



Approaching sound environment changes by anthropology and ecology combined: a case study along a gradient of human pressure in Southern Arizona

Anne Sourdril¹, Luc Barbaro²
& François-Michel Le Tourneau³

¹ Ladyss, CNRS, Nanterre, France.

² Dynafor, INRA, Toulouse and Cesco, MNHN, Paris, France.

³ Iglobes, CNRS, Tucson, USA.

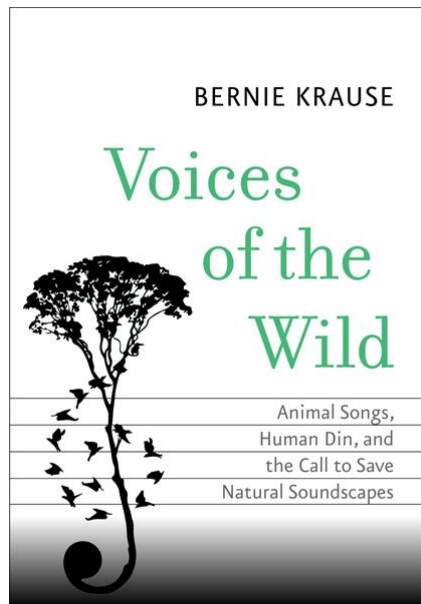
Human Challenges in Extreme Environments Workshop, November 12-14, 2018
iGlobes, CEMCA Udall Center, University of Arizona

Studying Southern Arizona in a context of change

How local diagnostics of changes are being built?

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- Rural and periurban areas around the world are affected by socio-ecological changes, including climate change, that seems not to be fully perceived by local communities : can local discourses on biodiversity give insights on what people notice as changing in their immediate environments? How do they notice the changes: to see, to hear?

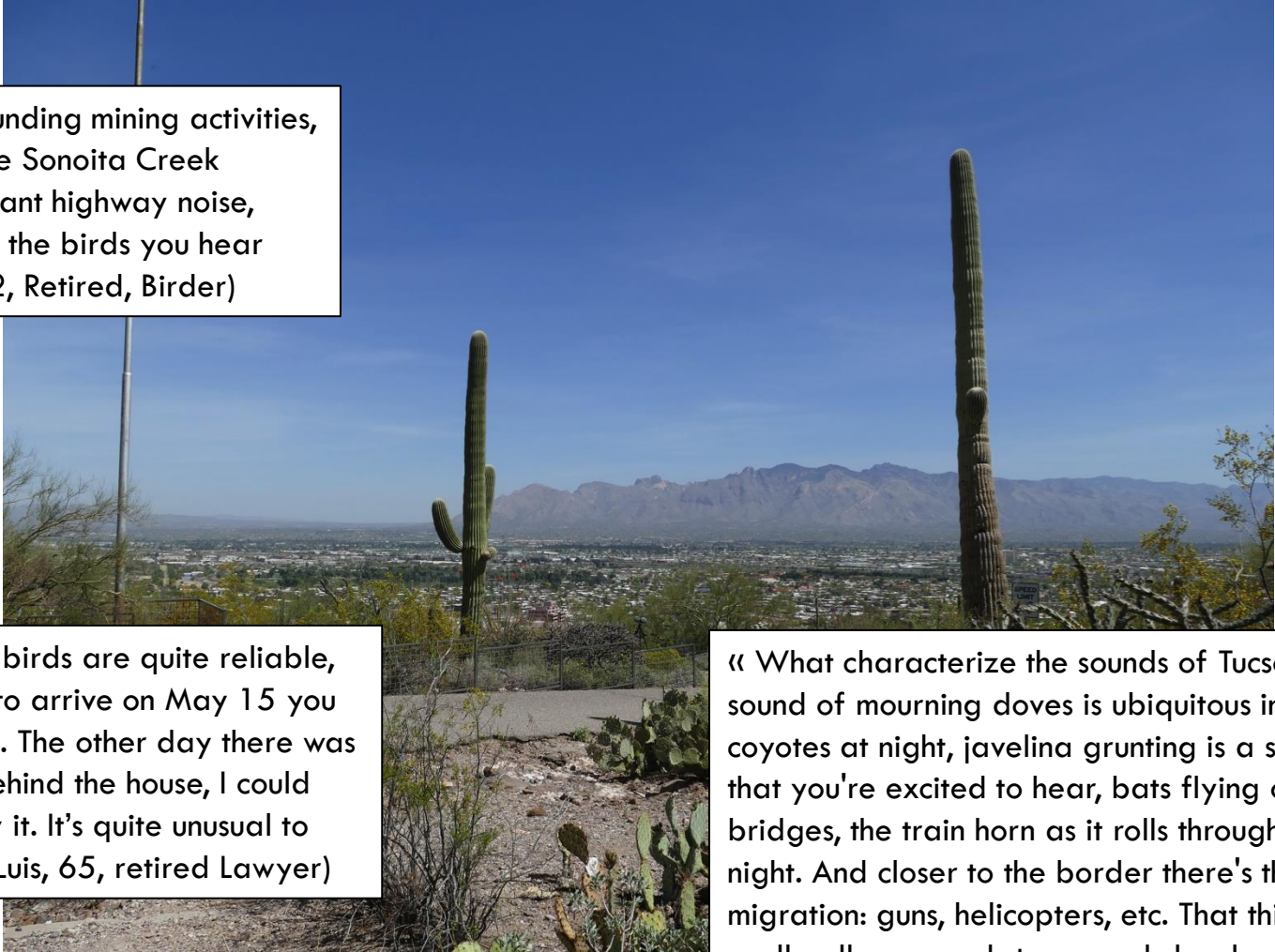


(Sounds of) Biodiversity as indicators of changes that help the communities understand the transformation of their land?

Studying Southern Arizona in a context of change

How to build diagnostics of changes through sounds?

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« Due to the surrounding mining activities, and the traffic, the Sonoita Creek preserve has constant highway noise, instead of hearing the birds you hear traffic » (Robin, 72, Retired, Birder)

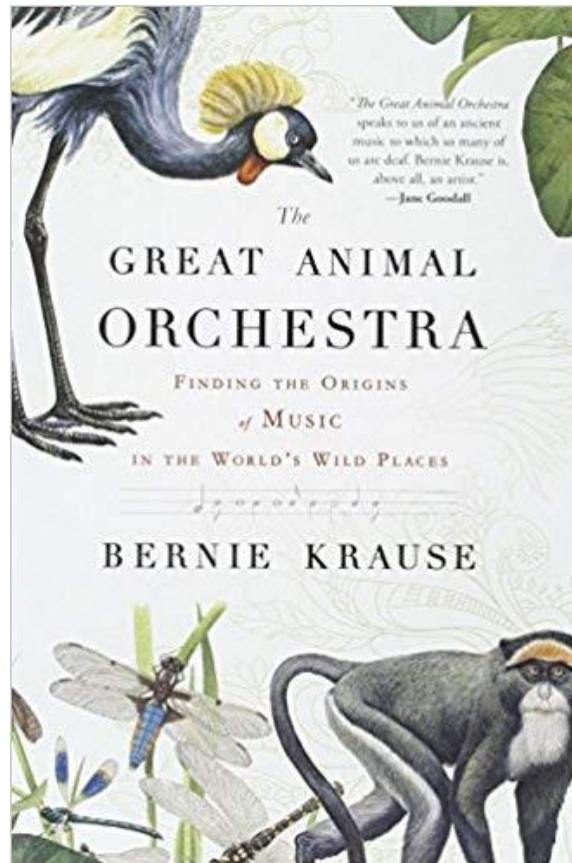
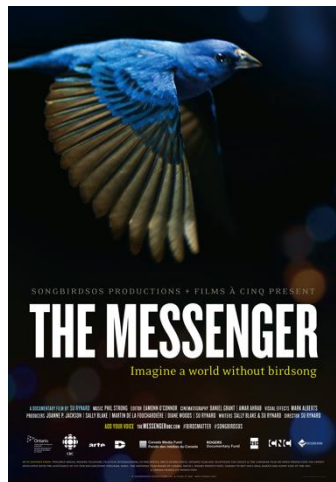
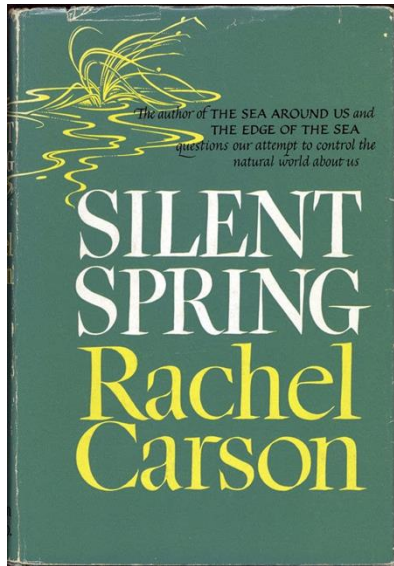
« In Madera Canyon, birds are quite reliable, if they are expected to arrive on May 15 you hear them on May 15. The other day there was a belted kingfisher behind the house, I could hear him before I saw it. It's quite unusual to have them around » (Luis, 65, retired Lawyer)

« What characterize the sounds of Tucson? ... the sound of mourning doves is ubiquitous in mornings, coyotes at night, javelina grunting is a special sound that you're excited to hear, bats flying out of the bridges, the train horn as it rolls through town at night. And closer to the border there's the sound of migration: guns, helicopters, etc. That thin desert air really allows sounds to spread clearly across the land! (Brian, 38, Researcher)

Studying sounds in the context of change

Sounds of nature as indicators: a hot topic

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Sur la zone-atelier du CNRS, étudiée sans interruption depuis 1994, la perdrix est désormais virtuellement éteinte.
McPHOTO / PICTURE ALLIANCE / BLICKWINKEL / MAXPPP

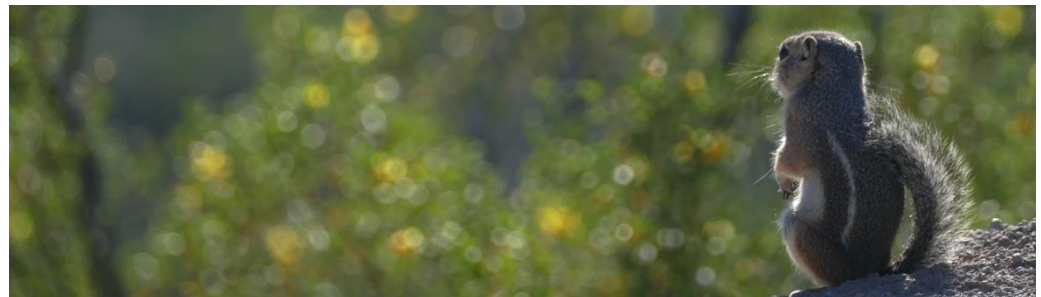
« **Spring may be silent this year.** The Museum of Natural History and the National Center for Scientific Research announce Tuesday, March 20, the main results of Breeding Bird Surveys on the French territory and evoke a phenomenon of "massive disappearance", "close to the ecological disaster ».

From **Le Monde Journal** – 03.20.2018

Sonatas: Listening to the SOunds of NATure to understand environmental chAngeS (OHMI funding 2018)

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- **Multidisciplinary Approach:** Sonatas invests the soundscape research field linking ecoacoustics, landscape ecology, geography & anthropology, to understand environmental changes impacts through the sounds of nature in Pima County.
- **Research questions:**
 1. What does **soundscapes tell us** about the changes affecting an ecosystem submitted to increasing human pressure (ecoacoustics and ecological approaches)?
 2. How do local **people hear their sound environment, listen to it, think it should sound like** and develop local ecological knowledge through sounds (geographical and anthropological approaches)?
 3. How could soundscapes and the way they are heard inform about the **state of the ecosystem and the interactions between societies and nature?**



Sonatas: Experiencing changes through sounds

Research questions

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- **Fieldsite:** Pima County which is confronted to multiple changes including climate warming, water scarcity, uncontrolled urbanization and especially rapidly developing mining project with potentially strong environmental consequences : **how sounds can be indicator of changes notably within the current monitoring attempts?**
- Focus on **bird songs and birders' perceptions** of the bird population changes (known as good ecological and local indicators of changes).

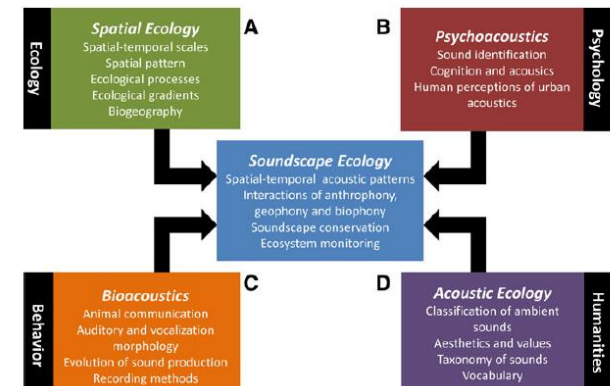
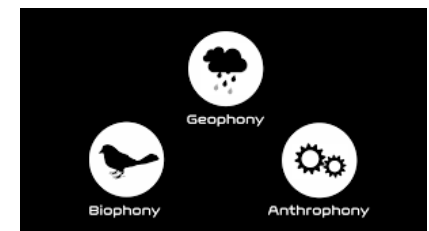
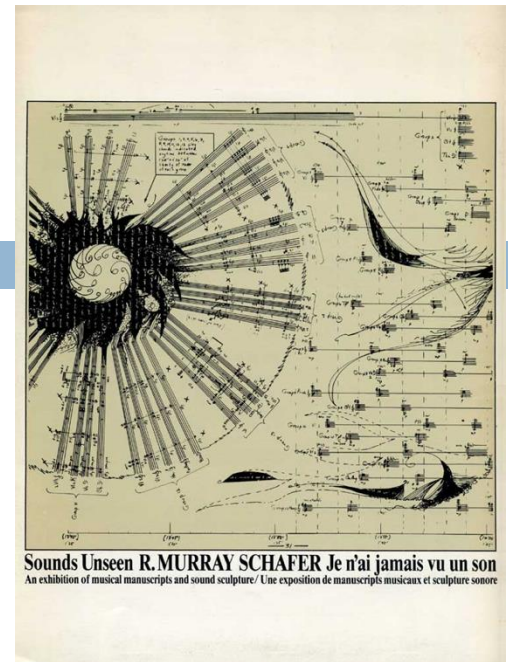


Sonatas backgrounds

What's a soundscape?

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- Soundscape refers in a holistic way to sound sources that compose a landscape from an esthetic, historical, physical, cultural or geographical point of view (Schafer, 1977).
- For ecologists, soundscapes are the collections of sounds detected at given locations and periods, and can reflect ecological status and changes of given landscapes. They can be broken down into 3 components: geophony, biophony, anthrophony.
- For social scientists, soundscapes or sound environments are witnesses or revelators of social representations, local knowledge and cultural affiliations and their components need to be apprehended globally together.
- Emerging research field benefit from recent technical advances in automatic acoustic sensors along with the development of acoustic diversity indices.



What is soundscape ecology? An introduction and overview of an emerging new science

Sonatas methods

Bioacoustic recording and ethnography

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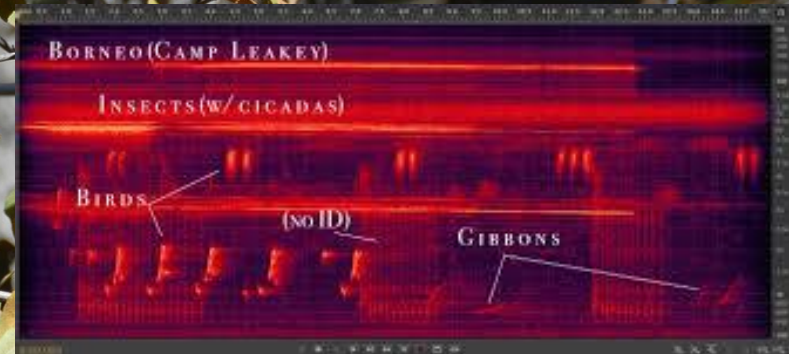
2 (almost) completed 10 days fieldtrips:

- **April 2018 (within ANR Piaf Program):** 'snapshot' recording, 30 min with Zoom H4N + ERTF ; Points counts ; Passive acoustic monitoring with SM4 24h.
- **August 2018:** help of Lisa Vincent, intern at the UMI iGlobes, who set up more acoustic monitorings.
- **November 2018:** Passive acoustic monitoring with SM4 24h, semi-directed interviews with 12 informants, Participant observations during birding fieldtrips with the Audubon Society.



Focus on ecoacoustics :

What do soundscapes or sound environments tell us about the changes affecting an ecosystem or a landscape submitted to increasing human pressure (ecoacoustic and ecological approaches)?

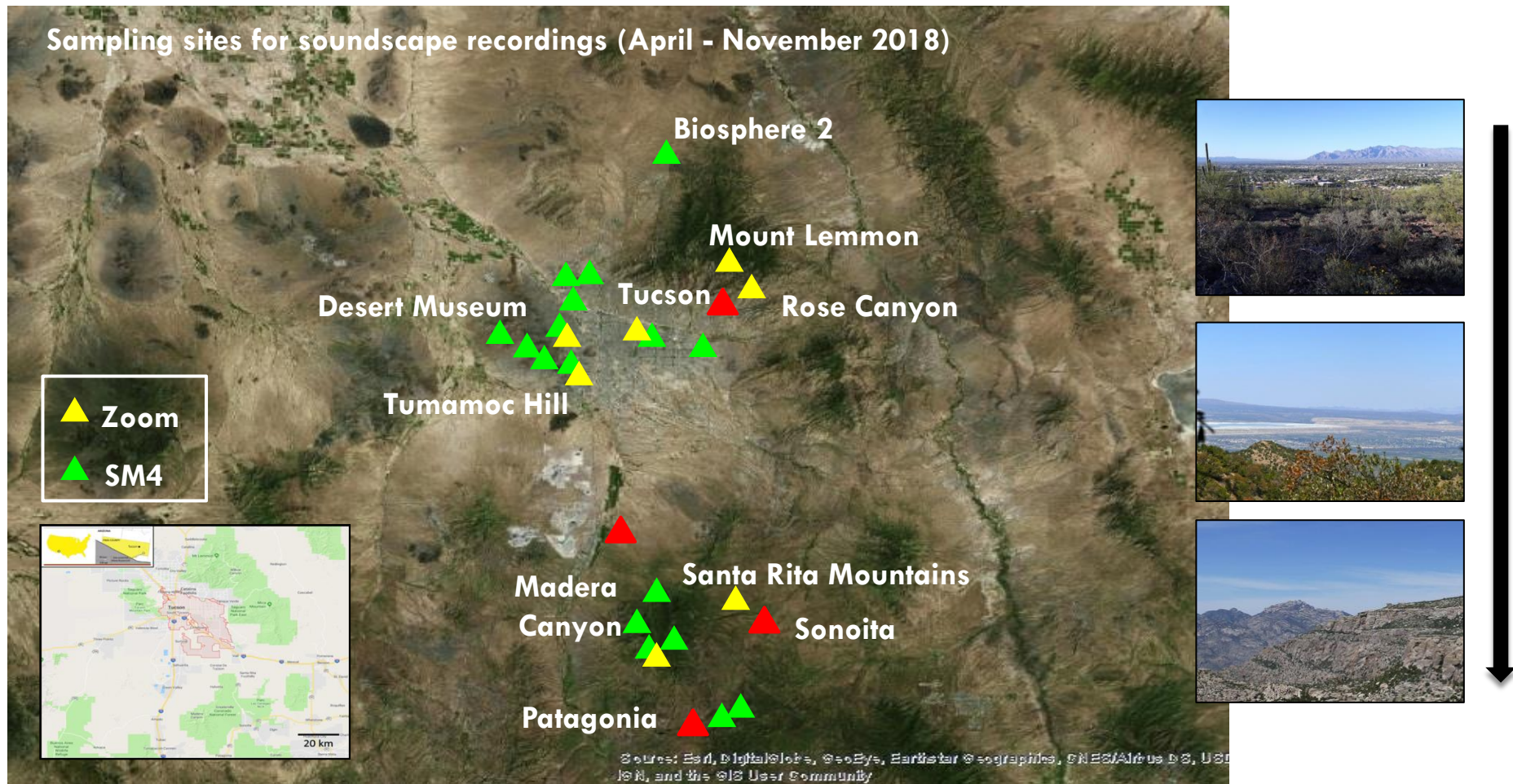


Sonatas fieldsites

Gradient of anthropic pressures

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- 28 locations, +900 hours of recordings using SoundMeter4 and ZoomH4N on 3 seasons.



Sonatas fieldsites

Focus on 8 samples recorded in April 2018

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« Suburban » area soundscape



Tumamoc Hill – protected saguaro desert

Ruth's garden – unprotected gardens and desert

Patagonia garden – unprotected gardens and desert

Paton Center – protected garden and riparian forest

« Rural » area soundscape



Chuparosa Lodge – protected pine-oak-sycamore forest

Sylvester Spring – protected pine-oak sycamore forest

Proctor Road – protected mesquite and riparian forest

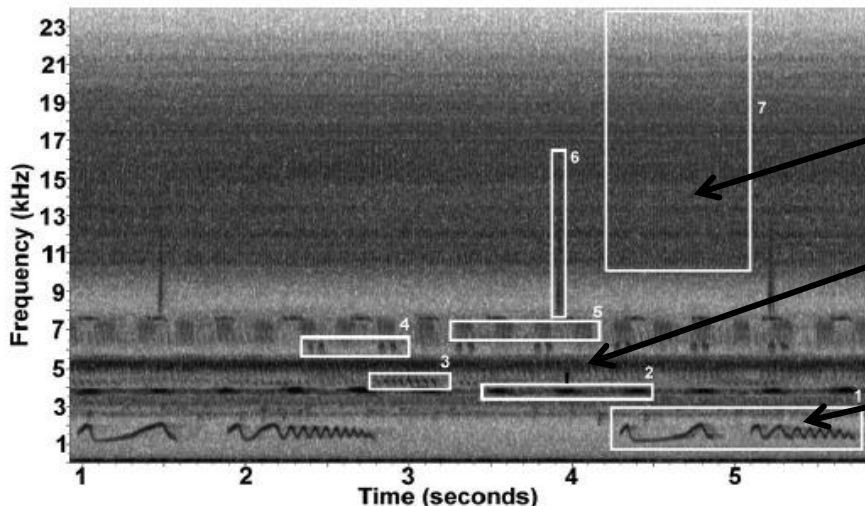
Santa Rita Road - unprotected mesquite-cactus desert

Focus on ecoacoustics

Soundscape analysis using ecoacoustic methods

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- **Ecoacoustics** use environmental sounds as a **non invasive reliable proxy** for investigating ecological complexity.
- What are the methods for **characterizing soundscape diversity with ecoacoustics**?
 - ▣ Spectrogram analyses based on spectrum amplitude and frequency
 - ▣ Classification of sounds based on active listening (bio-, geo- and anthrophony)
 - ▣ Integrative acoustic diversity indices (ratio between acoustic components)
- **Biophony** is the portion of soundscapes produced by the ‘acoustic community’



Katydid = high-frequency
broadband signals

Cricket = low-frequency narrowband
signals

Nightjar = low-frequency signal with
complex amplitude modulations

Use of ecoacoustics to determine biodiversity
patterns across ecological gradients

Paul B. C. Grant* and Michael J. Samways

Focus on ecoacoustics

Computing acoustic diversity indices

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A range of acoustic indices allows **quantifying the diversity** of recorded sounds and the **relative parts of biophony and anthrophony** in different soundscapes

α indices

Relative avian abundance	–	Area under spectrum in relation with an amplitude threshold	[43]
Temporal Entropy	H_t	Envelope complexity	[44]
Spectral Entropy	H_f	Spectrum complexity	[44]
Acoustic Entropy Index	H	Envelope and spectrum complexity	[44]
Ratio of biophony to anthrophony	ρ	Ratio of biophony to anthrophony	[54]
Acoustic Complexity Index	ACI	Spectrogram complexity	[50]
Biophony	–	Biophony level	[45]
Biophony peak	bioPeak	Biophony level	[56]
Acoustic Entropy Index	$AEI (= H)$	Envelope and spectrum complexity	[45]
Shannon's Index	H'	Spectrum complexity	[46]
Acoustic Richness	AR	Envelope complexity and intensity	[48]
Median of amplitude envelope	M	Median of amplitude envelope	[48]
Normalised Difference Soundscape Index	NDSI	Ratio of anthrophony to biophony	[55]
Acoustic Diversity Index	$ADI (= H')$	Spectrum complexity	[47]

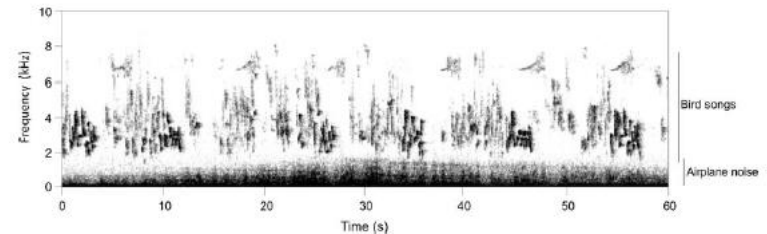
Acoustic Indices for Biodiversity Assessment and Landscape Investigation

Focus on ecoacoustics

2 examples: Bioacoustic Index et NDSI

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- The **Bioacoustic Index** is a function of both the **sound level** and the **number of frequency bands used by the avifauna**. It is not normalized to increase differences between recordings with **low-amplitude sounds** and **higher amplitude sounds**.



- The **Normalized Difference Soundscape Index** estimates the level of **anthropogenic disturbance on the soundscape** by computing the ratio of human-generated (anthrophony) to biological (biophony) acoustic components
 - Mechanical sounds are most prevalent **between 1 and 2 kHz** and biological sounds are most prevalent **between 2 and 8 kHz**.
 - NDSI is a ratio in the range $[-1 \text{ to } +1]$, where **+1 indicates a signal containing no anthrophony**
 - A low NDSI can also indicate the presence of certain species with low frequency call (i.e. common loon)



Focus on ecoacoustics

What is known and expected

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- Soundscape phenology shows daily / nightly and seasonal variations.
- The relative proportion of anthrophony decreases along the human pressure gradient and the relative proportion of biophony increases along the gradient but also depend on habitat structure (suburban gardens, cactus and mesquite deserts, mountain forests...).

B Seasonal variation

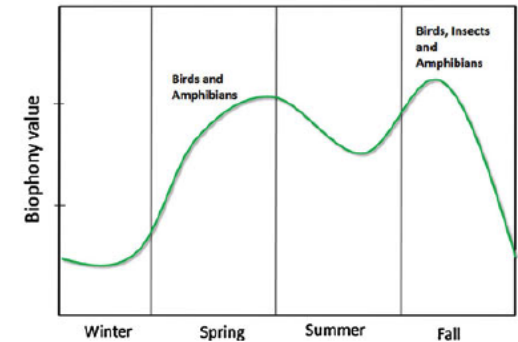


Fig. 4 Conceptual models of how biophony varies over different temporal scales (stylized after Truax 1978)

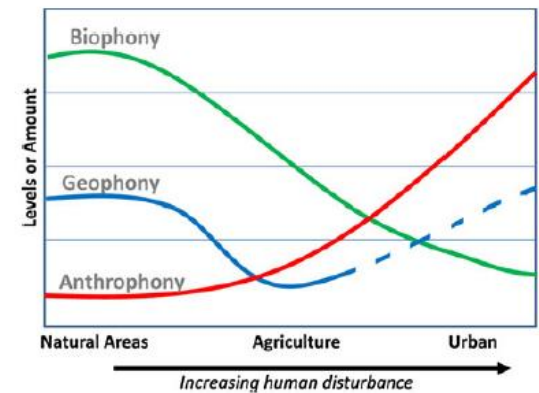


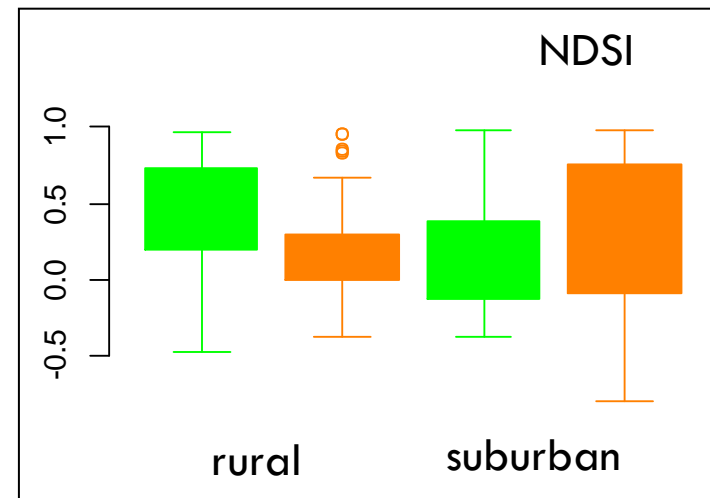
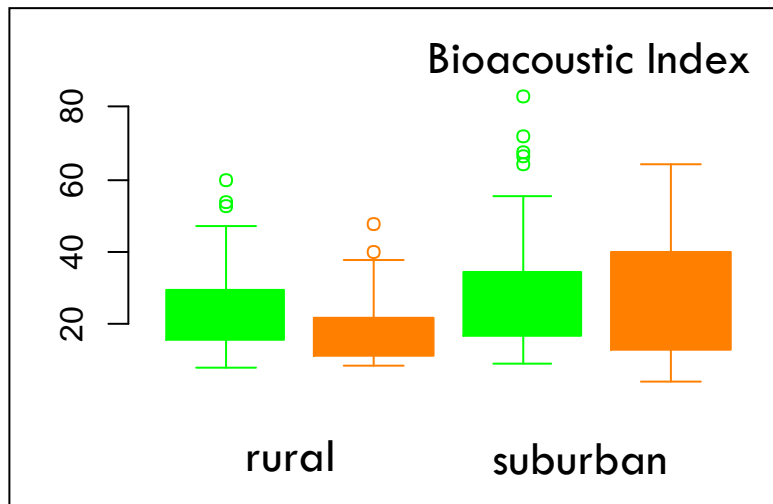
Fig. 5 Conceptual model of variations in soundscape elements across a human disturbance intensity gradient. *Dashed line* represents one possible pattern that could exist

Focus on ecoacoustics – Preliminary results

Biophony index and anthrophony/biophony ratio

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- Contrary to expectations, bioacoustic index is not lower and is more variable in suburban than non-urban areas, especially for unprotected habitats
- As expected, NDSI was lower in suburban areas but only for protected habitats



 **Within Protected Areas**

 **Unprotected**

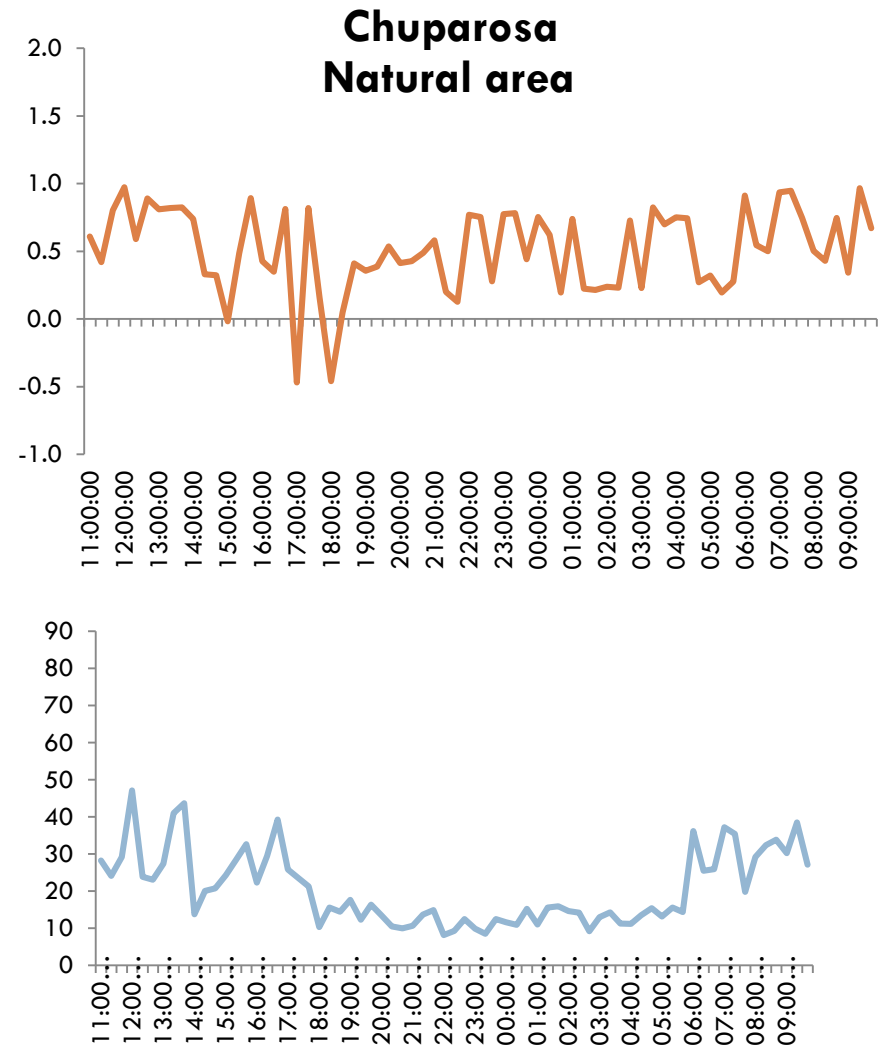
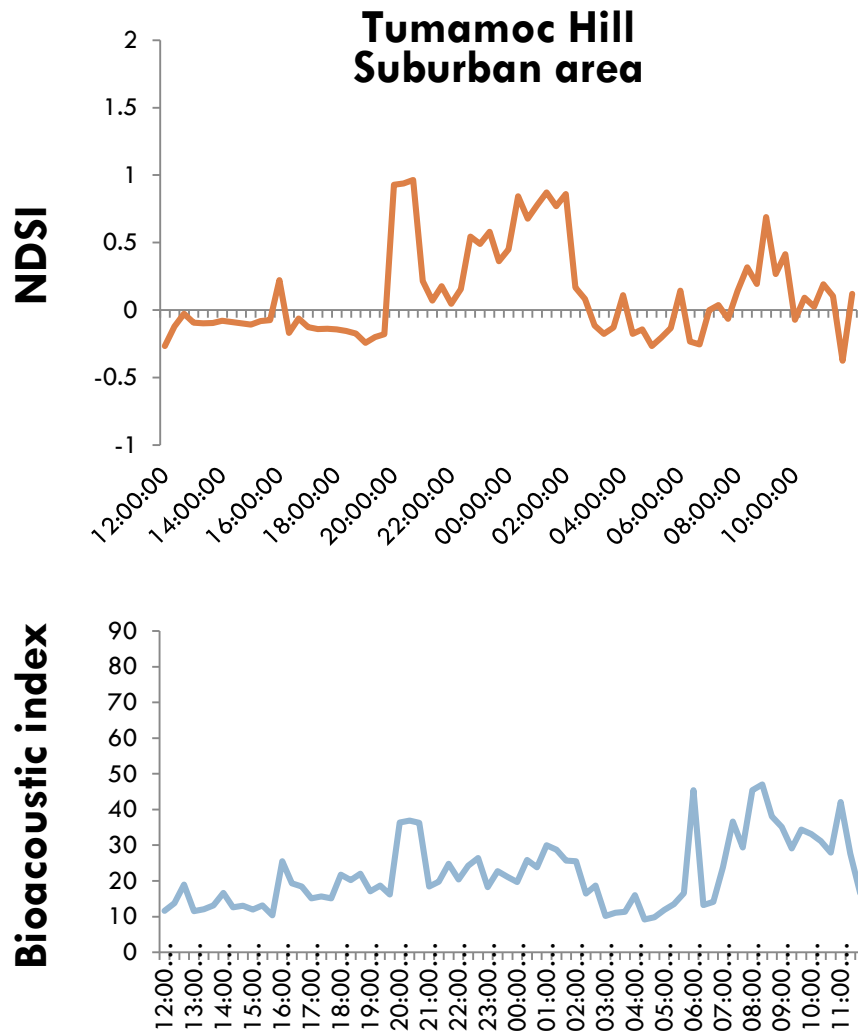
Anthrophony is lower in non urban habitats only when protected

Biophony is more variable in suburban habitats and lower in non urban habitats when unprotected

Focus on ecoacoustics – Preliminary results

Daily soundscape profiles for NDSI & bioacoustic index

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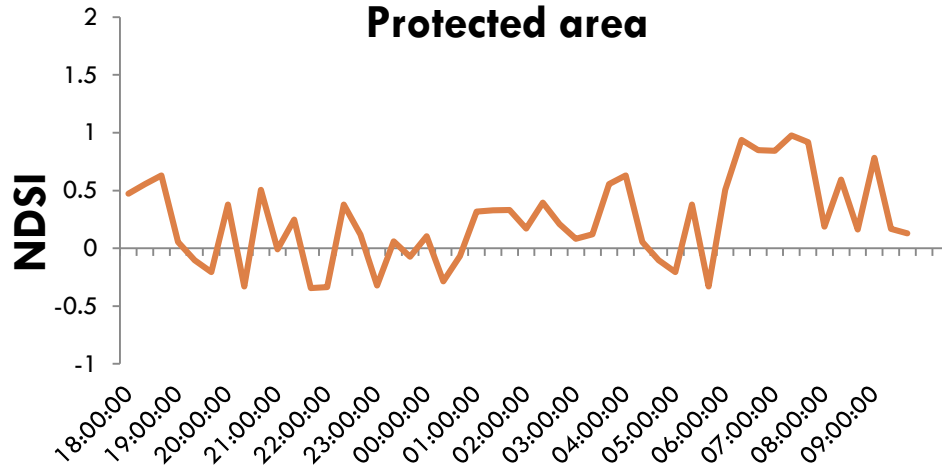


Focus on ecoacoustics – Preliminary results

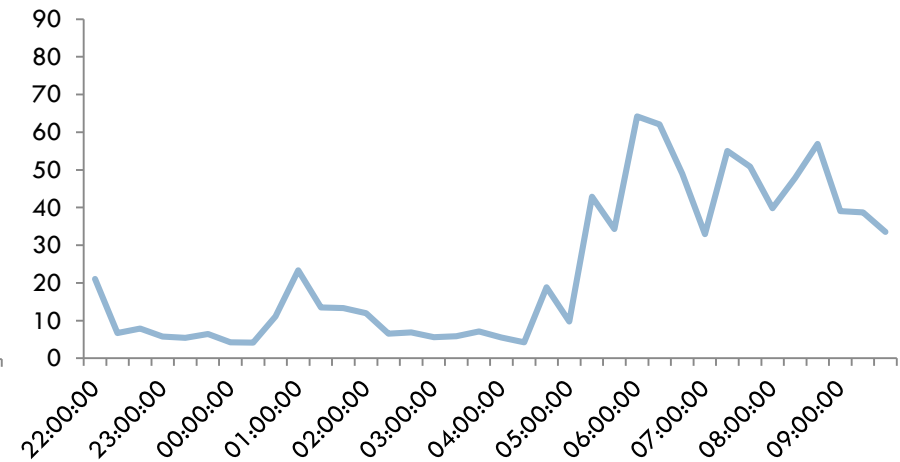
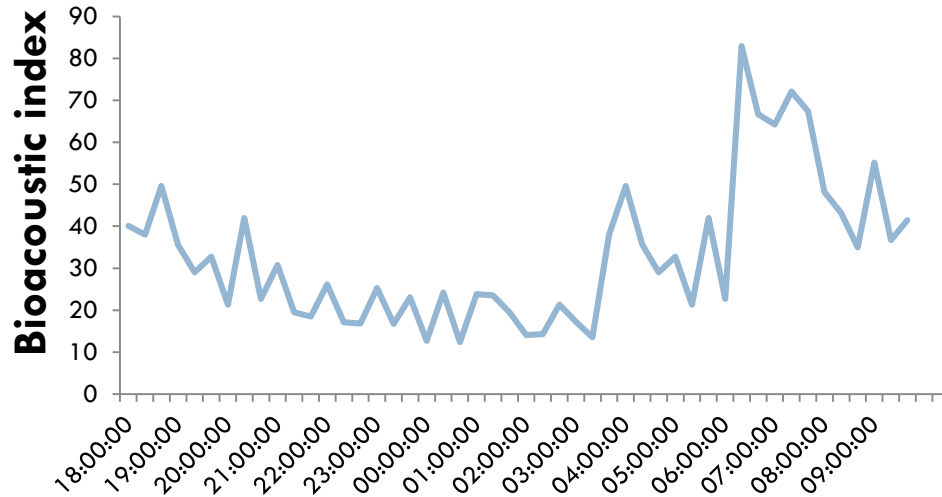
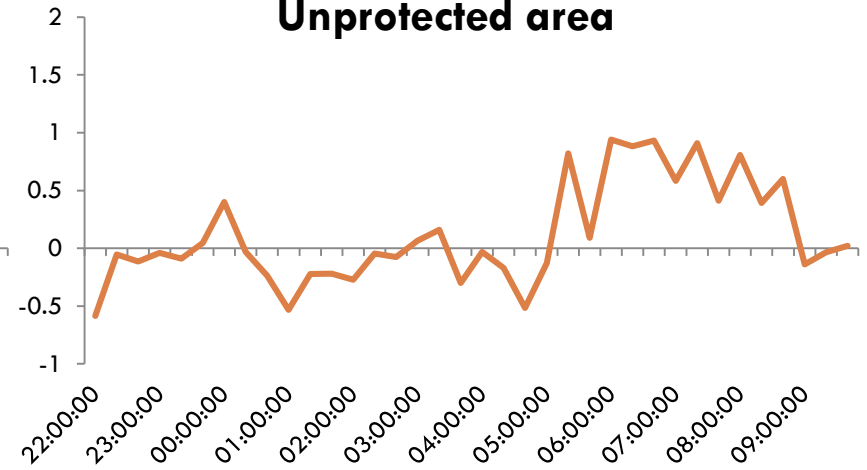
Daily soundscape profiles for NDSI & bioacoustic index

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Paton Center
Protected area



Patagonia
Unprotected area



Analysis in progress...

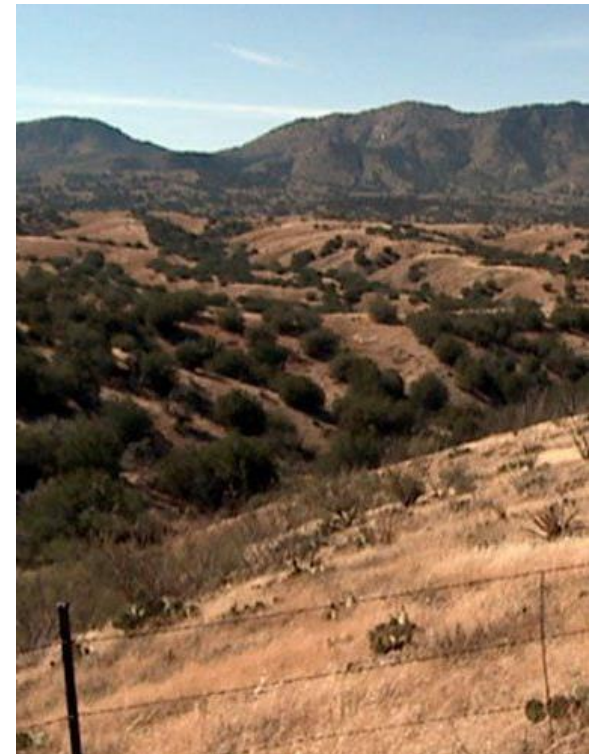
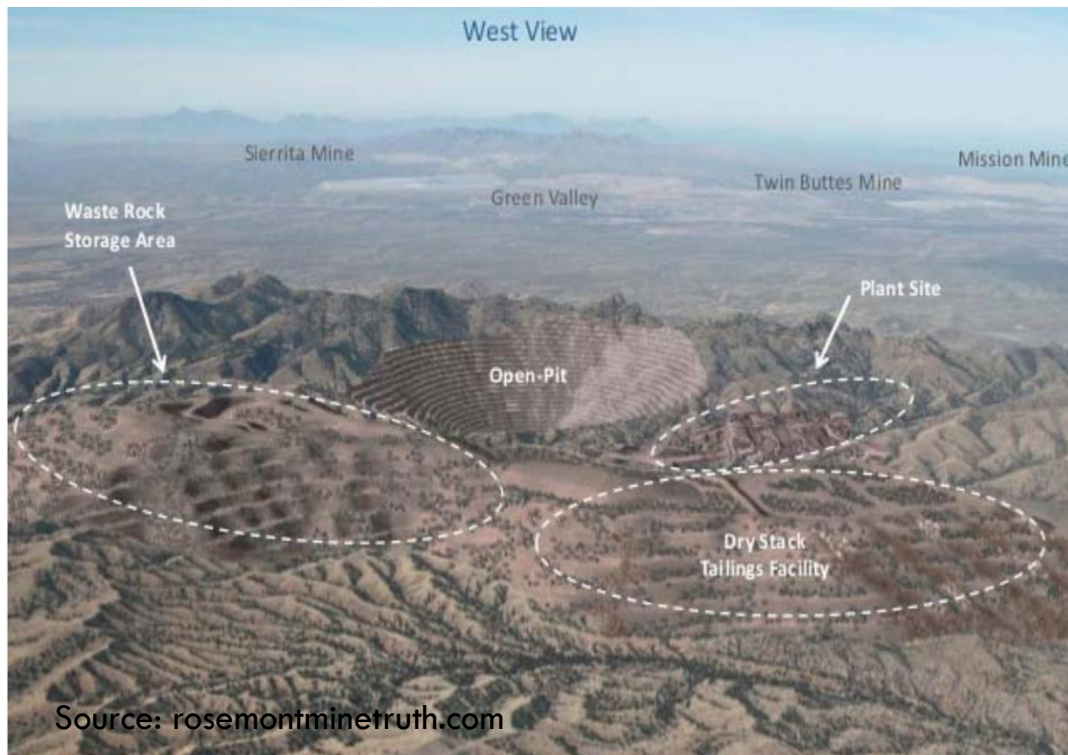


Sonatas perspectives

Recordings and sociological analysis in progress

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1. A longer term project? Recordings to be planned in April & November 2019 and 2020 in the same sites to build annual comparisons of acoustic characteristics to question seasonal and annual variations and to question impacts of major changes on soundscapes (if happening!).



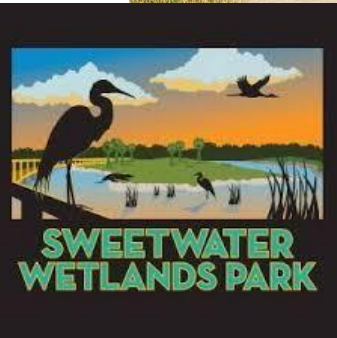
What will happen to sounds (soundscapes landscapes and local communities) if/ when the mines opens?

Sonatas perspectives

Compare what is recorded and what is heard

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1. Through interviews, with birdwatchers, and available databases (ebird) we will compare sonogram biophony analysis with local perception of sounds and bird songs to identify potential gaps between what is heard, seen and what is occurring in the studied sites. We also want to question what part birds play in the gobal soundscapes and how they can or not been seen as major indicators of changes compared to other sounds.
 - Focus on 2 sites in 2018: Sweetwater Wetland Park and Madera Canyon where we are doing recordings, interviews and participants observations.



Sonatas perspectives

Knowledge comparison and citizen sciences

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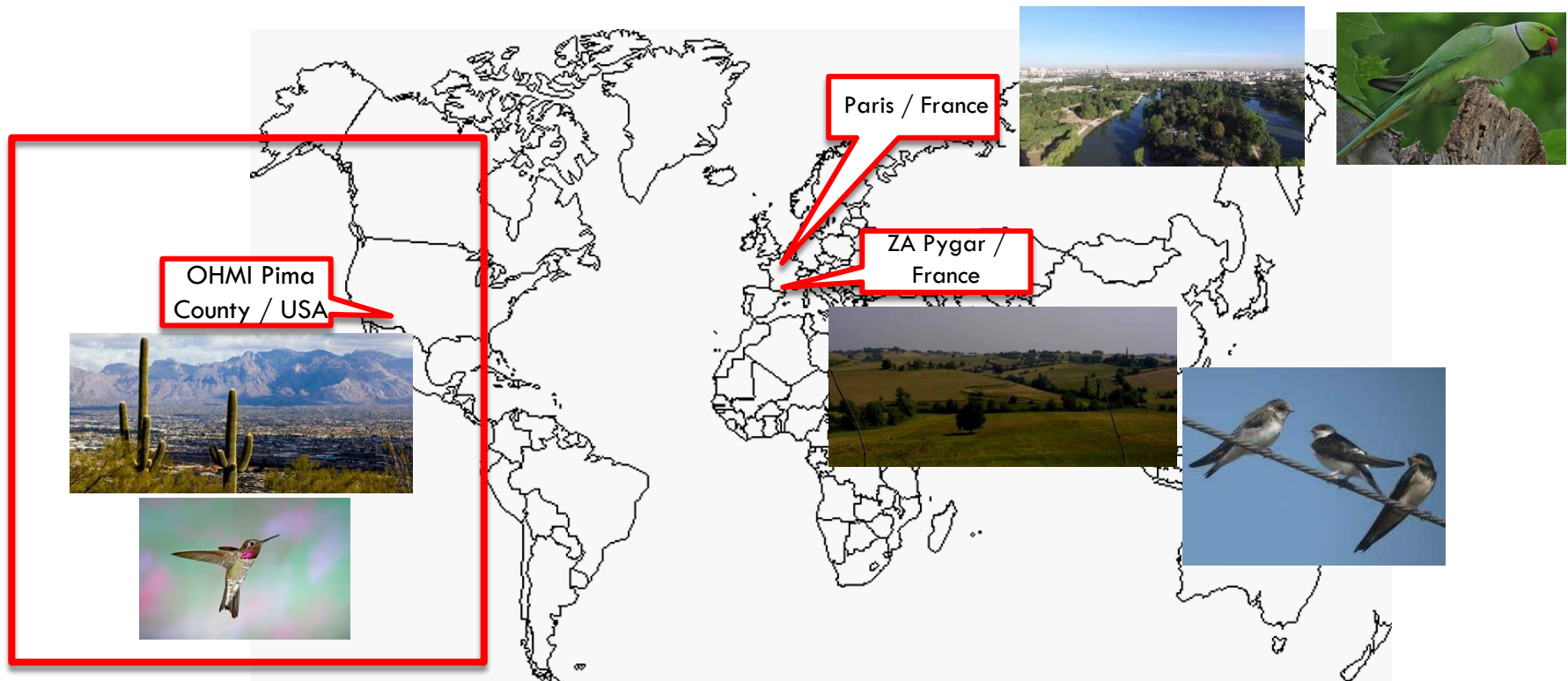
- Sonatas aims to **understand through sounds experiences and perceptions how the environment is conceived by local communities and whether it is seen as changing or immutable**. Our objective is to explore how different types of ecological knowledge coexist within those communities in the context of major mutations and how people could collaborate together to face those changes.
- **How can sounds be indicators of the quality of the environment and for whom?**
How can a soundscape be a policy tool to characterize and overcome noise pollution: what methods and tools to implement for qualifying the entire soundscape for action (cf. light pollution)?
- Sounds, soundscapes and citizen sciences and science education perspectives with Biosphere 2 and Desert Museum.

Sonatas and Sonates (2018-2020 LabEx Dynamite)

A larger project

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- **3 contrasted areas** chosen to test our questions and methodologies : urban parc near **Paris**, rural area near **Toulouse** (France), threatened protected area in **Pima County** (USA).



Thank you for your attention!

asourdril@parisnanterre.fr

luc.barbaro@inra.fr

Special thanks to:

The OHMI Pima County and the
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The Tucson Audubon Society

Sweetwater wetland park

Chuparosa Inn

The Friends of Madera Canyon

The Desert Museum

Biosphere 2

