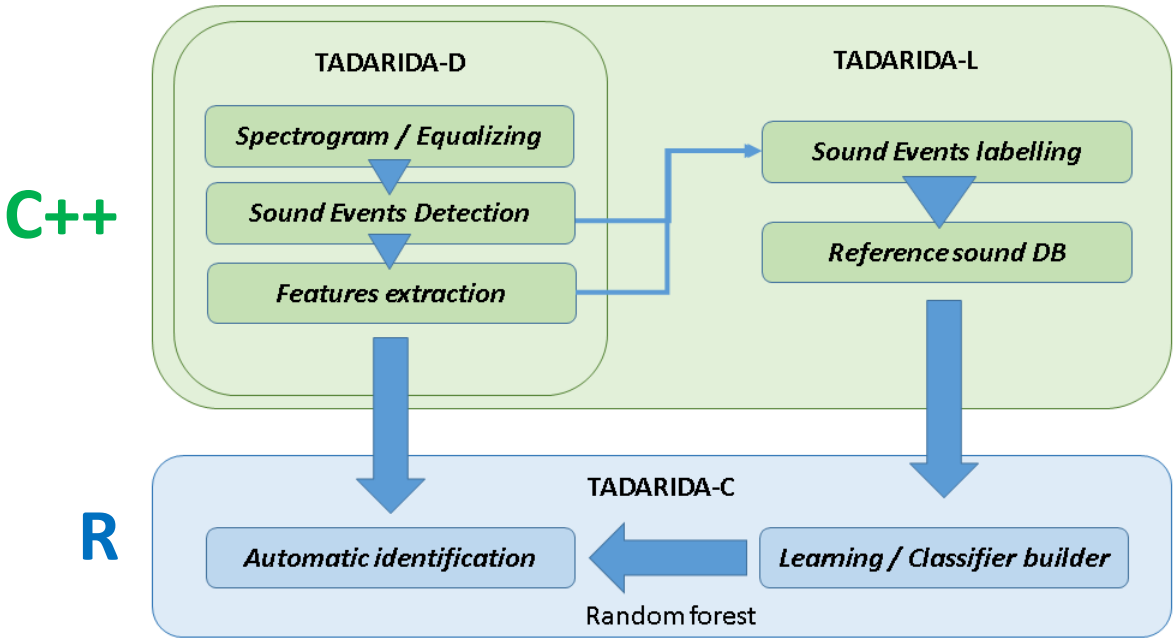

Bas et al. (2017) JORS

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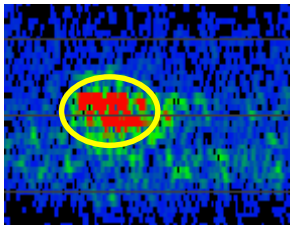
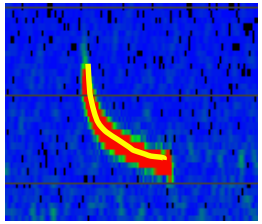
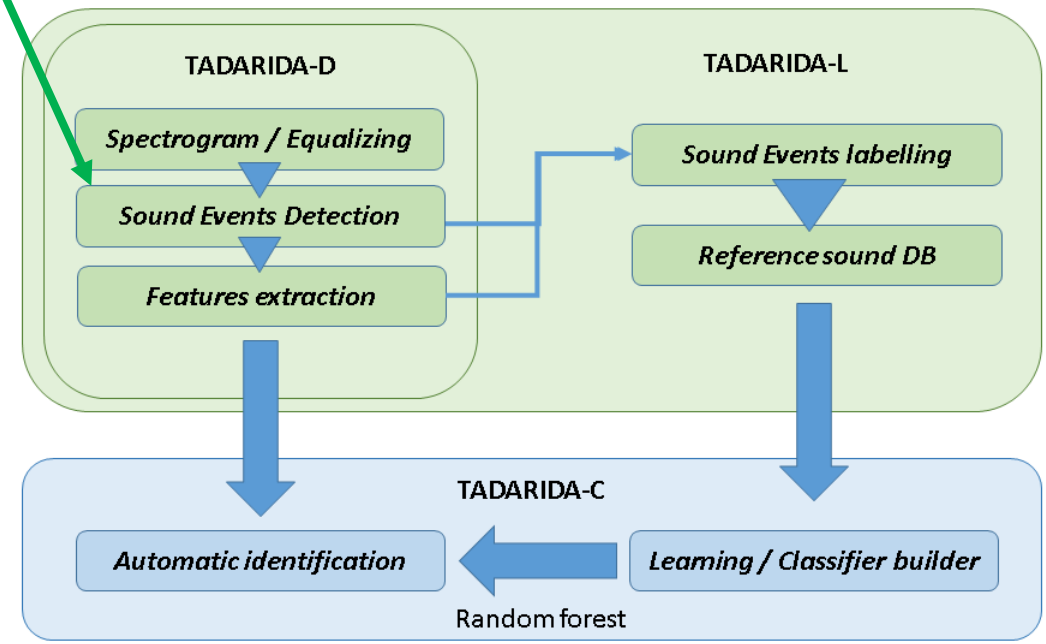


Generic time/freq. segmentation





Bas et al. (2017) JORS

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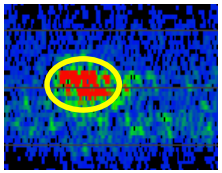
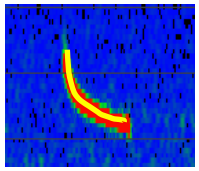


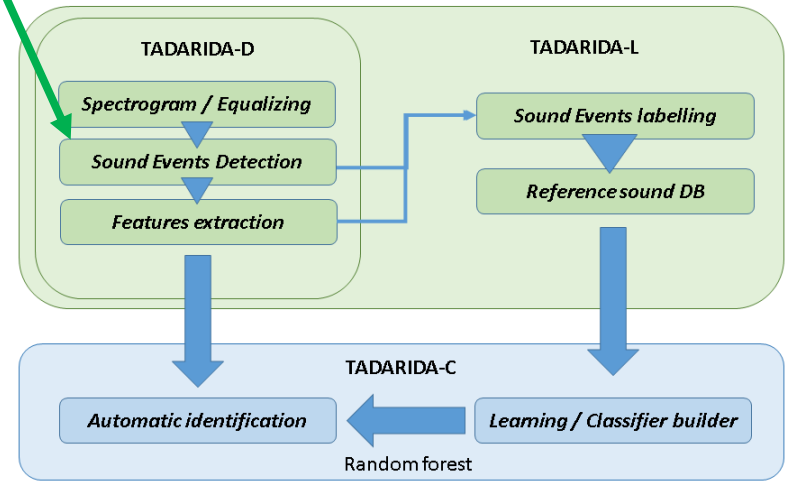
Generic acoustic event detector



High frequency mode (8-250 kHz)
FFT size : 0.8-1.6 ms
Overlap 75%

- Resolution :
  - 0.2-0.4 ms
  - 0.6-1.2 kHz

Background noise =
quantile 5% per frequency bands
Detection on start (26 dB SNR) and stop (20 dB SNR) threshold (hysteresis principle)



Bas et al. (2017) Journal of Open Research Software

How using auto id?

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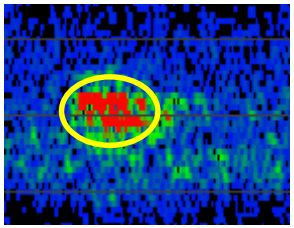

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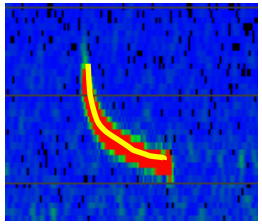
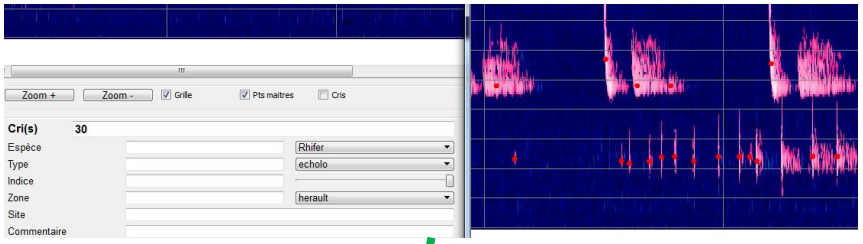
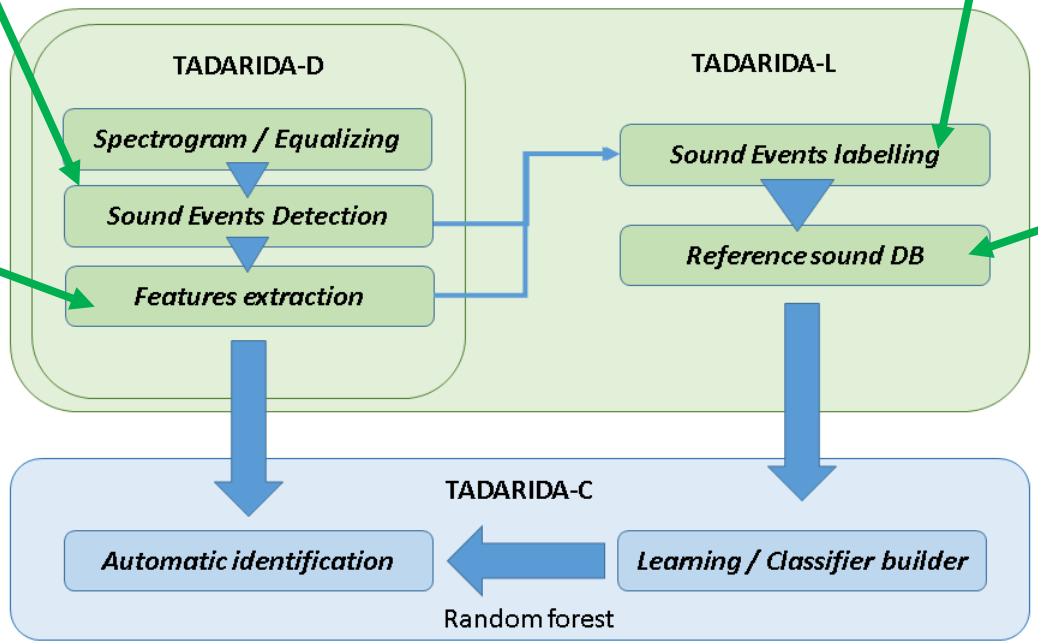




Extracting 271 numerical features per event, describing frequency / amplitude / rythm



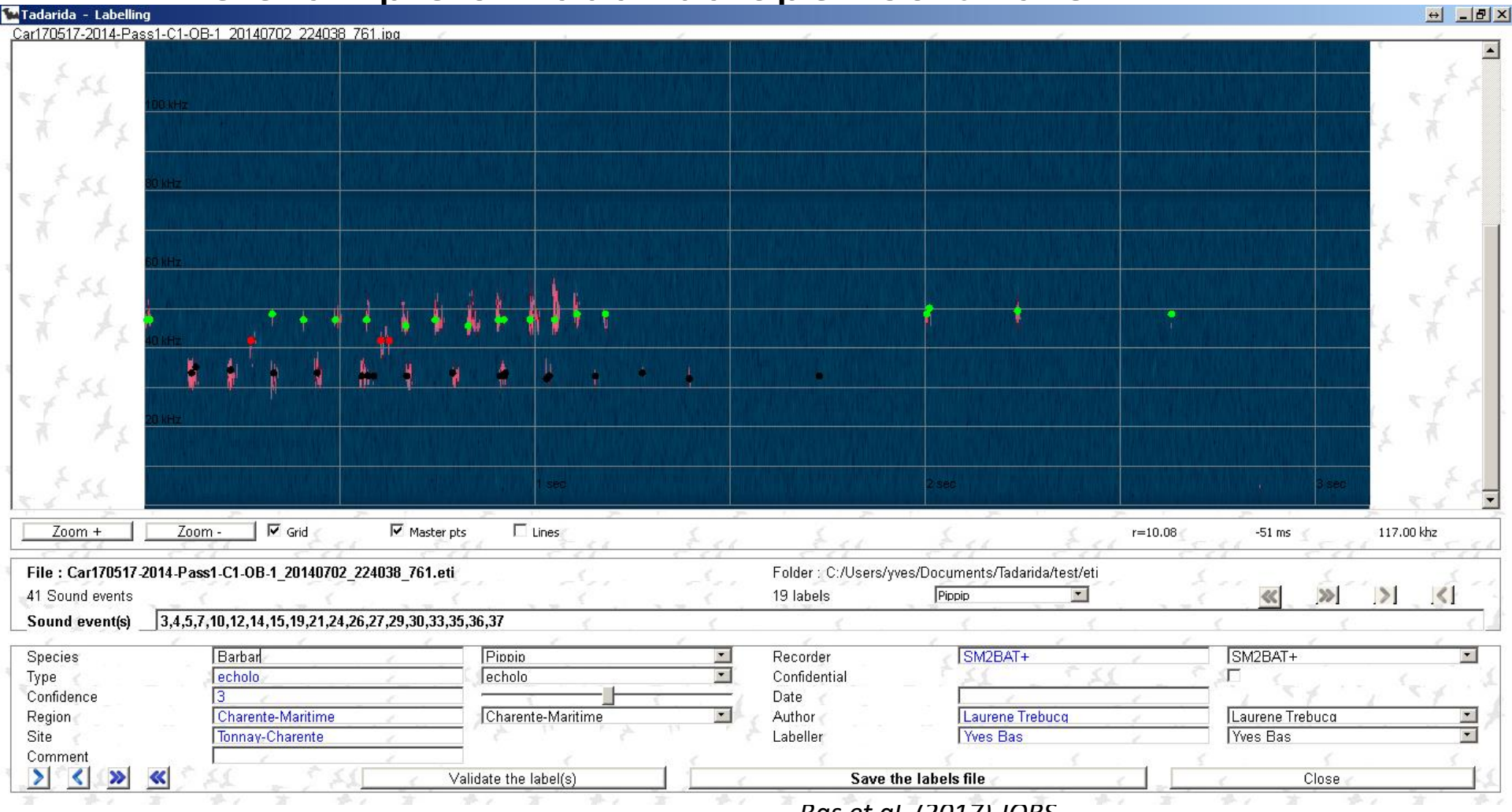
Graphical interface to **quickly label** sound events

⇒ **1 115 909 to date / 21365 files**

Bas et al. (2017) JORS

How using auto id?

- The example of Tadarida open software



Bas et al. (2017) JORS

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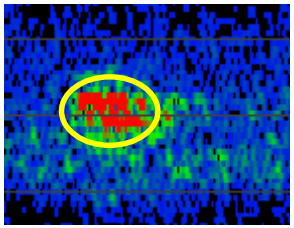

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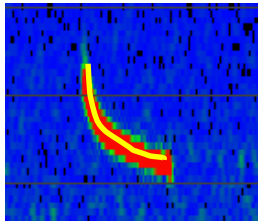

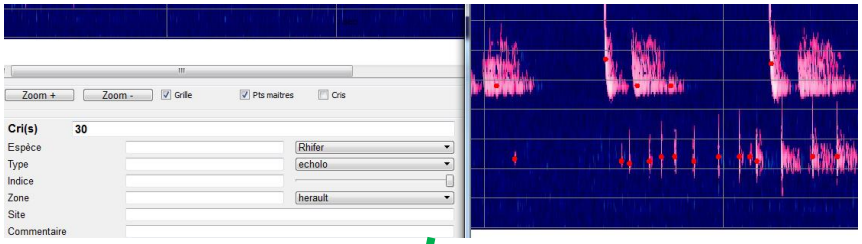

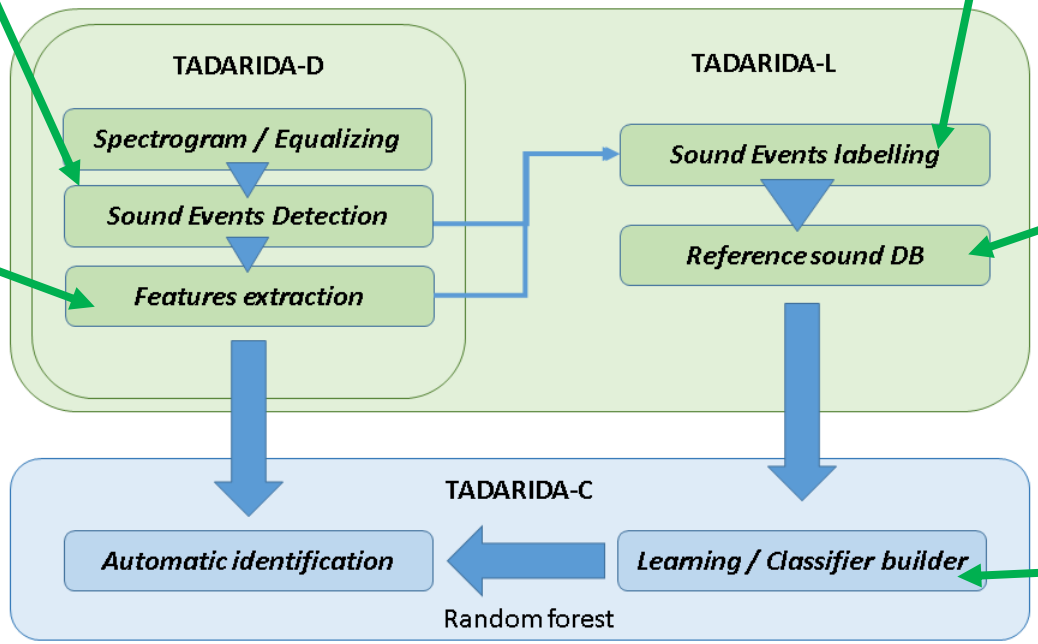

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Graphical interface to **quickly label** sound events
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Random forest classification detecting simultaneously several species

Bas et al. (2017) JORS

How using auto id?

- Tadarida-C
  - 3 classification layers:

1) Classification per calls

   Random forest with bootstrap of train samples stratified per sites

   Correcting unevenness of sample per classes/species (trade-off quantity / evenness)

   + Ad hoc Algorithm clustering clustering calls in sequences

AUC = 0.885

2) Classification of sequences (= different species or not)

   Random forest on train files from which species list are exhaustives

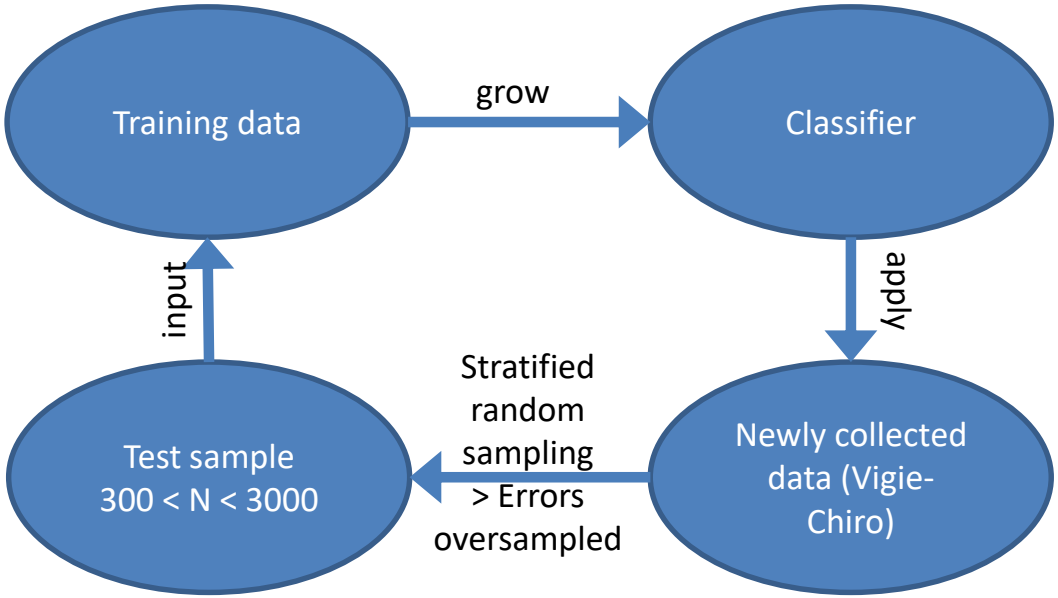
3) Error correction according to context

AUC = 0.967

   Random forest of sequences according to whole-night sampling information (scores of other occurrences, ratio of species occurrences)

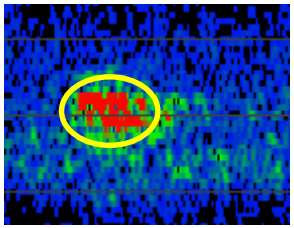
How using auto id?

- Tadarida-C
  - Training « round » :



How using auto id?

- The example of Tadarida open software



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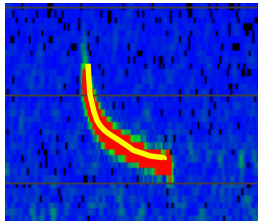
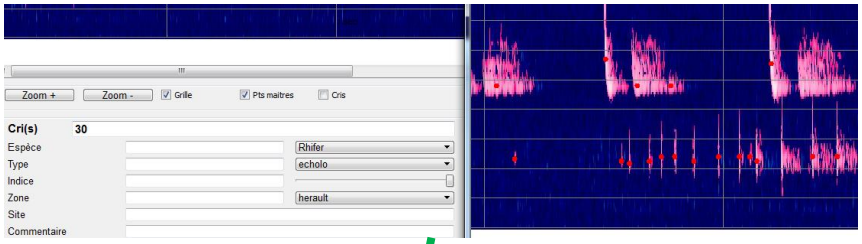
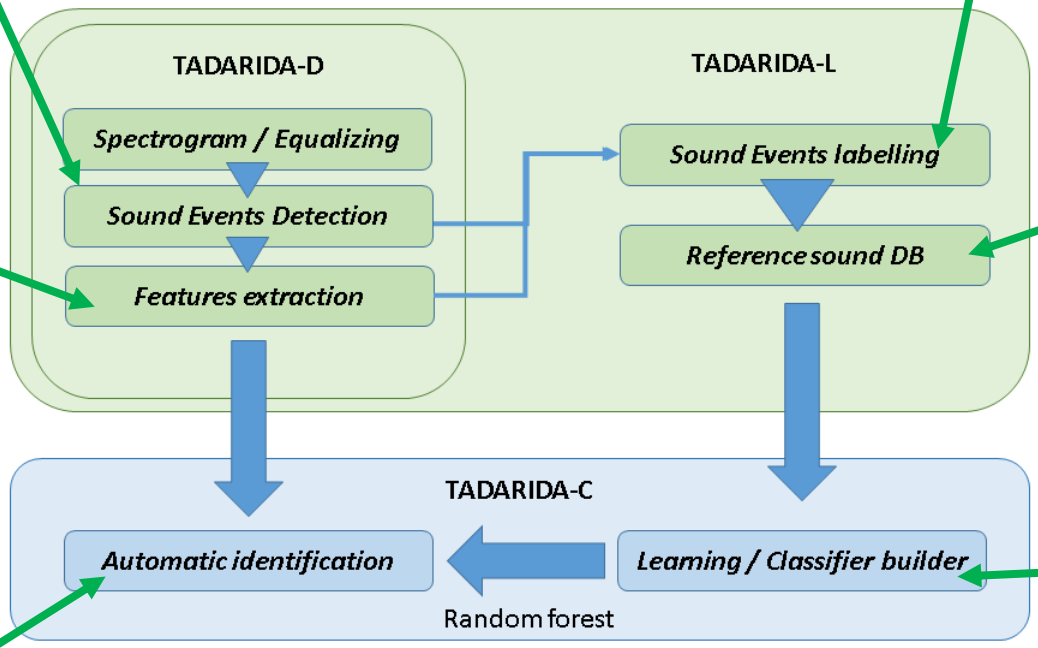






Extracting 271 numerical features per event, describing frequency / amplitude / rythm

Graphical interface to **quickly label** sound events
⇒ **1 115 909 to date / 21365 files**

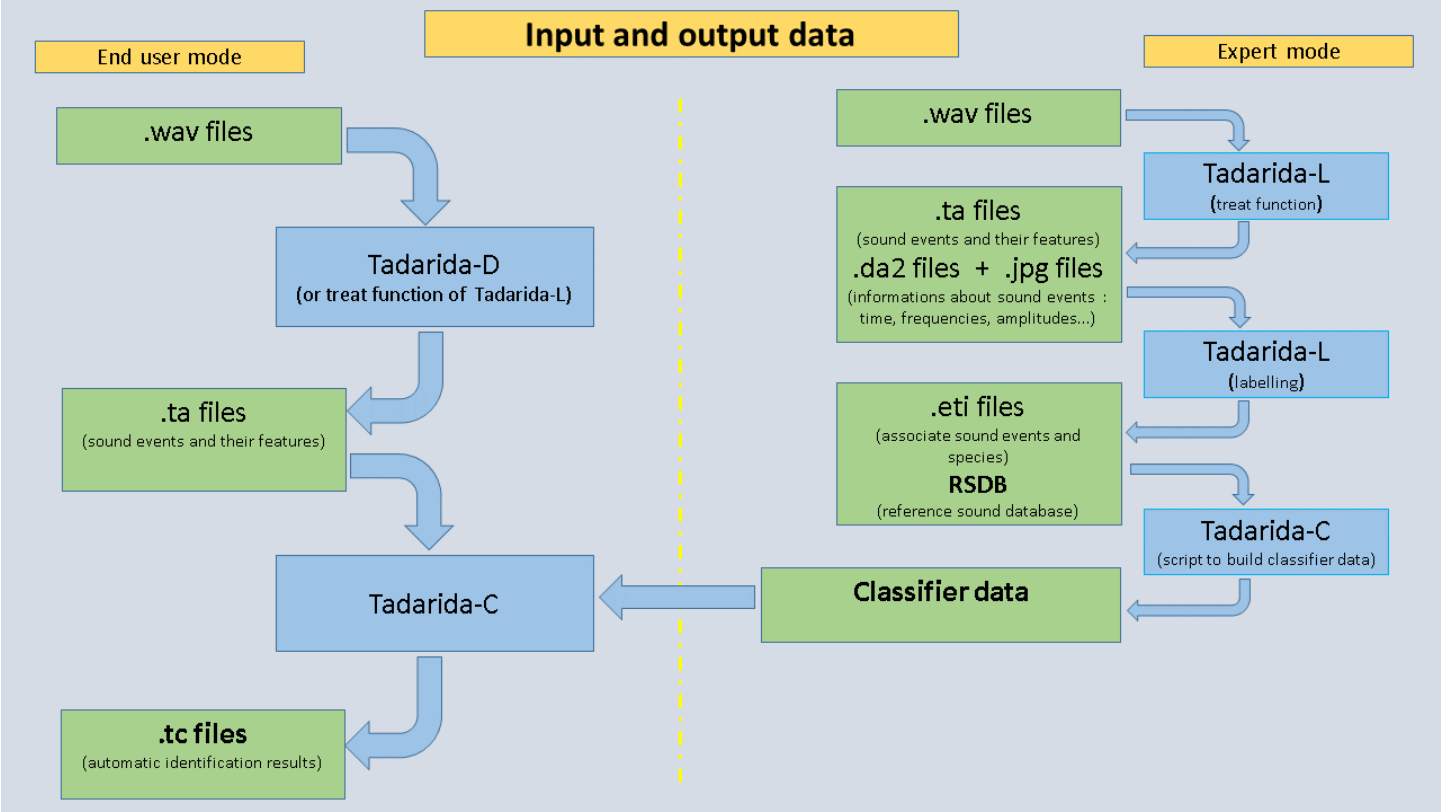
Random forest classification detecting simultaneously several species

Apply to any new data

Bas et al. (2017) JORS

How using auto id?

The workflow



Bas et al. (2017) JORS

Improvement perspectives

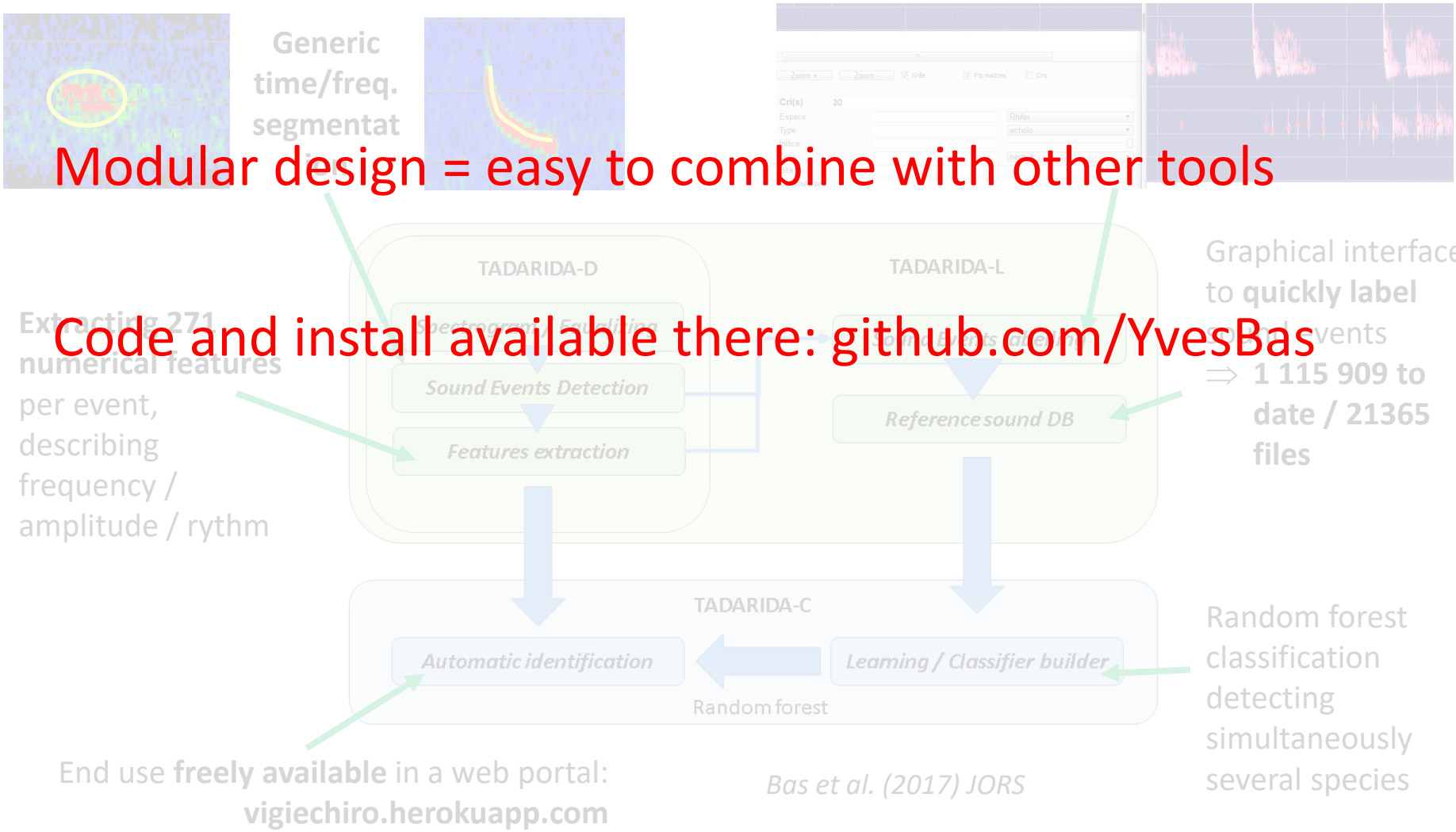
- Segmentation / detection :
  - Use of amplitude distribution within sound events to distinguish close syllables (bird songs)
  - Varying FFT size for narrowband vocalisation (ground-crickets)
  - More features accounting for « echo effects »

Improvement perspectives

- Classification :
  - New methods: deep learning winning BirdClef challenges starting 2016.
  - Improve sound references:
    - Quantity : collaborative > integrating Tadarida-L in a web site
    - Quality: minimising error risk in reference by recording close to known roosts
  - More predictors (acoustic features, context features)
  - Hiearchical classifiers (more species, behaviours)

How using auto id?

- The example of Tadarida open software

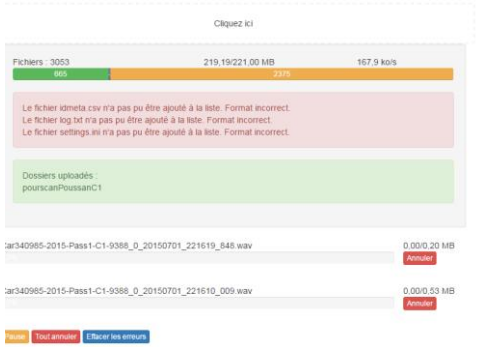


How using auto id?

- The example of Tadarida open software

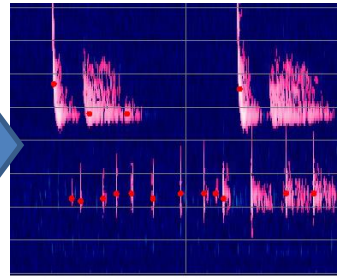
End use available through a web portal: vigiechiro.herokuapp.com

Data collection



Online data transfer

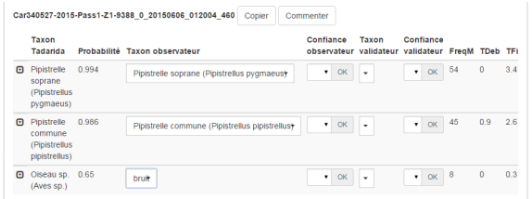
Automatic secure storage (iRODS - IN2P3)



Data processing (Tadarida)

#	Taxon parent	Nom	Nb contact min	Nb de contact
1	Chiroptères	Oreillard gris (Plecotus austriacus)	0	13
2	Chiroptères	Minioptère de Schreibers (Miniopterus schreibersii)	1	2
3	Chiroptères	Pipistrelle soprane (Pipistrellus pygmaeus)	3252	3334
4	Chiroptères	Noctule de Leisler (Nyctalus leisleri)	43	110
5	Chiroptères	Murin de Daubenton (Myotis daubentonii)	0	11
6	Chiroptères	Murin à oreilles échancrées (Myotis emarginatus)	0	1
7	Chiroptères	Pipistrelle de Kuhl (Pipistrellus kuhlii)	642	702
8	Chiroptères	Sérotine commune (Eptesicus serotinus)	0	26
9	Chiroptères	Murin de Capaccini (Myotis capaccinii)	0	1
10	Chiroptères	Pipistrelle de Nathusius (Pipistrellus nathusii)	3	5

Automatic feedback



Online manual checking

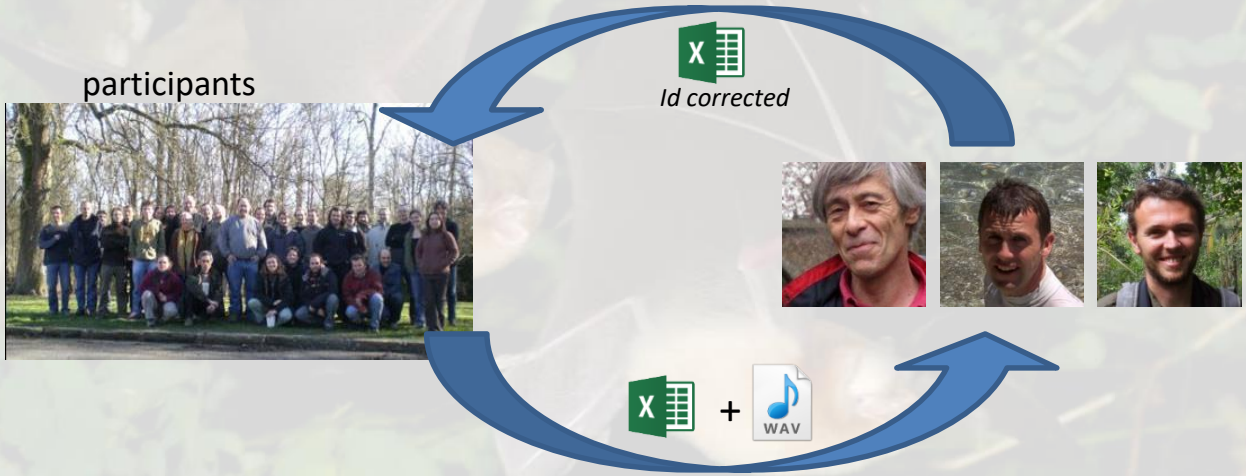
SCILLE

https://github.com/Scille/vigiechiro-front

https://github.com/Scille/vigiechiro-api

Back to history (2006-2010)

- A virtuous cycle

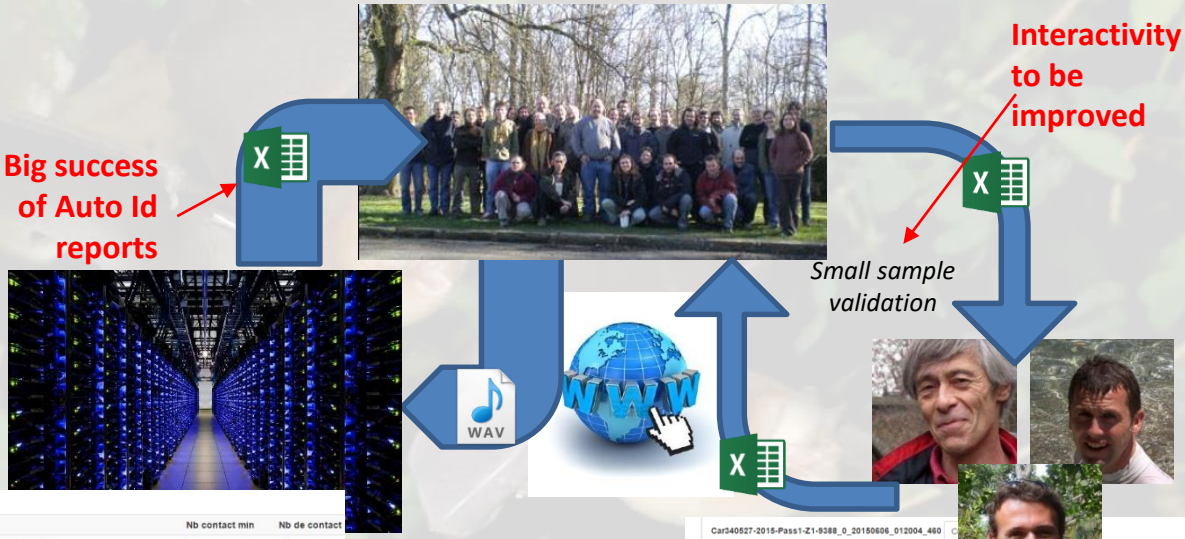


2011-2014: hard to follow…

- Increasing participation slowed the cycle…

2015-2016: Web portal and Tadarida implementation

- Towards a quicker cycle



Bilan de la participation

#	Taxon parent	Nom	Nb contact min	Nb de contact
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4	Chiroptères	Noctule de Leisler (Nyctalus leisleri)	43	110
5	Chiroptères	Murin de Daubenton (Myotis daubentonii)	0	11
6	Chiroptères	Murin à oreilles échancrées (Myotis emarginatus)	0	1
7	Chiroptères	Pipistrelle de Kuhl (Pipistrellus kuhlii)	642	702
8	Chiroptères	Sérotine commune (Eptesicus serotinus)	0	28
9	Chiroptères	Murin de Capaccini (Myotis capaccinii)	0	1
10	Chiroptères	Pipistrelle de Nathusius (Pipistrellus nathusii)	3	5

Car340527-2015-Pass1-Z1-9388_0_20150606_012004_460

Taxon Tadarida	Probabilité	Taxon observateur	Confiance validateur	FreqM	TDeb	TFi
Pipistrelle soprane (Pipistrellus pygmaeus)	0.994	Pipistrelle soprane (Pipistrellus p	OK	54	0	3.4
Pipistrelle commune (Pipistrellus pipistrellus)	0.986	Pipistrelle commune (Pipistrellus pipistrellus)	OK	45	0.9	2.6
Oiseau sp. (Aves sp.)	0.65	bruit	OK	8	0	0.3

Vigie-Chiro

1) Introduction aux chiroptères (chauves-souris) et leur étude par l'acoustique
2) Les protocoles standardisés et participatifs
3) L'activité acoustique comme mesure d'abondance relative
4) L'identification automatique
5) La gestion des erreurs et la qualification des données

How's automatic acoustic monitoring doing?

- Norfolk Bat Survey

Table 2
Results showing the process involved in analysing and validating acoustic bat data collected through this project, and the number of recordings

Identity	Step 1. Initial analysis	Step 2. Secondary recoding		Step 3. Manual analysis of recordings: re	
	Initially assigned to species	Recordings removed (confidence index < 3 and/or < 3 calls)	Confidence index at end of Step 2 (median, range)	Recordings manually checked	% unchanged
Mdau	5403	3635	3 (3–6)	1768	90%
Mmys/Mbra	3471	1950	3 (3–6)	1521	28%
Mnat	1793	491	4 (3–10)	1302	85%
Nnoc	8032	785	8 (3–10)	7247	88%
Nlei	673	357	5 (3–10)	316	87%
Eser	4053	1623	4 (3–9)	2430	99%
Ppip	338,260	8969	10 (3–10)	1000 (sample)	99%
Ppyg	179,482	6826	10 (3–10)	1000 (sample)	99%
Pnat	1740	733	5 (3–10)	1007	91%
Paur	4224	2264	5 (3–10)	1960	99%
Bbar	2732	744	8 (3–10)	1988	100%

Low error rate for many species

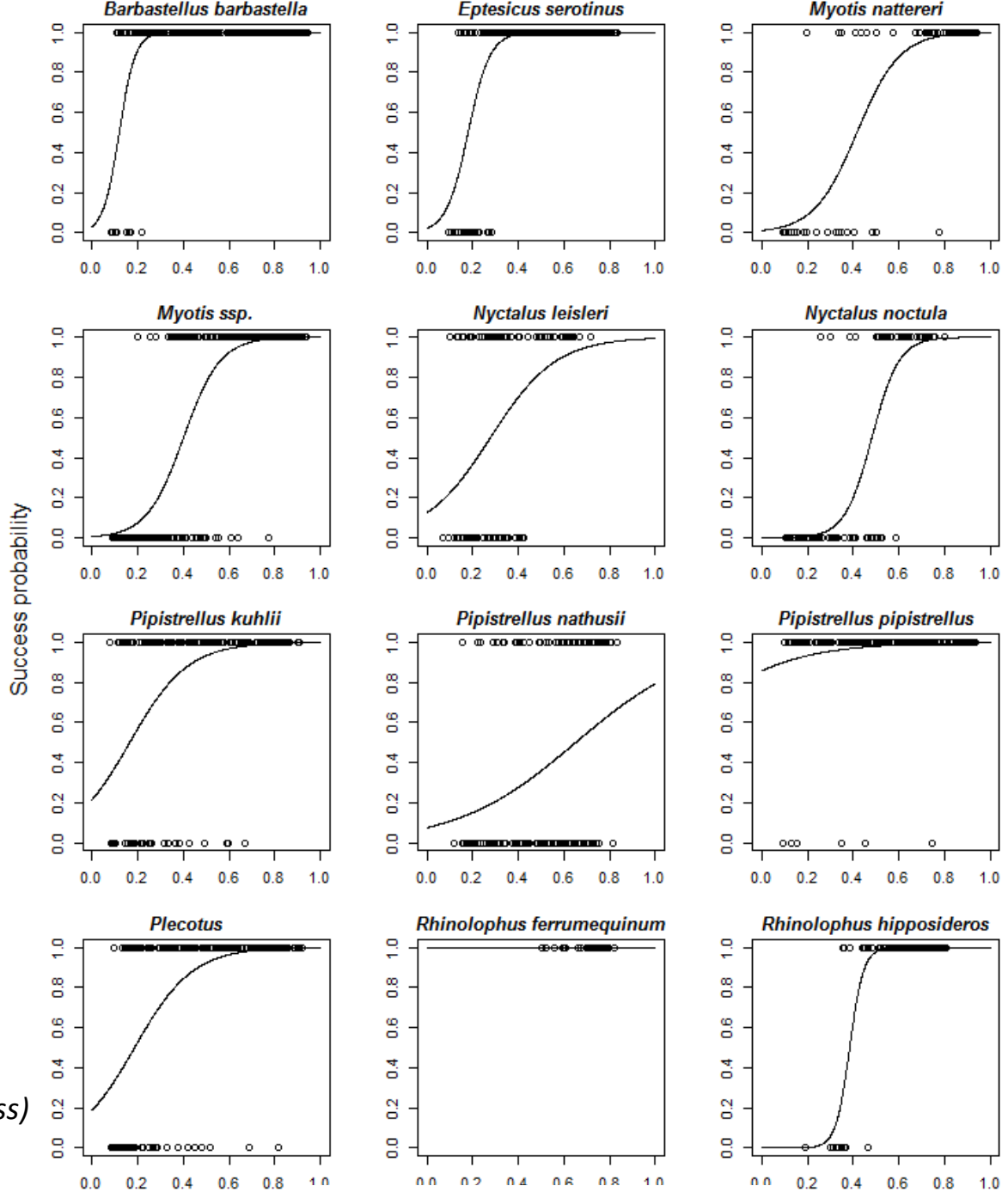
Newson et al. (2015)
Biological Conservation

Auto id: Score reliability

- Correlate error risk / confidence score
  - identifying selection thresholds

Confirmed id ~ software confidence

(Barré et al. 2019 MEE, in press)

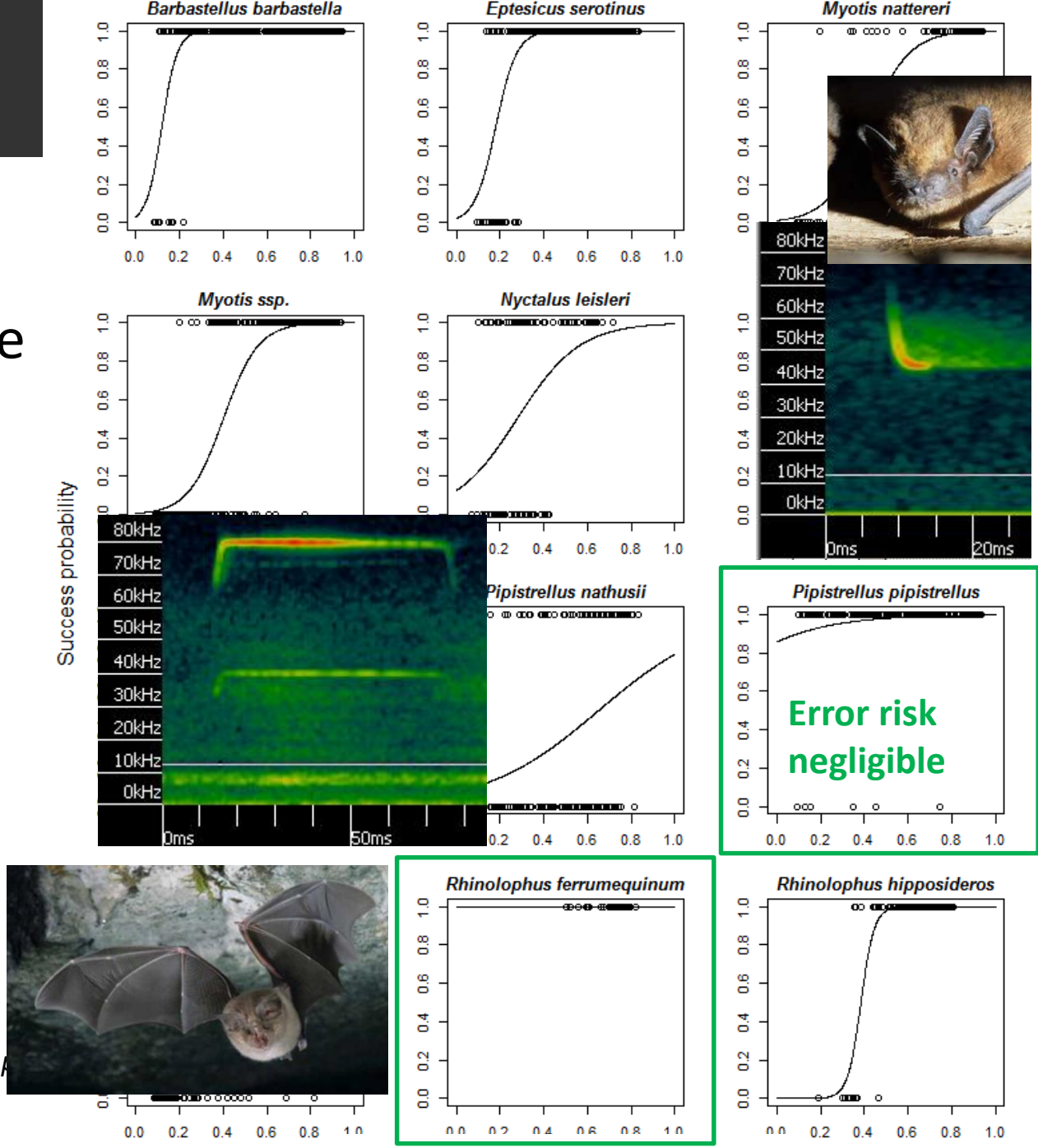


Error modelling

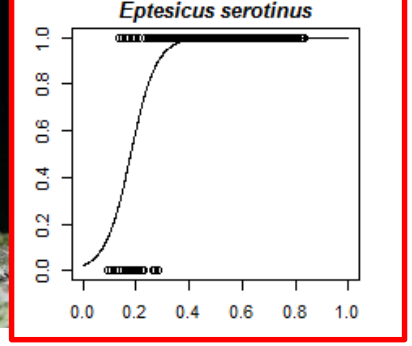
- Correlate error risk / confidence score
  - identifying selection thresholds

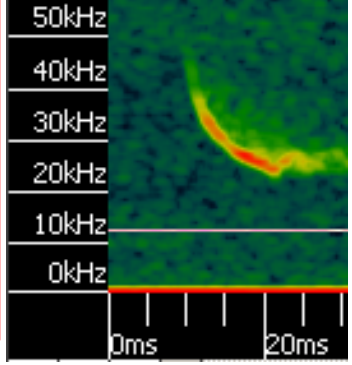
Confirmed id ~ software confidence

(Barré et al. 2019 MEE, in p



Error modelling





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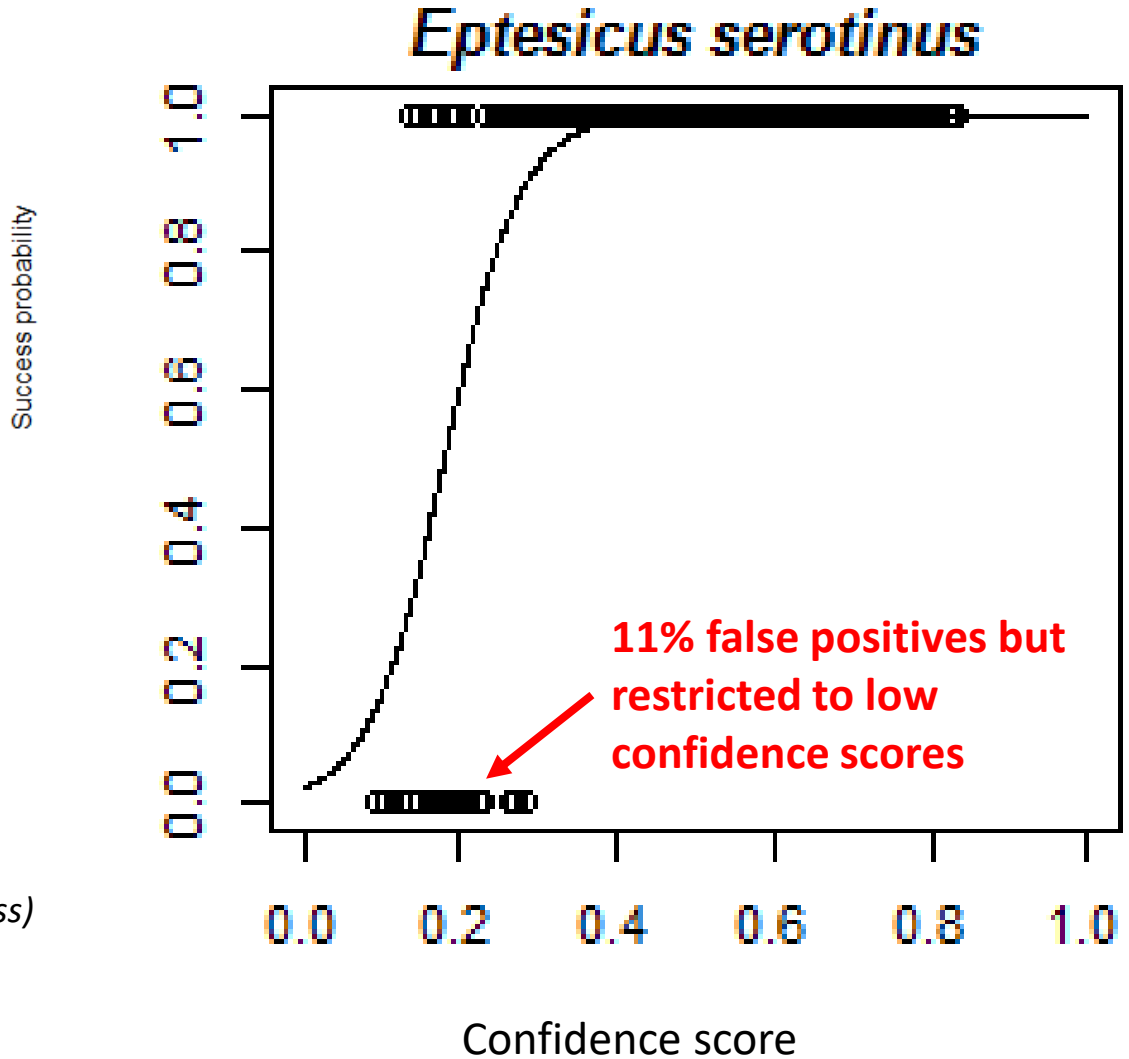
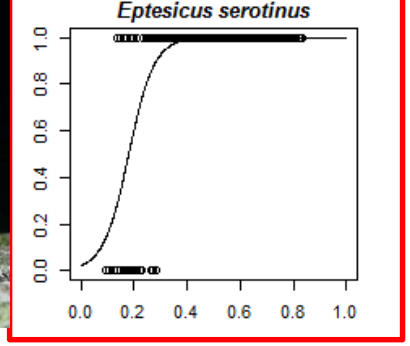
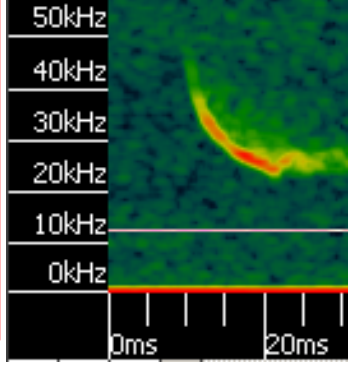
(Barré et al. 2019 MEE, in press)



Error modelling





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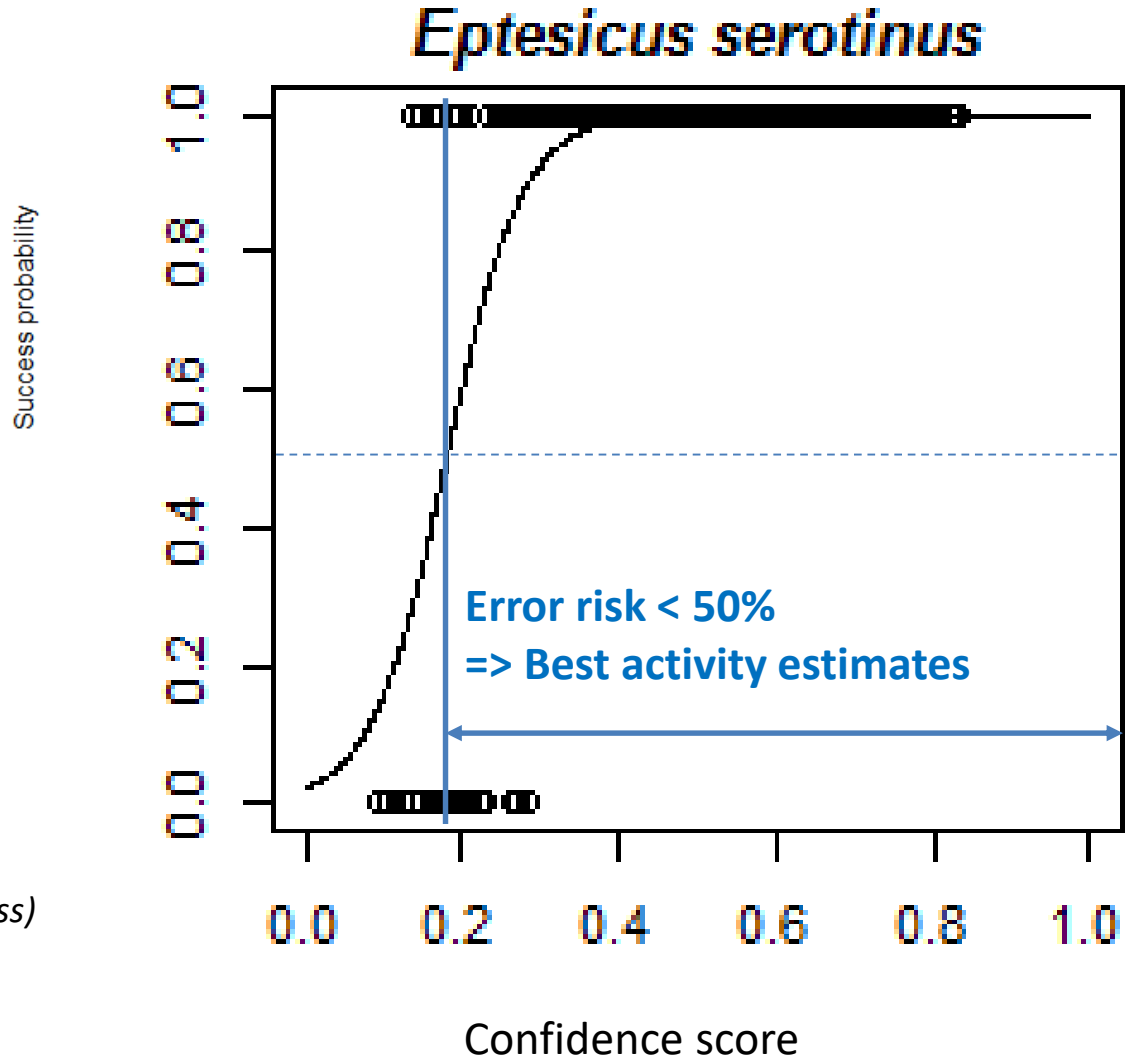
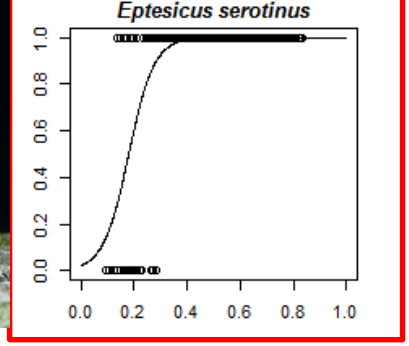
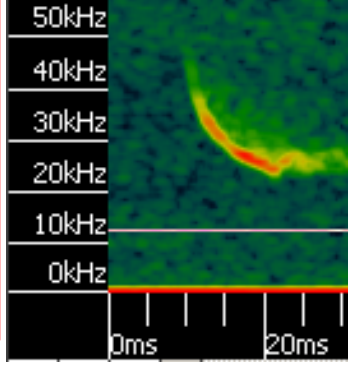


Error modelling





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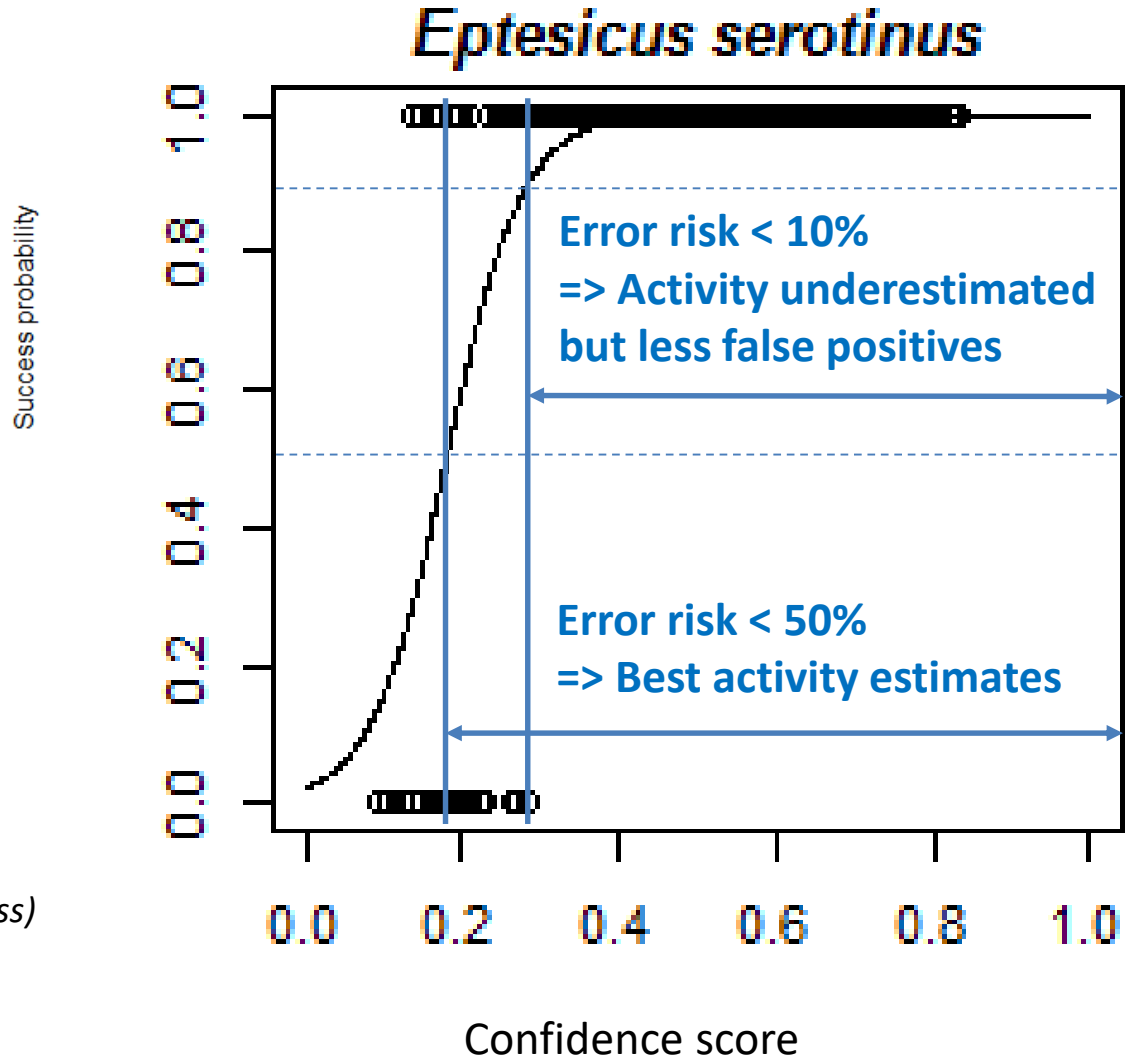

Error modelling

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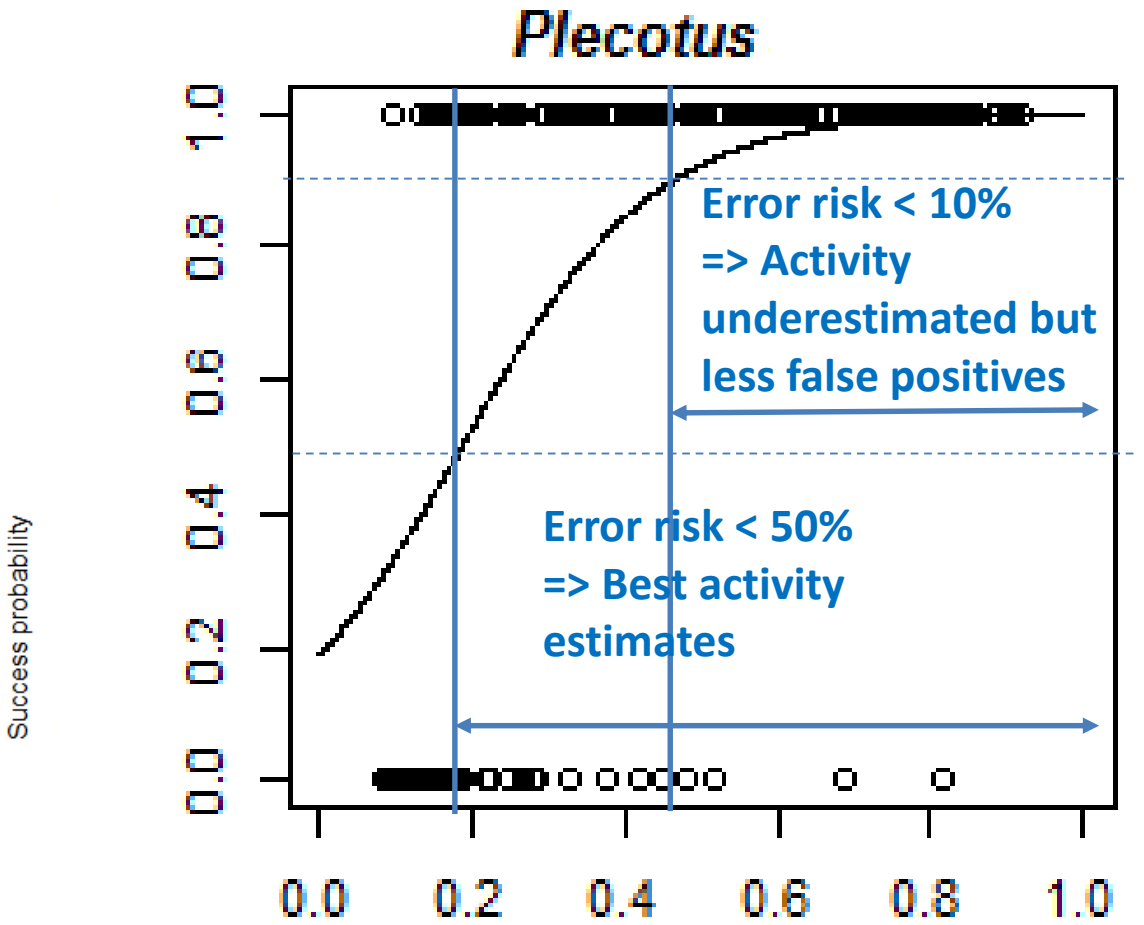

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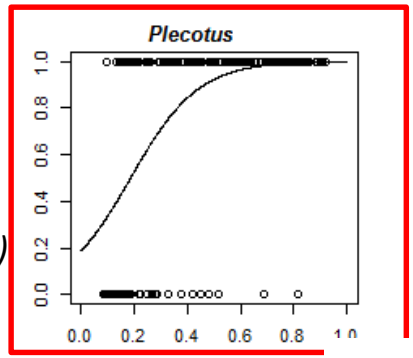

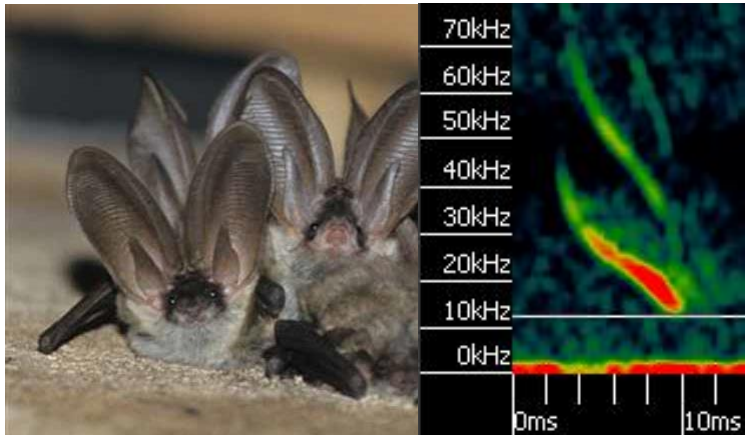

Error modelling

- Correlate error risk / confidence score
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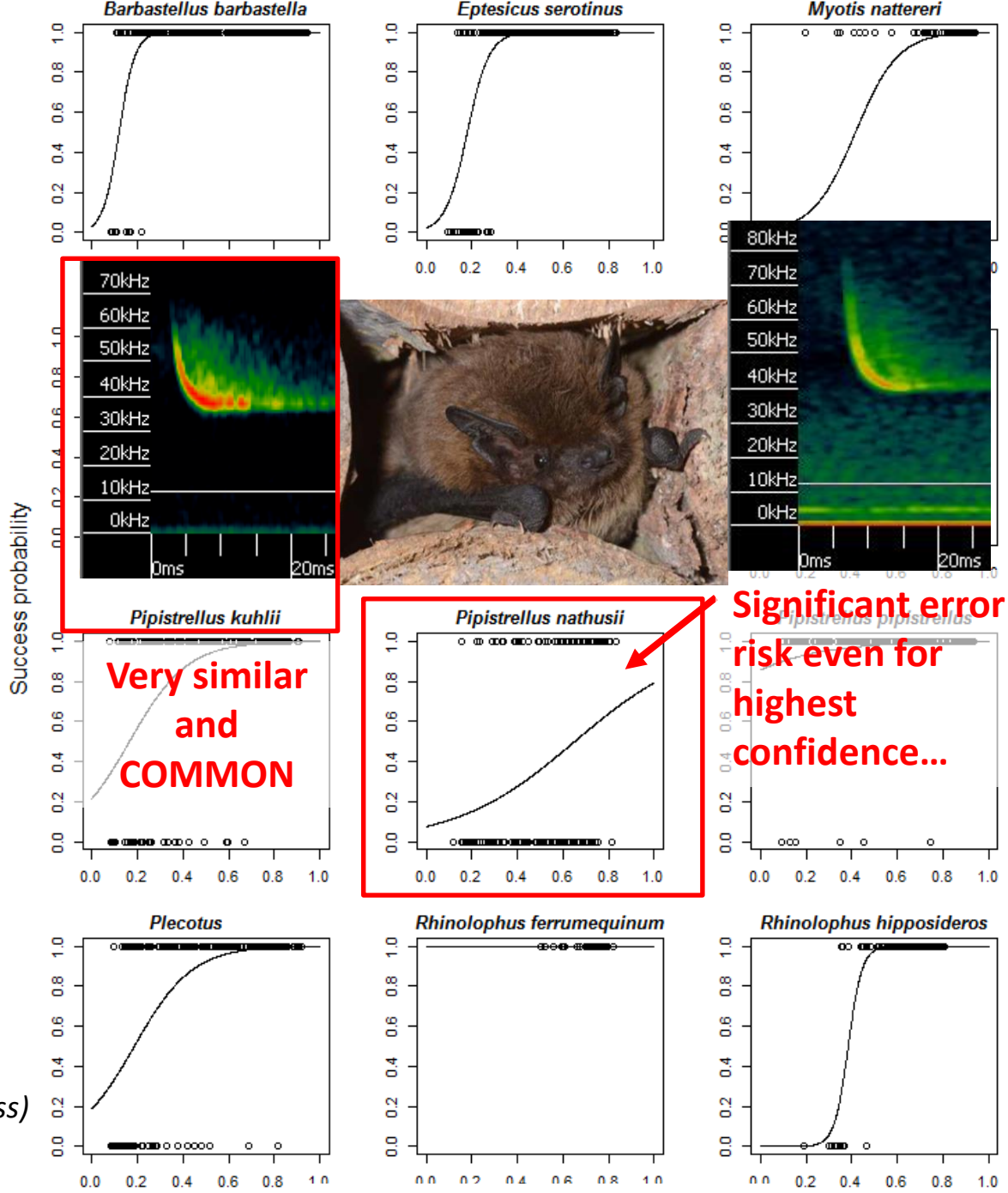
(Barré et al. 2019 MEE, in press)



How's automatic acoustic monitoring doing?

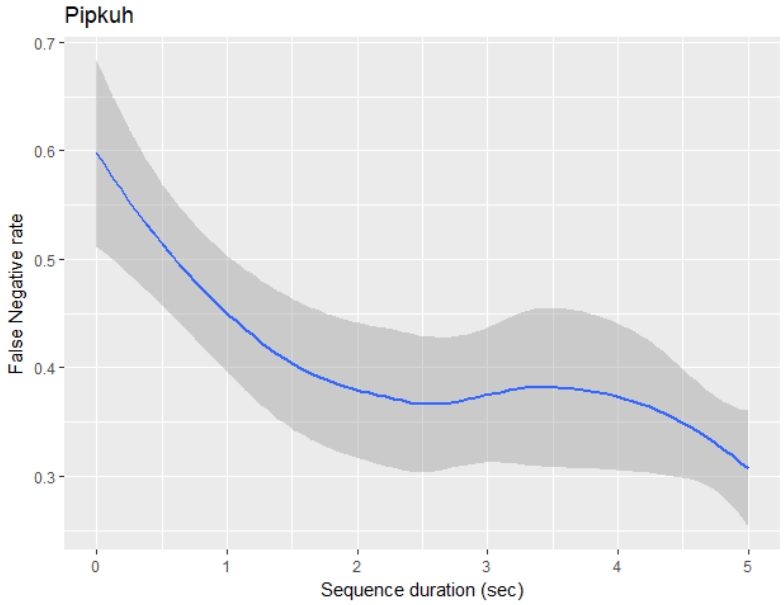
- Are errors biased / ecological patterns?

Error type	False negative rate	False positive rate
Causes		

How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?

Error type	False negative rate
Causes	Mostly influenced by **sound quality** ⇒ Distance to receiver ⇒ Alteration by vegetation density (=> habitat-dependent)



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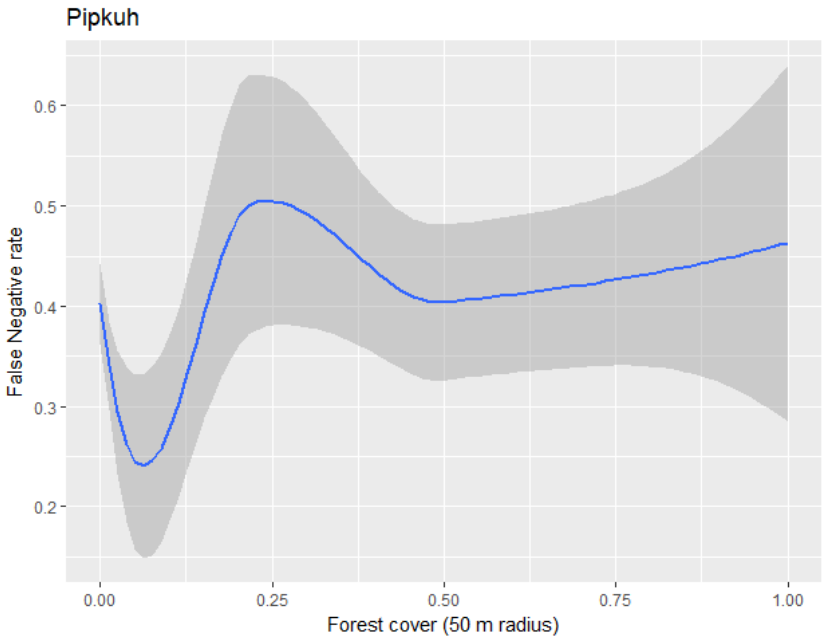


How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?

Error type	False negative rate	False positive rate
Causes	Mostly influenced by **sound quality** ⇒ Distance to receiver ⇒ Alteration by vegetation density (=> habitat-dependent)	

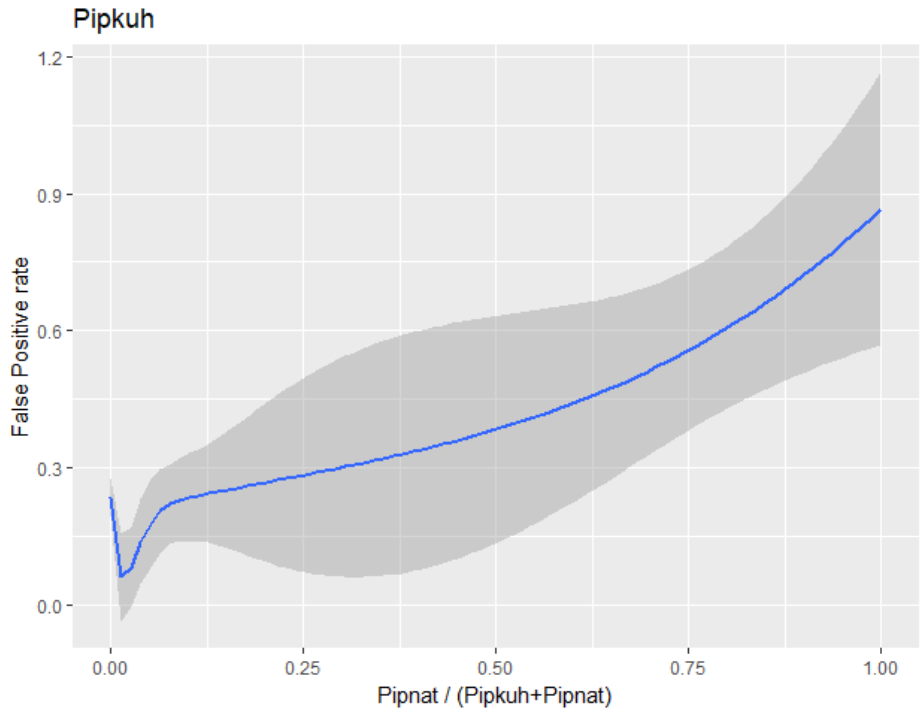
How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?

Error type	False negative rate	False positive rate
Causes	Mostly influenced by **sound quality** ⇒ Distance to receiver ⇒ Alteration by vegetation density (=> habitat-dependent)	Mostly influenced by **species relative abundance**

How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?

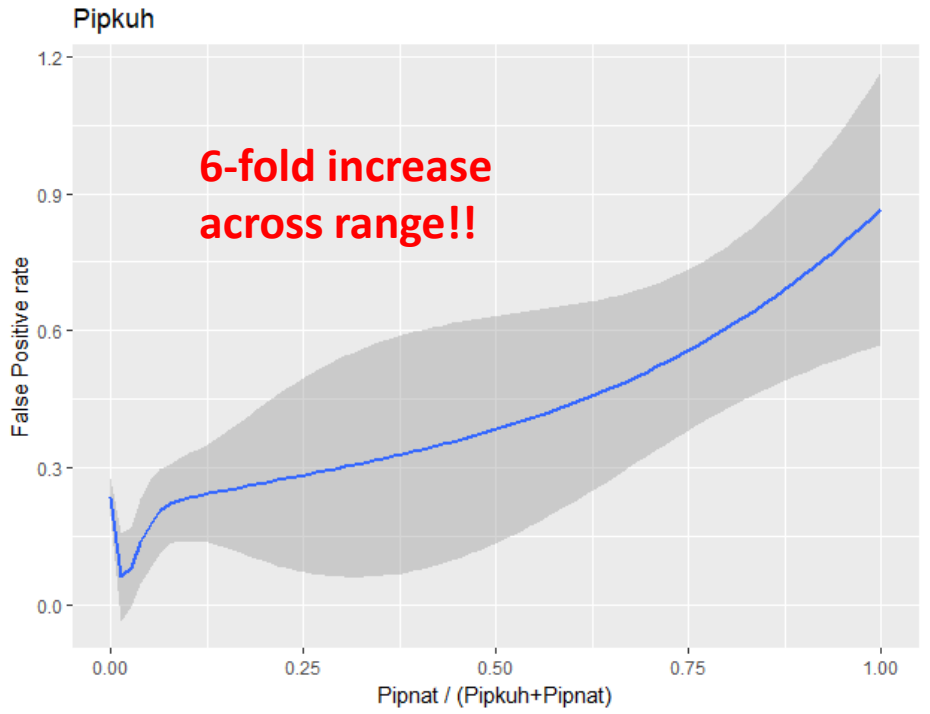


False positive rate

Mostly influenced by **species relative abundance**

How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?

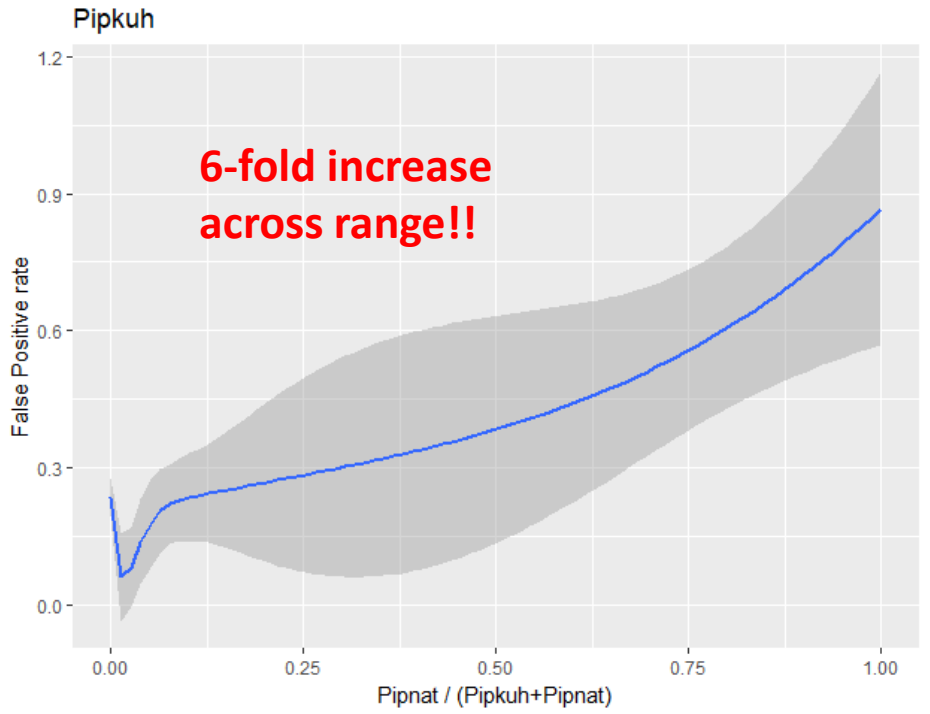


False positive rate

Mostly influenced by **species relative abundance**

How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?



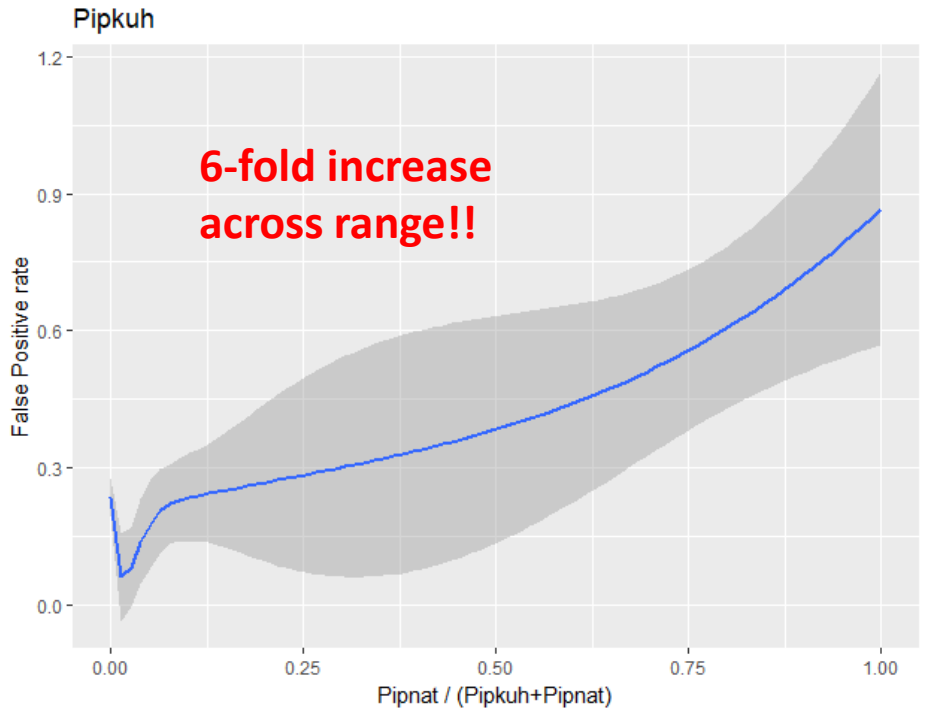
False positive rate

Mostly influenced by **species relative abundance**

⇒**Strongly spatially structured**

How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?



False positive rate

Mostly influenced by **species relative abundance**

⇒**Strongly spatially structured**

⇒Pretty bad for **rare species**…

How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?

Error type	**False negative rate**	**False positive rate**
Causes	Mostly influenced by **sound quality** ⇒ Distance to receiver ⇒ Alteration by vegetation density (=> habitat-dependent)	Mostly influenced by **species relative abundance** ⇒**Strongly spatially structured** ⇒Pretty bad for **rare species**…
Biased?		

How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?

Error type	**False negative rate**	**False positive rate**
Causes	Mostly influenced by **sound quality** ⇒ Distance to receiver ⇒ Alteration by vegetation density (=> habitat-dependent)	Mostly influenced by **species relative abundance** ⇒**Strongly spatially structured** ⇒Pretty bad for **rare species**…
Biased?	may be a little	

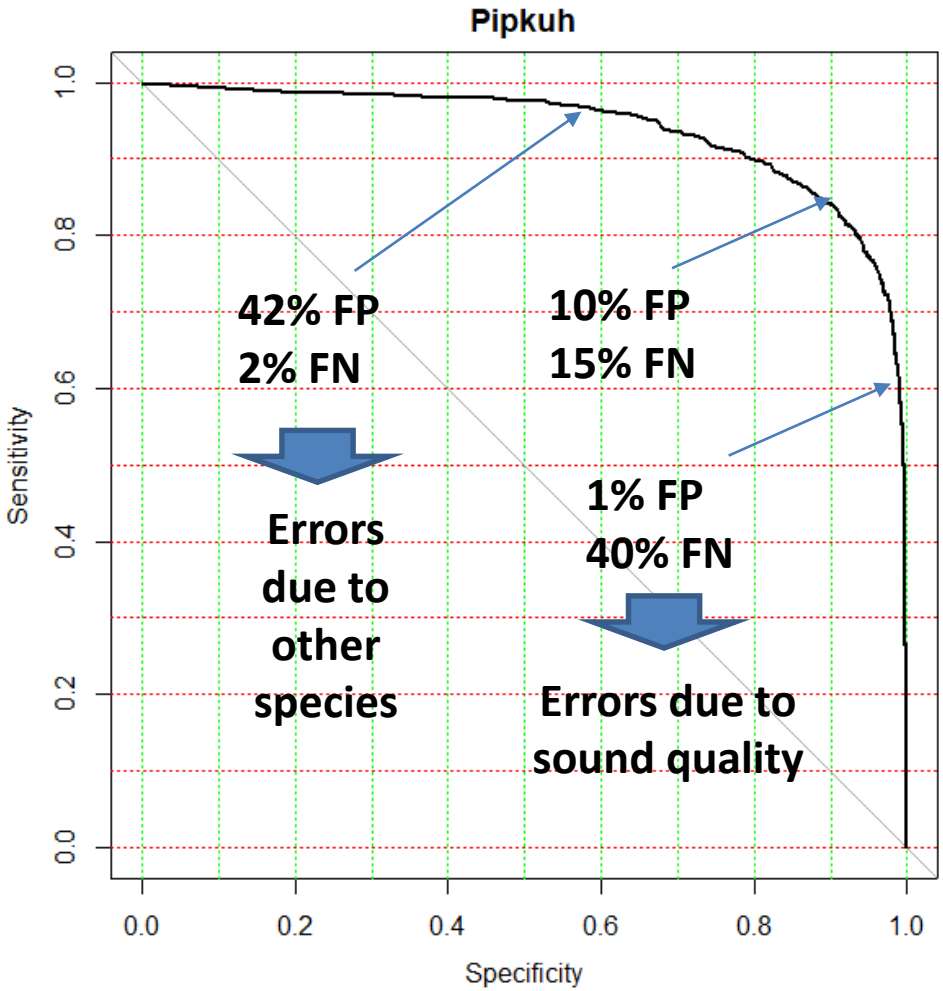
How's automatic acoustic monitoring doing?

- Are errors biased / ecological patterns?

Error type	**False negative rate**	**False positive rate**
Causes	Mostly influenced by **sound quality** ⇒ Distance to receiver ⇒ Alteration by vegetation density (=> habitat-dependent)	Mostly influenced by **species relative abundance** ⇒**Strongly spatially structured** ⇒Pretty bad for **rare species**…
Biased?	may be a little	**Often heavily!**

How's automatic acoustic monitoring doing?

- A threshold to minimise bias?

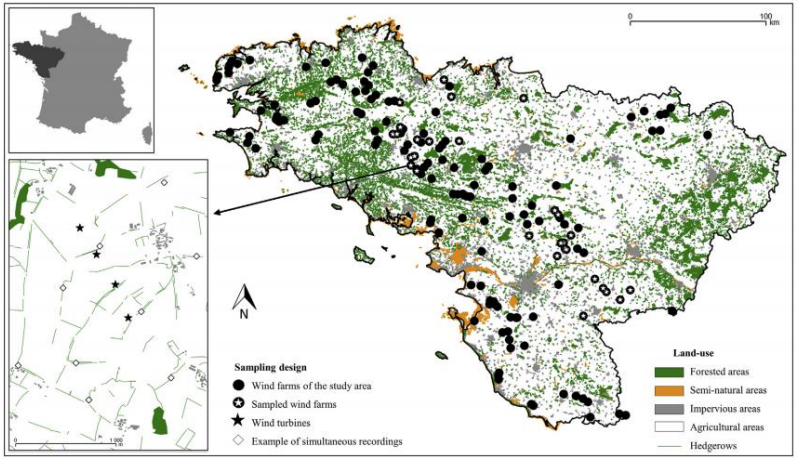


All thresholds will lead to **potentially biased** measures but sources of bias differ

Solution: checking consistency of ecological inference with varying thresholds (FP/FN rates)

Varying thresholds

- A study of the effect of distance to wind turbine on bats *(Barré et al. 2018 Biol Cons)*



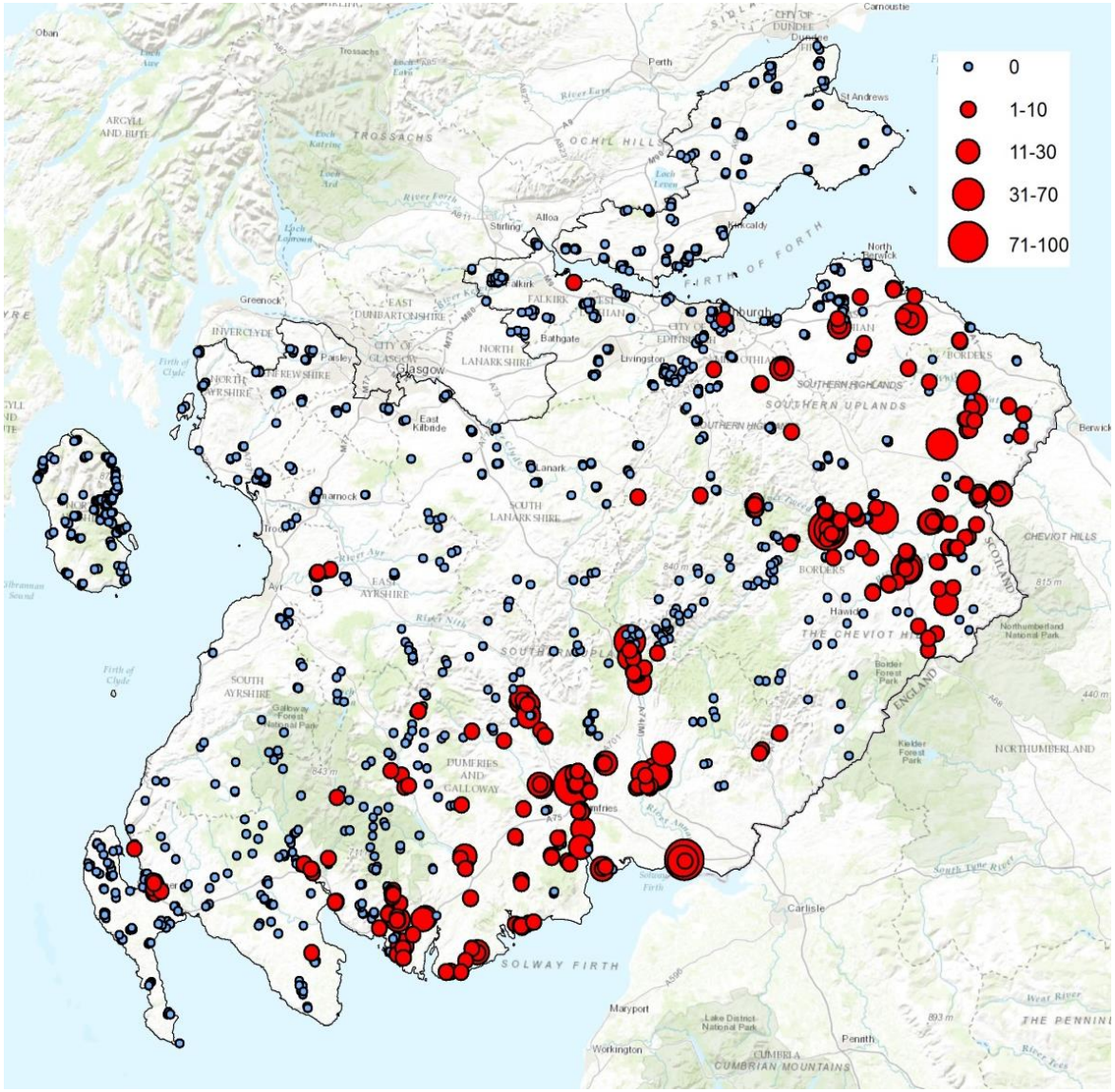
- Estimates vary little!

⇒ Inferences are robust against id errors!

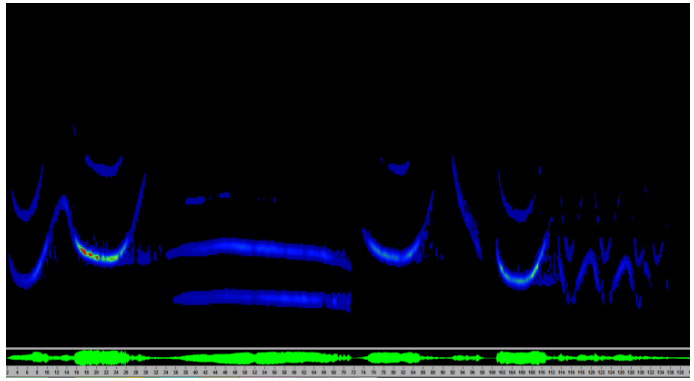
Species	Threshold type	
	FP = FN	FP << FN
Barbastella barbastellus	**0.237 ± 0.107**	**0.237 ± 0.107**
Eptesicus serotinus	0.132 ± 0.169	0.141 ± 0.179
Myotis nattereri	0.132 ± 0.106	0.038 ± 0.044
Myotis spp.	**0.260 ± 0.091**	**0.245 ± 0.096**
Pipistrellus kuhlii	-0.004 ± 0.100	-0.005 ± 0.103
Pipistrellus pipistrellus	**0.413 ± 0.100**	**0.413 ± 0.100**
Plecotus spp.	**0.309 ± 0.096**	**0.233 ± 0.102**

Method replicated for artifical light *(Pauwels et al. in review)*, motorways *(Claireau et al. in review)*, etc

Accurate data: spatial



Southern Scotland Bat Survey



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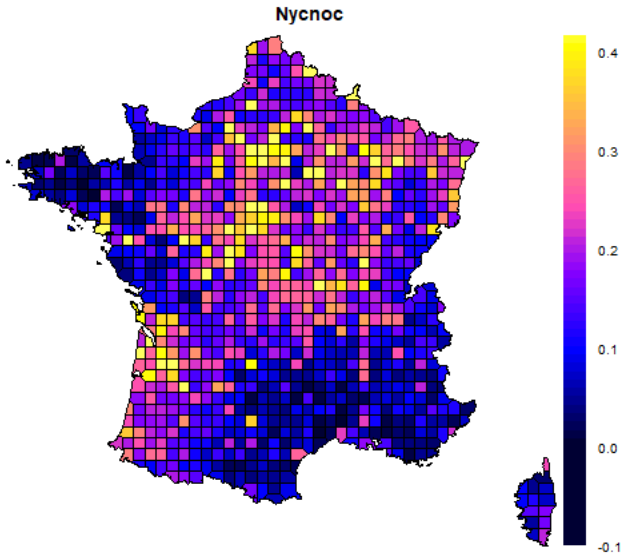
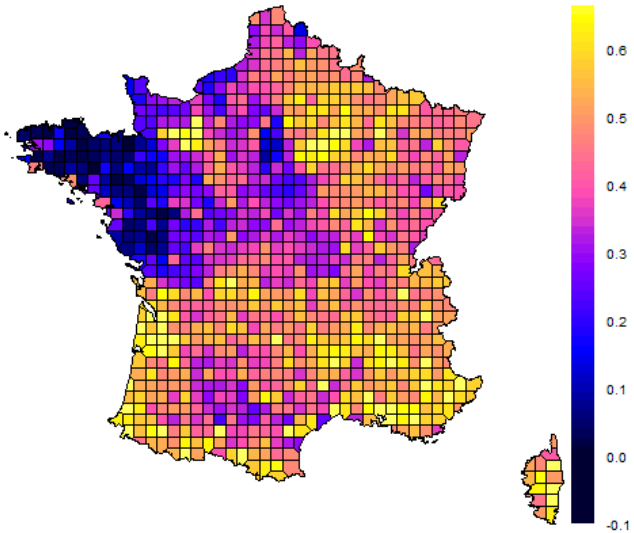
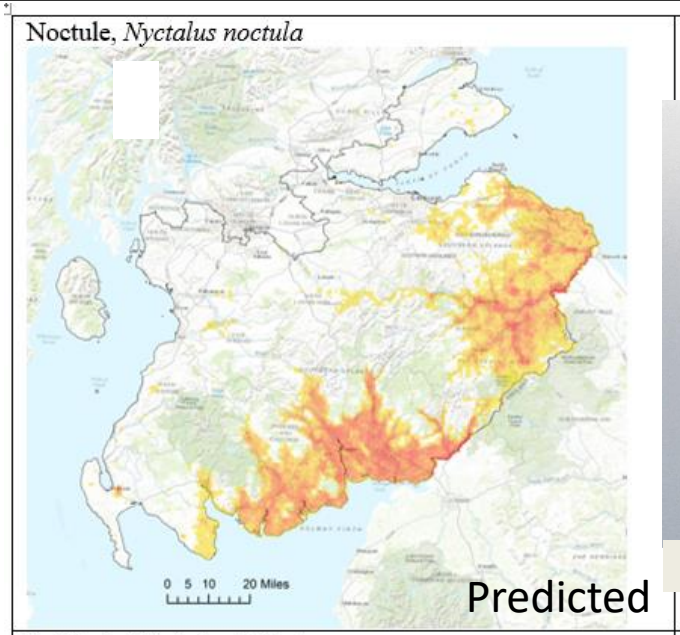
Raw data

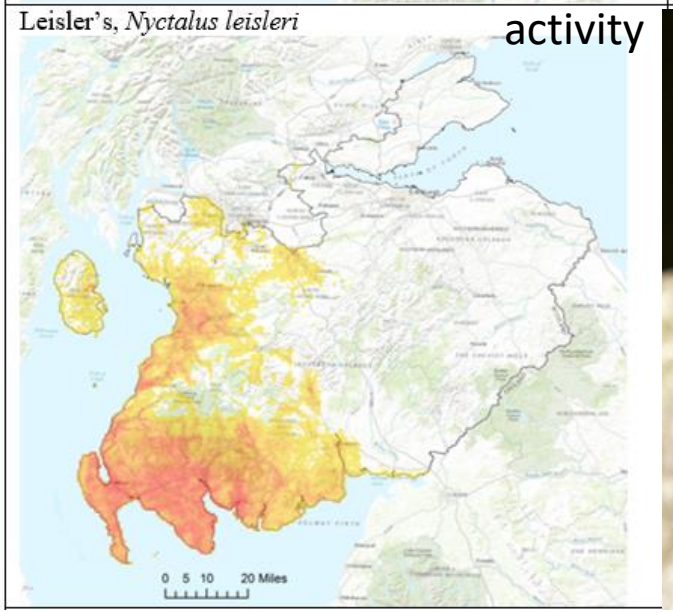
Nyctalus noctula

Accurate data: spatial









Predicted activity

Newson et al. 2017 Biological Conservation

© Dennis Atherton

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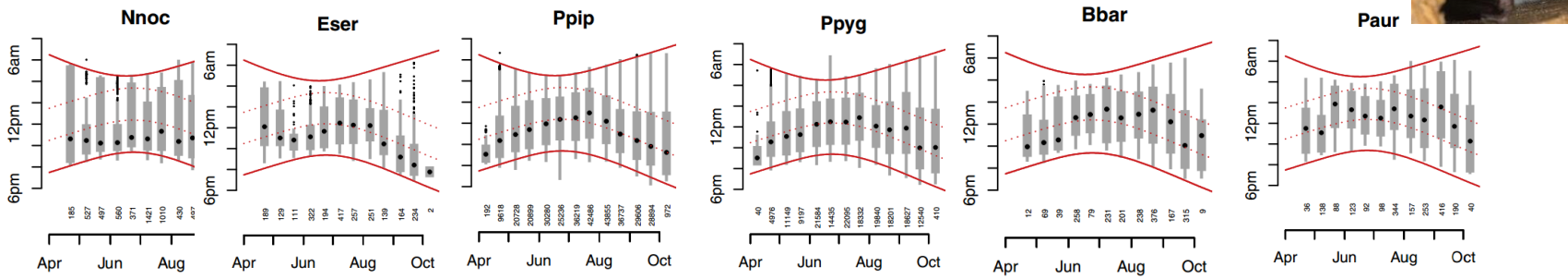
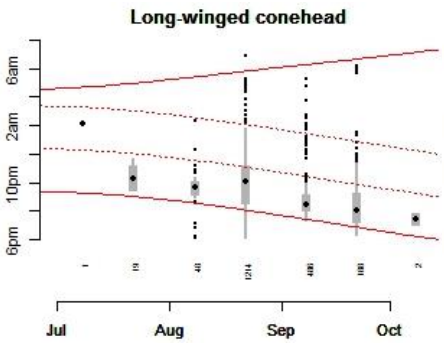
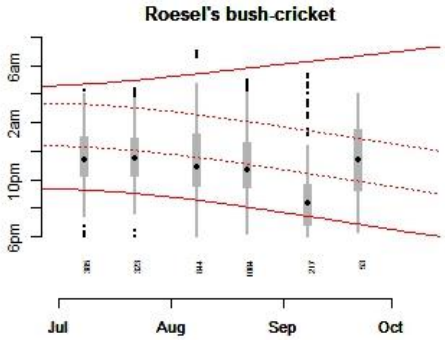
Accurate data: phenology

Newson et al. (2015)
Biological Conservation

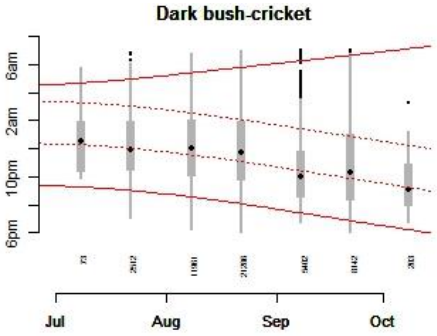


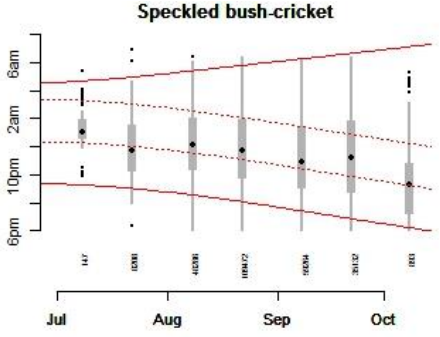
Crepuscular activity





Whole-night activity



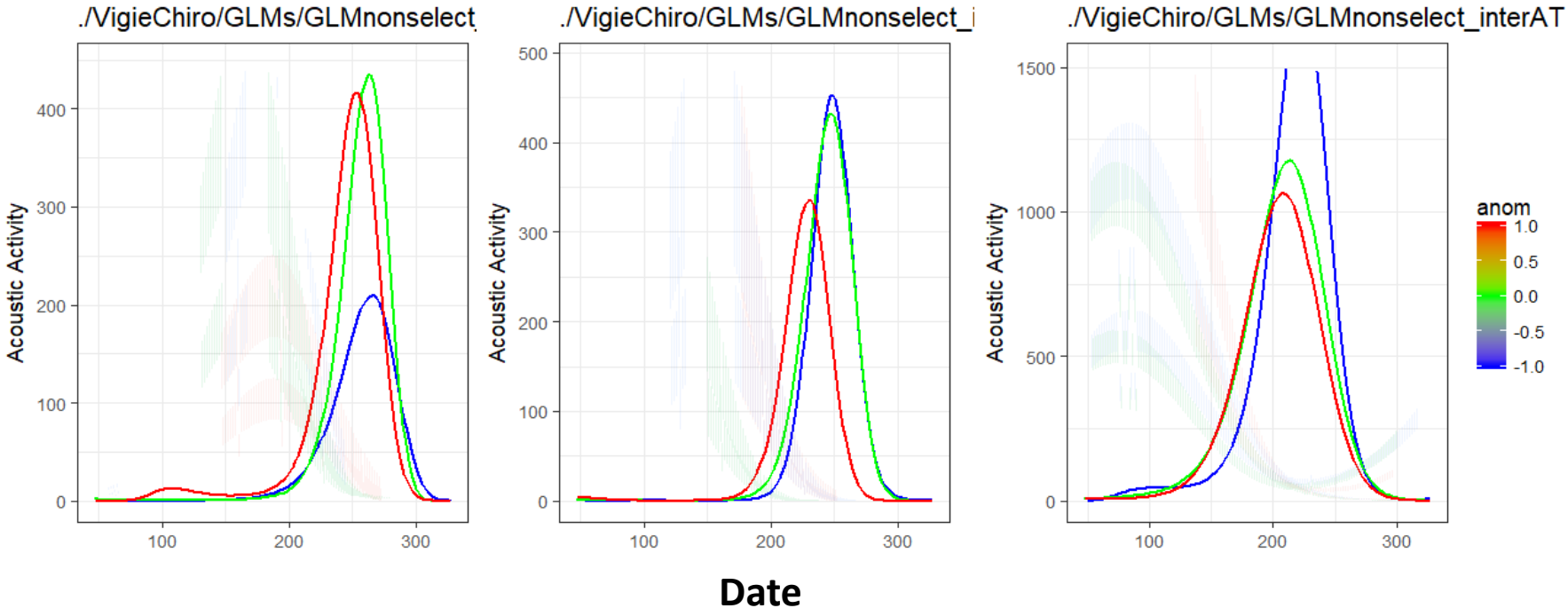


Newson et al. (2017) Methods in Ecology and Evolution

Accurate data: phenology

Bas et al. (in prep)

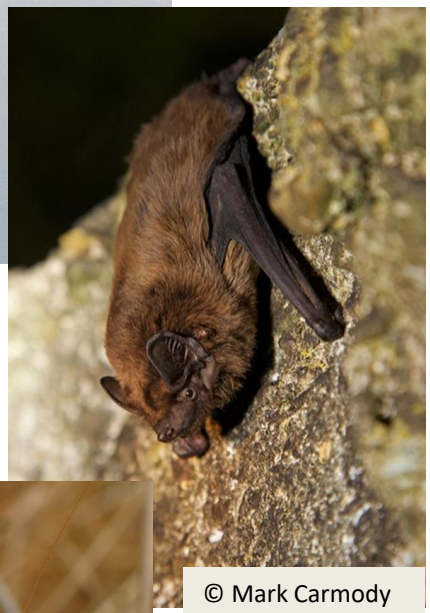
- Detecting seasonal phenological shifts



And already some species trends

Strongly declining in France

© Dennis Atherton



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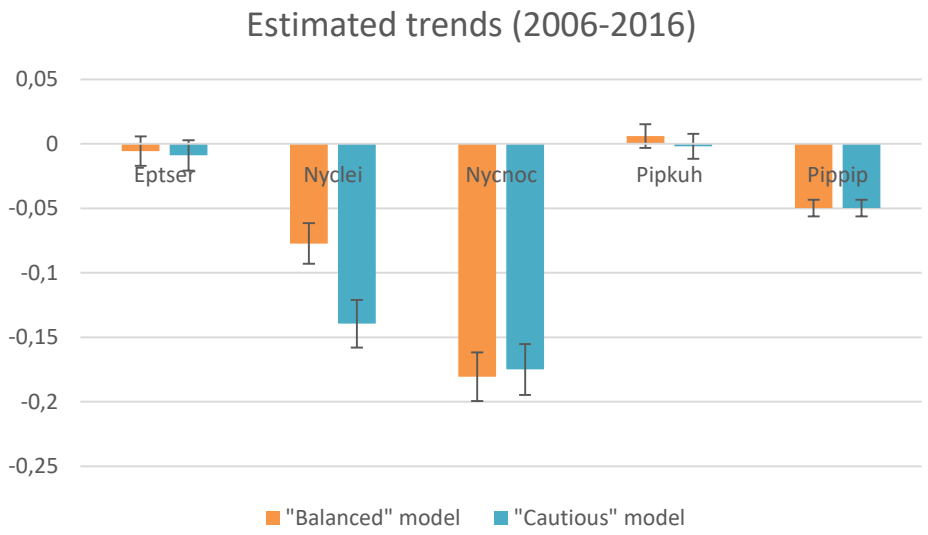
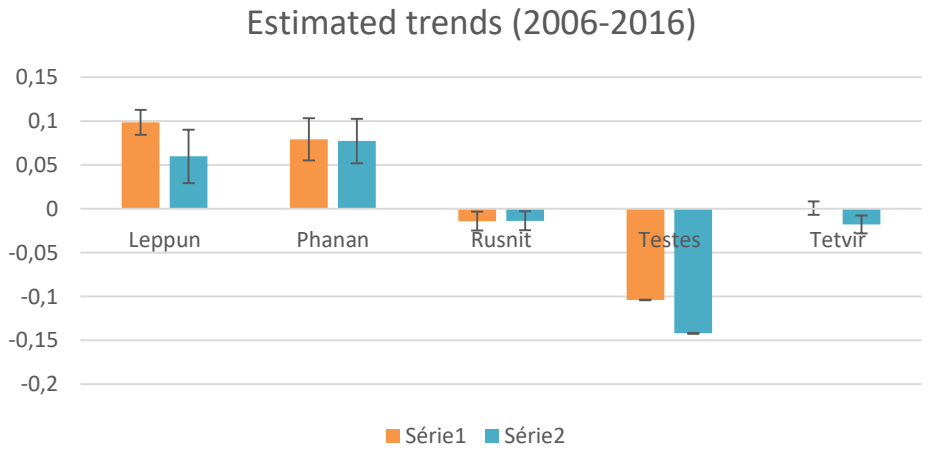




…declines not previously suspected…

Conclusion

1) Large-scale ecoacoustic monitoring works!
   - Citizen science + auto id + free web services = unprecedented data accuracy in space and time!
   - Generic sound event detection = multi-taxonomic targets = sharing costs and benefits!

2) Prospects:
   - Further investigating biases in acoustic data
   - Improving auto id
     - More reference data => collaborative work needed
     - Adding contextual information in training (i.e. species relative abundance)

Thank you for your attention! And many thanks to participants of Vigie-Chiro, Norfolk Bat Survey and South Scotland Bat Survey!!

But, is it dangerous??

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

The use of automated identification of bat echolocation calls in acoustic monitoring: A cautionary note for a sound analysis

Danilo Russo [a,b,*], Christian C. Voigt [c,d]

[a] Wildlife Research Unit, Laboratorio di Ecologia Applicata, Sezione di Biologia e Protezione dei Sistem
Università degli Studi di Napoli Federico II, Via Università 100, 1-80055 Portici, Napoli, Italy
[b] School of Biological Sciences, Life Sciences Building, University of Bristol, 24 Tyndall Avenue, Bristol
[c] Department of Evolutionary Ecology, Leibniz Institute for Zoo and Wildlife Research, Alfred-Kowalke
[d] Department of Animal Behaviour, Institute of Zoology, Freie Universitat Berlin, Takustr. 6, 14195 Ber

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Testing the performances of automated identification of bat echolocation calls: A request for prudence

Jens Rydell [a,*], Stefan Nyman [b], Johan Eklöf [c], Gareth Jones [d], Danilo Russo [d,e]

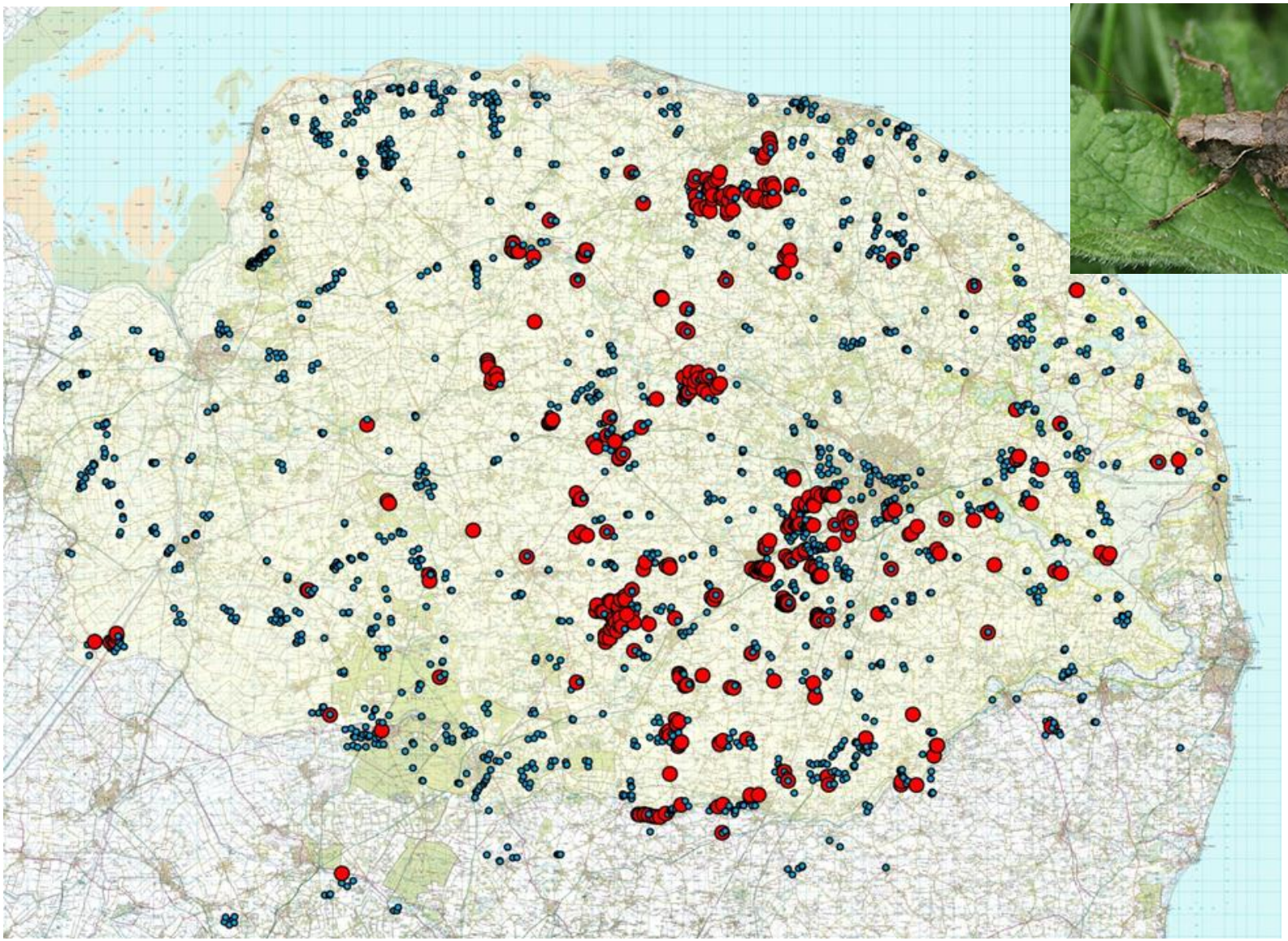
[a] Biology Department, Lund University, SE-223 62 Lund, Sweden
[b] Skarpskyttevägen 30D, SE-226 42 Lund, Sweden
[c] Krokdalsvägen 88, SE-51734 Bollebygd, Sweden
[d] School of Biological Sciences, Life Sciences Building, University of Bristol, 24 Tyndall Avenue, Bristol BS8 1TQ, UK
[e] Wildlife Research Unit, Laboratorio di Ecologia Applicata, Sezione di Biologia e Protezione dei Sistemi Agrari e Forestali, Dipartimento di Agraria, Università degli Studi di Napoli Federico II, Via Università 100, Portici (Napoli), Italy

- Well, it's obviously not perfect, so you cannot neglect error rates! You still NEED to:

1) Estimate error rates
2) Account for it in your analysis (w or w/o covariates)

=> That's what we call « semi-automatic id »

Also works for bush-crickets: Dark Bush-cricket (42,132 recordings)



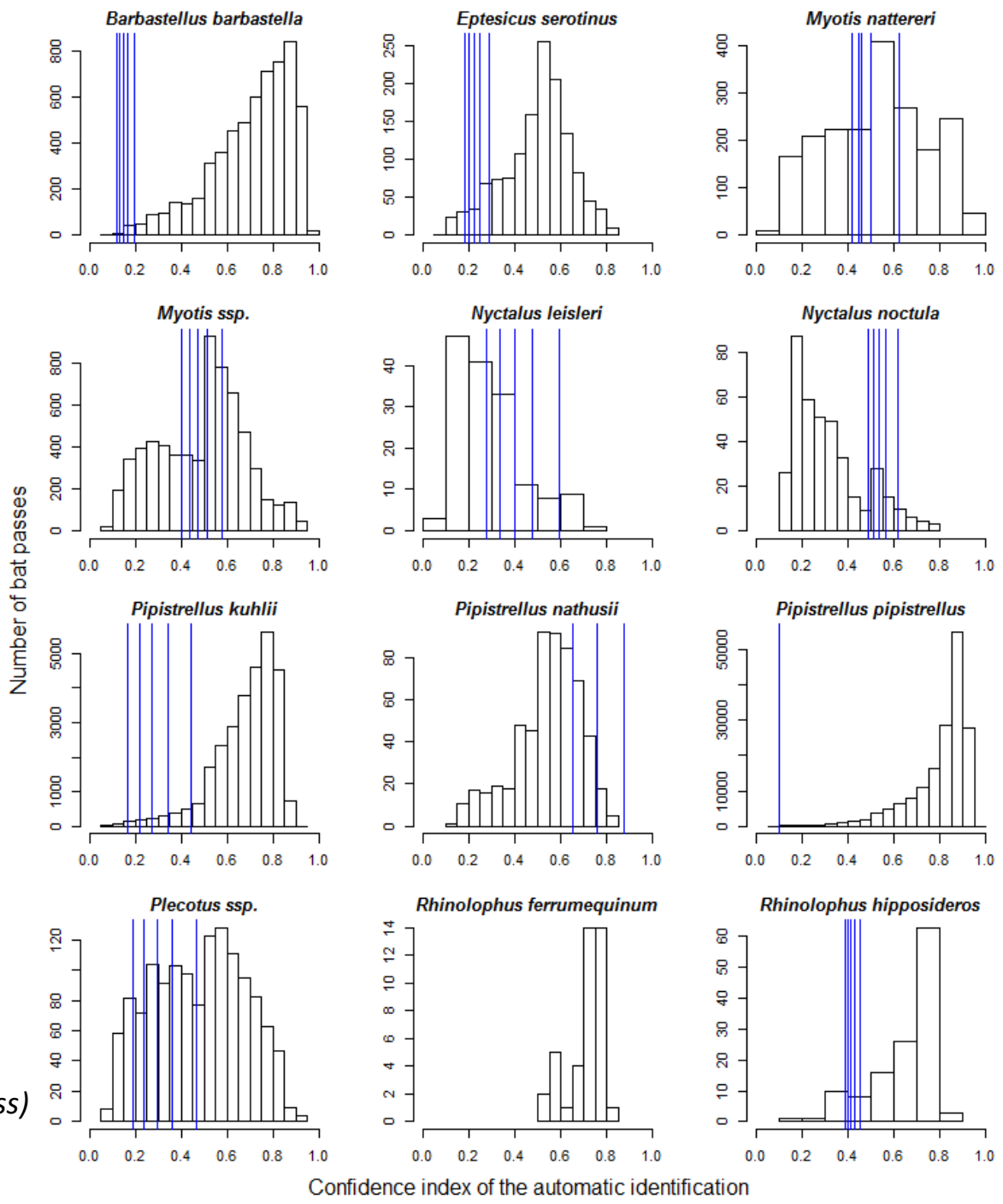
Norfolk Bat Survey

Auto id: Score reliability

- Correlate error risk / confidence score
  - identify selection thresholds

Confirmed id ~ software confidence

(Barré et al. 2019 MEE, in press)



Auto id:
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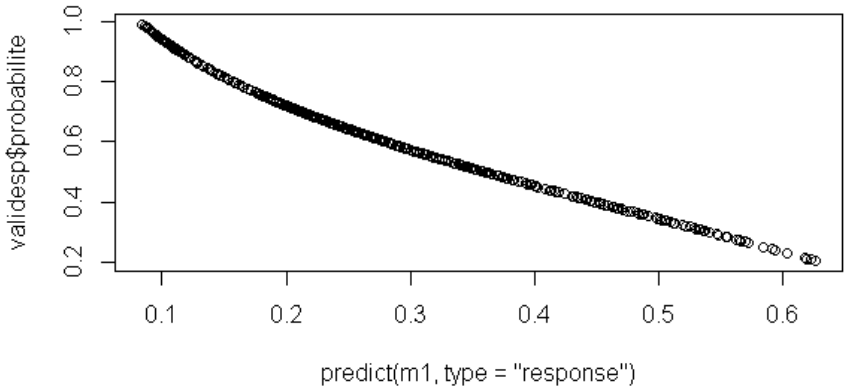
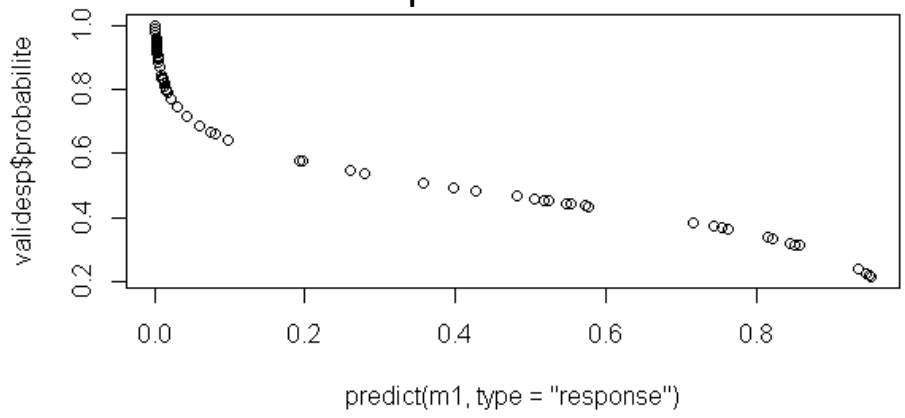
(Barré et al. 2019 MEE, in press)

Tettigonia viridissima



Ruspolia nitidula



Auto id:
Score reliability

- Correlate error risk / confidence score
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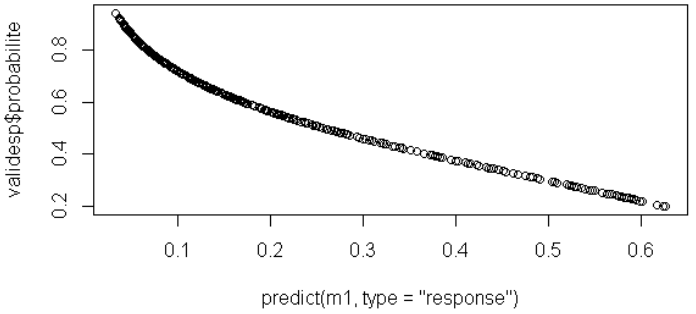
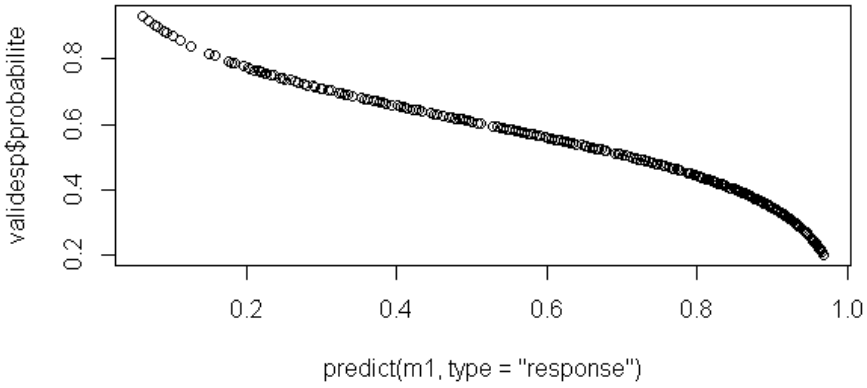
(Barré et al. 2019 MEE, in press)

Leptophyes punctatissima



Pholidoptera griseoaptera



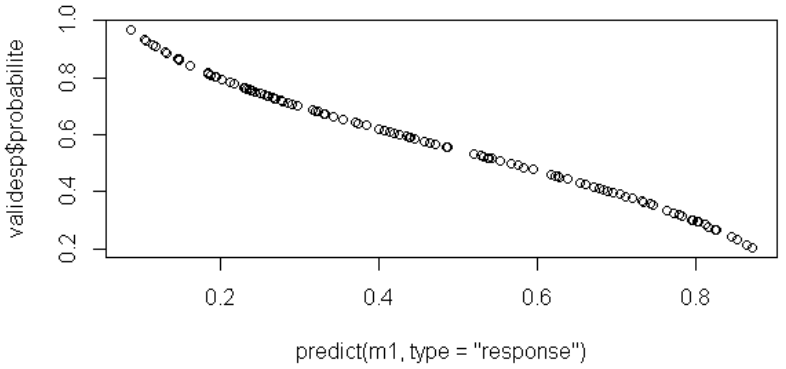
Auto id:
Score reliability

- Correlate error risk / confidence score
  - identify selection thresholds

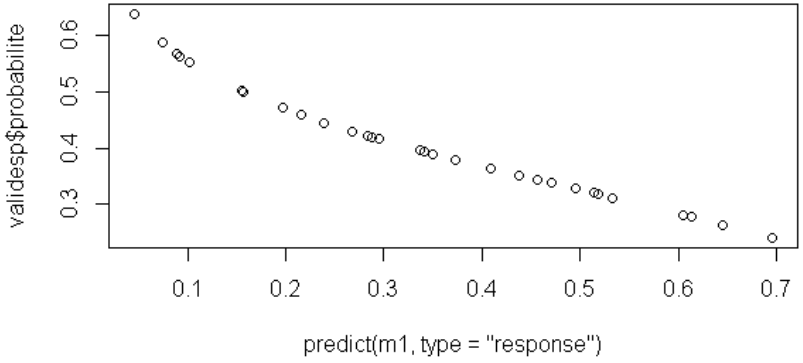
Confirmed id ~ software confidence

(Barré et al. 2019 MEE, in press)

Tessellana tessellata



Platycleis albopunctata



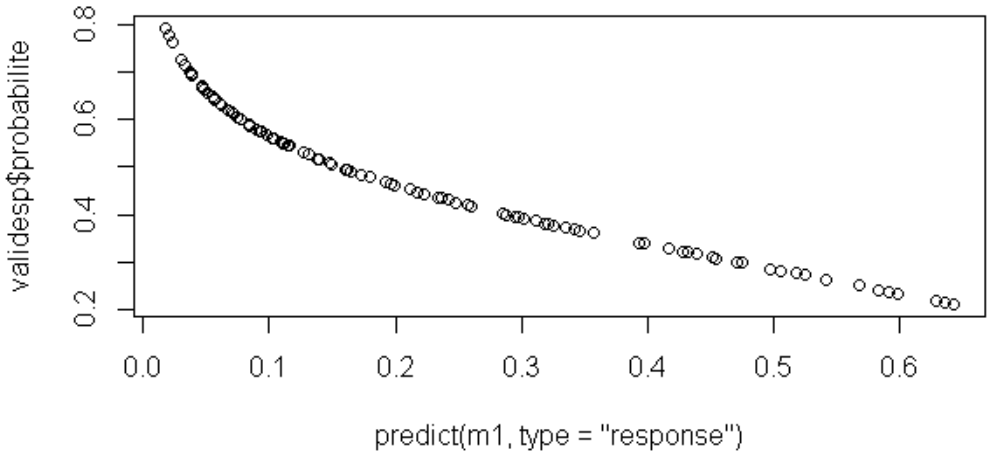
Auto id:
Score reliability

- Correlate error risk / confidence score
  - identify selection thresholds

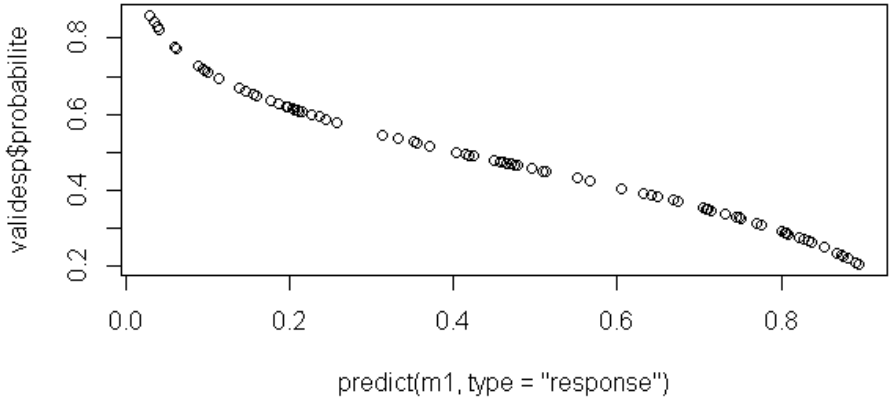
Confirmed id ~ software confidence

(Barré et al. 2019 MEE, in press)

Phaneroptera nana



Ephippiger ephippiger



Varying thresholds

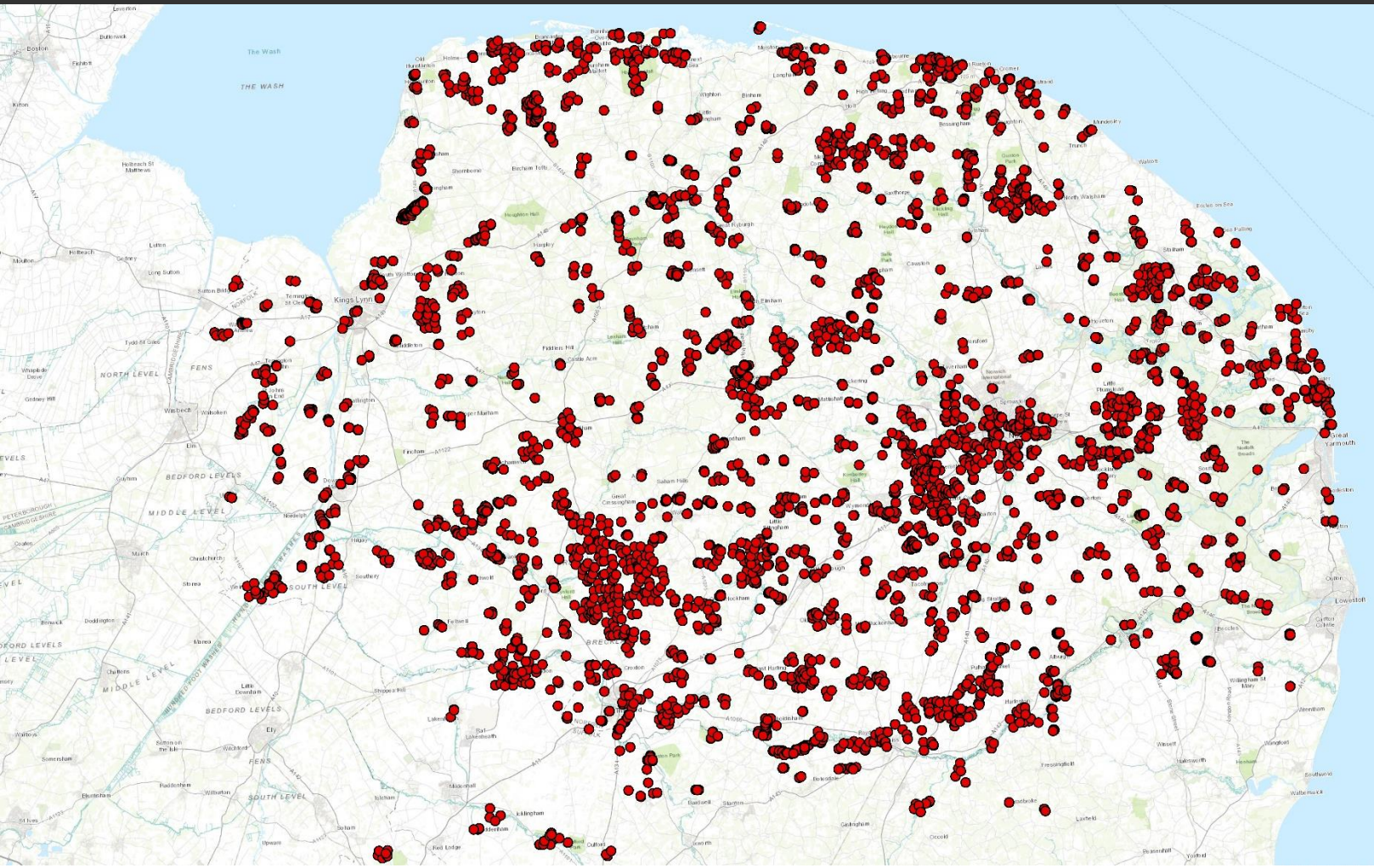
- Hedgerow effect (Barré et al. In prep)

⇒ Estimates vary little!

⇒ Inferences are robust against id errors!

Species	Environmental variables	Error risk tolerance	
		0.5	0.1
Barbastellus barbastella	Open vs. edge habitat	-2.91±0.23 ***	-2.94±0.24 ***
Eptesicus serotinus	Open vs. edge habitat	-0.60±0.40	-0.52±0.42
Myotis nattereri	Open vs. edge habitat	-1.20±0.25 ***	-1.08±0.33 ***
Myotis ssp.	Open vs. edge habitat	-1.64±0.20 ***	-1.87±0.27 ***
Nyctalus leislerii	Open vs. edge habitat	-0.41±0.29	0.92±0.66
Nyctalus noctula	Open vs. edge habitat	1.27±0.28 ***	1.27±0.50 *
Pipistrellus kuhlii	Open vs. edge habitat	-2.08±0.26 ***	-2.17±0.27 ***
Pipistrellus nathusii	Open vs. edge habitat	0.68±0.32 *	/
Pipistrellus pipistrellus	Open vs. edge habitat	-2.93±0.19 ***	-2.93±0.19 ***
Plecotus ssp.	Open vs. edge habitat	-0.89±0.19 ***	-0.81±0.20 ***
Rhinolophus ferrumequinum	Open vs. edge habitat	0.23±0.99	0.23±0.99
Rhinolophus hipposideros	Open vs. edge habitat	-3.01±0.72 ***	-2.98±0.73 ***

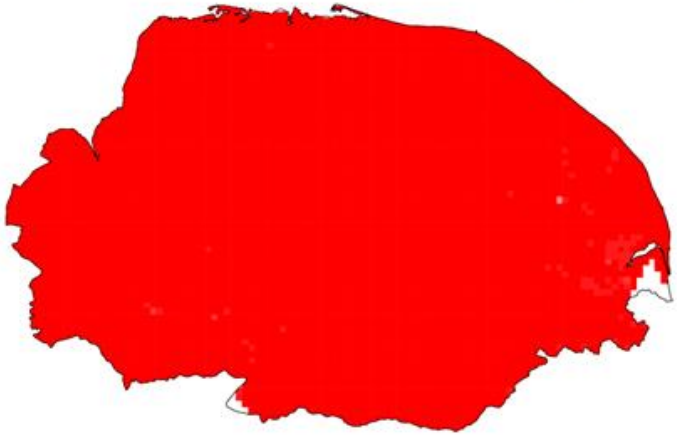
Survey coverage

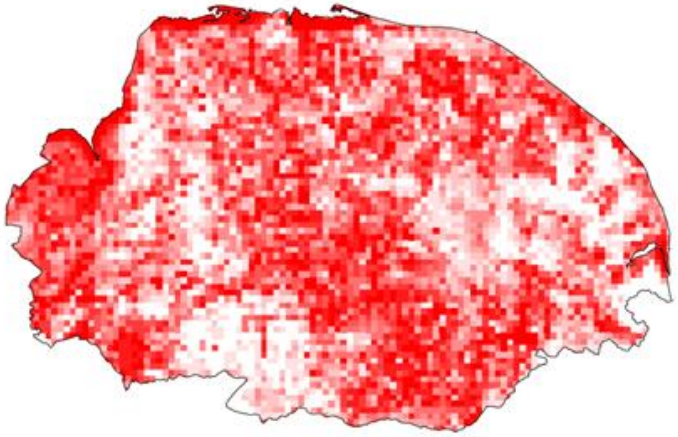


- 1,445 1-km squares surveyed (27% of Norfolk) 2013-2016
- 6,246 complete nights of recording
- > 1.4 million bat recordings

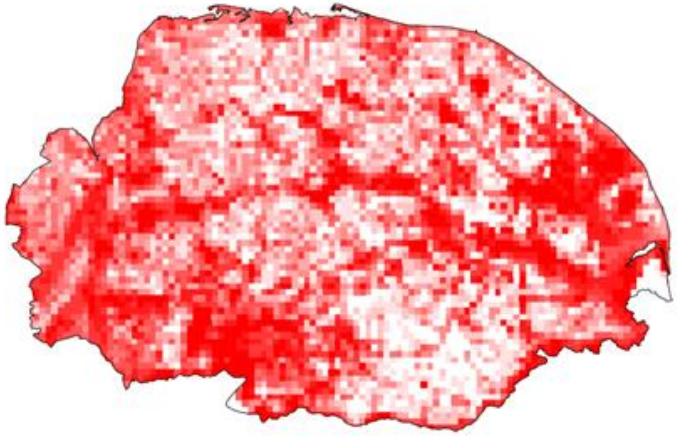
Predicted occurrence (left) and activity (right)

Common pipistrelle, *Pipistrellus pipistrellus*





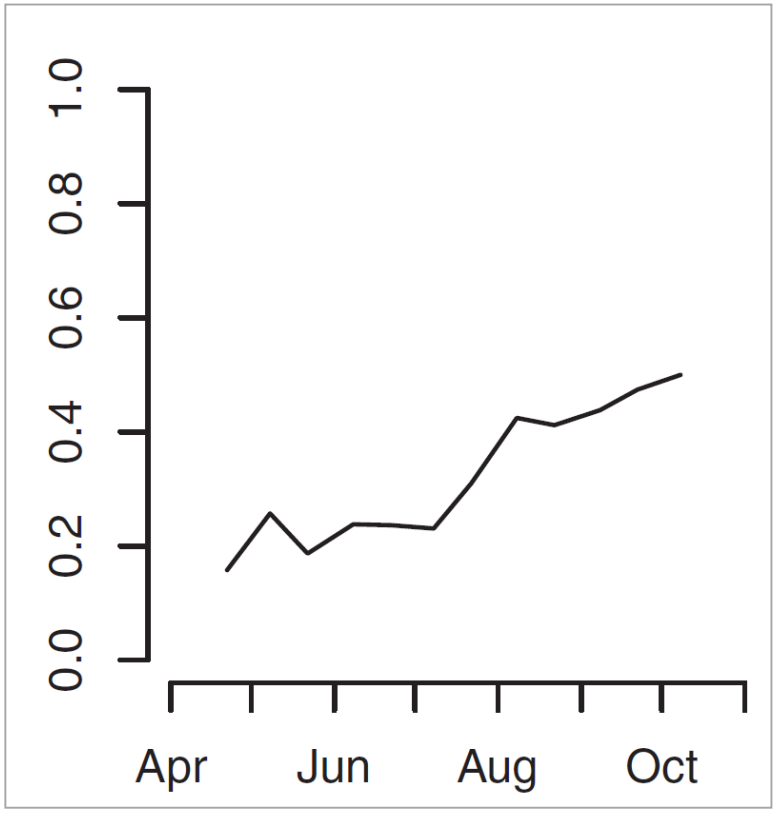
Soprano pipistrelle, *Pipistrellus pygmaeus*

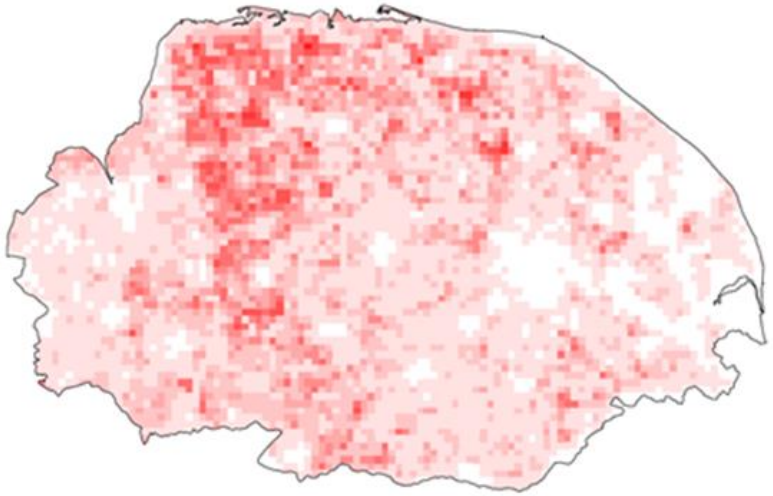


Newson, Evans & Gillings. Biological Conservation (2015)

Insight into seasonal movements

Barbastelle - *Barbastella barbastellus*

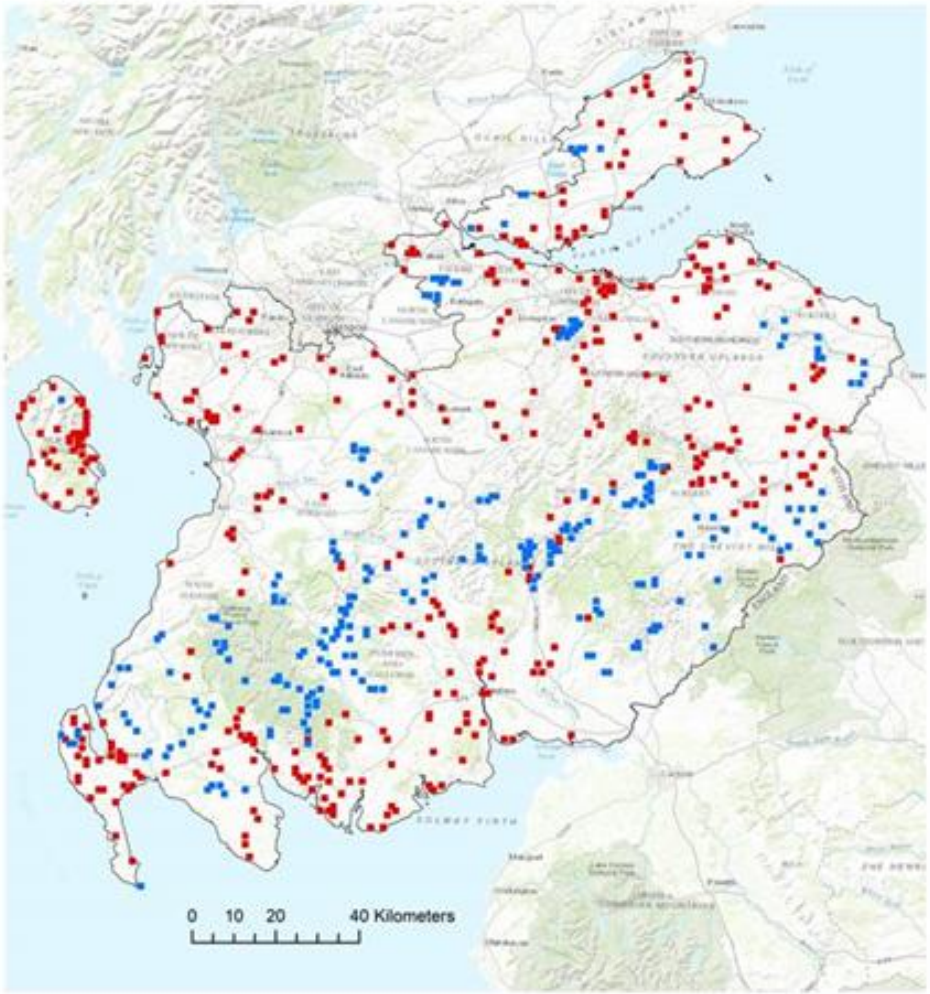




Newson, Evans & Gillings. Biological Conservation (2015)

Survey coverage

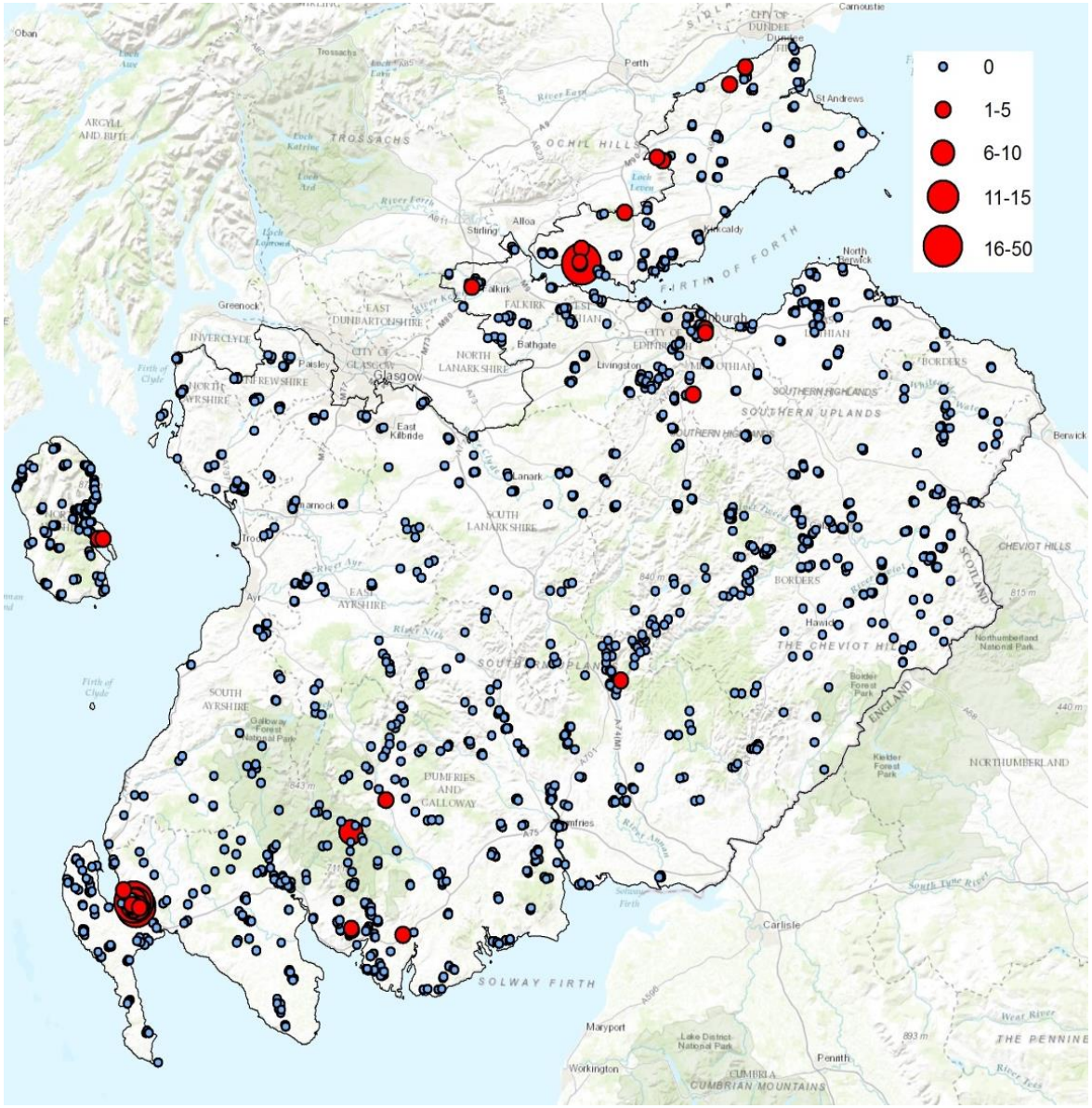
Red = Volunteers
Blue = BTO fieldworkers

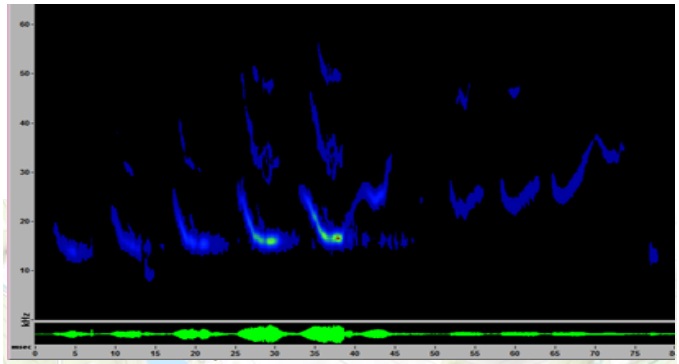


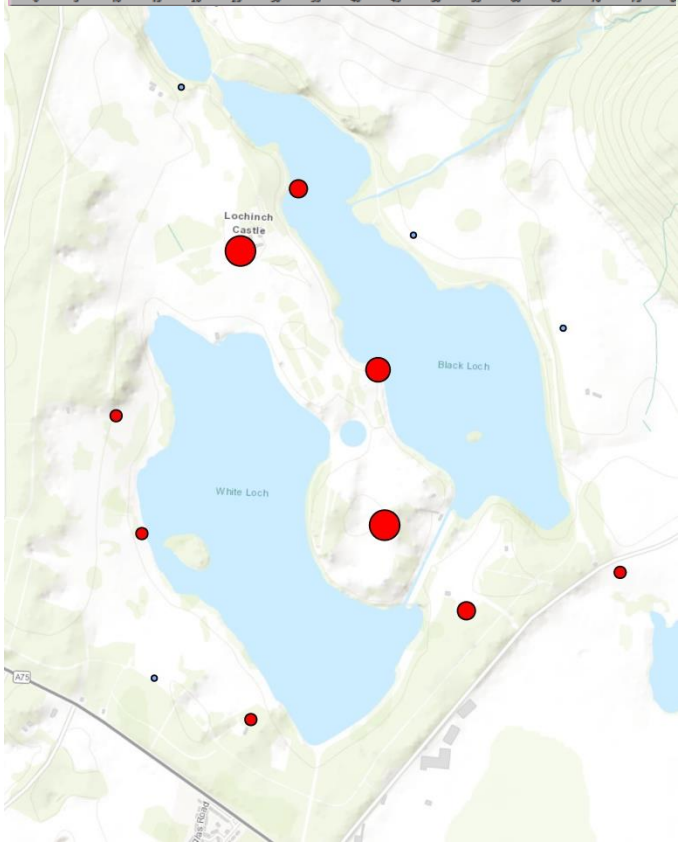
- 715 1-km's
- 1,537 nights of recording
- 399,242 bat recordings
- 275 volunteers - 375 squares
- Two BTO fieldworkers - 339 squares

Newson, Evans, Gillings, Jarrett & Wilson. In review

Nathusius' pipistrelle (0.05% of recordings)

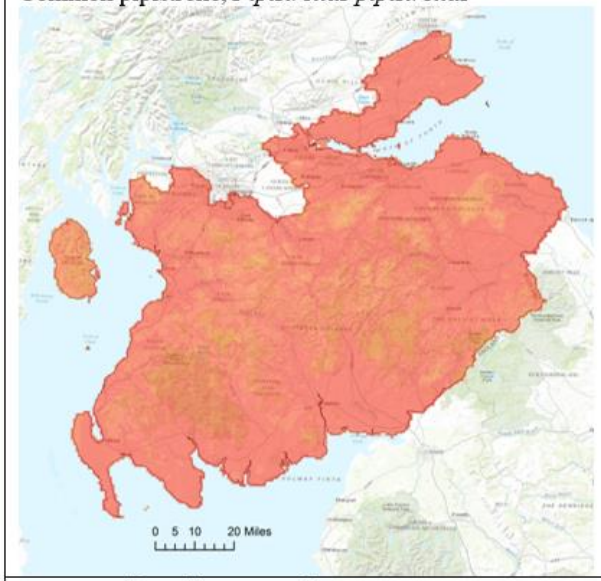


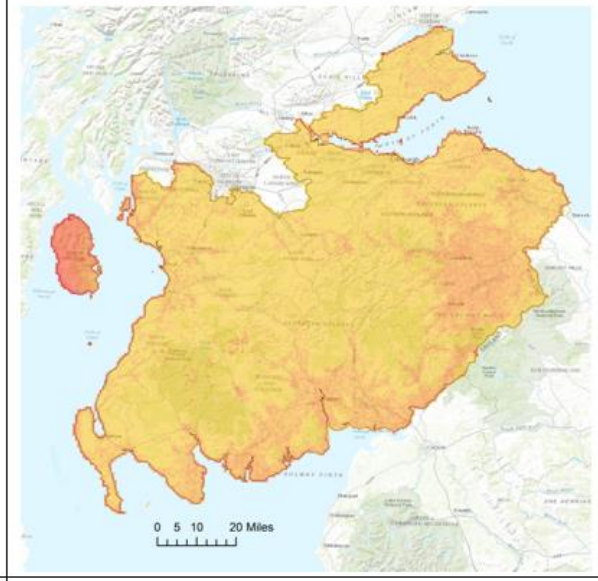




Predicted occurrence (left) and activity (right)

Common pipistrelle, *Pipistrellus pipistrellus*





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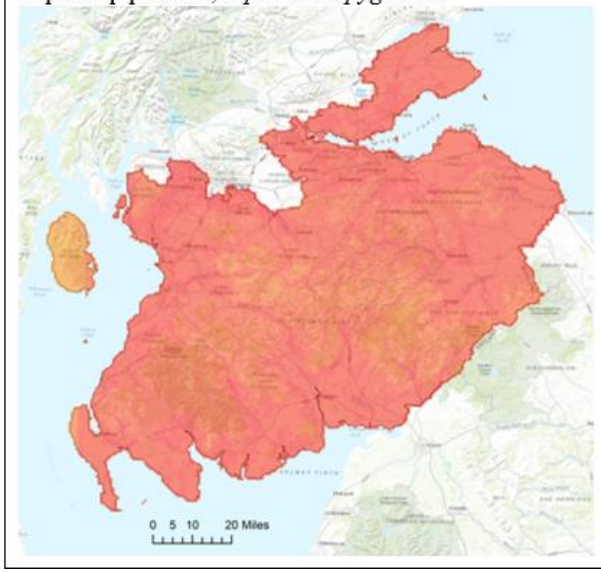
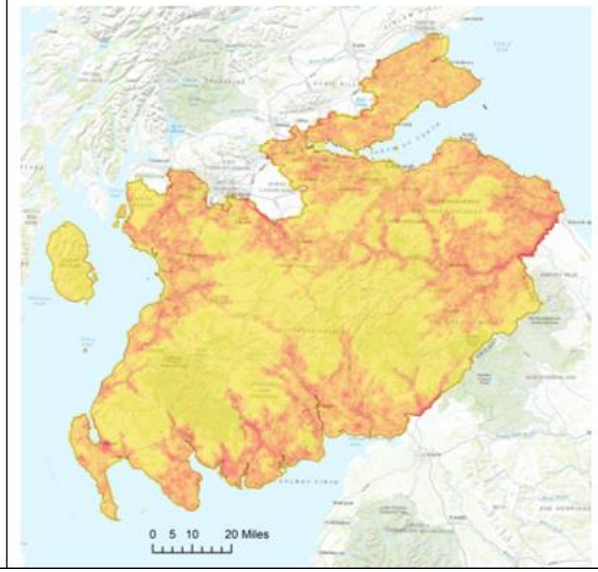


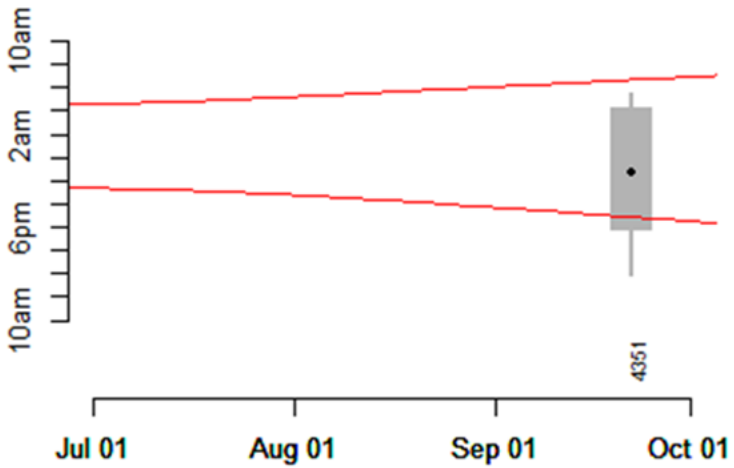


© Sam Cents

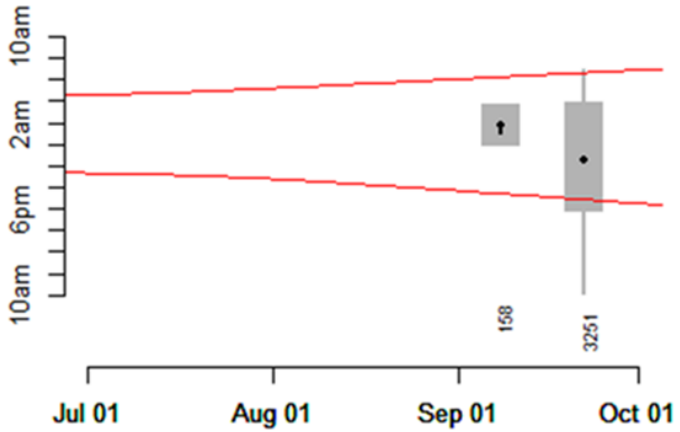
© John Dixon

Detectors recording over the day and night

Dark bush-cricket

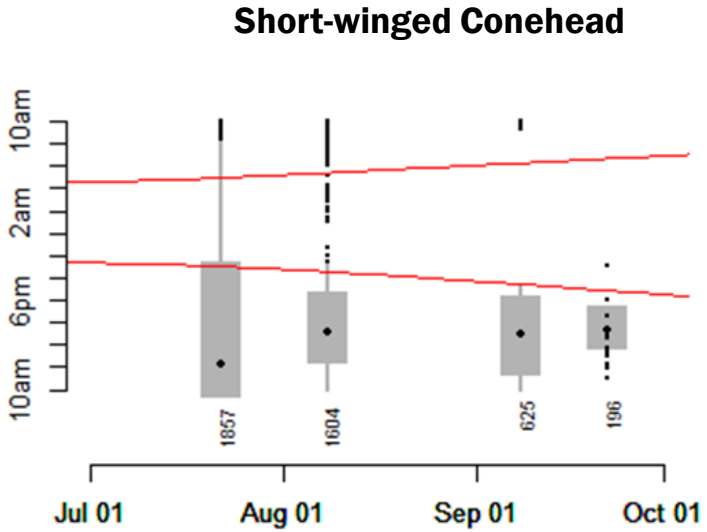


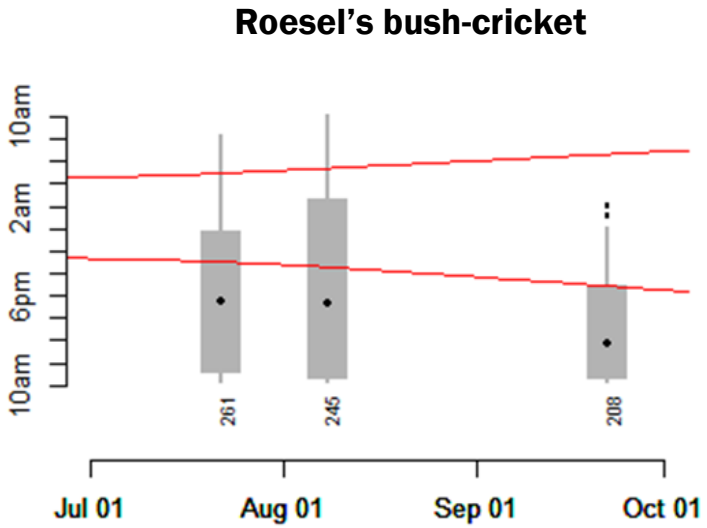
Speckled bush-cricket



Newson *et al*. (2017). Methods in Ecology & Evolution

Detectors recording over the day and night

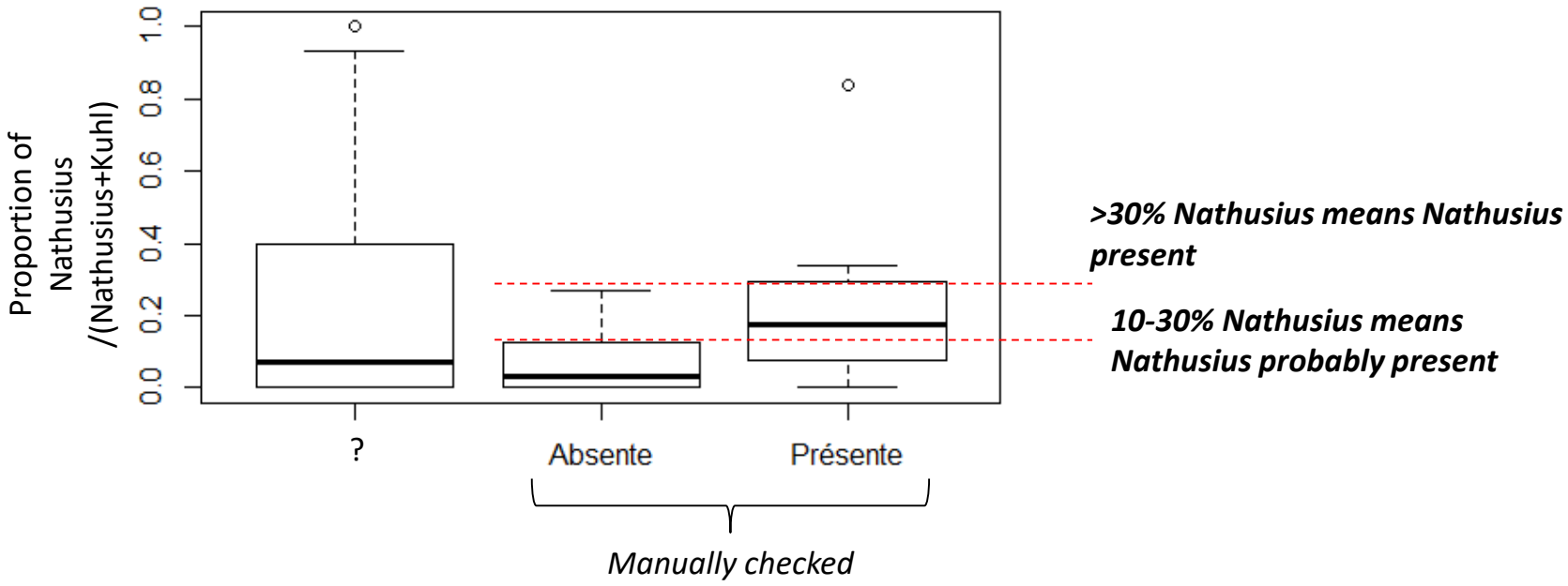




Newson *et al*. (2017). Methods in Ecology & Evolution

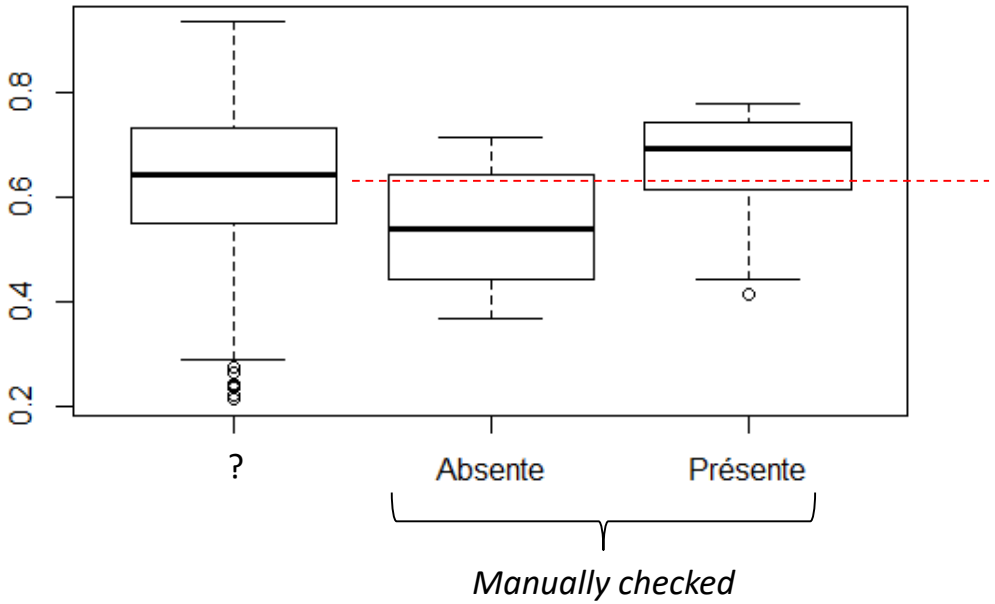
Limits of the "auto id"

- Solution: looking at other « auto id » results on the same location
  1) Rate of Nathusius' positive id among « Kuhl's + Nathusius' »



Limits of the "auto id"

- Solution: looking at other « auto id » results on the same location
  2) Maximum random forest score among Nathusius' positive id

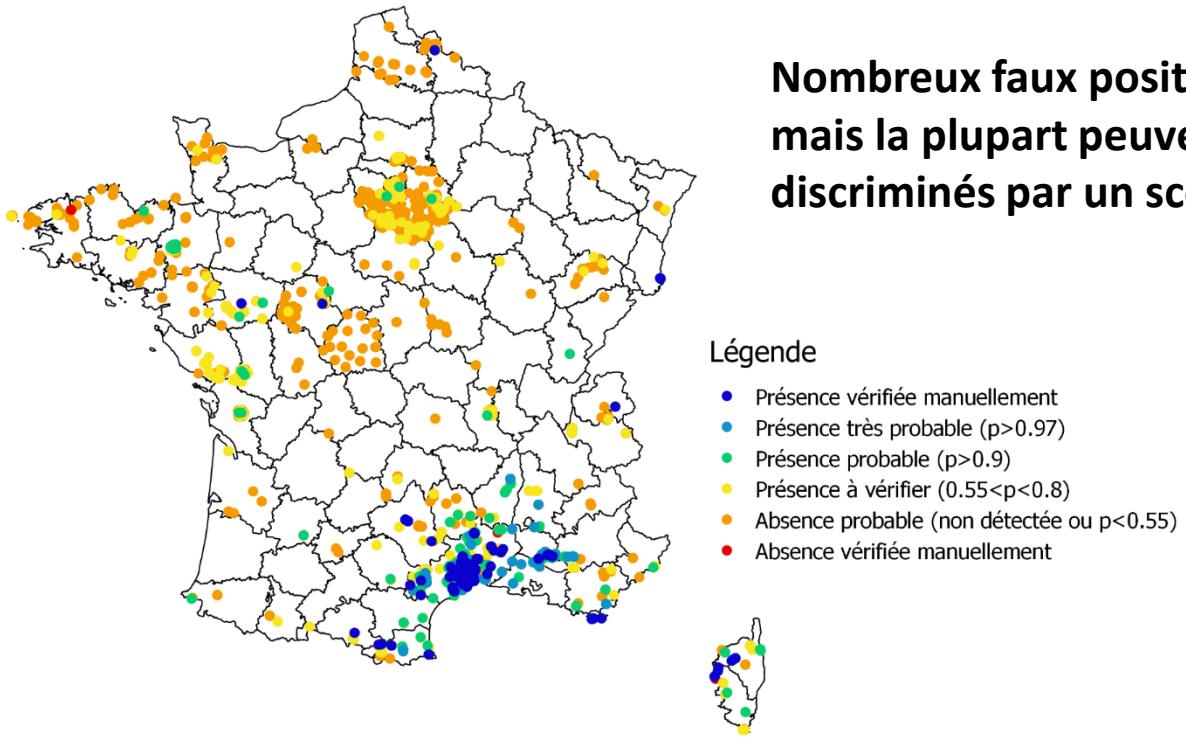


Little overlap but…

25% sites where Nathusius' Pipistrelle present but no good score…

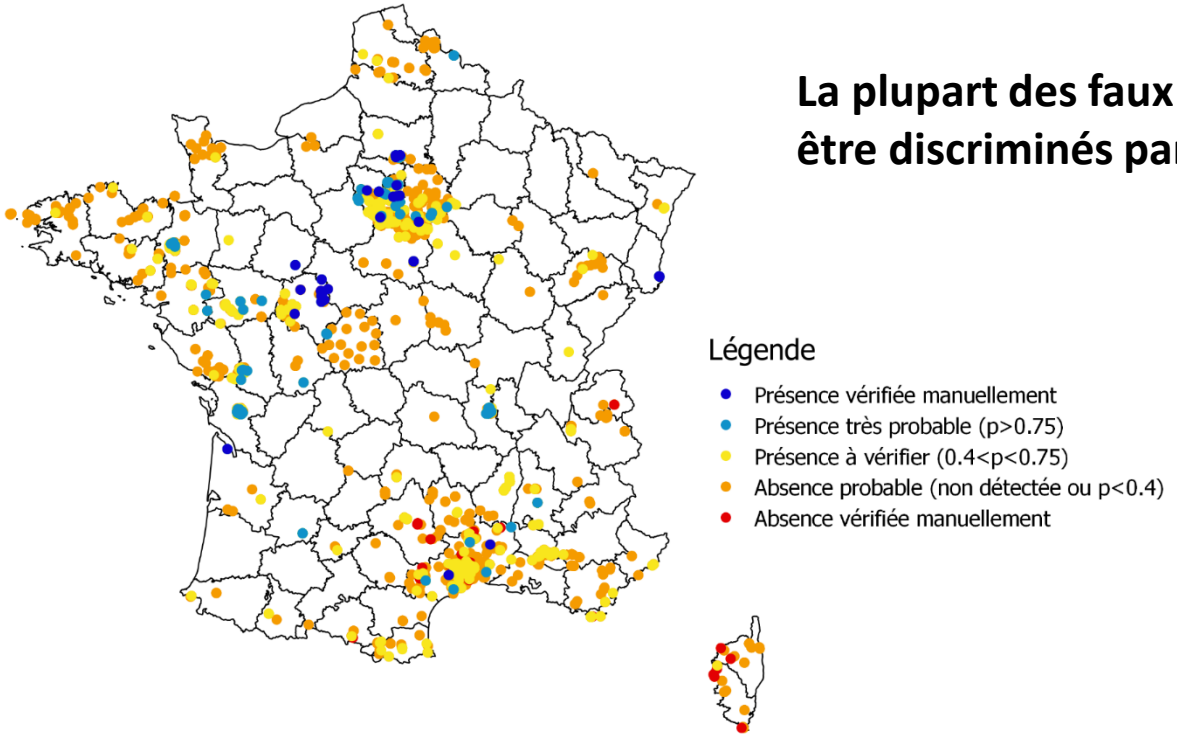
More complex modelling in progress: integrating features measured at several temporal scale (call sequence, minute, hour, night, etc) = ***2nd layer of classification***

Pipistrelle soprane : présence-absence



Nombreux faux positifs dans le Nord, mais la plupart peuvent être discriminés par un score faible

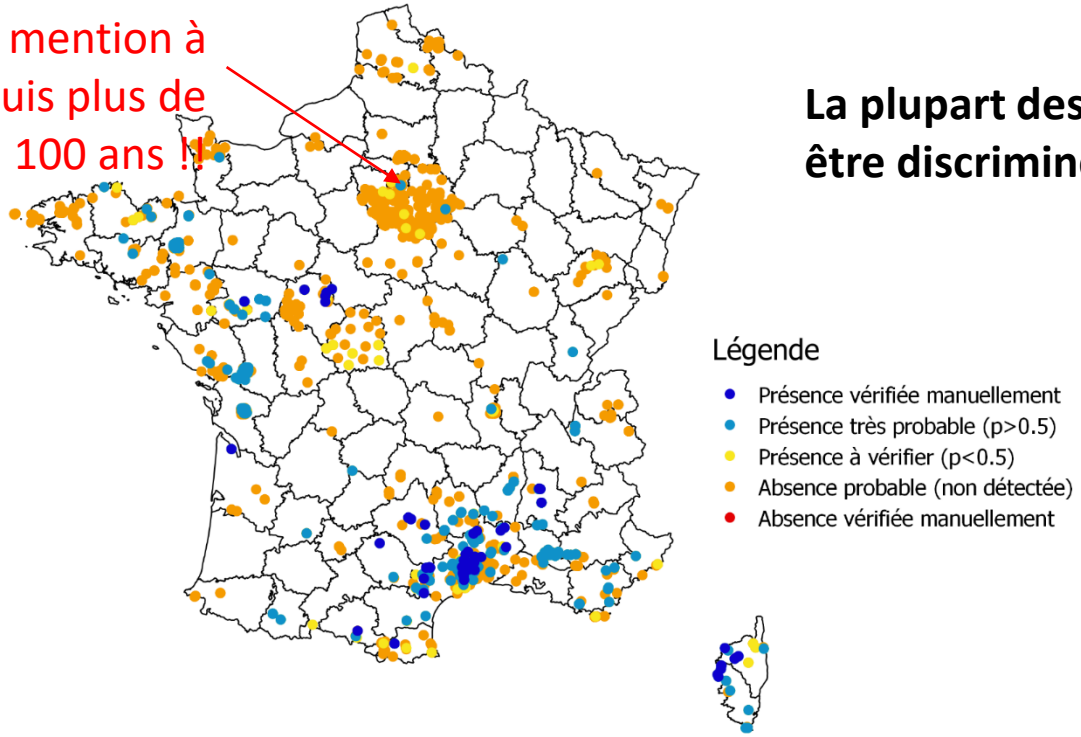
Noctule commune : présence-absence



La plupart des faux positifs peuvent être discriminés par un score faible

Petit Rhinolophe : présence-absence

1ere mention à Paris depuis plus de 100 ans !!

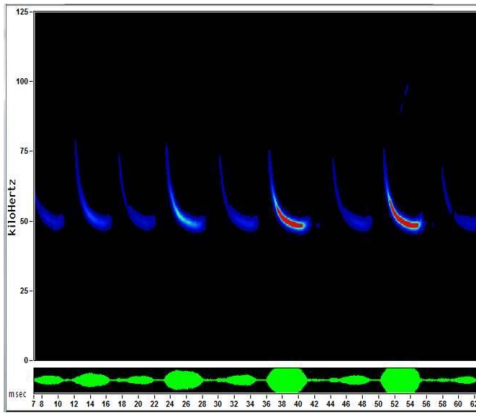


La plupart des faux positifs peuvent être discriminés par un score faible

Data collection, analysis, feedback pipeline

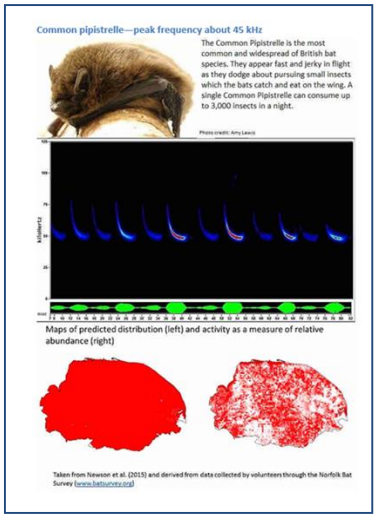
Data collection

Data transfer



Data processing

Data storage



Feedback