北京生物多样性论坛

被动声学监测在翼手目动物研究中的应用与进展

Passive acoustic monitoring in bat ecology and conservation

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目 录

图：崔建国, 肖治术

被动声学监测简介

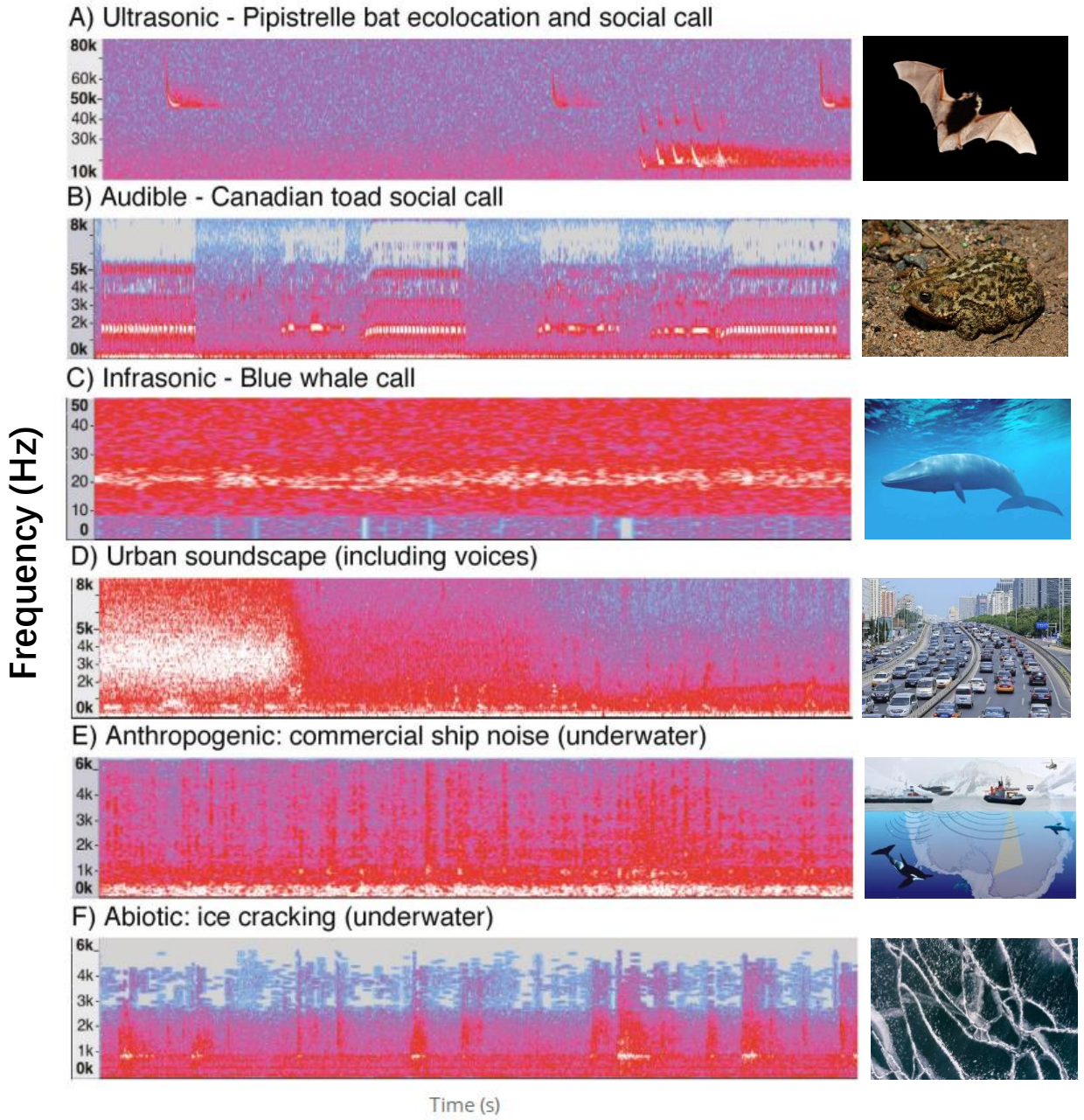
- 历史背景
- 常见问题
- PAM & 翼手目

内容一：被动声学监测简介

万物有声•倾听自然

动物利用声音进行交流、回声定位、求偶和领域防御，生物声学监测包括记录这些声音来推断动物的分布、生理状态、丰度和行为。

声学监测可用于研究各种各样的类群，只要它们能发出可检测的声音，迄今为止已应用于鸟类、蝙蝠、海洋哺乳动物、两栖动物、节肢动物等多个动物类群。



声学监测在海洋动物中的应用

历史上，声学监测技术首先被应用于水生动物的监测和研究。

- 物种识别与种群监测
- 海洋动物行为研究（交配、觅食、领域）
- 生境利用及空间分布
- 种群健康监测
- 威胁监测（如船舶噪音、钻探和军事活动）
- 气候变化对海洋动物的影响
- 保护和管理
- …

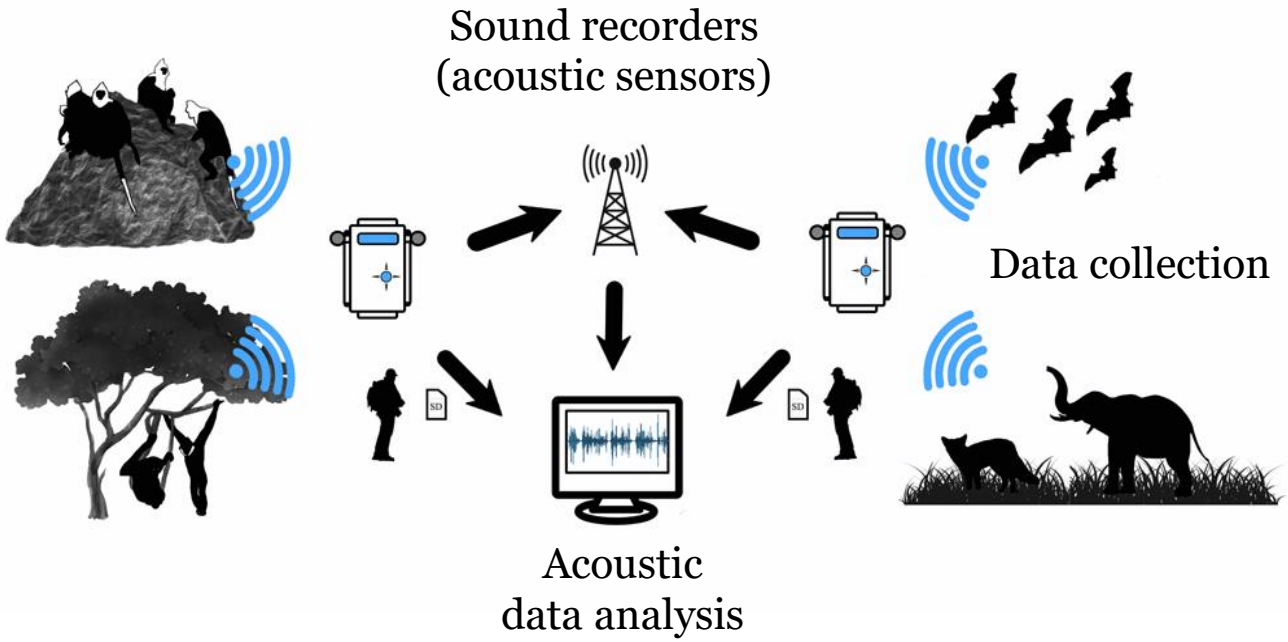
Passive acoustic monitoring as a marine conservation tool

被动声学监测(passive acoustic monitoring, PAM)

What is passive acoustic monitoring? And why is it used for wildlife monitoring?

被动声学监测（Passive Acoustic Monitoring, PAM）是一种通过监听和记录自然环境中的声音来进行监测的方法。

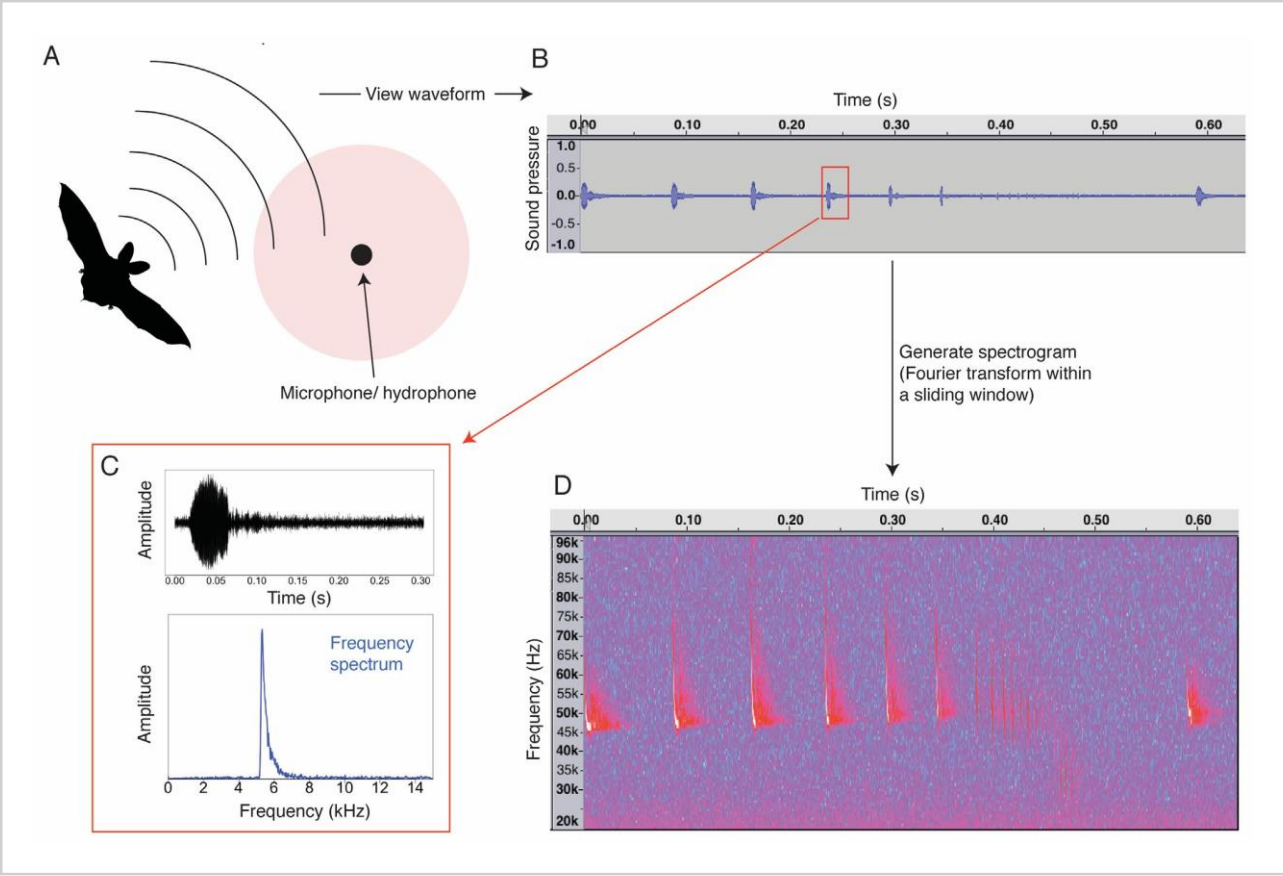
生物声学监测包括记录声学数据，然后通过声音分析软件对收集到的数据进行处理和分析，提取有用的生态数据，以推断动物的分布、生理状态、丰度和行为等信息。



Audio recorders are better than cameras because they can record species over far larger areas.

被动声学监测 (passive acoustic monitoring, PAM)

How do acoustic sensors work, and what data do they collect?



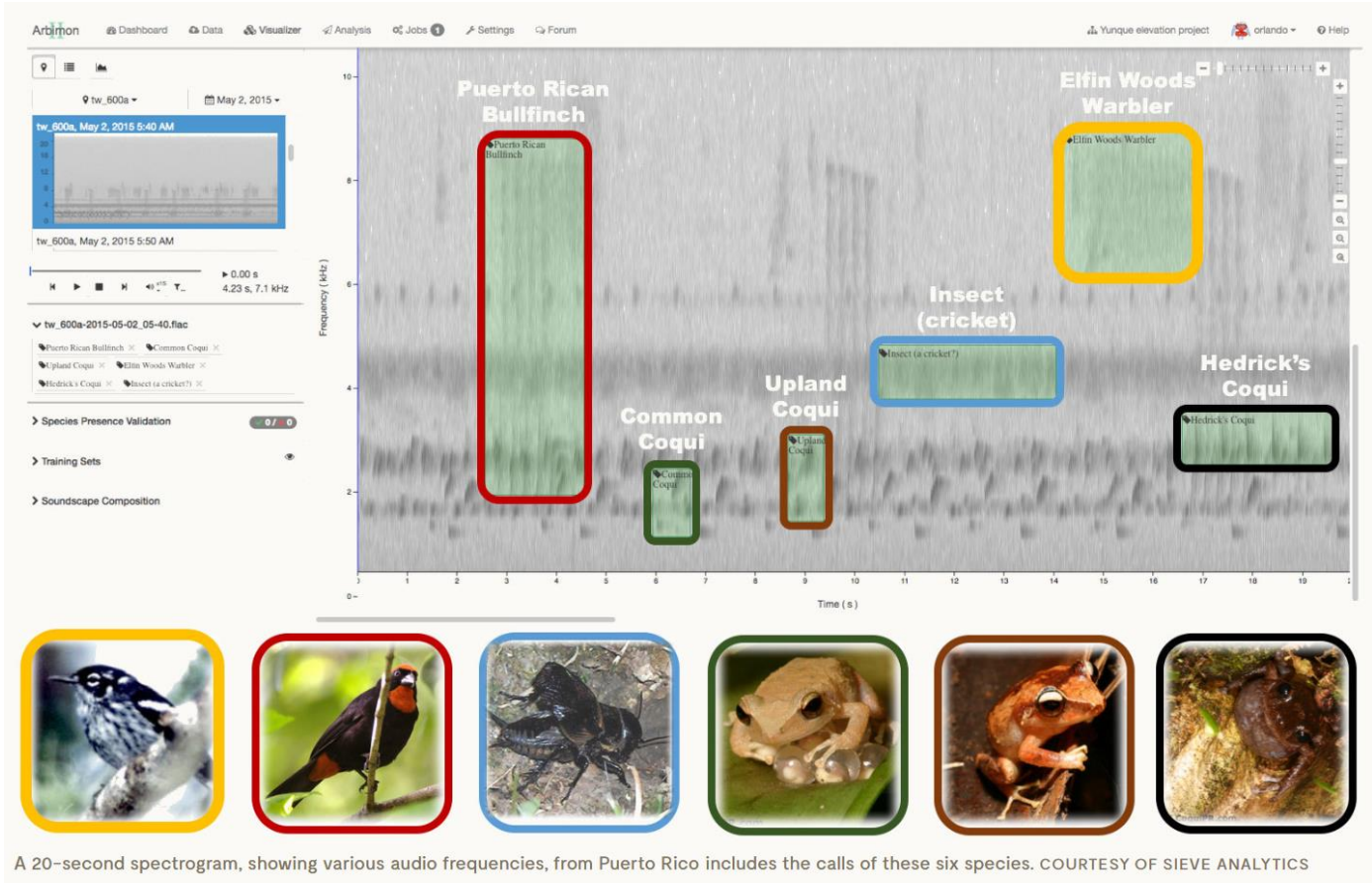
Recording and processing of an acoustic signal

- 信号发出者发出声信号
- 声学探测器捕获声信号
- 声信号转换为电信号
- 信号处理-计算声信号参数
- 通过傅里叶变换生成频谱图

被动声学监测 (passive acoustic monitoring, PAM)

Why is Passive Acoustic Monitoring Important?

- Non-invasive Monitoring
- Long-term Data Collection
- Detection of Cryptic Species
- Habitat Use and Migration Studies
- Environmental Impact Assessments
- Biodiversity Monitoring
- Soundscapes and Ecosystem Health
- Policy and Conservation
- …



A 20-second spectrogram, showing various audio frequencies, from Puerto Rico includes the calls of these six species. COURTESY OF SIEVE ANALYTICS

PAM已成为生物多样性评估的一项重要手段

(Yale E360)

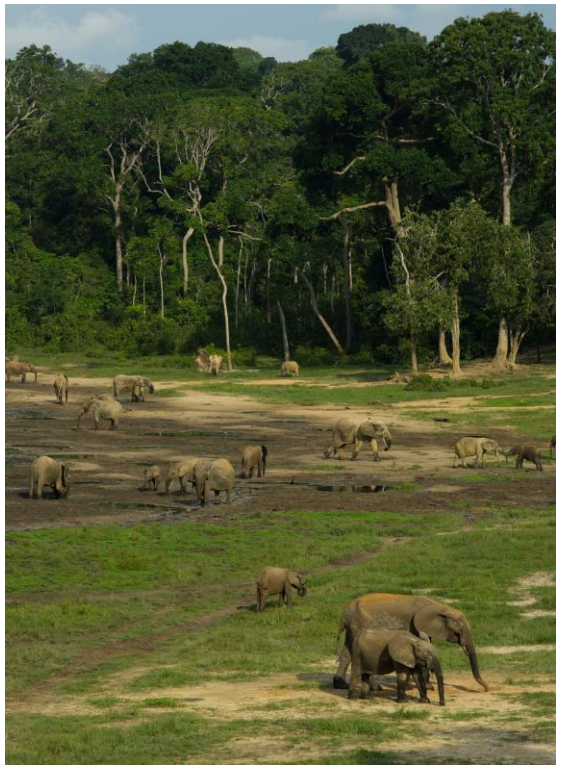
被动声学监测 (passive acoustic monitoring, PAM)

Where can passive acoustic monitoring be useful for ecologists and conservationists?

Acoustic sensors are **small**, **increasingly affordable** and **non-invasive**, and can be deployed in the field for **extended times** to monitor wildlife and their acoustic surroundings.

The data can then be used for estimation of species **occupancy**, **abundance**, **population density** and **community composition**, monitoring **spatial** and **temporal** trends in animal behaviour, and calculating acoustic proxies for metrics of biodiversity.

Provided the challenges of data analysis are addressed carefully, this can make acoustic sensors valuable tools for **cost-effective monitoring of species and ecosystems** and their **responses to human activities**.

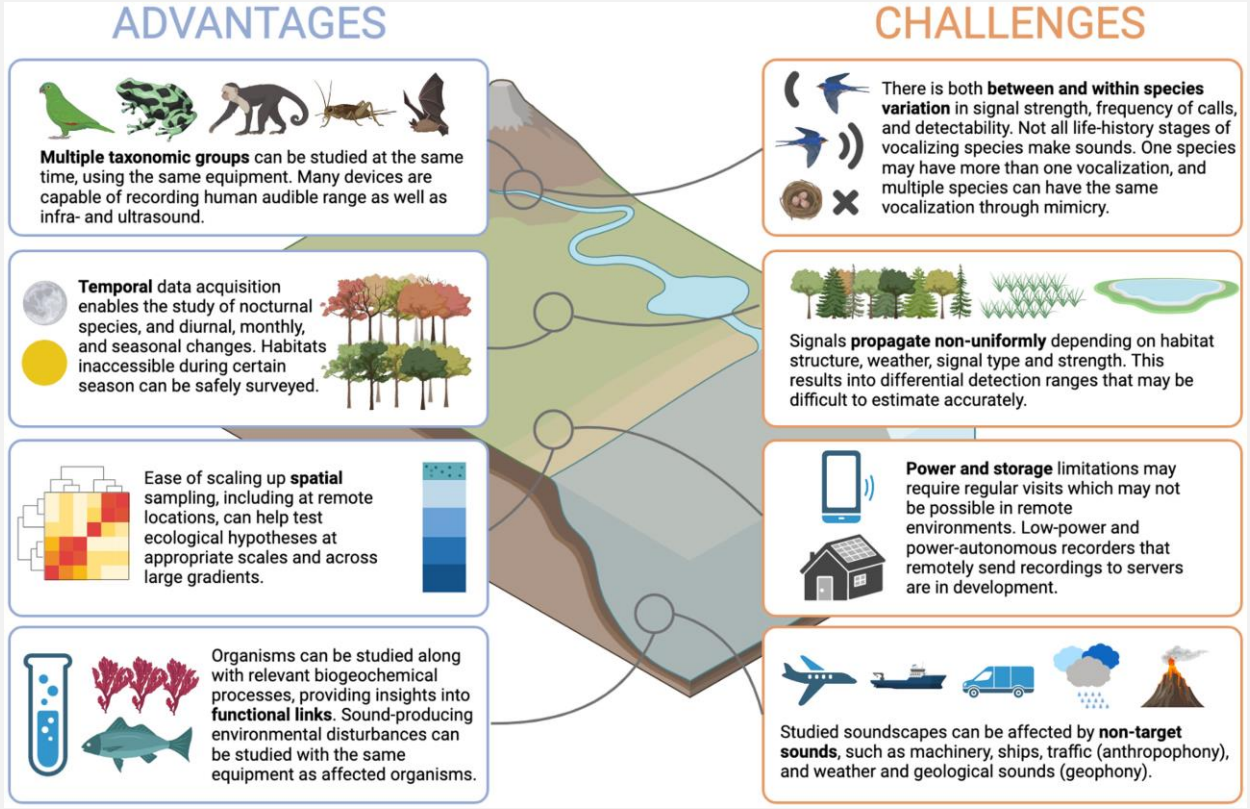


Acoustic sensors are increasingly being used to monitor biological diversity, illegal human activities such as the poaching of wildlife and illegal logging.

被动声学监测的优势与局限性

PAM优势

1.非侵入性监测
2.长期监测
3.自动化和实时监测
4.大范围监测
5.数据丰富
6.昼夜监测
7.行为与生态研究



PAM局限性

1.声音识别的复杂性
2.声音掩盖
3.数据处理量大
4.距离限制
5.技术和成本
6.环境因素影响
7.无法提供全面信息
8.物种特异性

Ross P R S et al. Passive acoustic monitoring provides a fresh perspective on fundamental ecological questions[J]. Functional Ecology,2023,37(4).

内容一：被动声学监测简介

被动声学监测在陆生动物中的应用

主要研究主题

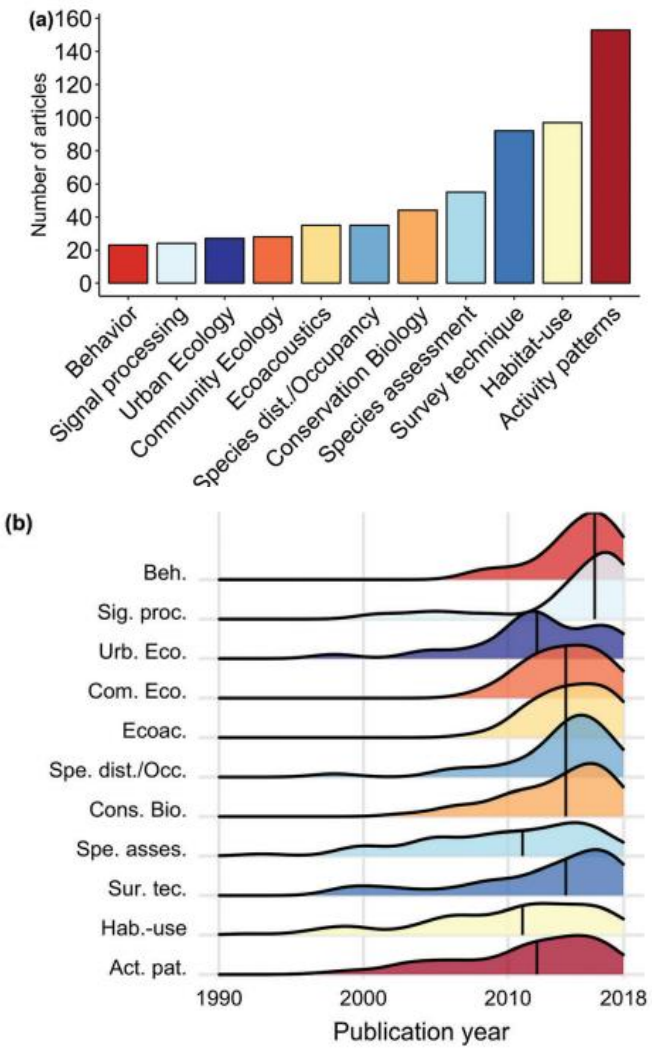
- 活动模式
- 生境利用
- 调查技术
- 物种评估

主要研究类群

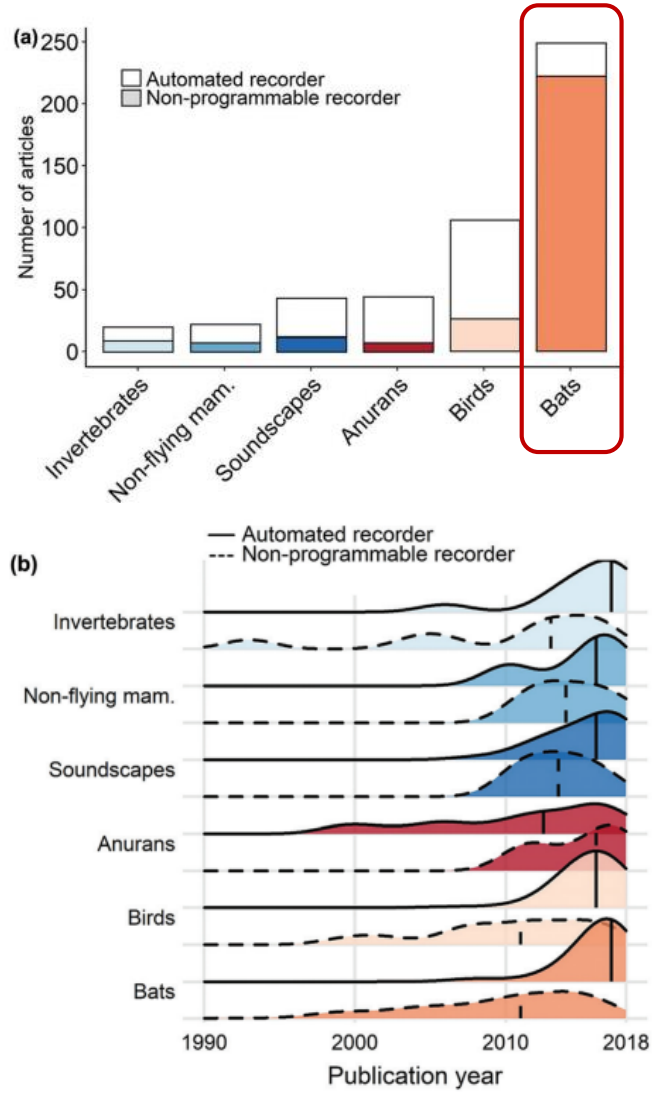
- 蝙蝠
- 鸟类

蝙蝠——声学监测的模式生物

不同研究主题发表的文章数量

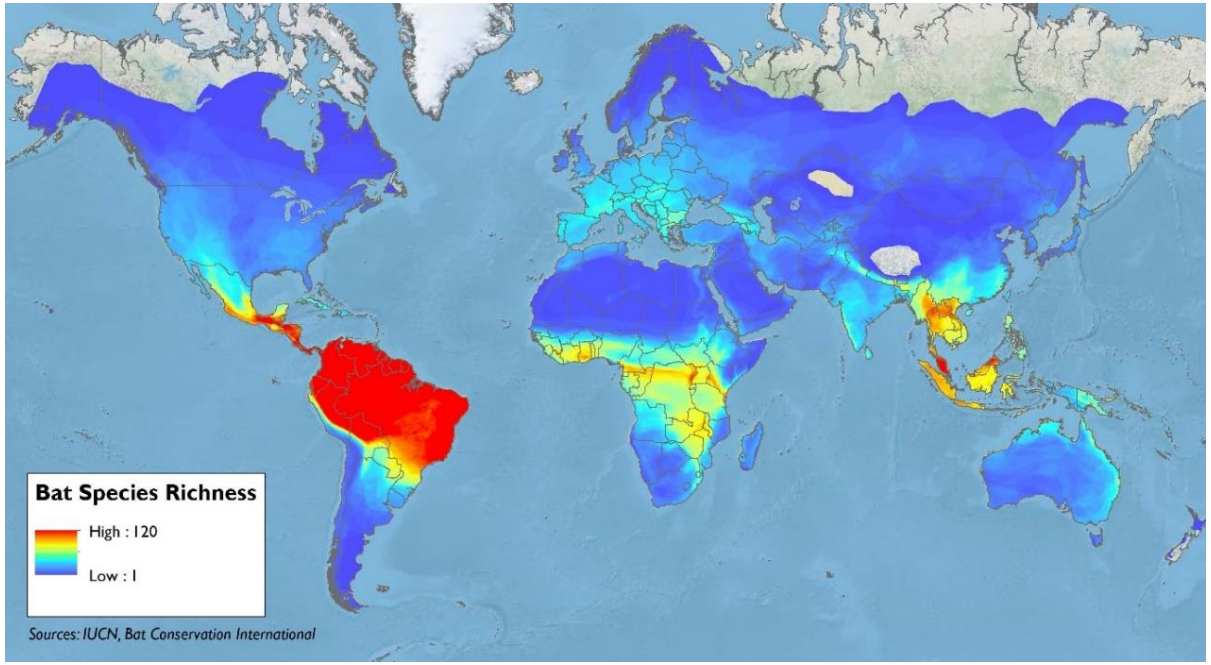


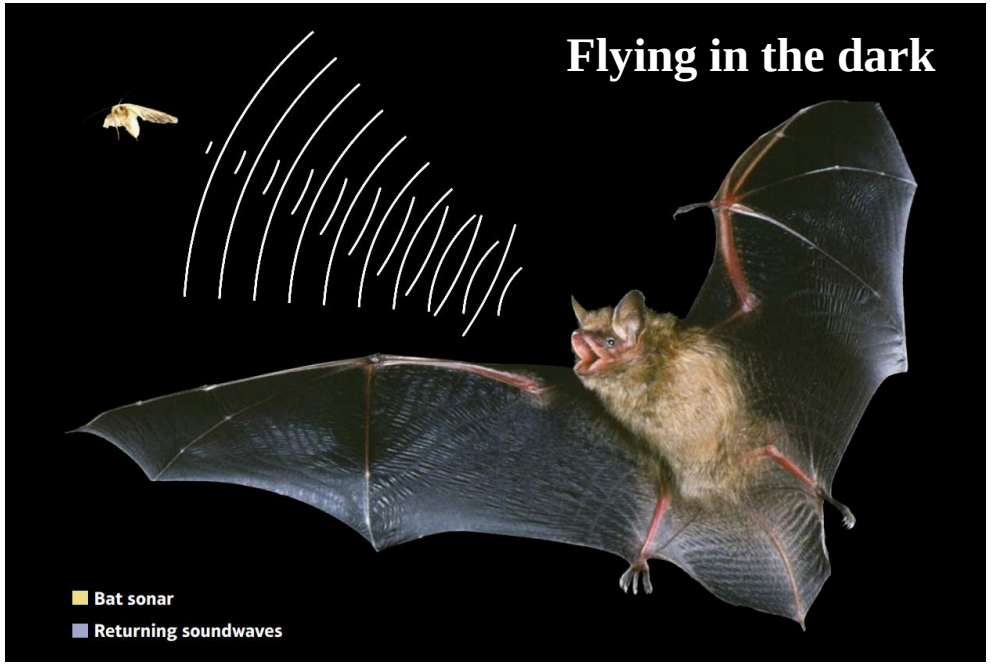
不同研究类群发表的研究数量



Sugai M S L ,Silva F S T ,Jr R W J , et al. Terrestrial Passive Acoustic Monitoring: Review and Perspectives[J]. Bioscience,2019,69(1).

蝙蝠 ——声学监测的模式生物





翼手目（蝙蝠）是最广泛分布的陆生哺乳动物，目前超过 1400 种，占哺乳动物的 20% 左右。蝙蝠占据独特的夜空生态位，能够发出主导不同功能的回声定位声波和通讯叫声进行空间感知、定位导航、追踪猎物和信息交流。

蝙蝠声信号的类型及特征

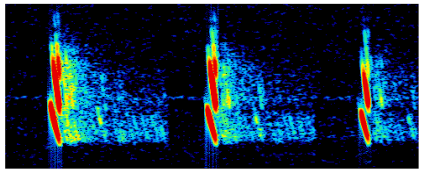
回声定位类型和声波组分

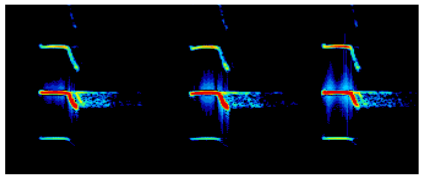
回声定位声波

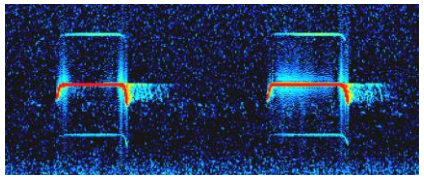
喉部回声定位
Laryngeal echolocation

阳蝙蝠亚目
+菊头蝠总科(阴蝙蝠亚目)

- **调频型 FM** — **FM**
- **恒频型 CF** — **CF-FM**
- **FM-CF-FM**



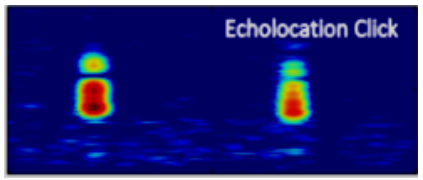




舌部回声定位
Lingual echolocation

少部分狐蝠科(阴蝙蝠亚目)

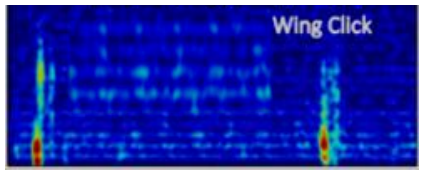
- **舌敲击声 Clicks**



翼部回声定位 (回声感知)
Wing click-based echo sensing

少部分狐蝠科(阴蝙蝠亚目)

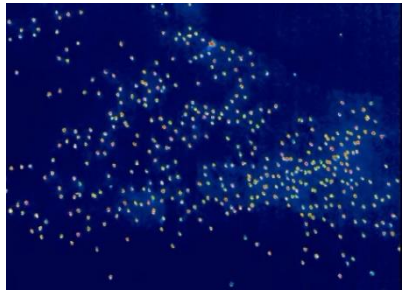
- **拍翼滴答声 Wing clicks**



蝙蝠声信号的类型及特征

交流声波（通讯叫声）

求偶交配



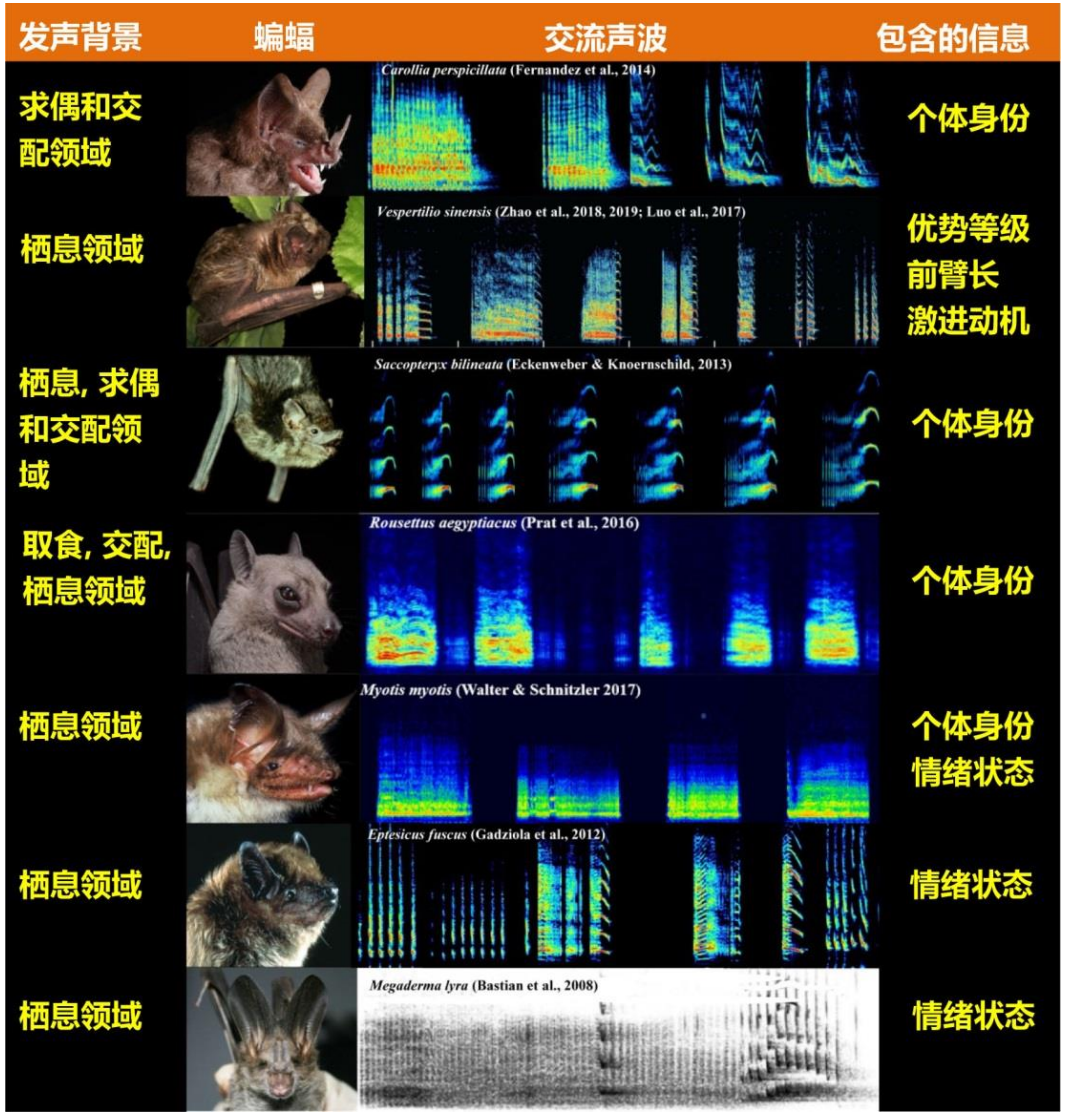
保护领域

社群交流

母婴交流

恐吓威胁

激进打斗



蝙蝠行为生态研究的挑战及声学研究优势

蝙蝠研究中的挑战

- 夜行性
- 回声定位
- 自主飞行

- 体型较小机动性强
- 流动性强
- 物种多样性高

- 栖息在人迹罕至的地方
- 空间异质性强
- 对环境变化敏感

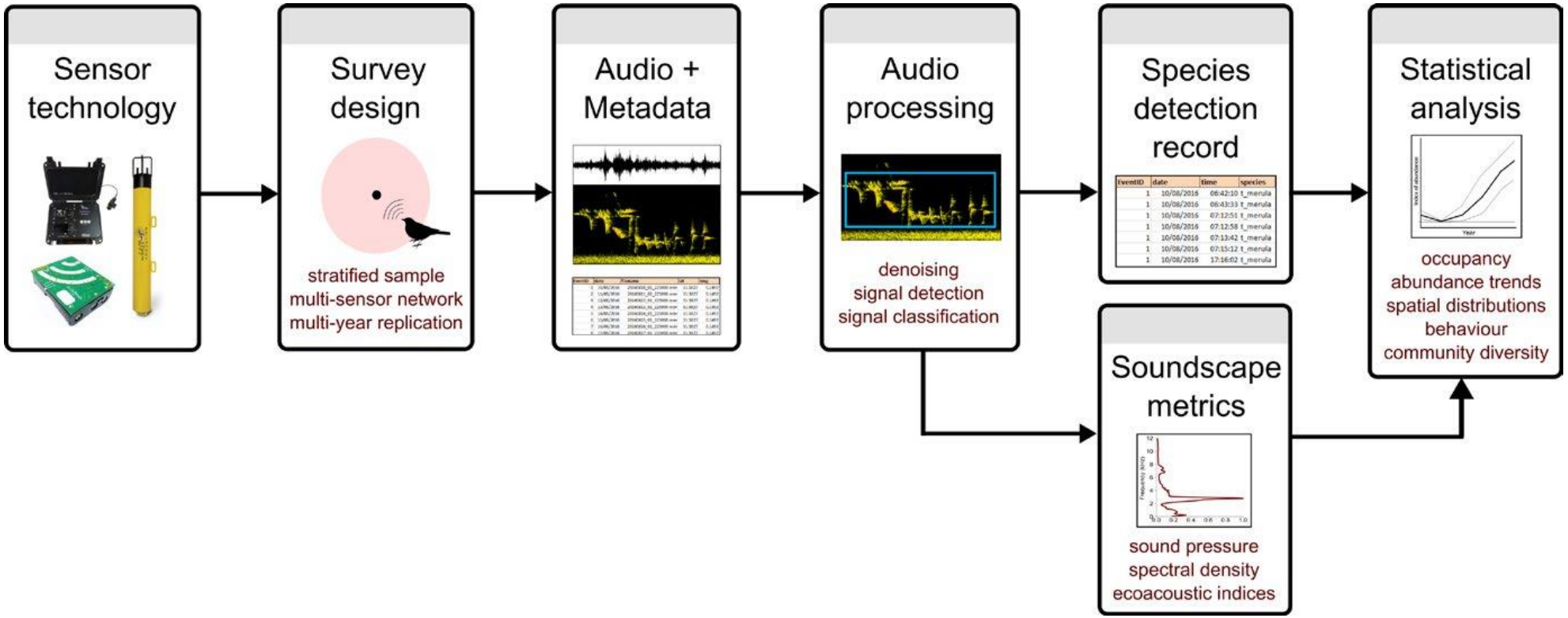
蝙蝠声学研究的优势

- 非侵入性
- 接近自然状态

- 无需人工值守
- 监测成本更低

- 调查范围更广
- 时空尺度更大等优势

A typical passive acoustic monitoring workflow



Emerging opportunities and challenges for passive acoustics in ecological assessment and monitoring

蝙蝠声学监测设备

- 常用监测设备比较
- 工作原理

内容二：蝙蝠声学监测设备

声学监测设备——Choose the ‘correct’ bat detector

麦克风

准确性

降噪

便携性

…

https://batmanagement.com/collections/bat-detector-buyers-guide-active-detectors

声学监测设备——Choose the ‘correct’ bat detector

声学监测设备的选择

- 采样频率
- 探测范围
- 声学数据质量
- 存储/续航
- 通道数量
- 结果准确性
- 劳动力强度
- 采样距离
- 防水性能
- 定位系统
- 温度传感器
- 价格
- …

https://batmanagement.com/collections/bat-detector-buyers-guide-passive-detectors

声学监测设备——Avisoft UltraSoundGate

Avisoft Bioacoustics

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Avisoft-UltraSoundGate

High-Quality Ultrasound Recording and Playback

The Avisoft-UltraSoundGate system is an integrated PC-based hardware and software solution for recording and playing back ultrasonic signals both in the field and in the laboratory, which has been specifically designed for bioacoustic applications.

声学监测设备——Avisoft UltraSoundGate

01 Avisoft-UltraSoundGate is a turn-key system that consists of a rugged data acquisition hardware with USB interface and a PC-based harddisk recording software. Depending on the specific application, various ultrasound microphones or hydrophones can be attached (see the signal flowchart),

02 Selectable sample rates of up to 750 kHz with adaptive anti-aliasing filter,

03 The accompanying Avisoft-RECORDER USGH software provides a real-time spectrogram display, advanced triggering facilities and many other useful features.

04 Balanced analog inputs for high immunity against electromagnetic interferences,

05 Multichannel recording with guaranteed synchronity from up to 12 channels,

06 Acoustic real-time (broad-band) monitor (models 116xx only),

07 Overload indicator & peak level meter (model 116Hm and 116Hme only),

08 Gain adjustment potentiometer either continuous (standard version) or stepwise with eleven 3dB increments (optionally on request),

09 Trigger button for quick start and stop of recordings.

10 Digital inputs for external triggering and timecode acquisition,

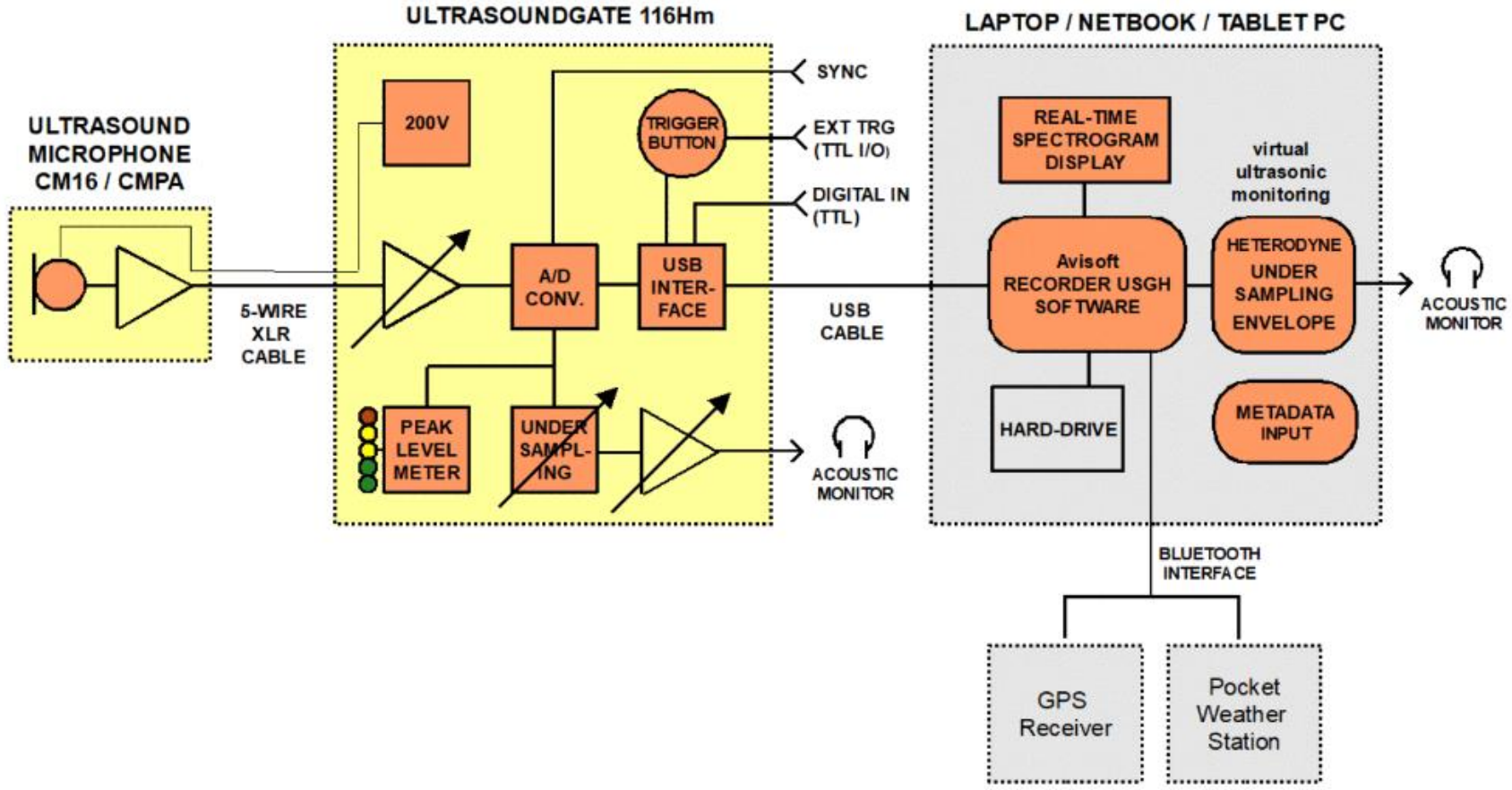
11 Easy plug-and-play installation,

12 Bus-powered operation (no need for extra power-supplies, which is important in the field),

13 Rugged and compact design suited for field use (all parts have been selected for best performance and maximum long-term reliability),

14 Watertight, dustproof and unbreakable transport box (model 116Hm only).

声学监测设备——Avisoft UltraSoundGate



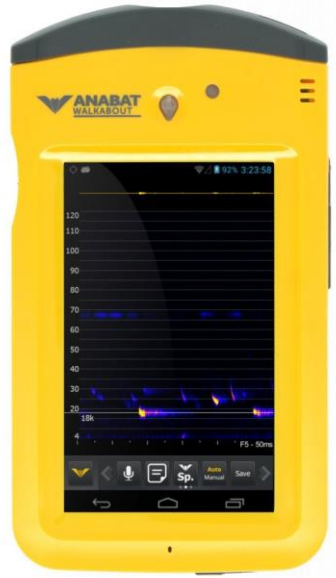
Principle of the UltraSoundGate system

https://www.avisoft.com/

声学监测设备——Anabat

Detector	How it works	Advantages	Disadvantages	Price range
Time Expansion (TE)	Broadband detector. Captures a short sample of sound and plays it back at a slower speed for recording.	Sounds are recorded in very high detail making the call structure very clear and enabling precise measurements of call parameters.	While the detector is playing back the slowed-down sounds it is not detecting so bats can be missed.	Mid-high price range.
Full spectrum/Direct Sampling	Broadband detector. Records sounds in real time at their original frequency.	"Best of both worlds" between FD/TE. Sounds recorded in high detail with continuous detection in real time.	Very high sampling rate required which creates large files.	Higher price range but cheaper models are also available.

Pettersson D-240X
Heterodyne and time expansion



Anabat Walkabout Bat Detector-Full spectrum or zero crossing

内容二：蝙蝠声学监测设备

声学监测设备

Detector	How it works	Advantages	Disadvantages	Price range
Heterodyne	Tuneable detector. The bat calls are converted to distinctive sounds within the frequency range humans can hear.	A range of species can be identified in the field. Visual clues can be used as ID is made while the bat is present. They are simple to use.	Not suitable for spectrogram analysis. ID can't be verified at a later date. Only detects within a limited frequency range at a time so some species could be missed.	Cheapest of the detectors.
Frequency division (FD)	Broadband detector. Detected sound is outputted in real time. Frequencies divided by ten for recording.	Allows continuous detection so bats are less likely to be missed.	Calls are recorded in less detail making sound analysis more challenging.	Cheapest of the broadband detectors. Overall mid-high price range.
Zero Crossing (ZC)	Broadband detector. Records sounds as data points which plot how frequency changes over time.	Creates very small files so can be left in the field for a long time before the SD or CF card fills up.	Spectrograms less detailed than from full spectrum and time expansion detectors.	Mid-high price range.

Magenta 4 & Magenta 5 – Heterodyne

Baton & Duet – Frequency Division

声学监测设备

AudioMoth

AudioMoth | HydroMoth | AudioMoth Dev | µMoth | Waterproof Case | Underwater Case

AudioMoth is a low-cost, full-spectrum acoustic logger, based on the Gecko processor range from Silicon Labs. Just like its namesake the moth, AudioMoth can listen at audible frequencies, well into ultrasonic frequencies. It is capable of recording uncompressed audio to microSD card at rates from 8,000 to 384,000 samples per second and can be converted into a full-spectrum USB microphone.

- EFM32 Gecko processor
- Capable of recording at sample rates up to 384kHz
- Records uncompressed WAV files to microSD card
- Can be converted into a full-spectrum USB microphone
- Powered by 3 x AA batteries
- Analog MEMS microphone
- Analog pre-amplifier with adjustable gain
- Measures just 58 x 48 x 15 mm
- Configurable USB interface
- Onboard real-time clock keeps track of time in UTC
- Exposed header for 3.5mm jack mic from version 1.2.0 onwards

低成本的全频谱声学记录仪

Click Getting Started for help setting up a new AudioMoth.

To download a manual containing all AudioMoth information for offline usage click here.

https://www.openacousticdevices.info/audiomoth

声学监测设备

AudioMoth Dev

AudioMoth Dev is a variant of the standard AudioMoth 1.2.0 designed as a development board for skilled users to integrate into other boards and products.

- Power socket (JST-PH) supporting 3.7 - 6V batteries
- All controls, indicators and IO ports broken out to 5 JST-PH style headers
- 3.5 mm jack socket for external electret condenser microphones
- Compatible with all AudioMoth software

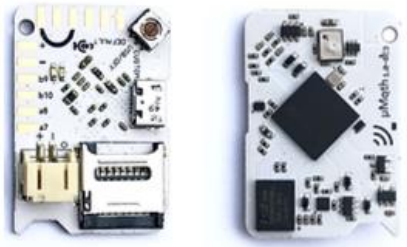
AudioMoth Dev是标准AudioMoth 1.2.0的一个变体，设计为开发板，供熟练用户集成到其他板和产品中。

MicroMoth

MicroMoth is a micro-size variant of the standard AudioMoth 1.1.0 open-source design, while maintaining full compatibility with all versions of the existing firmware.

- Power socket (JST-PH) supporting 3.7 - 6V batteries
- Measures just 32 x 24 mm
- Weighs just 5g (excluding battery)
- Compatible with all AudioMoth software

The MicroMoth datasheet is available here.



ZSL LET'S WORK FOR WILDLIFE ARRIBADA initiative

MicroMoth是标准AudioMoth 1.1.0开源设计的微型版本，同时保持与所有现有固件版本的完全兼容性。

https://www.openacousticdevices.info/audiomoth

声学监测设备——SONG METER SM4BAT

SONG METER SM4BAT FS ULTRASONIC RECORDER

Setting the standard for ultrasonic wildlife recorders.

Specially engineered to capture quality ultrasonic bat recordings, the Song Meter SM4BAT is the industry-leading bat detector and recorder.

$999.00 (USD)
SOLD OUT UNTIL END OF YEAR

Qty: 1 ADD TO CART

Microphone, batteries and flash cards sold separately.

https://www.wildlifeacoustics.com/products/song-meter-sm4bat

声学监测设备——SONG METER MINI BAT

SONG METER MINI BAT ULTRASONIC RECORDER

Big Features. Small Size.

An innovative tool for detecting and recording bat vocalizations, the Wildlife Acoustics Song Meter Mini Bat gives scientists an ultrasonic recorder specially designed to offer simplicity without sacrificing quality.

$749.00 (USD)
SOLD OUT UNTIL END OF YEAR

Qty: 1 ADD TO CART

Add Acoustic Microphone Stub for Mini Family to cart to record birds and land animals when not recording bats.

https://www.wildlifeacoustics.com/products/song-meter-mini-bat

声学监测设备——SONG METER

FEATURES

- Industry standard line of ultrasonic bat audio recorders, with over 20,000 SM4 family recorders sold to date
- Proven and reliable, with only 0.64% of recorders requiring in-warranty repairs
- 3-year warranty
- Weatherproof design suitable for any environment
- Designed for use with the low-noise, waterproof SMM-U2 microphone
- Built-in fail-safe and fault-tolerant tech, including two flash cards for failover and extensive internal diagnostics
- Compact, at 8.6" x 6.0" x 3.1" (218 mm x 152 mm x 78 mm)
- Extended field deployments, with up to 48 ten-hour nights of battery life using alkaline batteries, or even longer using external power.
- Choose a quick-start schedule or easily create your own
- GPS attachment allows you to set date, time and location for multiple recorders
- Advanced triggering to record only when bats are present
- Optional noise scrubber automatically deletes false triggers that do not contain bats
- Optional 16 kHz high pass filter to reduce lower frequency noise
- Capable of storing terabytes of data on two SDHC/SDXC flash cards
- Save card space via W4V compression, doubling the capacity of SD cards without degrading recording quality
- Compatible with Kaleidoscope Pro software to quickly review recordings and automatically suggest bat species (in supported regions)

song-meter-sm4bat

FEATURES

- Comparable recording quality to the industry standard Song Meter SM4BAT
- Records in Full Spectrum and/or Zero Crossing
- Lightweight, at just 0.64 lb/290 g (including batteries)
- The smallest ultrasonic bat recorder available, at just 4.9" x 5.3" x 1.4" (123 mm x 134 mm x 36 mm)
- Weatherproof design suitable for any environment
- Low-noise microphone detects and captures more bat recordings
- Advanced triggering records only when bats are present
- Optional noise scrubber automatically deletes false triggers that do not contain bat vocalizations
- Change settings and schedule wirelessly via Bluetooth on your mobile device
- Automatically sends recorder status to the app via Bluetooth
- Uses your mobile device to set date, time, time zone and location
- Optional microphone attachment ($75) allows you to also record birds, frogs and other vocal wildlife
- Record up to 25 ten-hour nights with 4 AA batteries (or 125 ten-hour nights with 6 lithium-ion batteries in optional lid)
- Compatible with Kaleidoscope Pro software to quickly review recordings and automatically suggest bat species (in supported geographies)
- Affordably priced at $749, including one built-in ultrasonic microphone

song-meter-mini-bat

声学监测设备——ECHO METER TOUCH 2

ECHO METER TOUCH 2 FOR ANDROID (USB-C)

Discover the Earth's echo-system with the most advanced bat detector — at any price.

Flying at night, using ultrasonic vocalizations — bats can be hard for people to detect. But with the sophisticated technology inside the affordably priced Echo Meter Touch 2, you can turn your smartphone or tablet into a professional-quality, interactive bat detector, allowing you to hear and record bats flying above you in real-time!

*Not compatible with Apple iOS devices, including those with USB-C connectors

$179.00 (USD)

IN STOCK [NOTE: NOT COMPATIBLE WITH APPLE IOS DEVICES, INCLUDING THOSE WITH USB-C CONNECTORS.]

Qty: 1 ADD TO CART

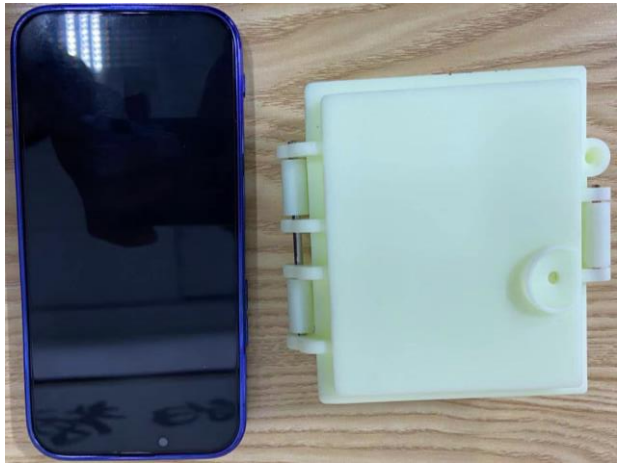
Requires an Android device with a USB-C connector. Android devices with Micro USB connectors require the use of an adapter. See list of compatible devices and adapter details here.

https://www.wildlifeacoustics.com/products/echo-meter-touch-2-android-2

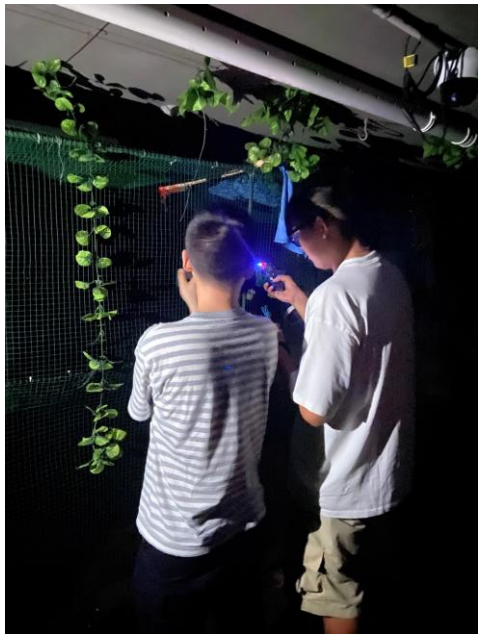
内容二：蝙蝠声学监测设备

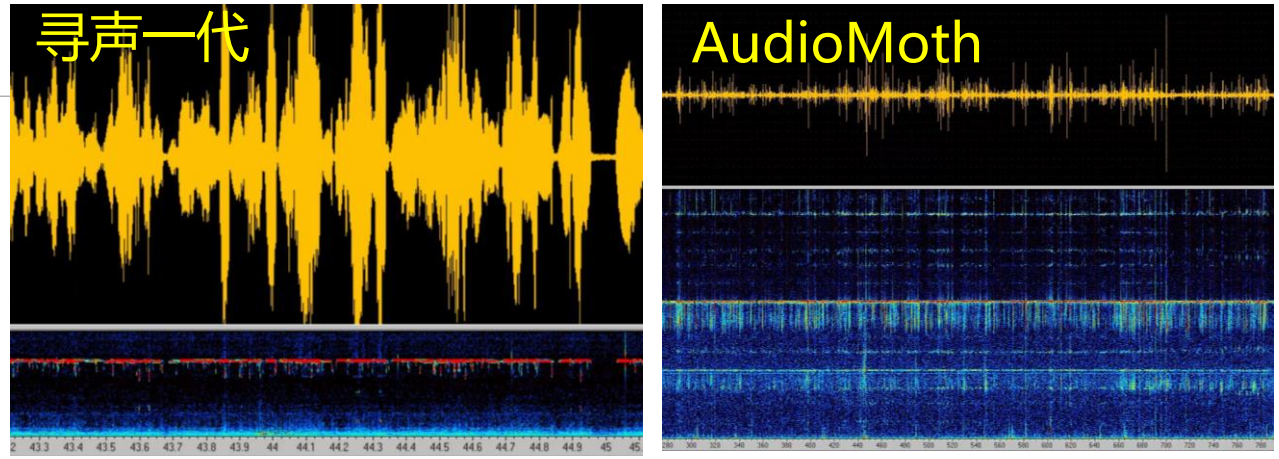
内容二：蝙蝠声学监测设备

国内声学设备的研发（寻声一代）



采样频率	最大可达384kHz
续航时间	30天
声纹识别	支持
远距离传输	广域网自适应
增益	调节
采样位深	16位





蝙蝠超声波测试（主频70kHz）

核心指标	寻声一代	AudioMoth
声波幅值	低	高
噪声	低	高
续航时间	30天	7天
声纹识别	支持	不支持
远距离传输	支持	不支持

PAM在翼手目动物中的应用

- 研究方向
- 研究案例

研究方向1：声学监测技术及分析方法优化

Choosing the 'correct' bat detector

声学监测设备的准确性比较

- 采样频率
- 声学数据质量
- 存储/续航
- 通道数量
- 结果可靠性
- 劳动力强度
- 采样距离
- 防水性能
- 定位系统
- 温度传感器
- 价格
- …

Avisoft UltraSoundGate 116 CM16/CMPA

AnaBat SD2 Compact Flash Bat Detector

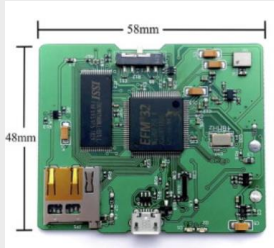
Pettersson D200

Pettersson D500X

Batcorder

Batlogger

Song Meter SM2BAT



AudioMoth

研究方向1：声学监测技术及分析方法优化

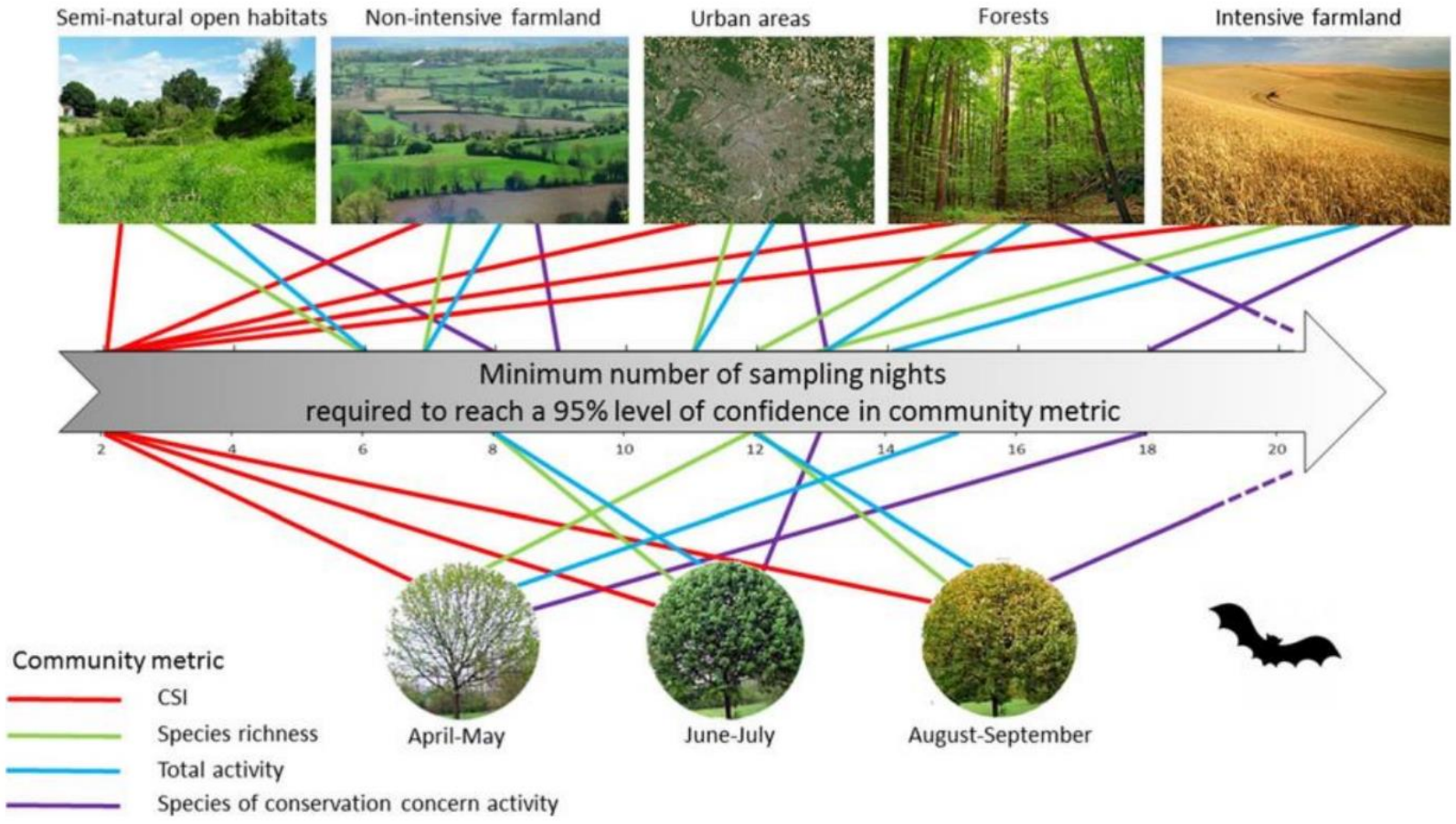
不同监测技术可靠性及最优方案比较

监测的模式可靠性比较

- 半自动长期声学监测
- 被动声学监测
- …

最优采样方案比较

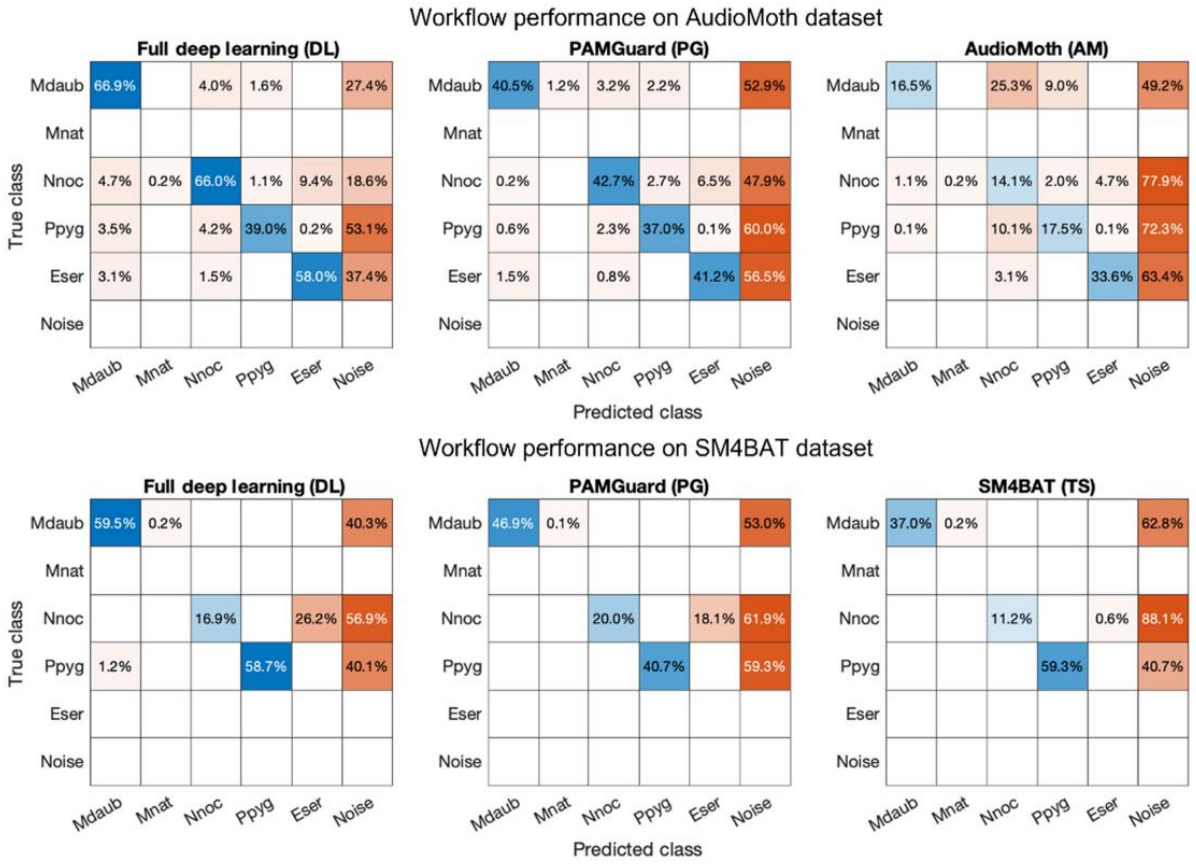
- 固定样点&活动样点
- 监测周期
- 采样时间
- 设备布设覆盖性
- …

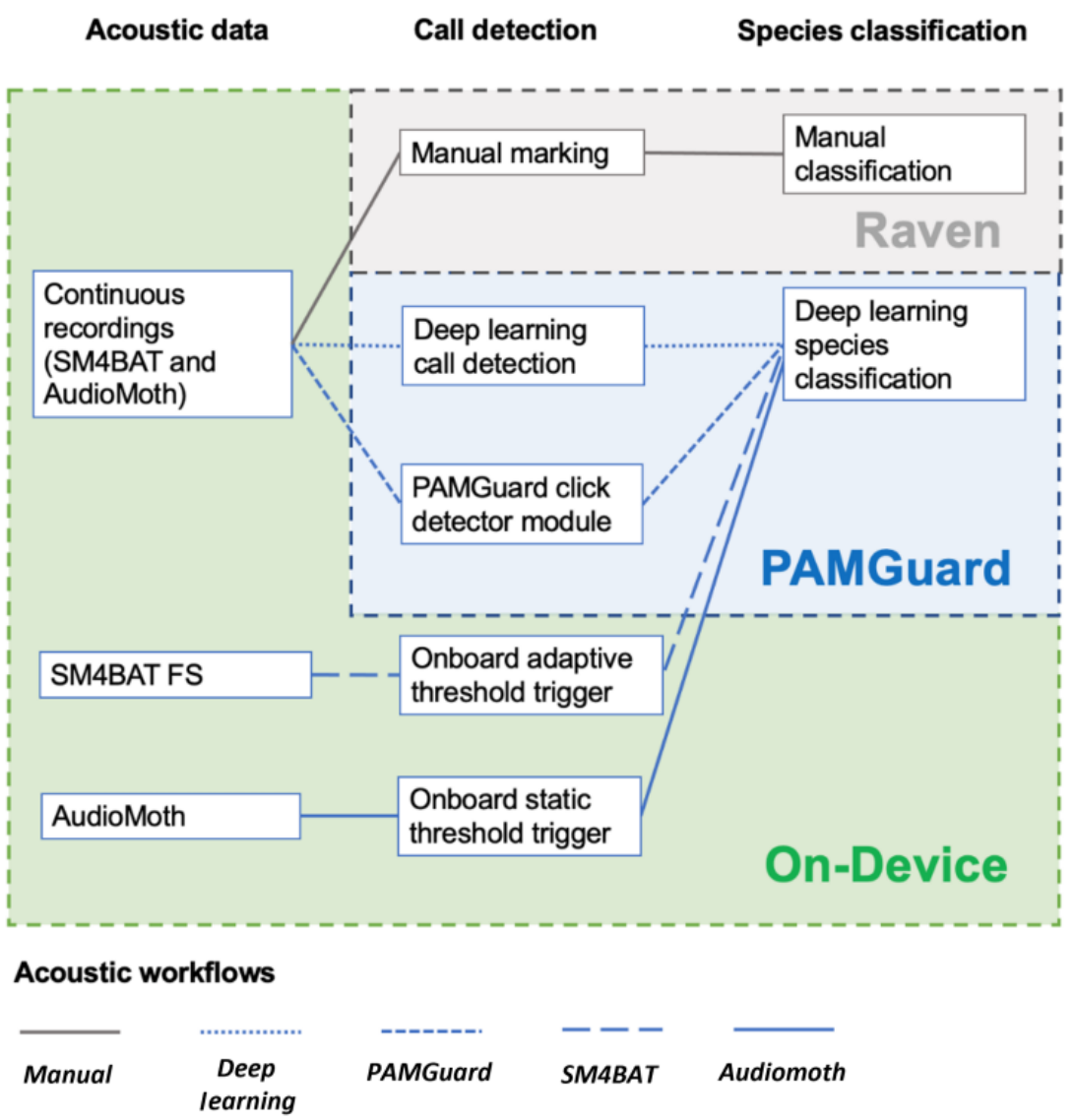


内容三： PAM在翼手目动物中的应用

研究方向1：声学监测技术及分析方法优化

研究案例：



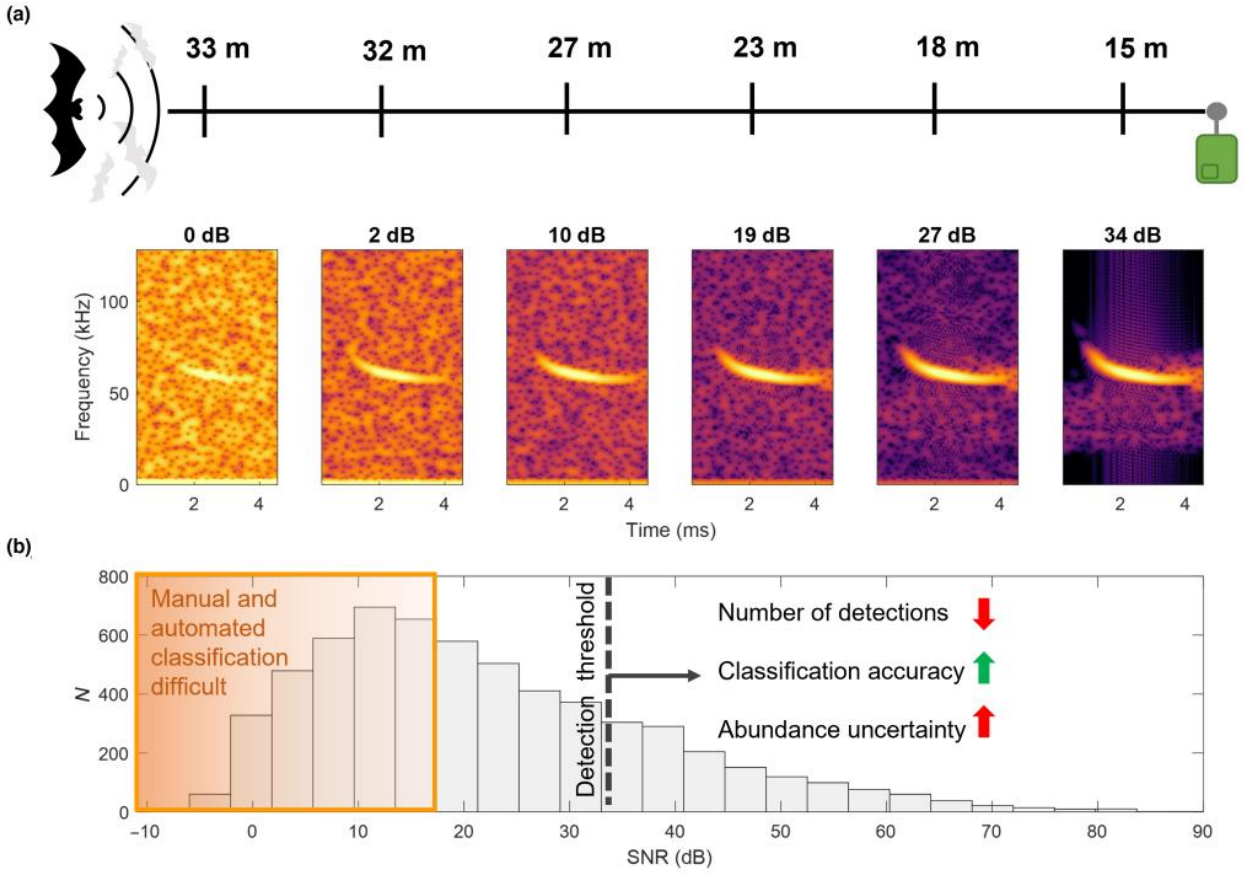


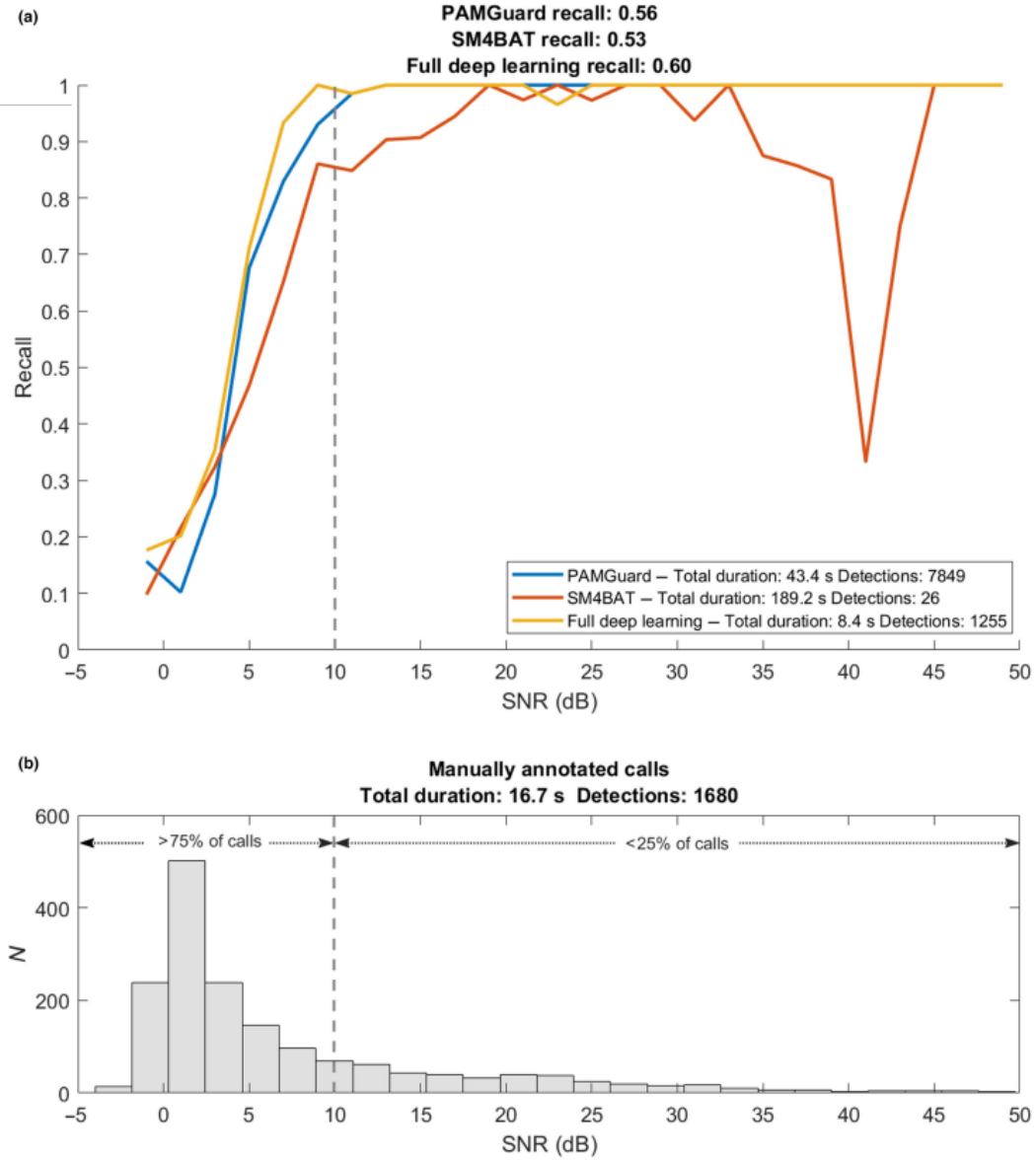
Brinkløv M M S ,Macaulay J ,Bergler C , et al. Open-source workflow approaches to passive acoustic monitoring of bats[J]. Methods in Ecology and Evolution,2023,14(7).

内容三：PAM在翼手目动物中的应用

研究方向1：声学监测技术及分析方法优化

研究案例：





Brinkløv M M S ,Macaulay J ,Bergler C , et al. Open-source workflow approaches to passive acoustic monitoring of bats[J]. Methods in Ecology and Evolution,2023,14(7).

内容三：PAM在翼手目动物中的应用

研究方向1：声学监测技术及分析方法优化

研究案例：

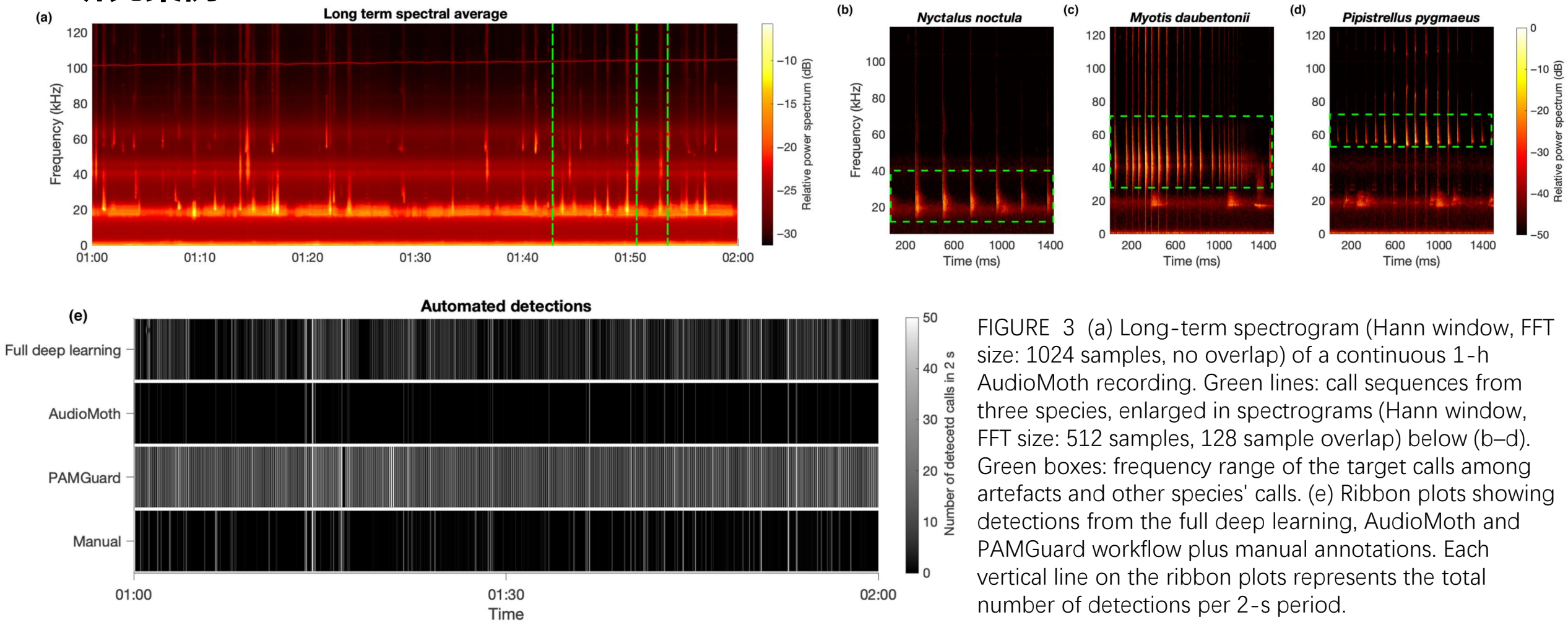
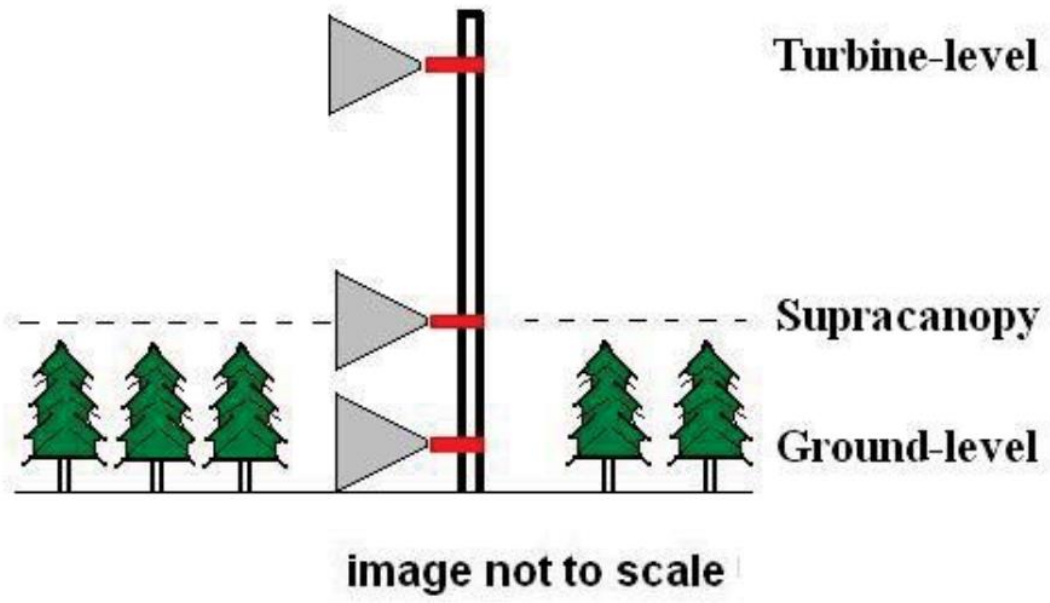


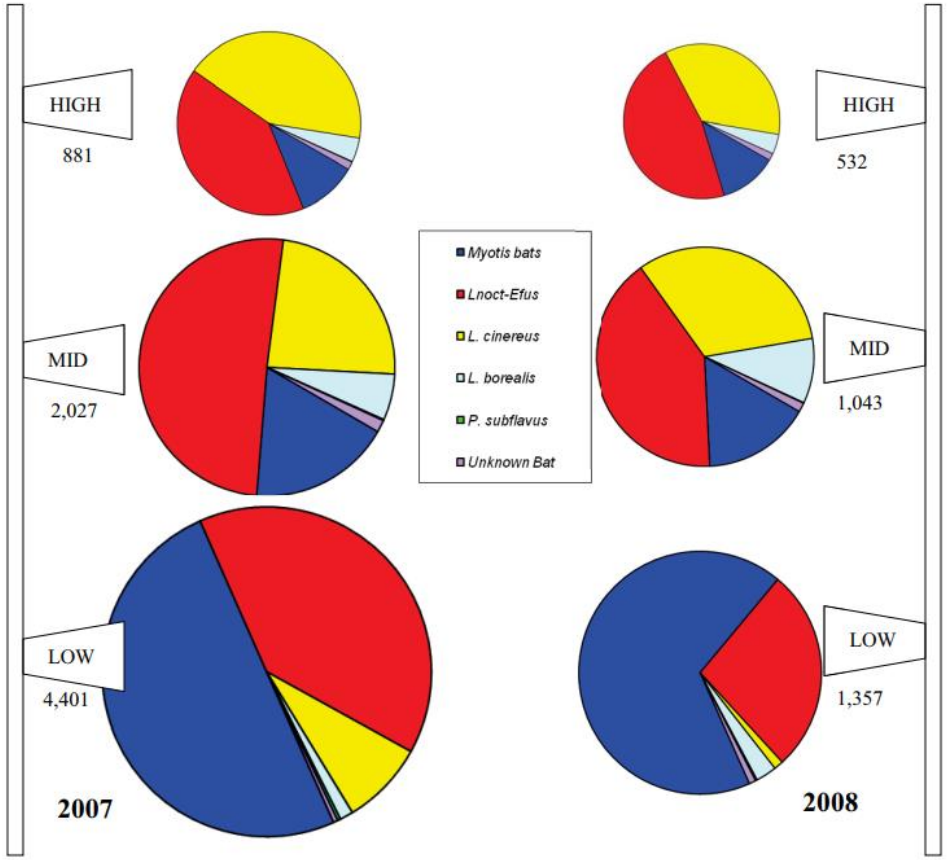
FIGURE 3 (a) Long-term spectrogram (Hann window, FFT size: 1024 samples, no overlap) of a continuous 1-h AudioMoth recording. Green lines: call sequences from three species, enlarged in spectrograms (Hann window, FFT size: 512 samples, 128 sample overlap) below (b–d). Green boxes: frequency range of the target calls among artefacts and other species' calls. (e) Ribbon plots showing detections from the full deep learning, AudioMoth and PAMGuard workflow plus manual annotations. Each vertical line on the ribbon plots represents the total number of detections per 2-s period.

Brinkløv M M S ,Macaulay J ,Bergler C , et al. Open-source workflow approaches to passive acoustic monitoring of bats[J]. Methods in Ecology and Evolution,2023,14(7).

研究方向1：声学监测技术及分析方法优化

研究案例：枫岭风电场项目蝙蝠的多年声学监测



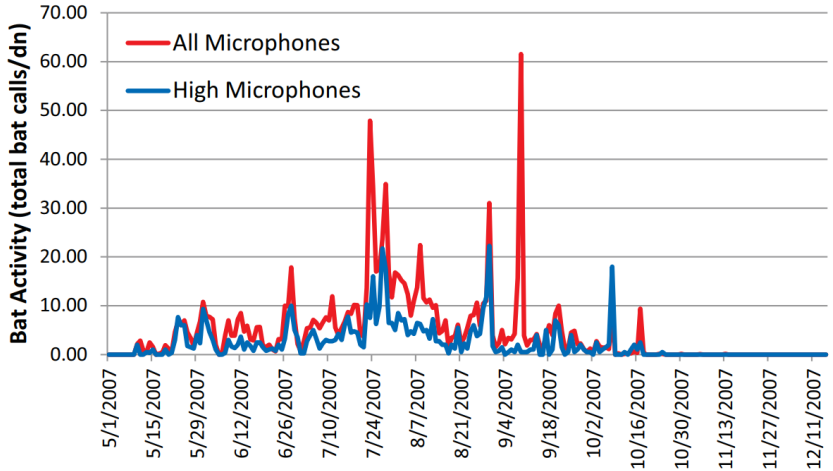


Distribution of Bat Activity across Microphone Heights at Flat Rock Site

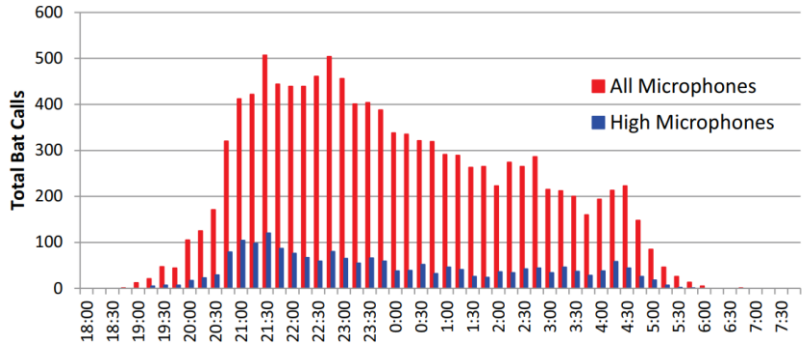
Report - Multi-Year Acoustic Monitoring of Bats at the Maple Ridge Wind Project. 2011.

研究方向1：声学监测技术及分析方法优化

研究案例：枫岭风电场项目蝙蝠的多年声学监测

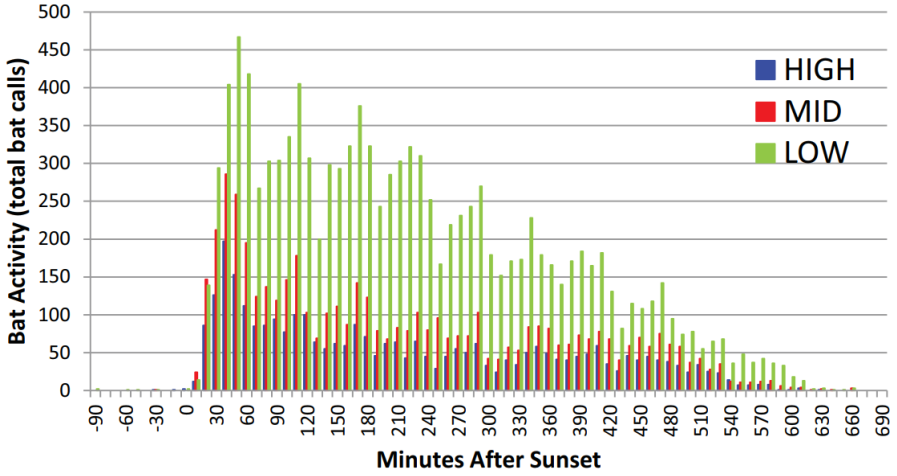


Seasonal Distribution in Bat Activity Across the MRWP Site

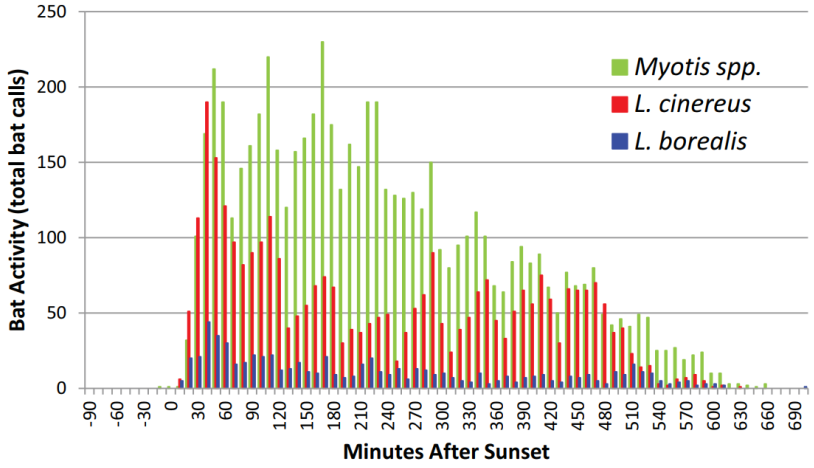


Temporal Variation in Bat Activity Across the MRWP Site

Spatial and Temporal Variation in Bat Activity



Temporal Variation in Bat Activity Relative to Sunset of different height



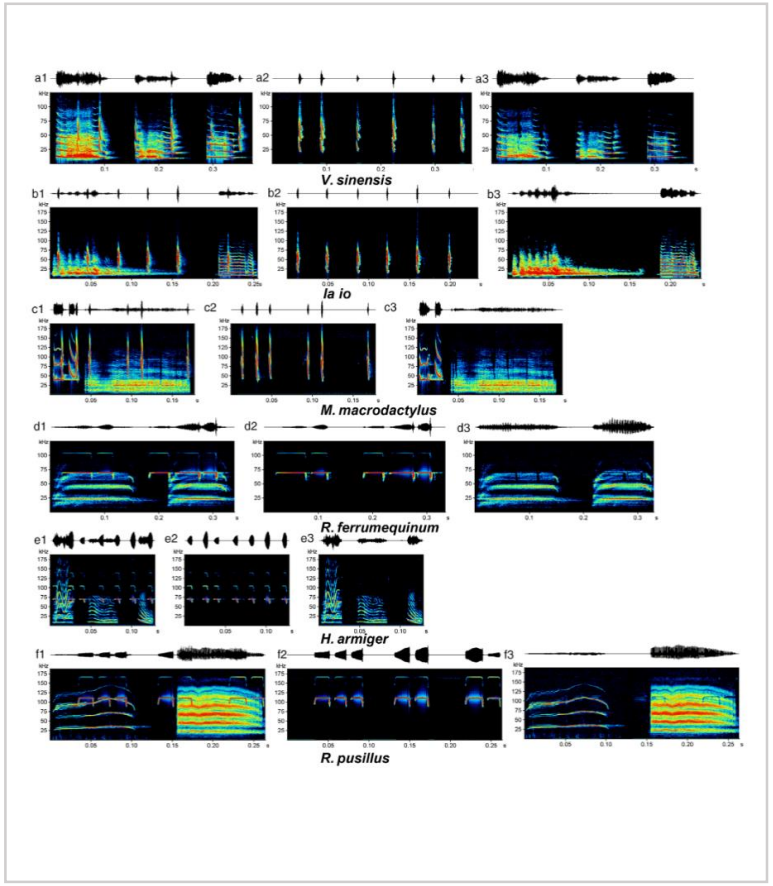
Temporal Variation in Bat Activity Relative to Sunset of different species

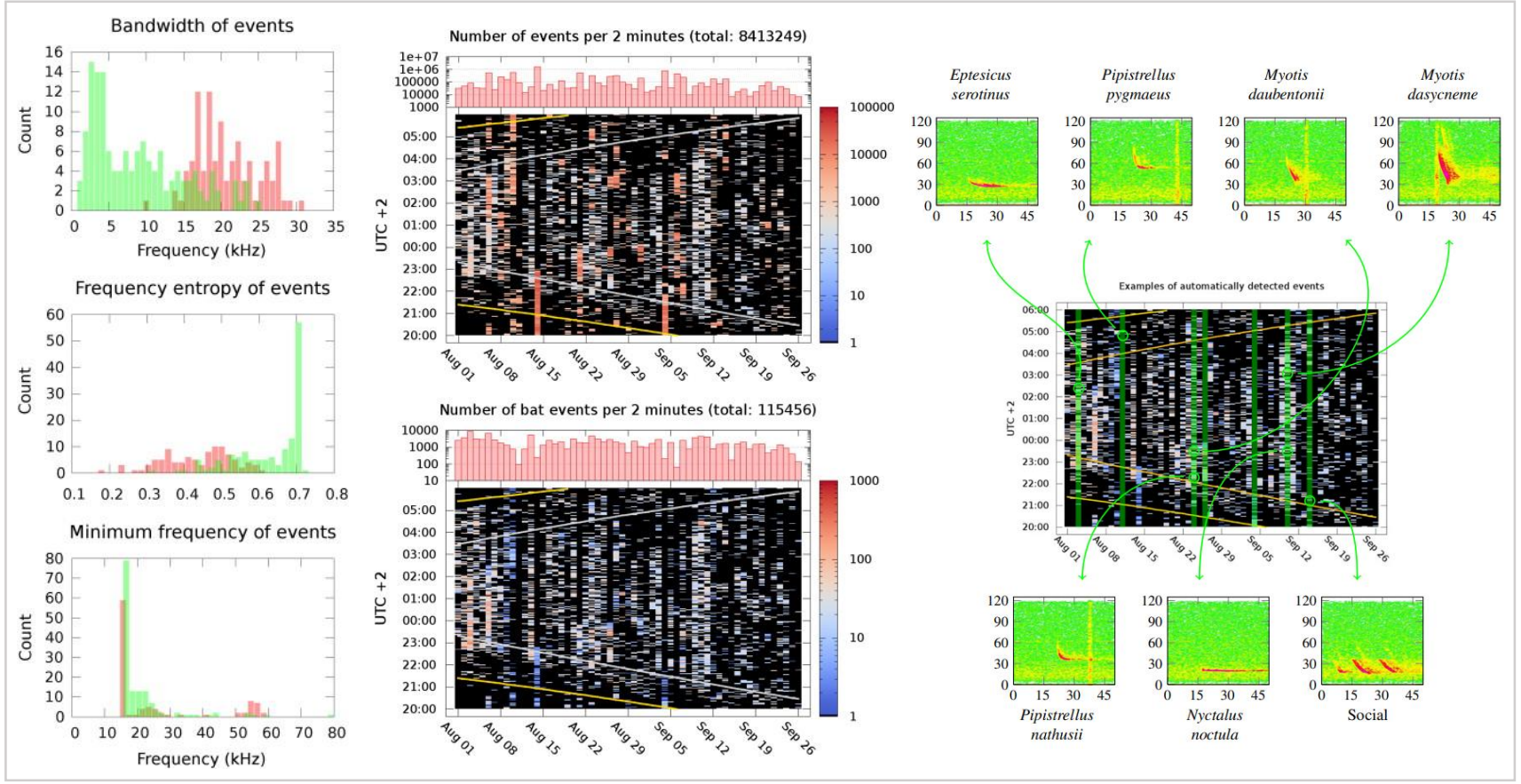
Report - Multi-Year Acoustic Monitoring of Bats at the Maple Ridge Wind Project. 2011.

研究方向1：声学监测技术及分析方法优化

数据处理及分析方法的优化

声波识别及分离技术 | **手动和自动化分类** | **深度学习**





双向长短期记忆网络，用于分离不同蝙蝠的重叠回声定位与通讯叫声

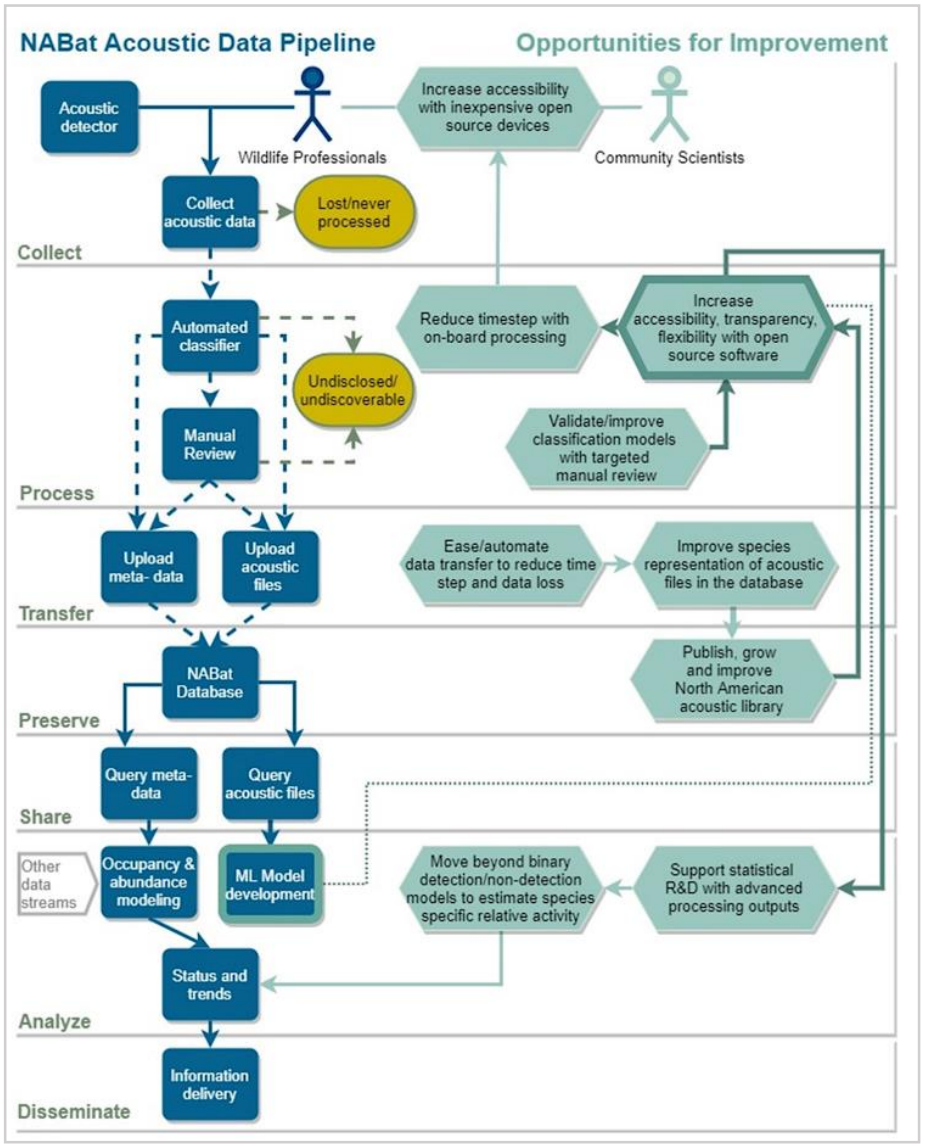
(Zhang et al., 2022, *INTEGR ZOOL*.)

从声音文件中自动识别并提取、自动分类蝙蝠声波

(Andreassen et al., 2014, *ECOL INFORM*.)

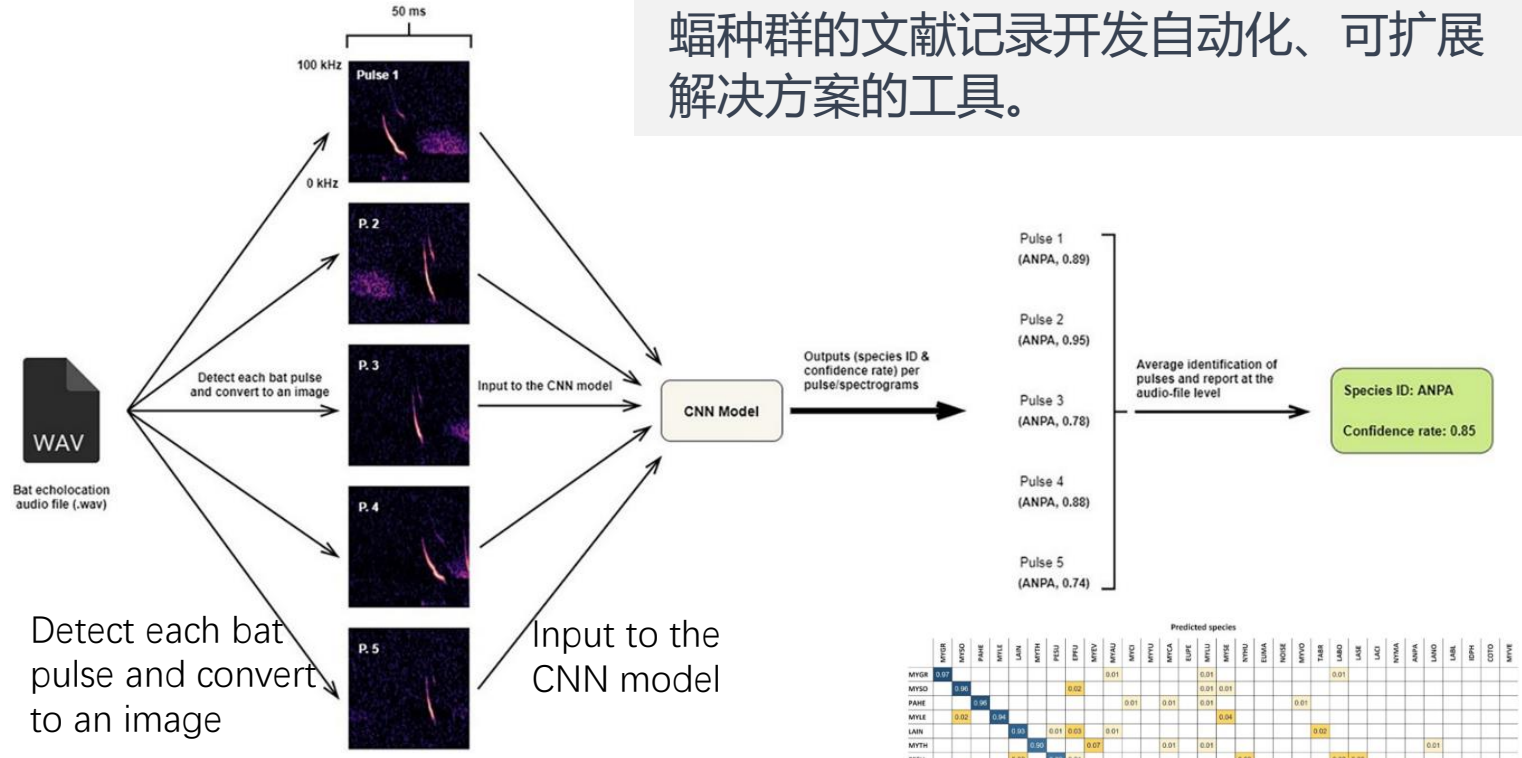
内容三：PAM在翼手目动物中的应用

研究方向1：声学监测技术及分析方法优化

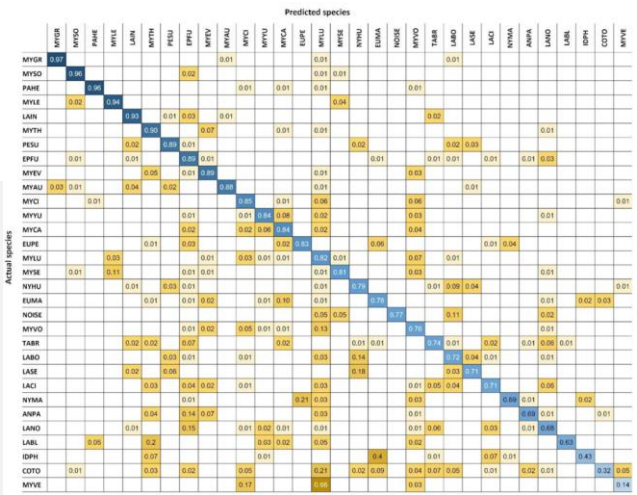


北美蝙蝠监测计划（NABat)

NABat ML： 一个利用深度学习为北美蝙蝠种群的文献记录开发自动化、可扩展解决方案的工具。



NABat ML成功区分了31个类别（30个蝙蝠物种和一个噪声类别），整体加权平均准确率和精确率达到了92%，在19个蝙蝠物种中，分类准确率≥90%。使用单个云环境计算实例，整个模型训练过程耗时<16h。



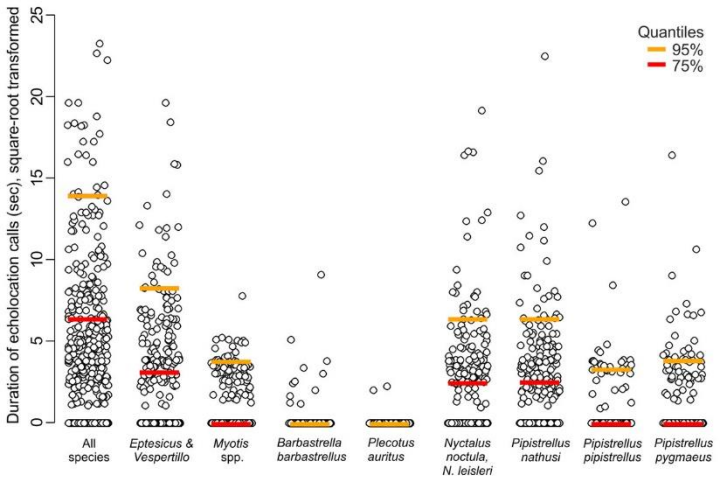
(Khalighifar et al., 2022, *J APPL ECOL.*)

内容三： PAM在翼手目动物中的应用

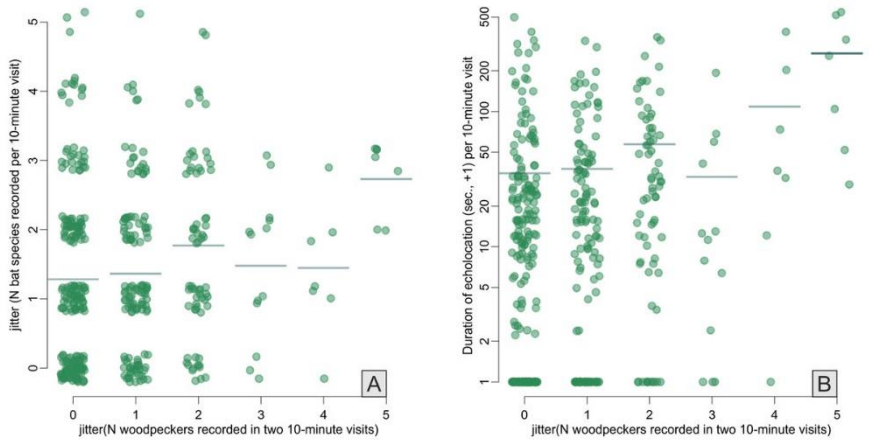
研究方向2. 物种识别、多样性调查及分布预测

研究案例：

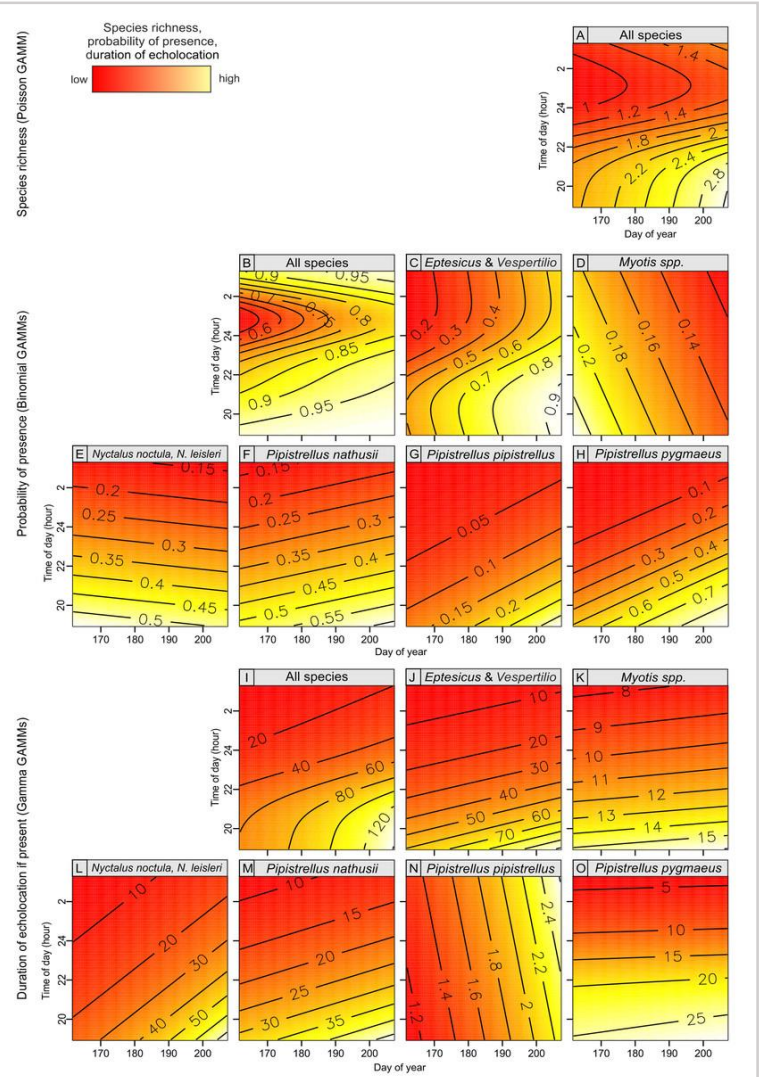
Distribution of 63 point-count sites in the Pisz Forest, NE Poland, sampled in 2011 for Great Spotted Woodpecker abundance, bat species richness, bat species occurrence and acoustic activity of bats.



Duration of echolocation calls of eight bat species



Correlations between Great Spotted Woodpecker abundance (x-axes) and number of bat species recorded (A) and duration of bat echolocation (B)



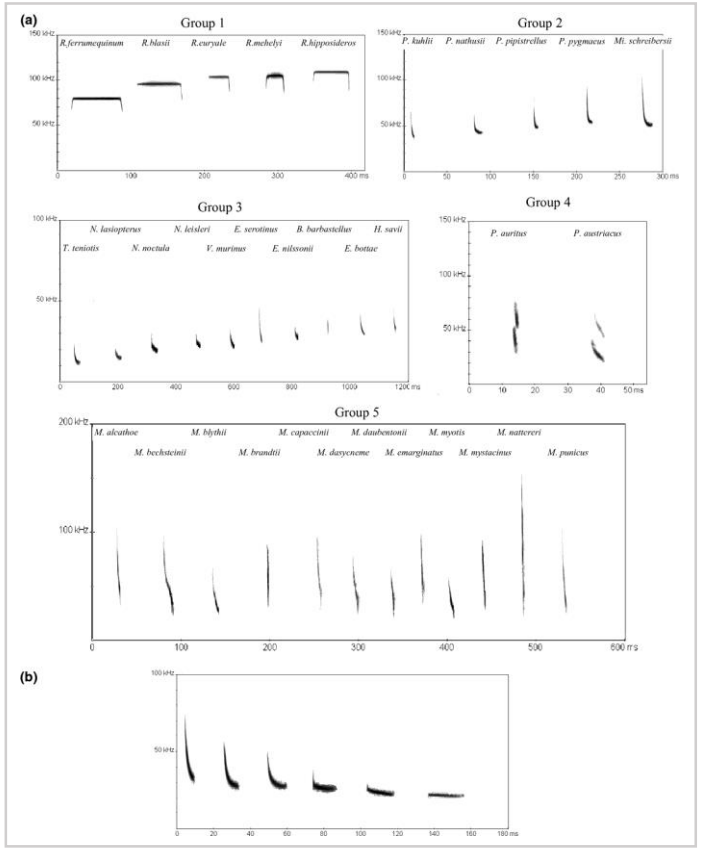
Bat species richness (A), probability of presence (B–H) and duration of echolocation calls (I–O) in relation to day of year and time of day

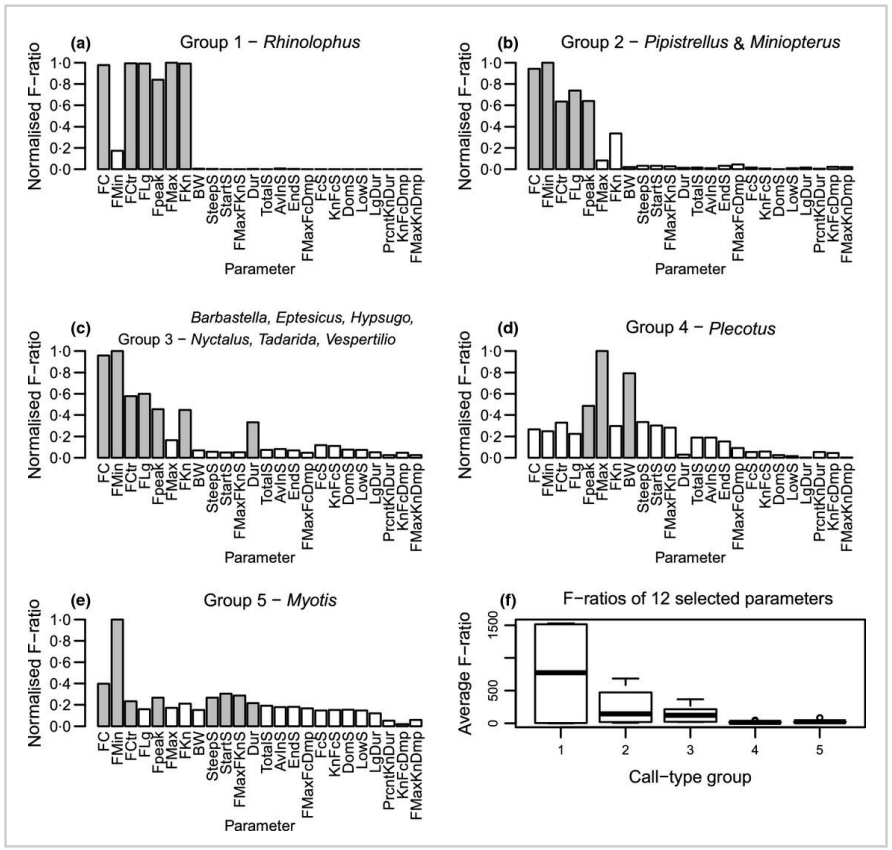
Dorota K ,Marcin Z ,Grzegorz O , et al. Spatial patterns of bat diversity overlap with woodpecker abundance.[J]. PeerJ,2020,8.

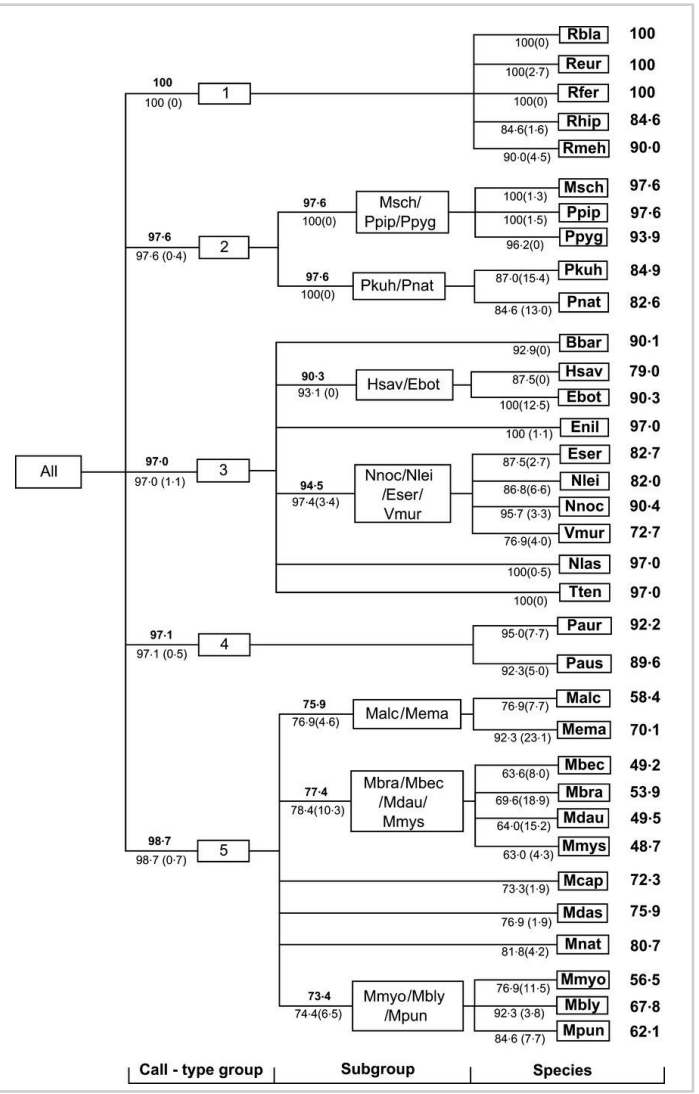
内容三： PAM在翼手目动物中的应用

研究方向2. 物种识别、多样性调查及分布预测

研究案例：







Step 1. 声音模板——蝙蝠代表性搜索阶段的回声定位声波语谱图

Step 2. 训练模型——使用不同的声波参数进行模型训练

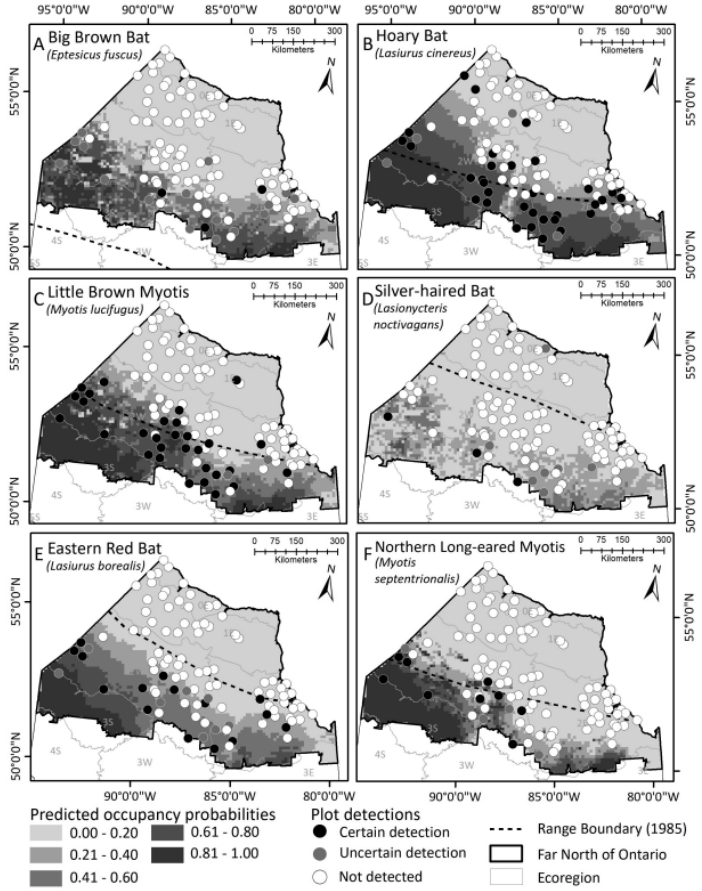
Step 3. 模型测试——测试多物种声学调查正确分类及假阳性结果比例，用于欧洲蝙蝠多样性调查

(Walters et al., A continental-scale tool for acoustic identification of European bats 2012, *J APPL ECOL.*)

内容三： PAM在翼手目动物中的应用

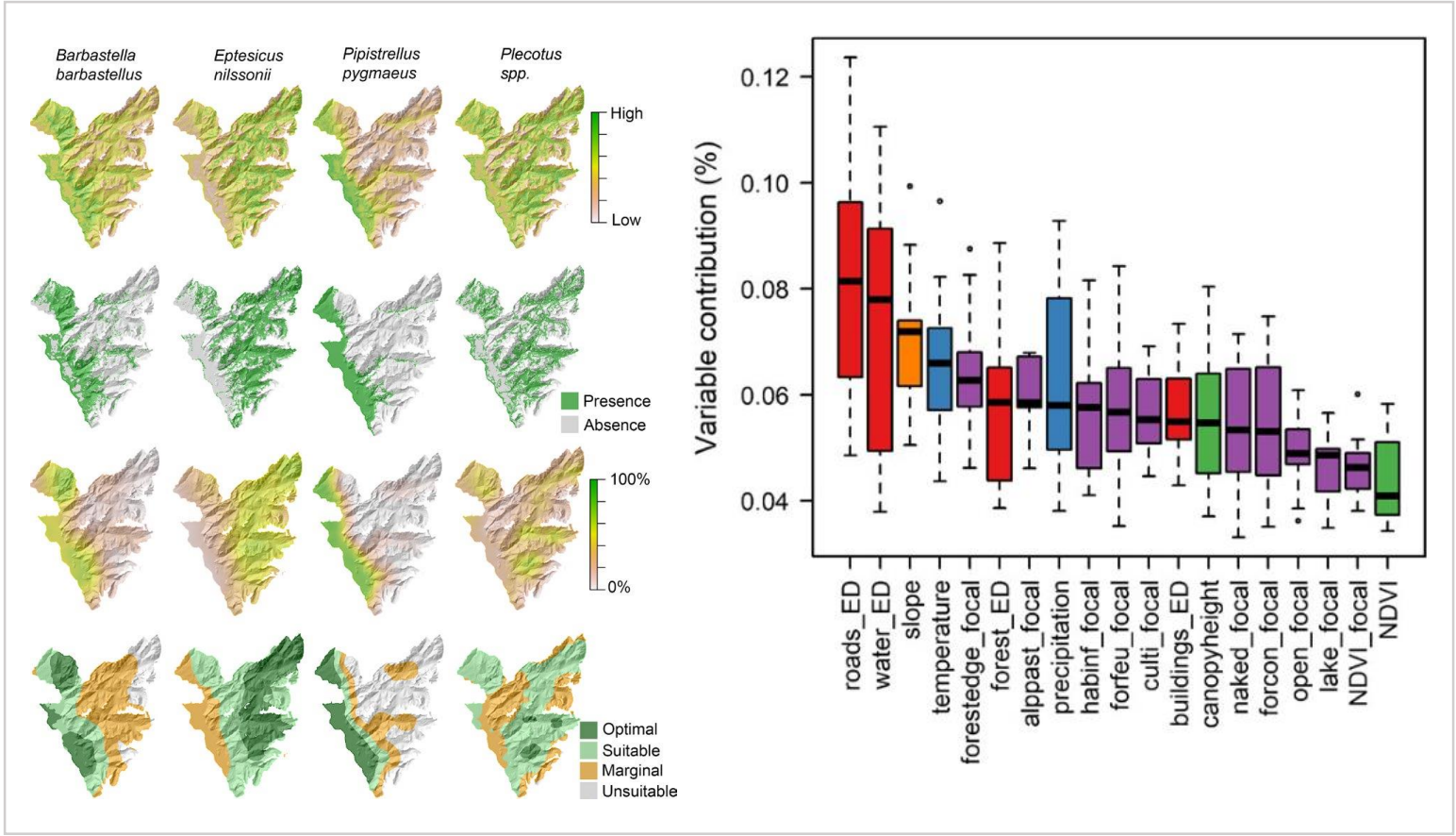
研究方向2. 物种识别、多样性调查及分布预测

研究案例：基于声学监测数据进行物种评估与分布预测及其影响因素



六种蝙蝠物种出现概率的预测分布图

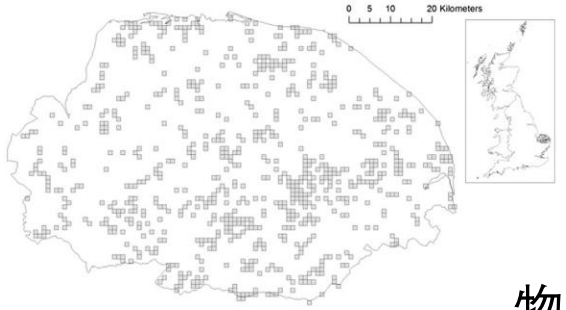
Layng M. et al., *J MAMMAL*, 2019.



基于声学调查技术评估蝙蝠种群和分布及相关因子的贡献率

(Scherrer et al., 2018, *DIVERS DISTRIB.*)

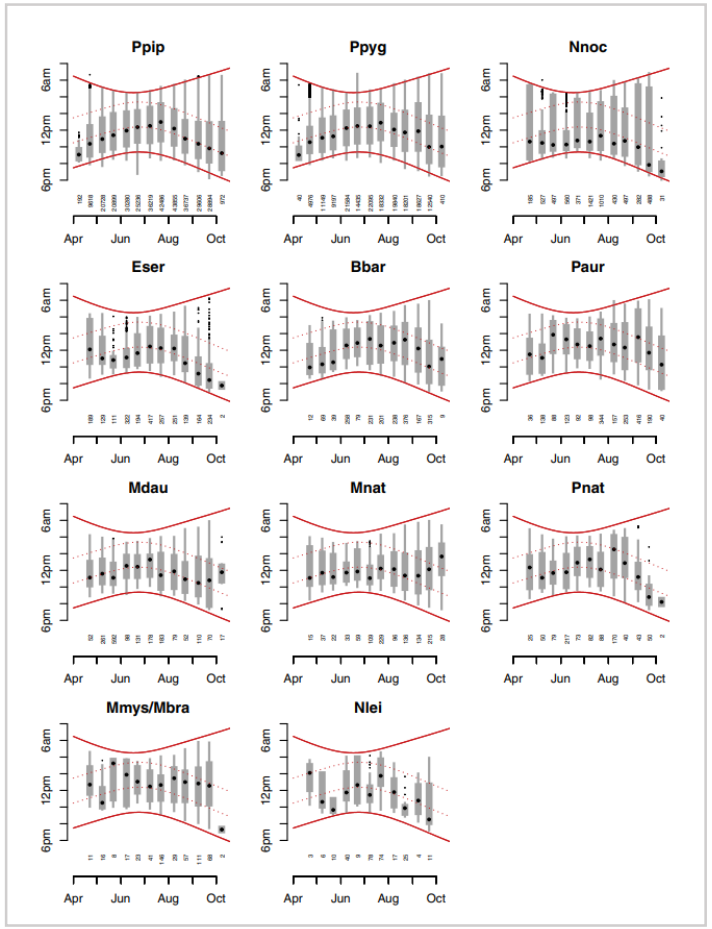
Bat Ecology, Evolution and Conservation Lab
School of Environment, Northeast Normal University, China



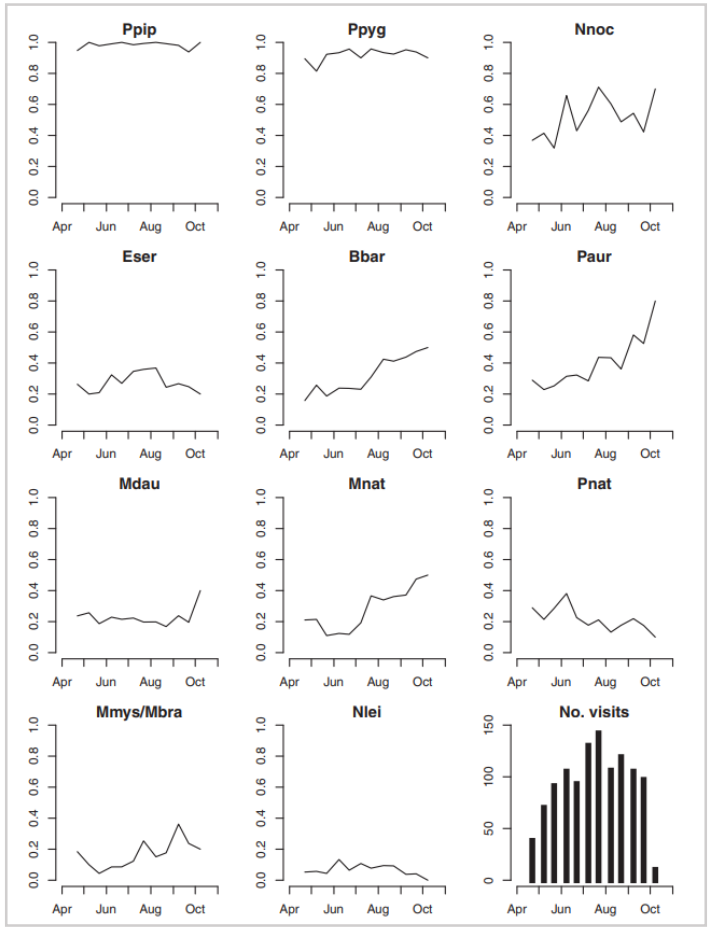
动员数百名公民志愿者参与调查工作

研究方向2. 物种识别、多样性调查及分布预测

研究案例：蝙蝠夜间活动模式、季节变化与分布及物种评估

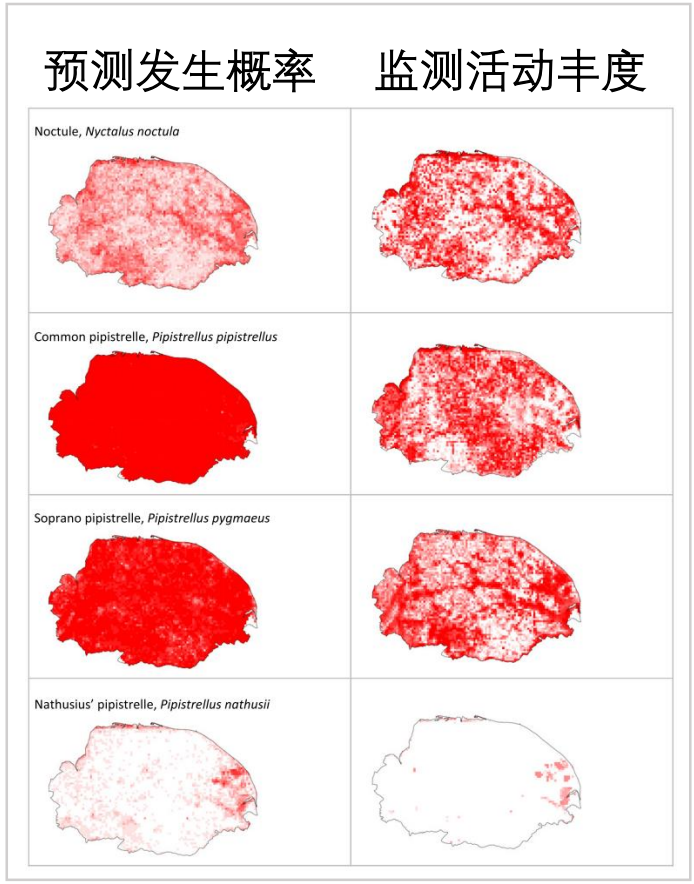


英格兰东部日落时间及蝙蝠整个季节的夜间活动模式



各物种监测比例的季节变化

物种评估



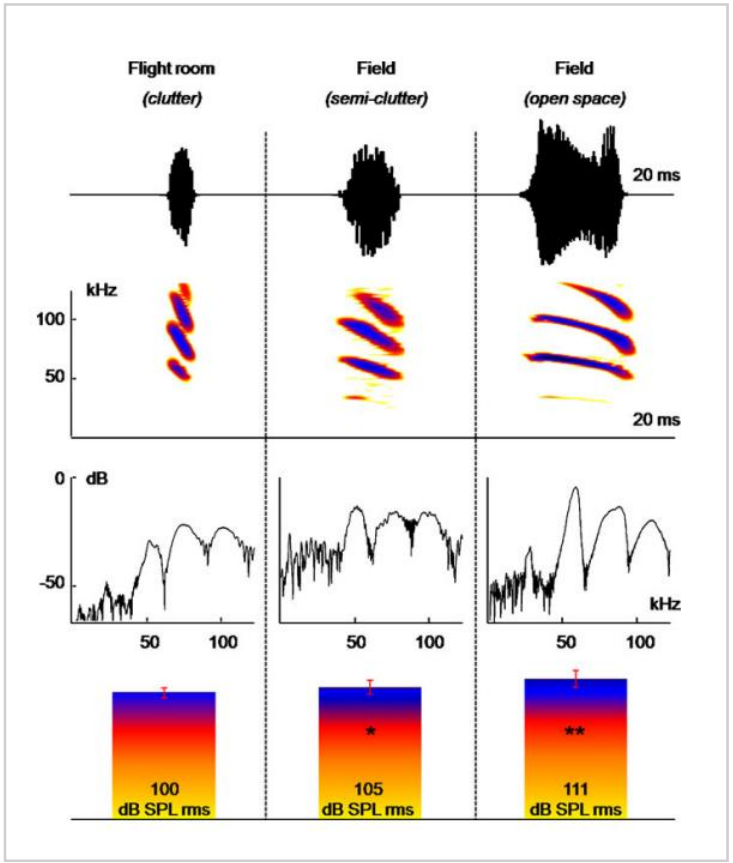
基于声学监测的英格兰东部四种蝙蝠的活动度及预测发生概率

(Newson et al., 2015, *BIOL CONSERV.*)

内容三：PAM在翼手目动物中的应用

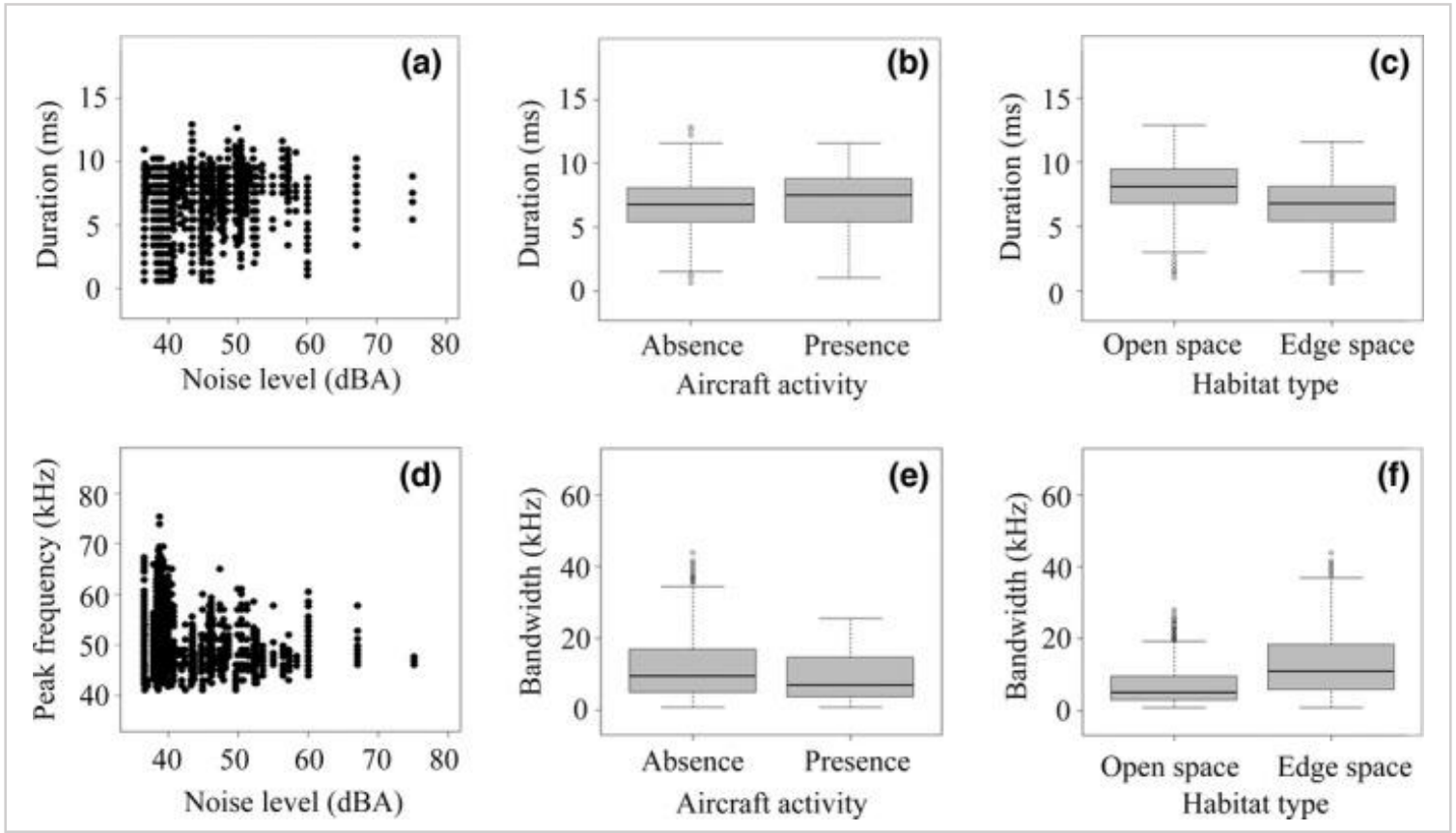
研究方向3. 生境利用及活动模式

觅食行为及发声可塑性：蝙蝠能够根据环境的变化而改变发声策略



*Macrophyllum macrophyllum*在不同生境复杂程度的发声调节

(Brinklov et al., 2010, *BEHAV ECOL SOCIOBIOL*.)



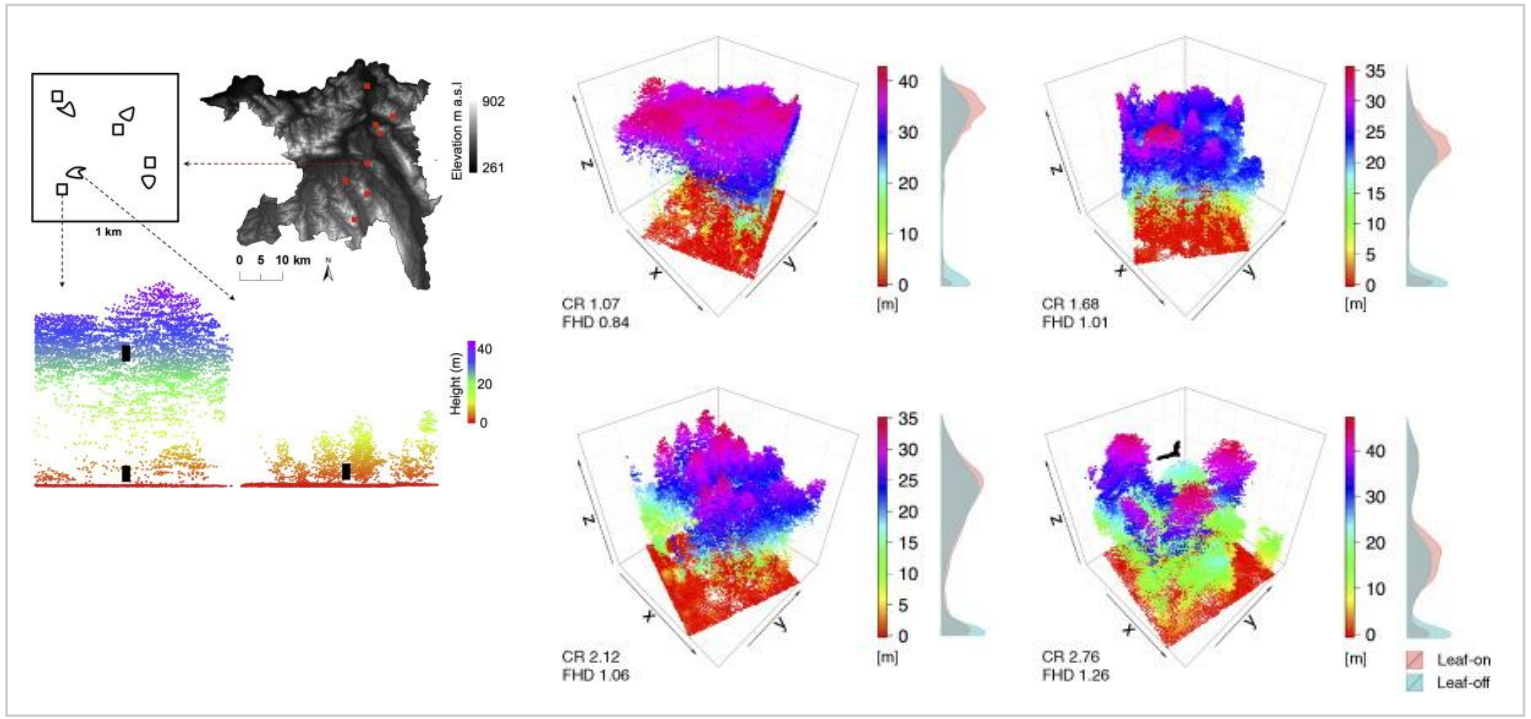
机场噪音环境下东亚伏翼的发声可塑性变化

(Wang et al., 2022, *ECOL EVOL*.)

内容三：PAM在翼手目动物中的应用

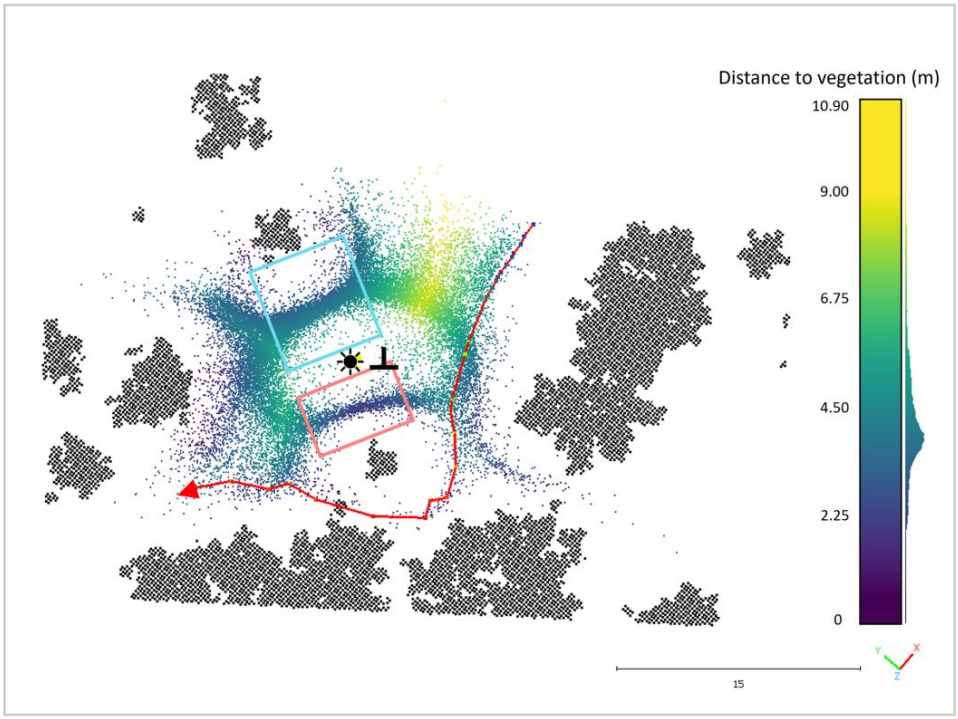
研究方向3. 生境利用及活动模式

研究案例：



结合声学调查和激光雷达揭示蝙蝠对森林结构的反应

(Jérémy S.P. et al., 2016, *REMOTE SENS ENVIRON*)



通过声学追踪结合激光雷达技术研究蝙蝠在三维空间中的飞行行为

(Hermans et al., 2023, *MOV ECOL*.)

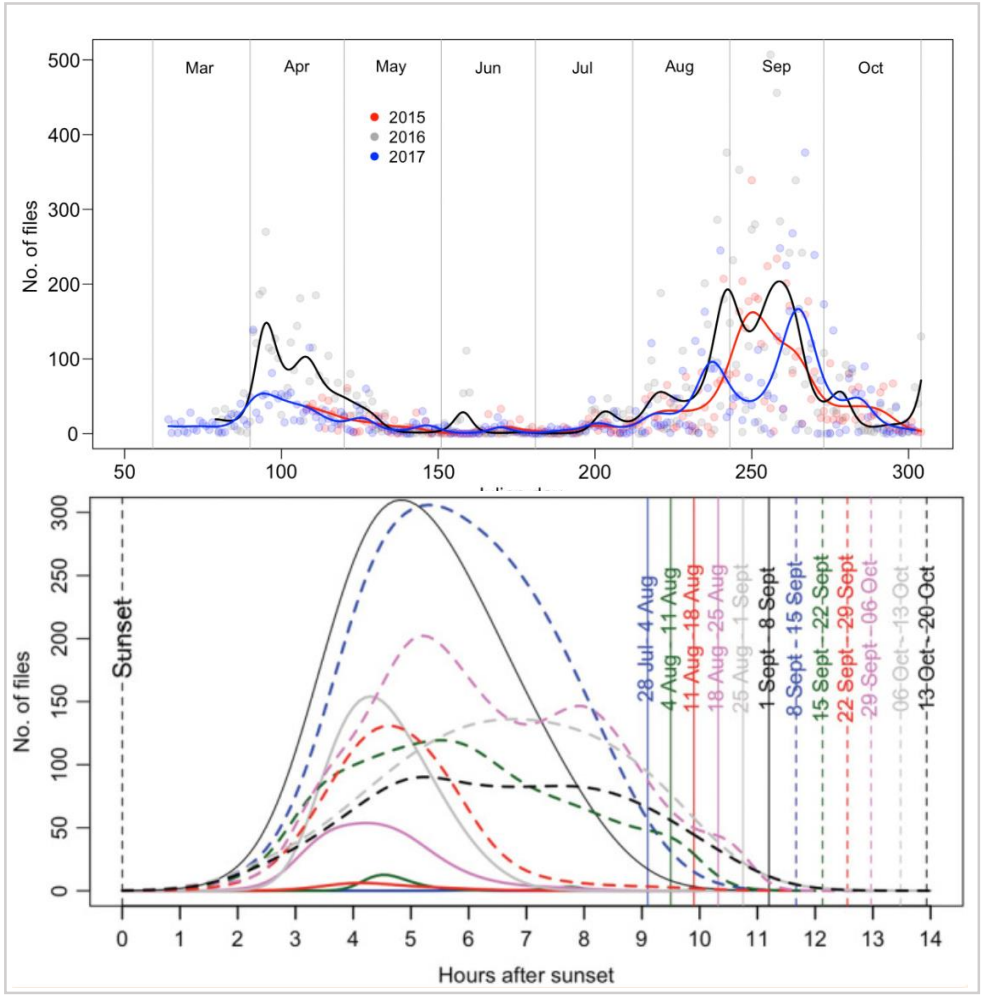
内容三： PAM在翼手目动物中的应用

研究方向3. 生境利用及活动模式

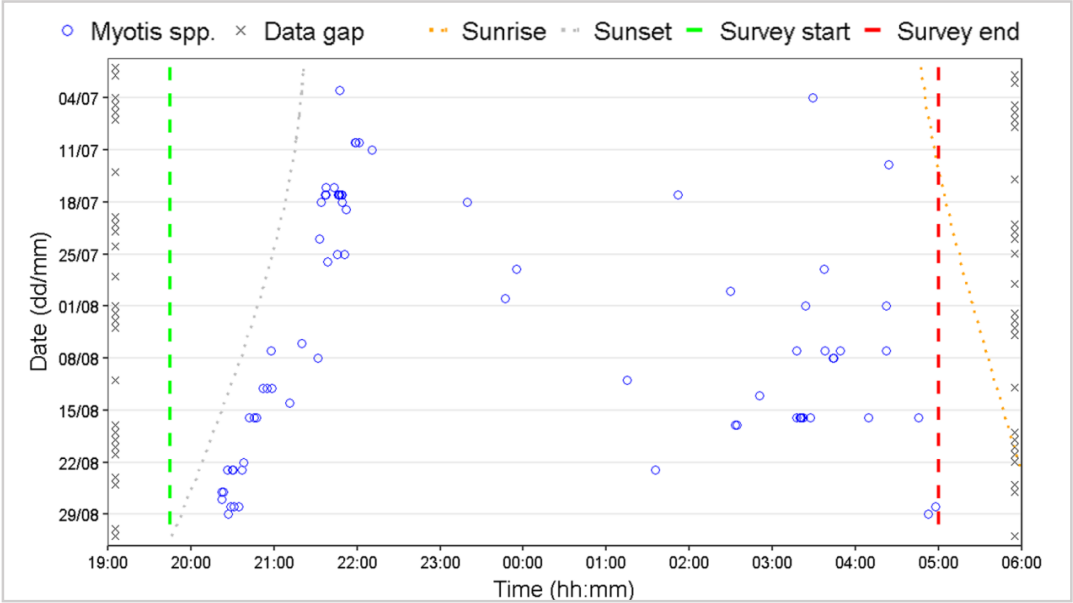
活动模式

节律

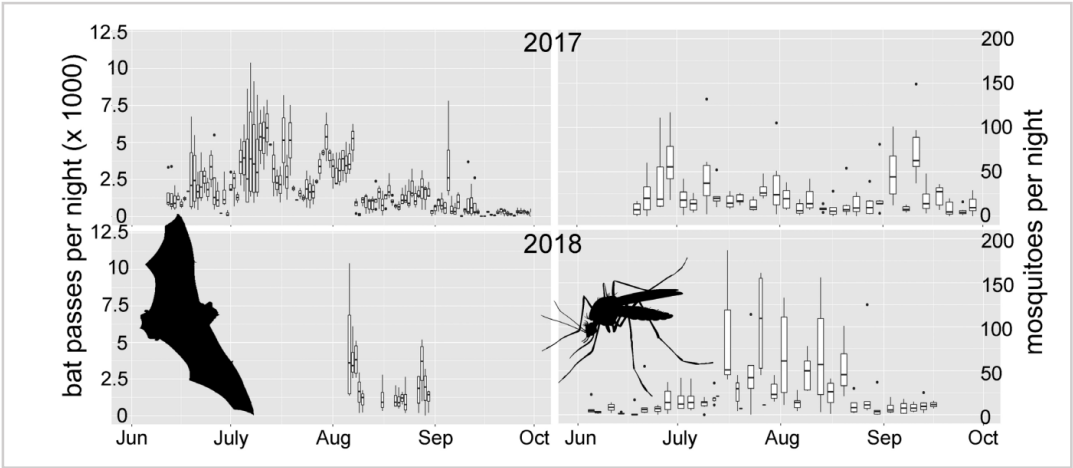
蝙蝠与猎物的相互关系



洞栖鼠耳蝠属蝙蝠季节性集群行为及活动变化



不同月份Myotis蝙蝠活动昼夜节律



蝙蝠与蚊子活动的相关性

(Thomas et al., 2022, *Ecol Evol*; Puig-Montserrat et al., 2020, *Pest Manag Sci*; Beason et al., 2020, *Ecol Indic.*)

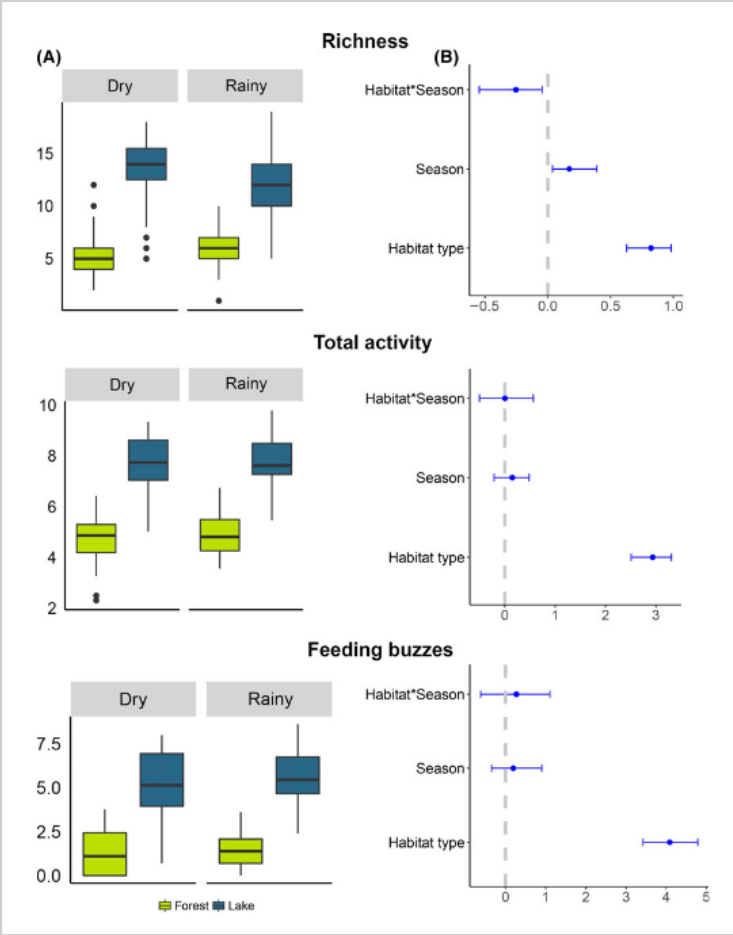
内容三：PAM在翼手目动物中的应用

研究方向4. 种群监测

栖息地使用

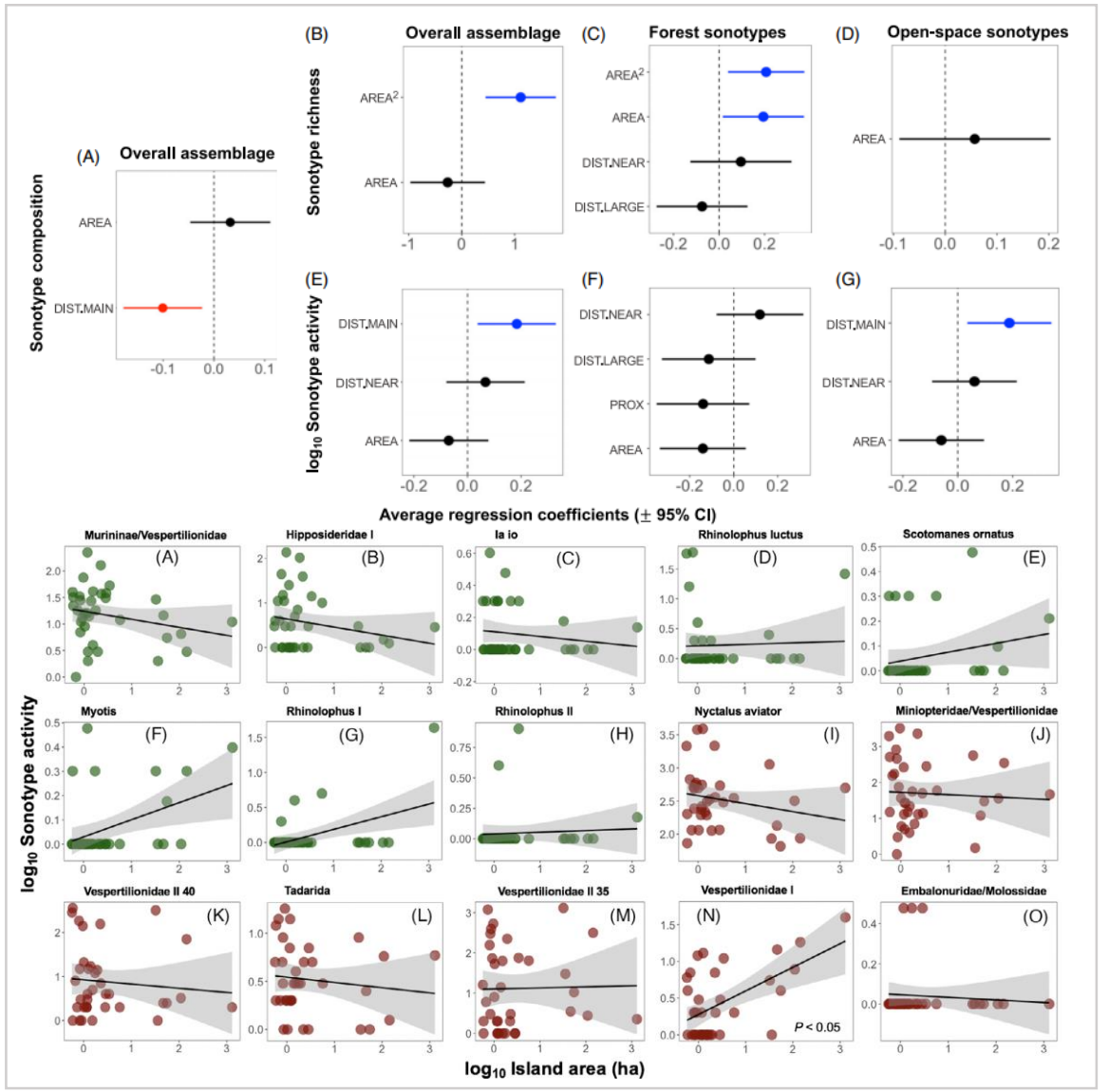
生境利用偏好

生境破碎化



不同季节亚马逊原始森林和湖泊中的蝙蝠数量、总活动量和每晚的捕食蜂鸣数量

(Torrent et al., 2018 *REMOTE SENS ECOL CON.*)



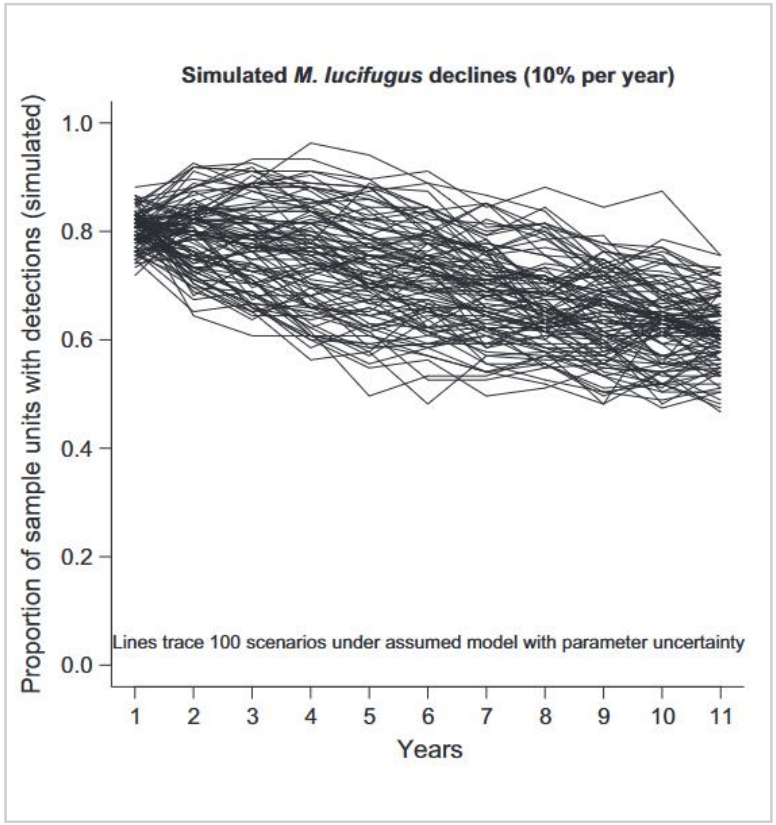
通过被动声学监测评估蝙蝠对中国东部千岛湖水电站森林破碎化的响应

(Lopez-Bosch et al., 2022, *REMOTE SENS ECOL CON.*)

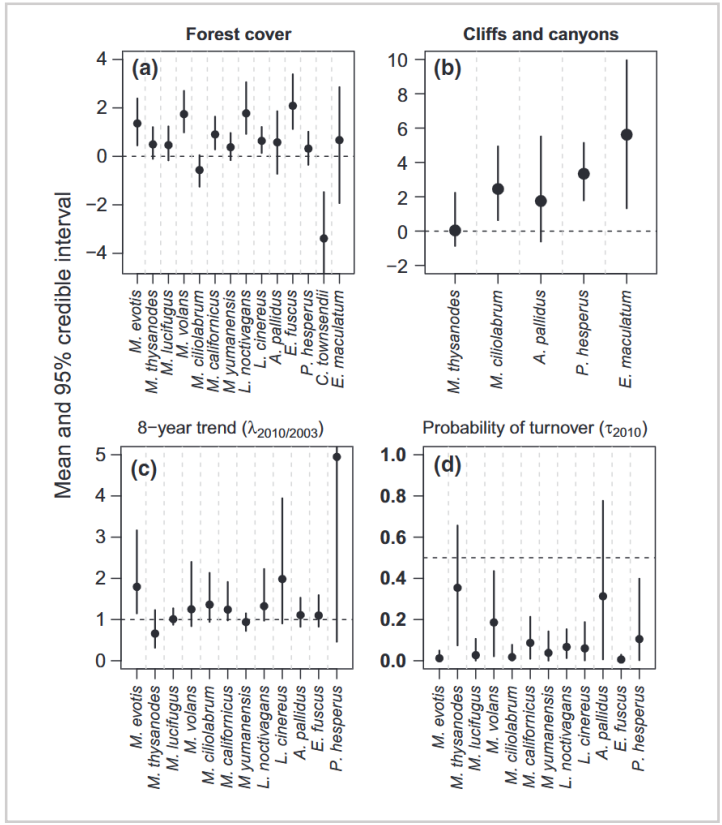
内容三： PAM在翼手目动物中的应用

研究方向5. 保护和管理

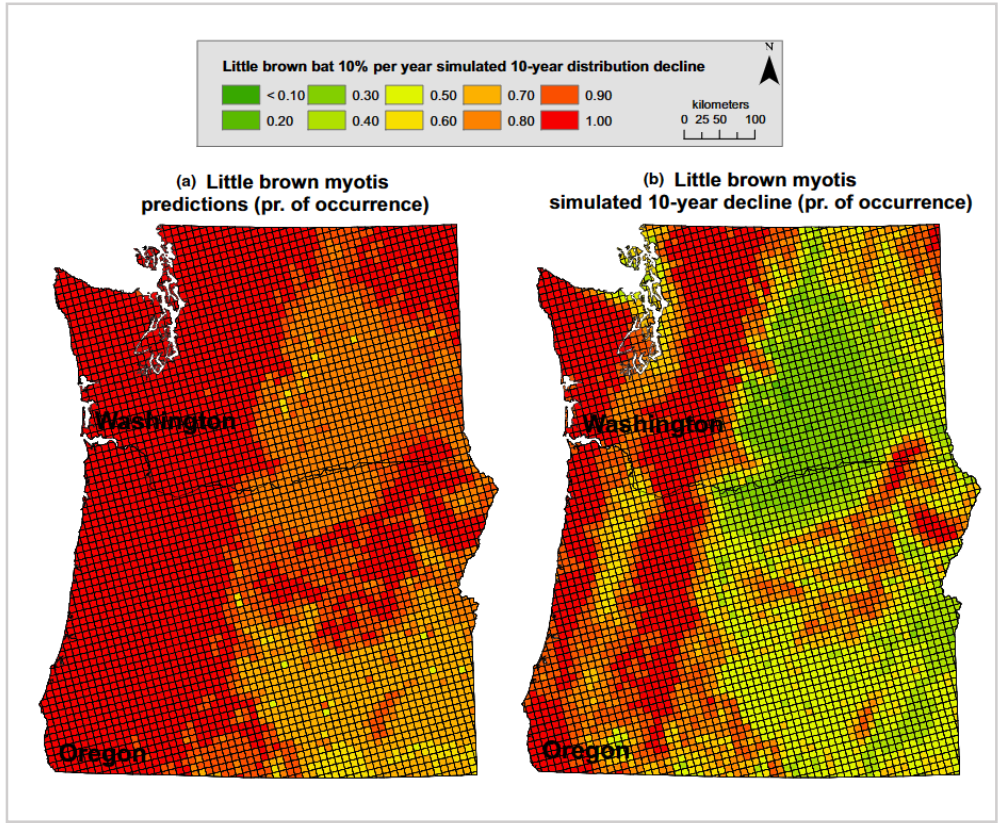
基于蝙蝠声学监测 → 提出种群保护框架 → 评估未来种群衰退基线 → 制定保护管理策略



模拟*Myotis lucifugus* 10年内种群数量下降的概率



基于声学数据的当前分布预测



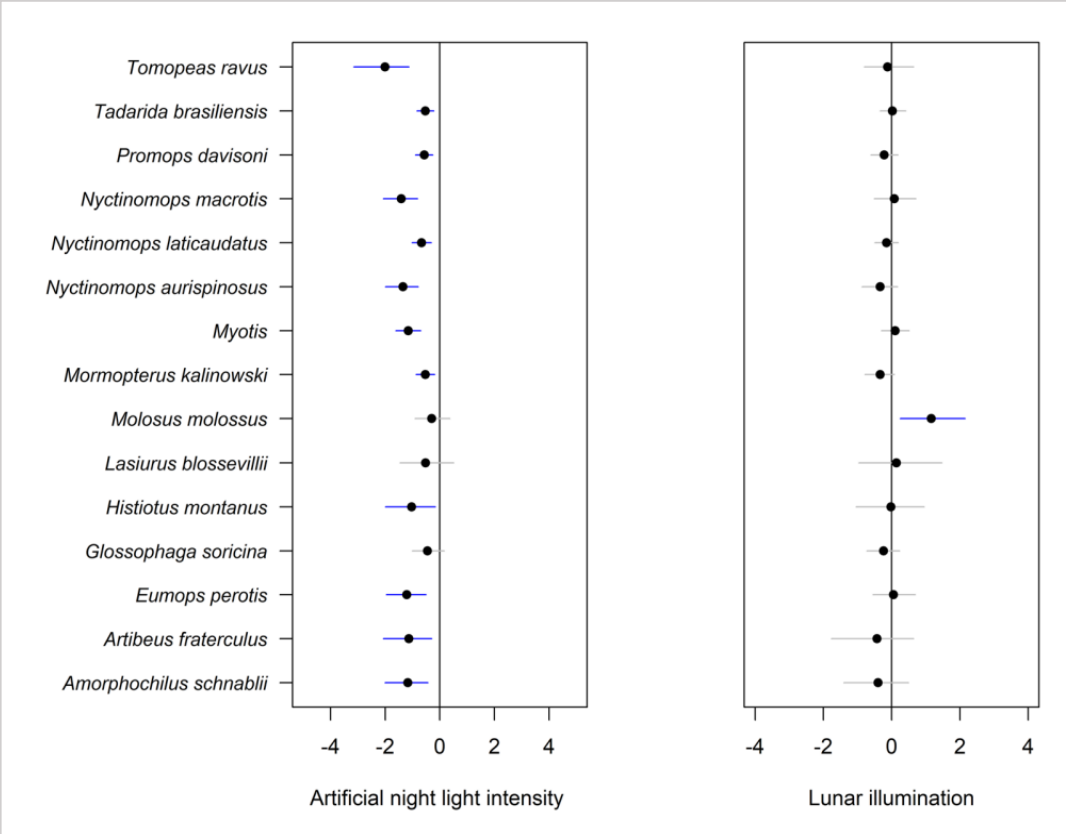
10年内施加10%的年递减线后模拟分布

(Rodhouse et al., 2015, *DIVERS DISTRIB.*)

内容三：PAM在翼手目动物中的应用

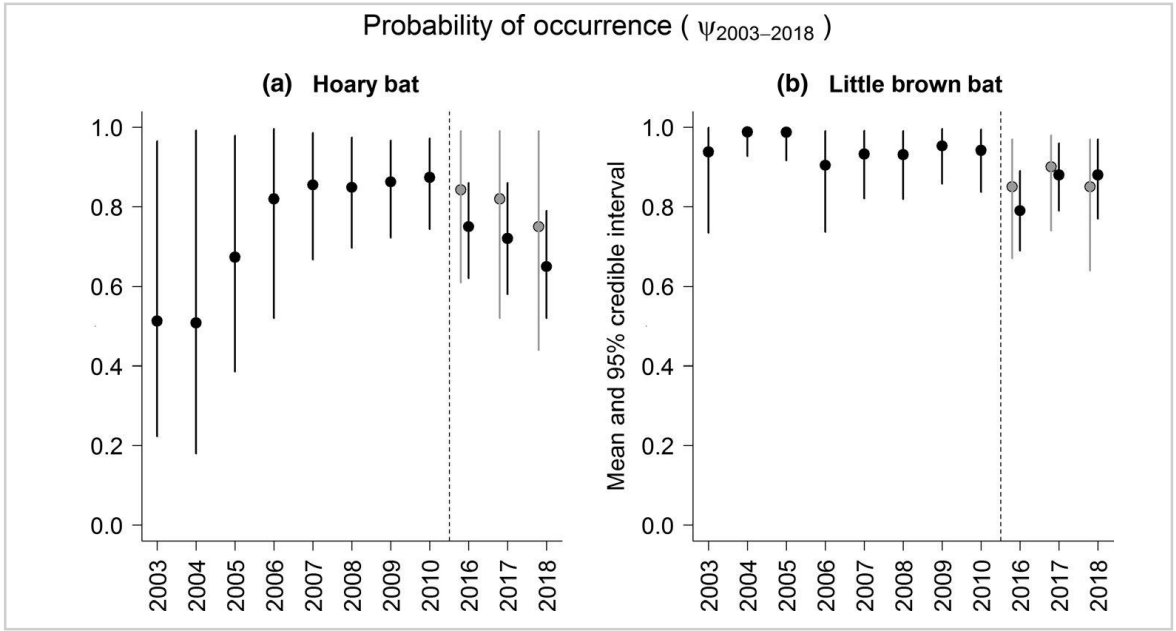
研究方向5. 保护和管理

人类活动对蝙蝠的影响



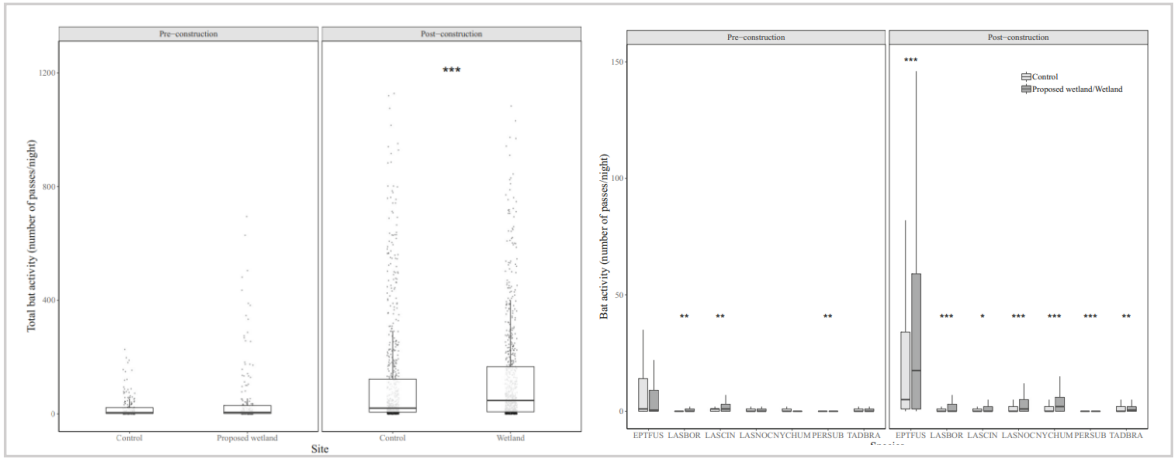
基于声学监测探究不同蝙蝠物种分别对城市人造光源和月光的行为响应

(Mena et al., 2021, *Urban Ecosyst.*)



基于声学监测探究白鼻综合症前后区域蝙蝠数量下降的证据

Rodhouse et al., 2019, *Ecol Evol.*

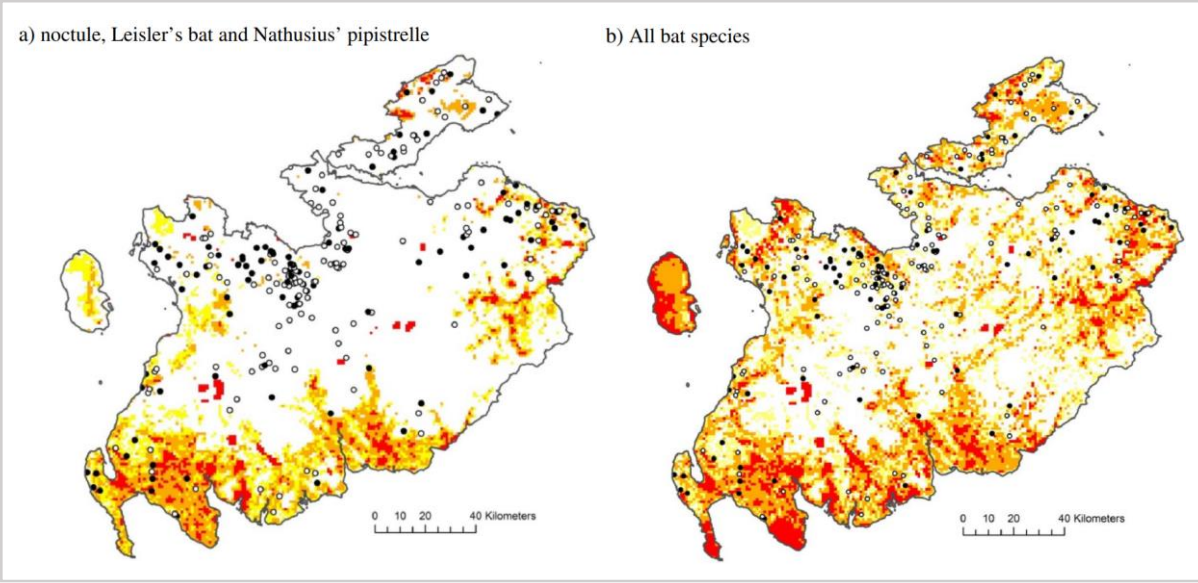


城市生态系统湿地建设后蝙蝠活动和多样性快速增加

(Parker et al., 2019. *Wetlands.*)

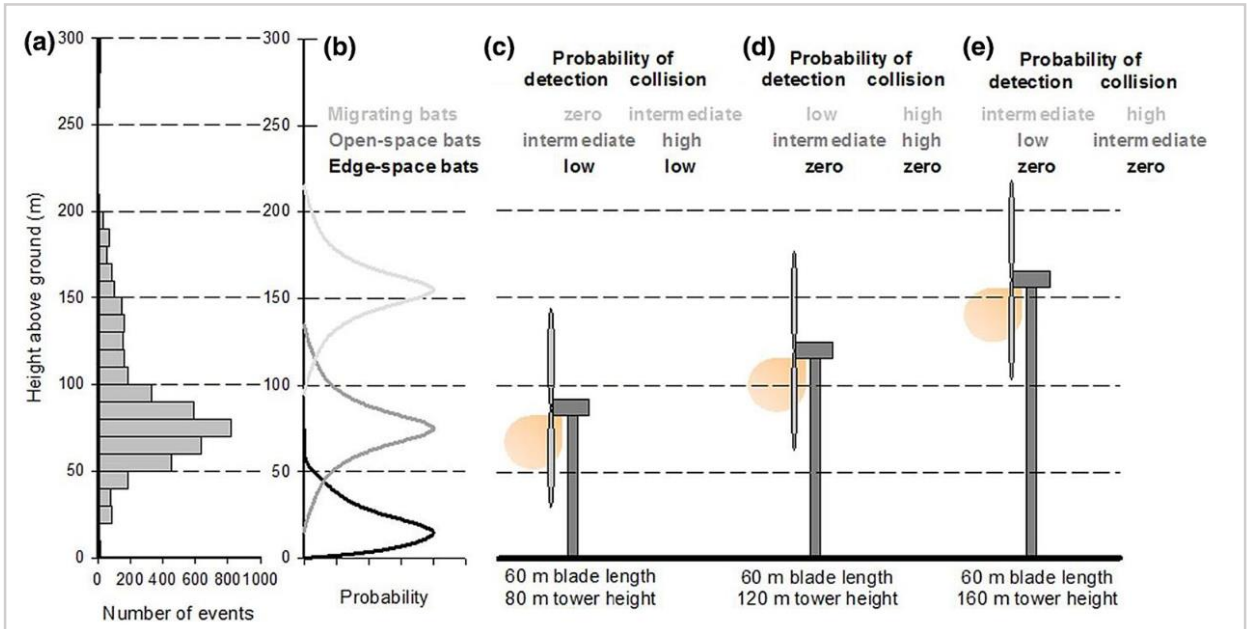
研究方向5. 保护和管理

种群监测和生态风险评估

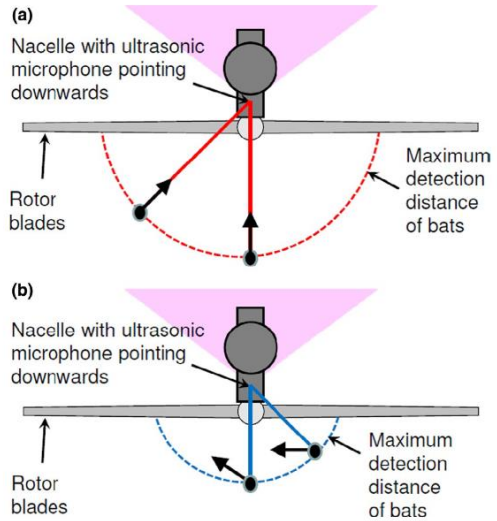


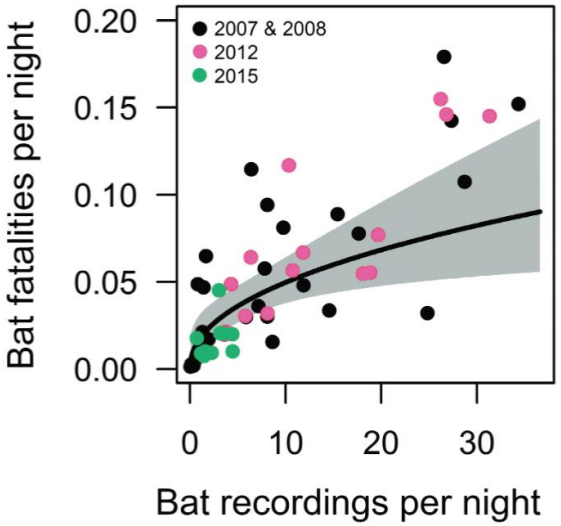
风电厂周边蝙蝠物种的发生和活动
现有风电场（白点） 已批准的风电场（黑点）

(Newsona et al., 2017, *BIOL CONSERV*.)



Comments:





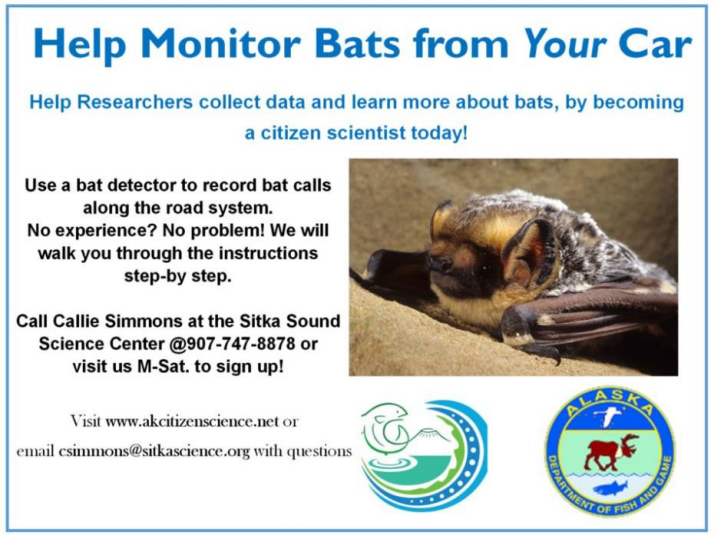
利用声学监测评估风力发电对蝙蝠活动及种群数量的影响

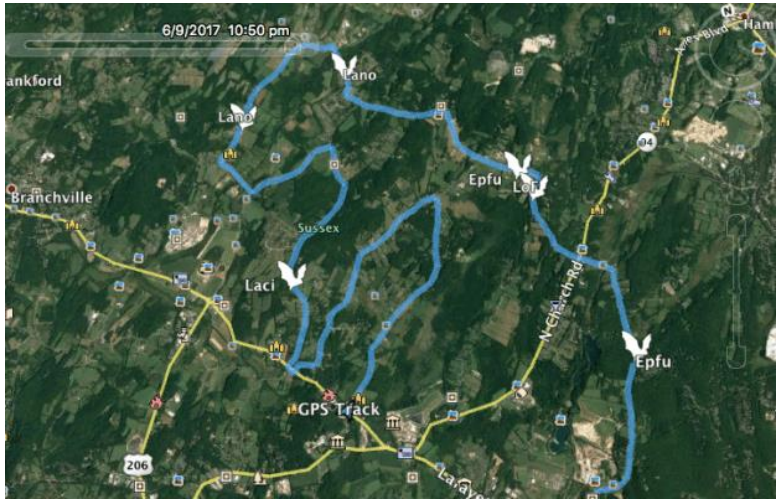
(Voigt et al., 2020, *MAMMAL REV*; Behr et al., 2023, *MAMMAL REV*.)

内容三：PAM在翼手目动物中的应用

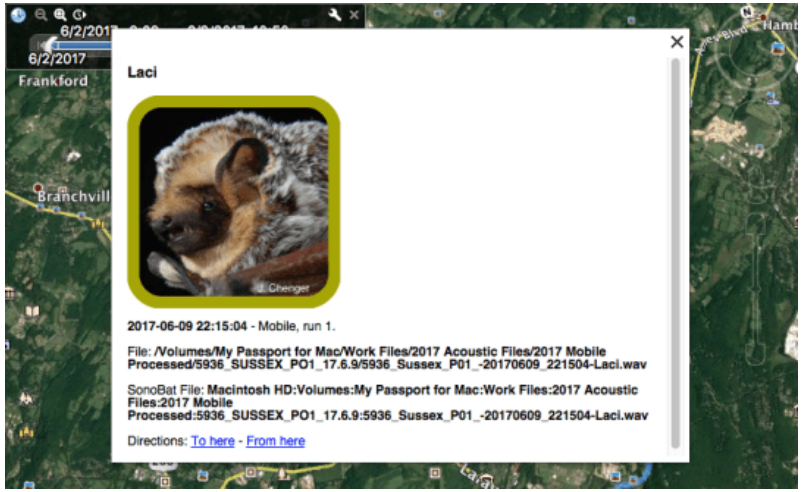
研究方向5. 保护和管理

ACOUSTIC MONITORING DRIVES EFFORTS TO BAT CONSERVATION





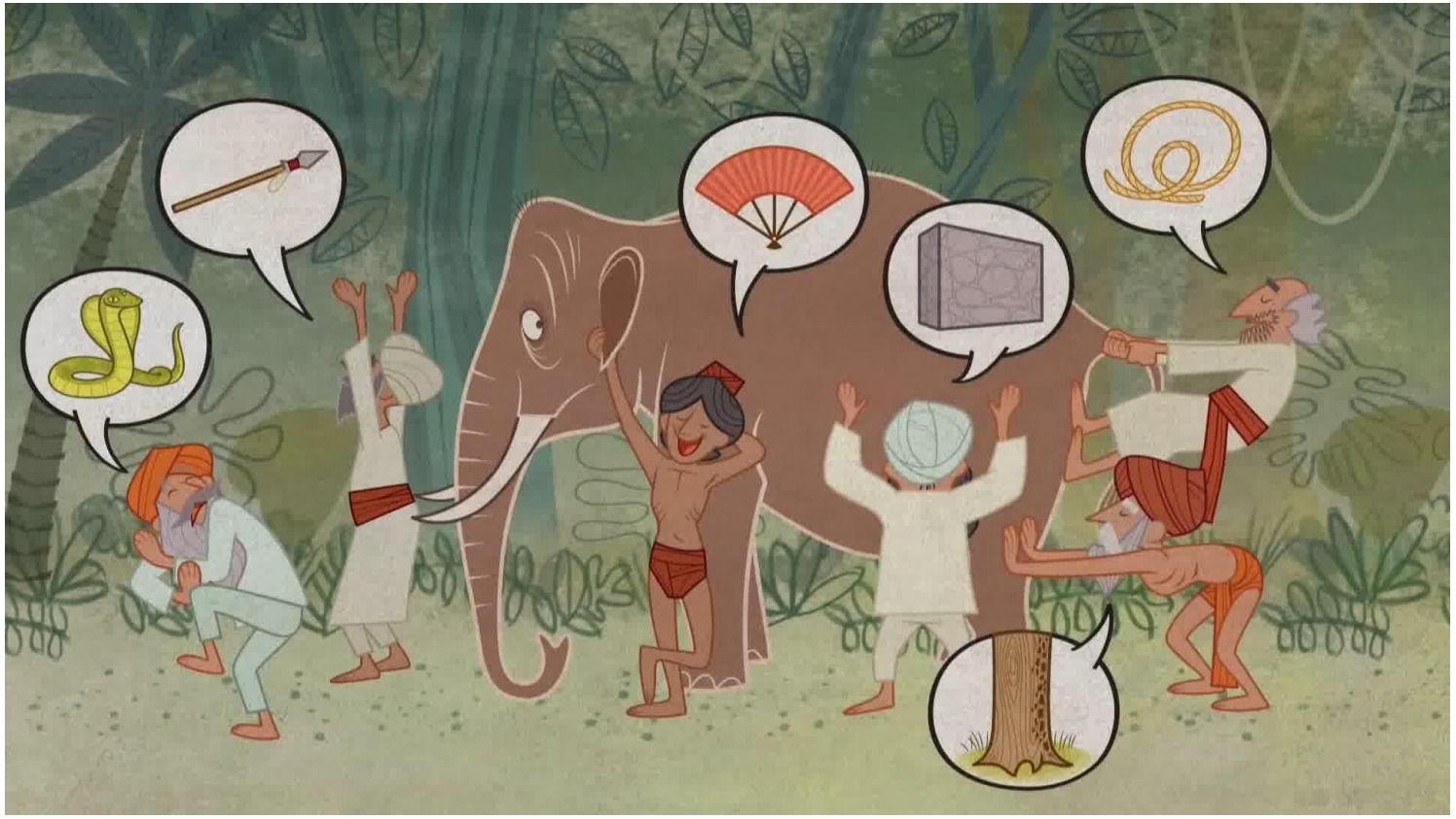
GPS track with bat calls overlaid that were picked up along the transect, shown in Google Earth Pro.



Zoom in of species ID info that is shown on track, in Google Earth Pro.

展 望：中国蝙蝠声学监测思考

- 技术进步与创新
- 方法论的提升
- 完善蝙蝠声波数据库/物种声音识别
- 建立声学监测系统 完善声学监测网络
- 数据共享
- 跨学科合作
- 公众参与与教育



北京生物多样性论坛

谢谢大家！ 敬请批评指正！

Passive acoustic monitoring in bat ecology and conservation

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Email：jiangtl730@nenu.edu.cn

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