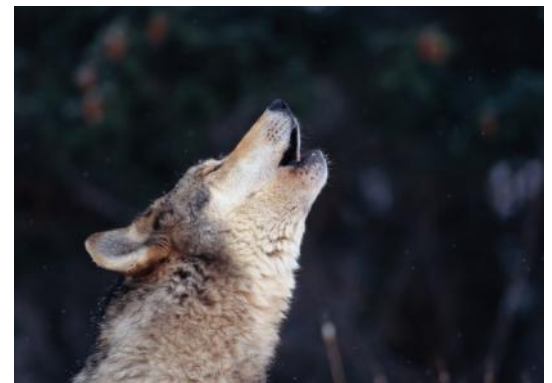# Bioacoustics: bird vocalizations in the Alpine environment

Sèbe F. , Grison J., Mazagole P-O., Marin-Cudraz T., Aubry P., Muffat-Joly B., Desmet J-F., Novoa C.
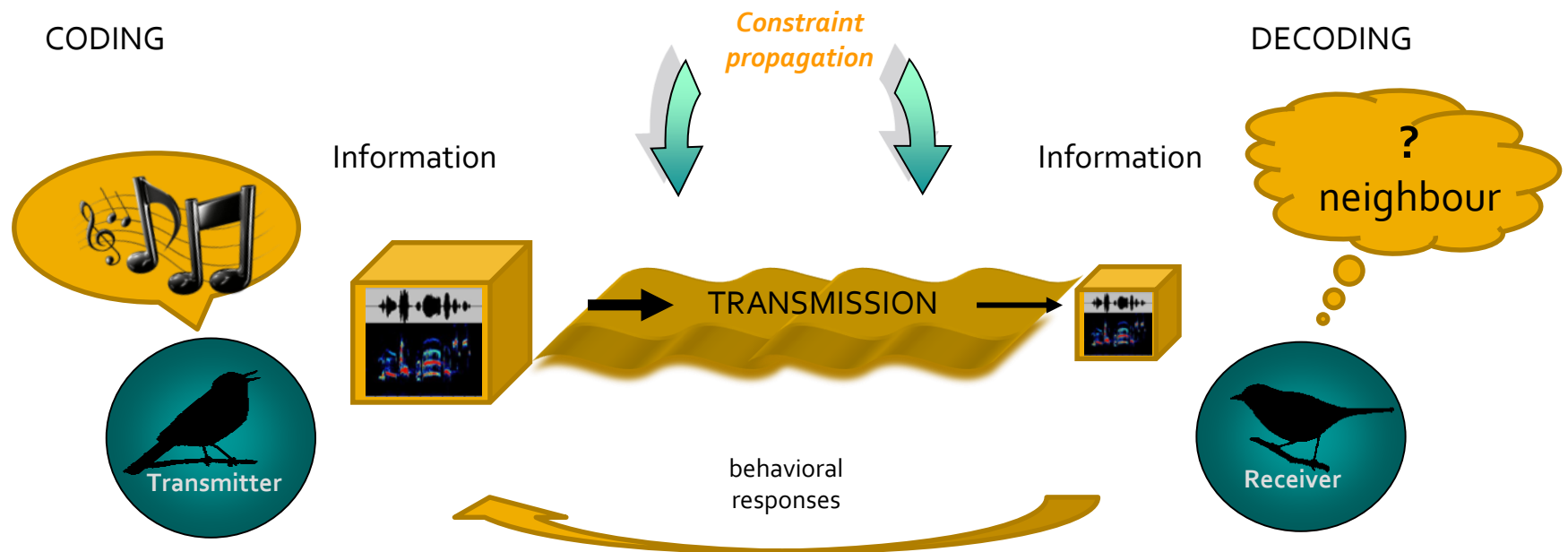
Introduction

- What is bioacoustic?
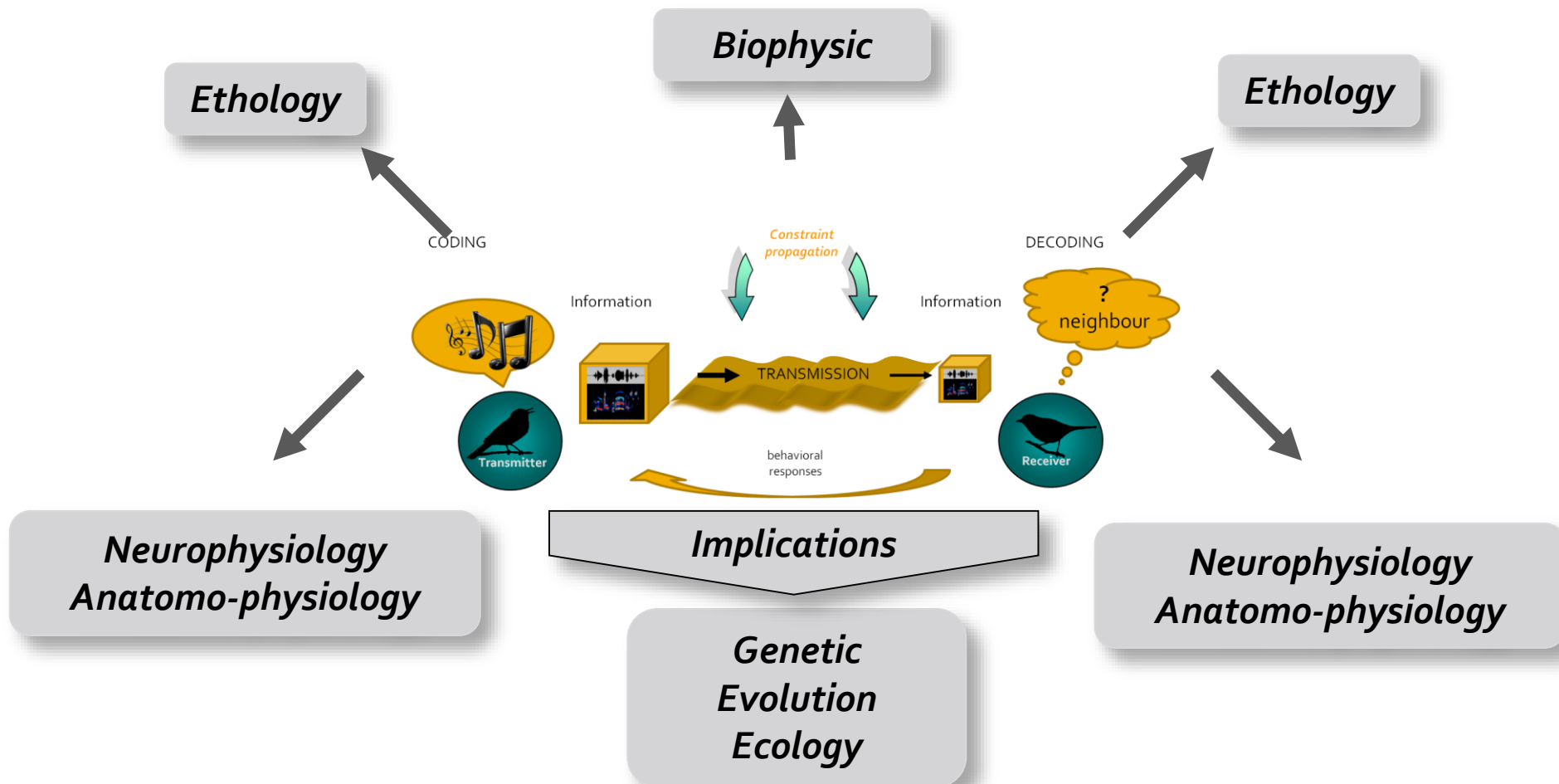 - The study of acoustic communications of animals

Introduction

- ## What is bioacoustic?

  - ### The study of acoustic communications of animals
  - ### Acoustic communication: exchange of information

(Shannon et Weaver 1949)

Introduction

Introduction

-Information encoded and decoded in the signal

- •Signature of species
- •Group signature
- •Individual signature
- •Vocal expression of emotion
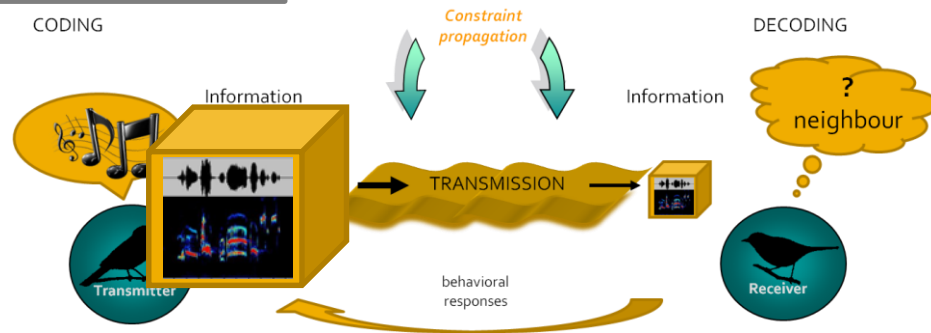
Introduction

-Information encoded and decoded in the signal

- •Signature of species
- •Group signature
- •Individual signature
- •Vocal expression of emotion

-Propagation constraints

- •Habitat
- •Noise
- •Landform

CODING

Constraint
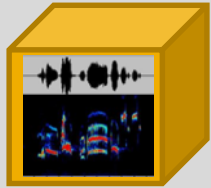
DECODING
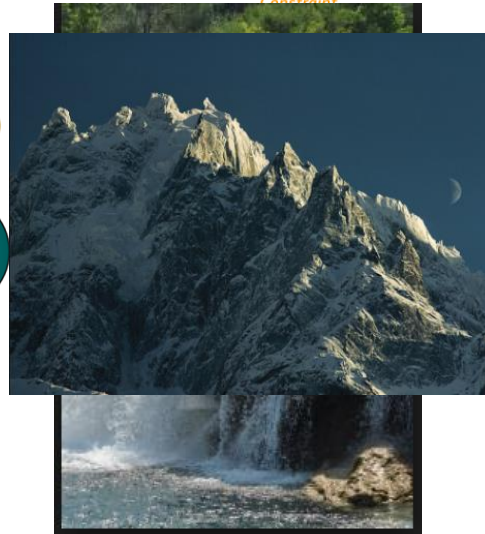
ation

neighbour

?

Transmitter

Receiver

Introduction

-Information encoded and decoded in the signal
- Signature of species
- Group signature
- Individual signature
- Vocal expression of emo
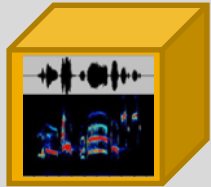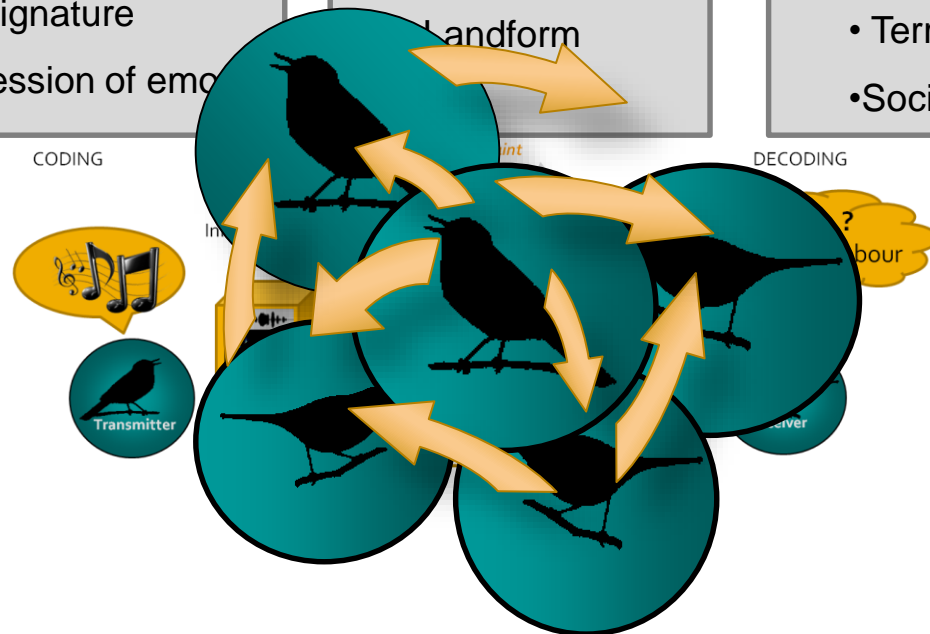
-Propagation constraints
- Habitat
- Noise
- Landform

-Context in which the signal is used
- Speciation, phylogeny, dialect
- Mother-young recognition
- Territorial defense
- Social acoustic network

CODING

DECODING

Transmitter

-How the different informations are integrated in networks?

-How the context and propagation constraints affect communication networks?

Introduction

- The landform drive the active and detection space of singing of high mountain birds

The rock ptarmigan

- **Theorical reseach:** Space investigation of acoustic communication networks

- **Applied research:** Wildlife managment, conservation of biodiversity

→To develop and improve counting methods in ptarmigan using acoustic signals

Introduction

- active space?

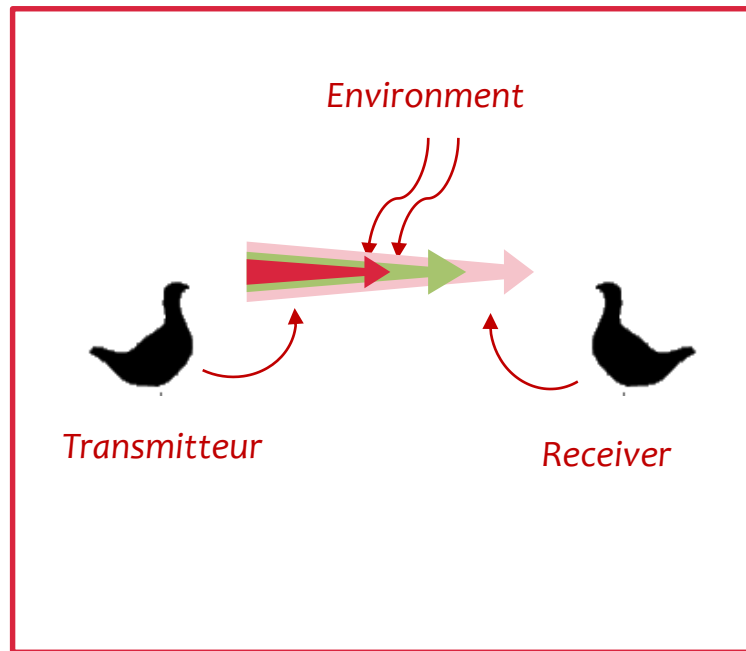"Active space" (Marten & Marler 1977) = "effective" distance of the signal
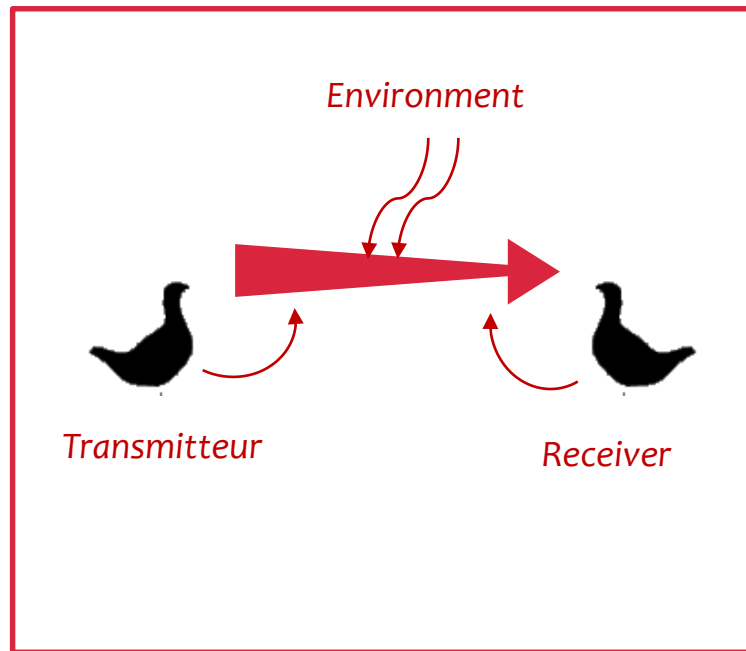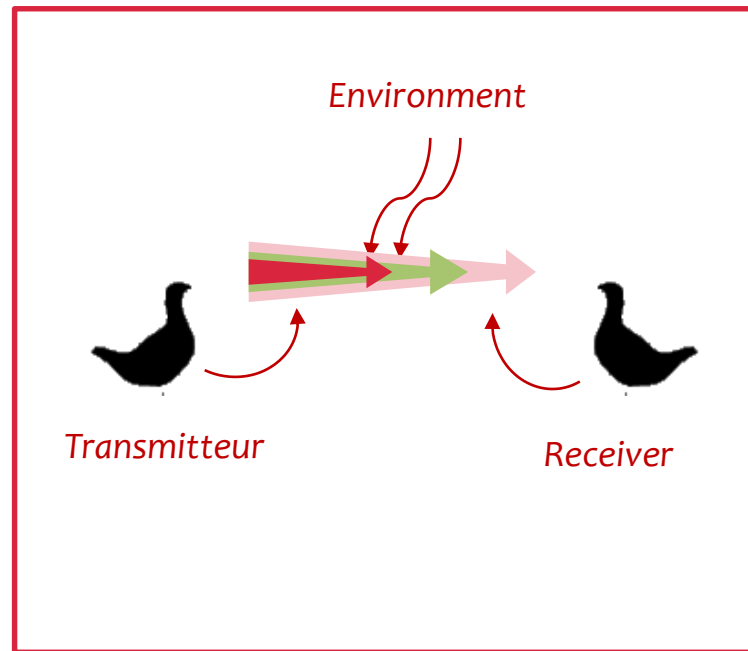

Dyadic scheme of communication

Introduction

- active space?

"Active space" (Marten & Marler 1977) = "effective" distance of the signal

Dyadic scheme of communication

Introduction

- ## active space?

"Active space" (Marten & Marler 1977) = "effective" distance of the signal
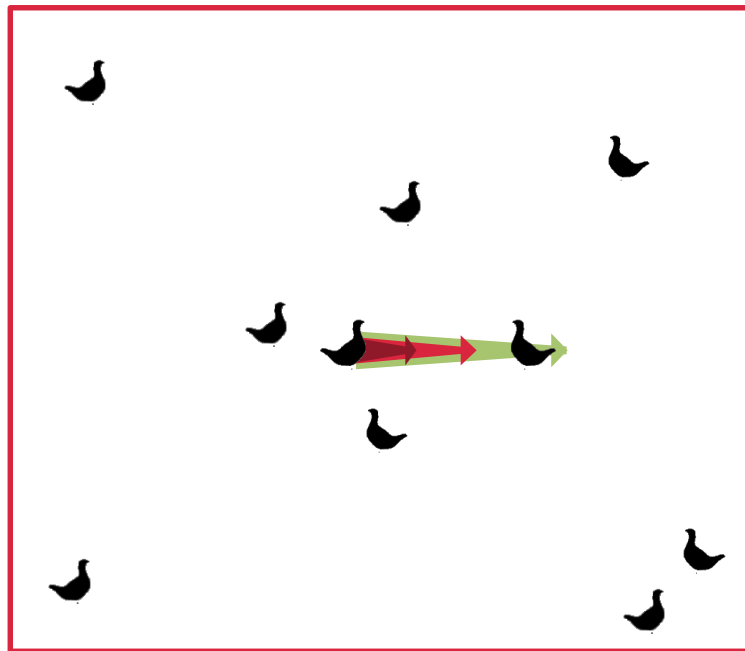

Dyadic scheme of communication

New paradigm: the theory of communication networks
(McGregor & Dabelsteen 1996, McGregor 2005)

Introduction

- active space?

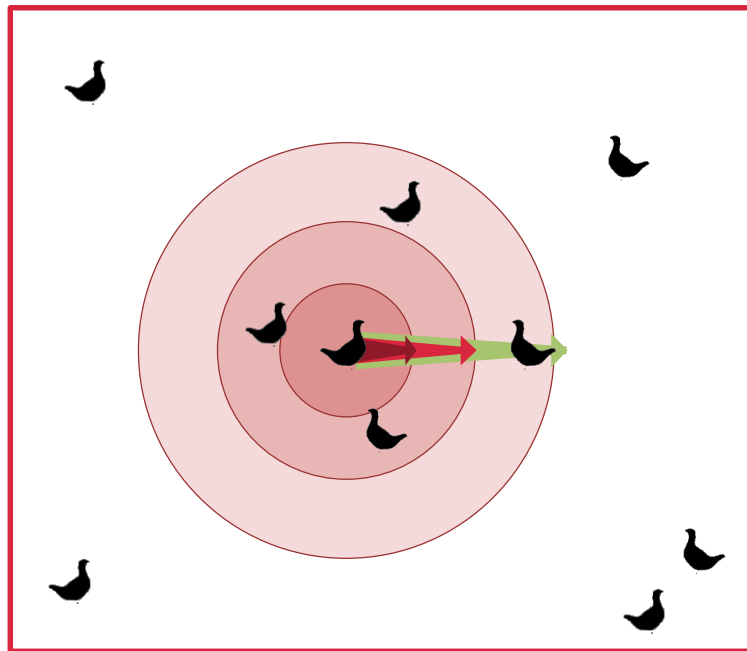"Active space" (Marten & Marler 1977) = "effective" distance of the signal

New paradigm: the theory of communication networks
(McGregor & Dabelsteen 1996, McGregor 2005)

Introduction

- ## active space?

"Active space" (Marten & Marler 1977) = "effective" ~~distance~~ area of the signal
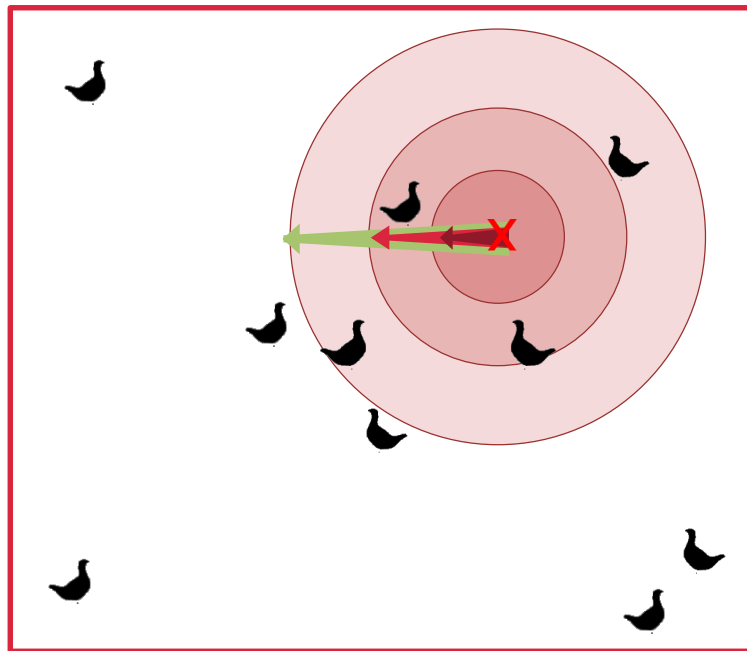

New paradigm: the theory of communication networks
(McGregor & Dabelsteen 1996, McGregor 2005)

Introduction

- Detection space?

detection space = detectability area of a signal
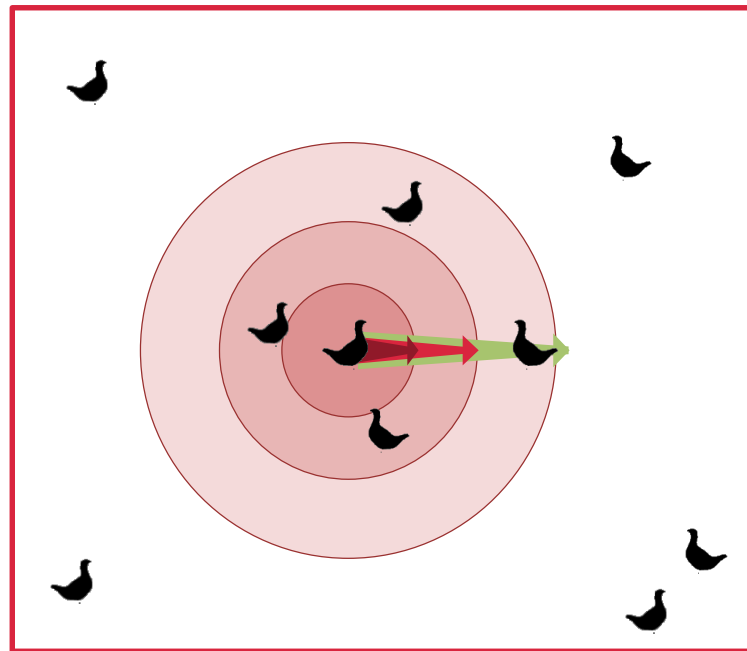
Listening area for humans or birds

New paradigm: the theory of communication networks
(McGregor & Dabelsteen 1996, McGregor 2005)

Introduction

- Circular active and detection space

"Active space" (Marten & Marler 1977) = "effective" ~~distance~~ area of the signal
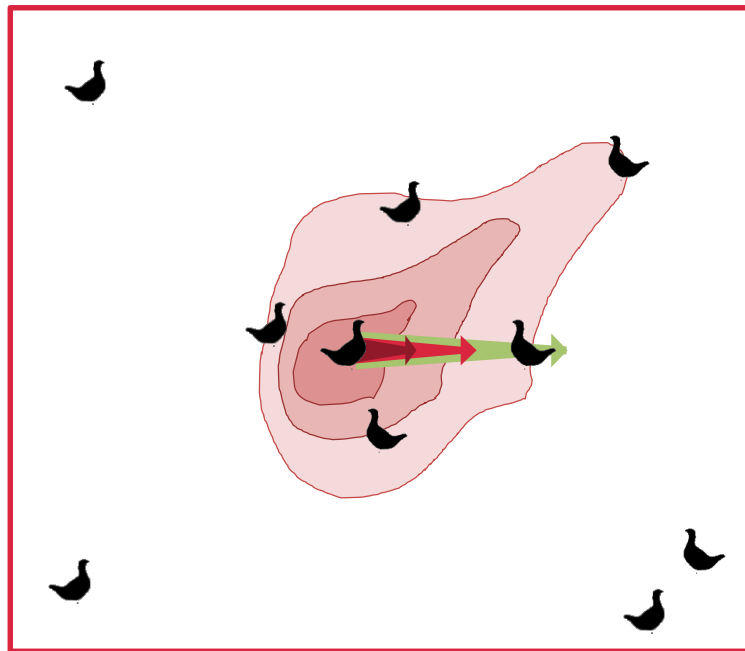
circle
homogeneous
environment

Introduction

- ## active space?

"Active space" (Marten & Marler 1977) = "effective" ~~distance~~ area of the signal

Non-homogeneous environment ?

New paradigm: the theory of communication networks
(McGregor & Dabelsteen 1996, McGregor 2005)

Introduction

- Aim of study

    1) modeling the active spaces of Rock Ptarmingam vocalization to integrate macro variations of landform
    2) test of the micro variations of landform
    3) modeling the detection spaces of Rock Ptarmingam vocalization
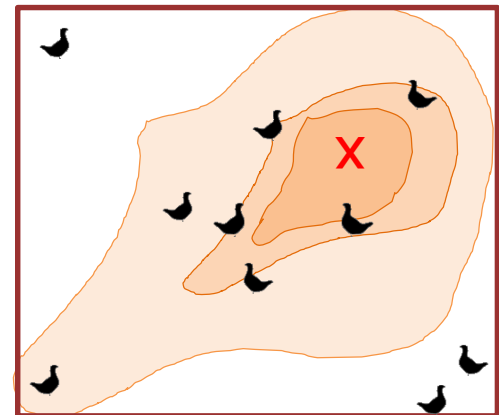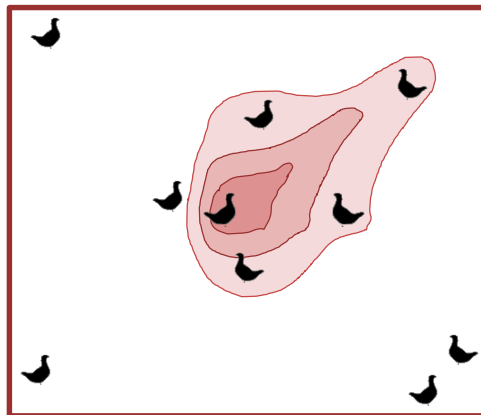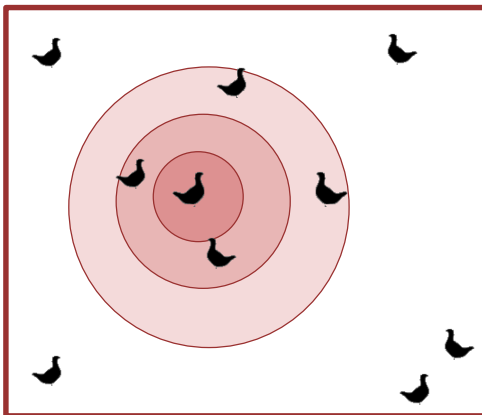
Animal model

- ## Why Rock ptarmigan

•Vocalisations
•Acoustic communication

•Territorial
•Performs display flights
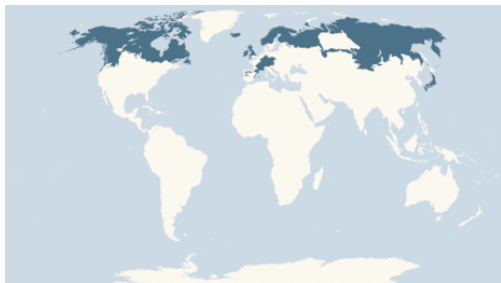
•Lives in the mountains (relief + wind)

Animal model

■ Rock ptarmigan

Family : Phasianidés
Gender : *Lagopus*
Specie : *muta*

• Strong conservation issues : population in danger
• Counting by the human ear
• Heavy Logistics → Error of double counting
→ Error of detectability: bad estimation of listening surface

Acoustic active and detection spaces → improve counting methods in ptarmigan

Introduction

- ## Aim of study

    1) modeling the active spaces of Rock Ptarmingam vocalization to integrate macro variations of landform
    2) test of the micro variations of landform
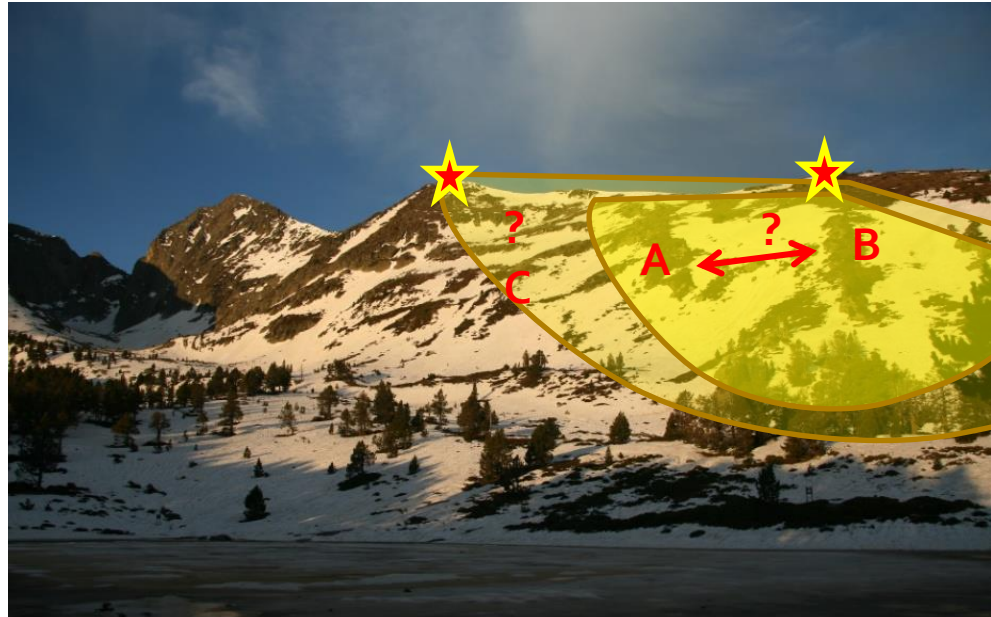   3) modeling the detection spaces of Rock Ptarmingam vocalization
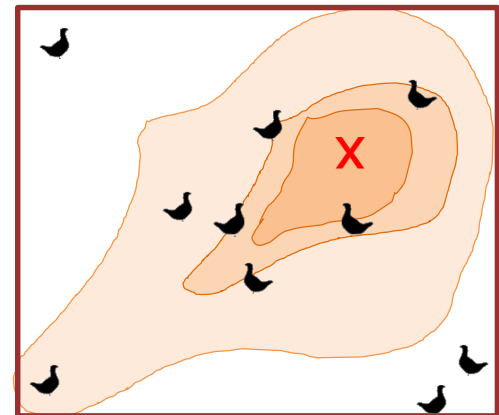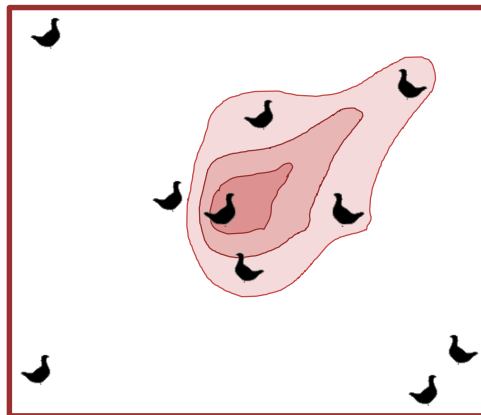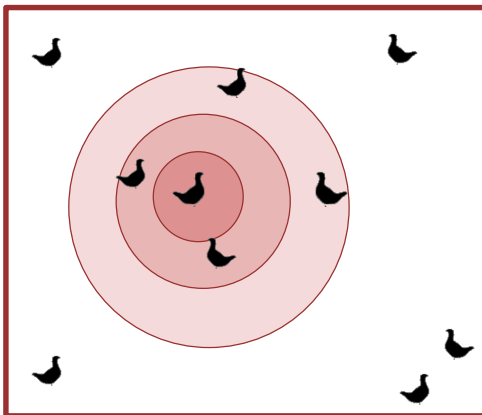
I. Modeling the active spaces

- Spread Gis   an ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting   *(SE Reed, JL Boggs & JP Mann, 2012)*

I. Modeling the active spaces

- ## Spread Gis

an ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting *(SE Reed, JL Boggs & JP Mann, 2012)*
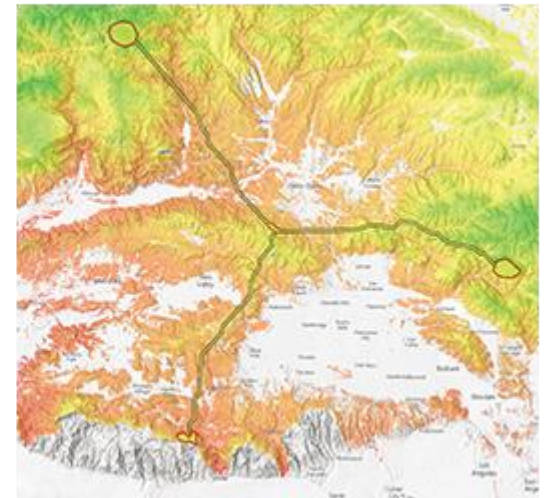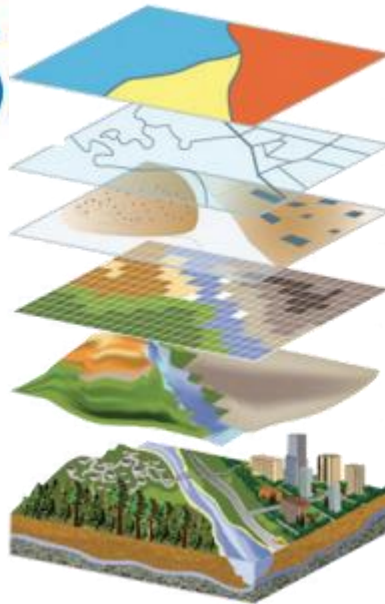
SPreAD calculation method to predict the propagation of noise and eight one-third octave frequency bands (400, 500, 630, 800, 1000, 1250, 1600, and 2000 Hz) in all directions throughout the area of interest.

The SPreAD calculation introduces 5 factor that influences how sound propagates through space

1. Spherical Spreading Loss
2. Atmospheric Absorption
3. Foliage & Ground Cover Loss
4. Upwind & Downwind Loss
5. Ground Effects

digital elevation model (DEM)

I. Modeling the active spaces

- ## Spread Gis
an ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting   *(SE Reed, JL Boggs & JP Mann, 2012)*

Ski resort of Flaine (Haute-Savoie, France).
Here at 2500m lives a population of Rock Ptarmigan
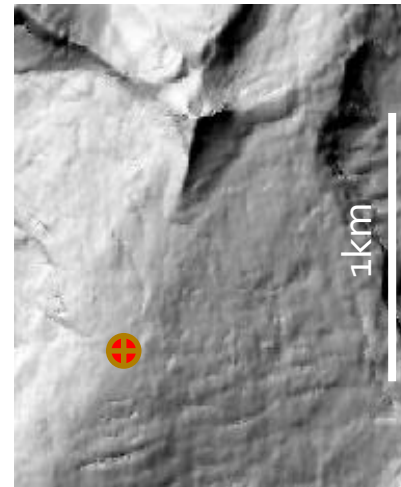
Topography (DEM)
the source location
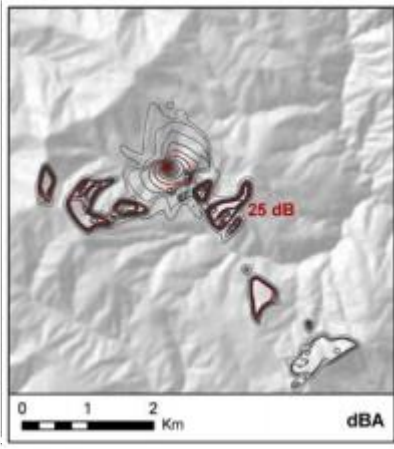environmental condition

Land Cover

I. Modeling the active spaces

■ **Spread Gis**   an ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting   *(SE Reed, JL Boggs & JP Mann, 2012)*

Ski resort of Flaine (Haute-Savoie, France).
Here at 2500m lives a population of Rock Ptarmigan

Topography
the source location
environmental condition

Active space for 1000Hz

Propagation of frequency
bands 1000 Hz

The sound pressure level (dB) is obtained for each pixel (30mx30m) of the map, for an intensity of 100dB at the emission point. The model takes into account elevation, land cover, temperature, wind direction and intensity.
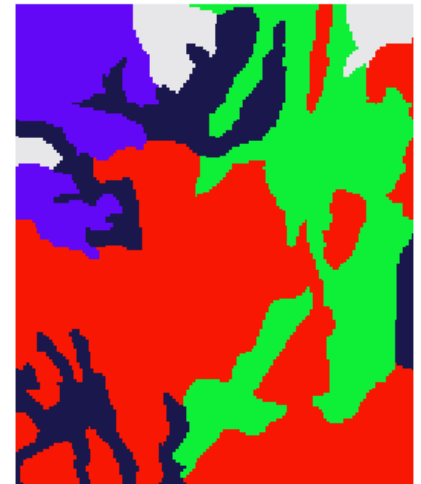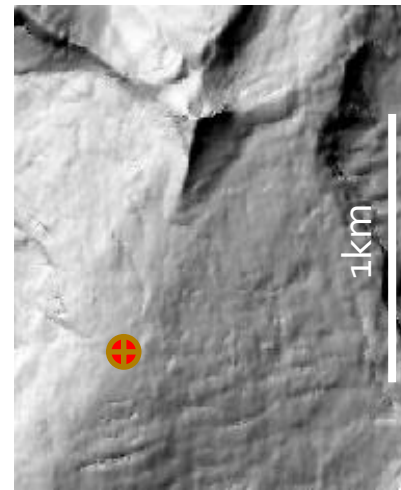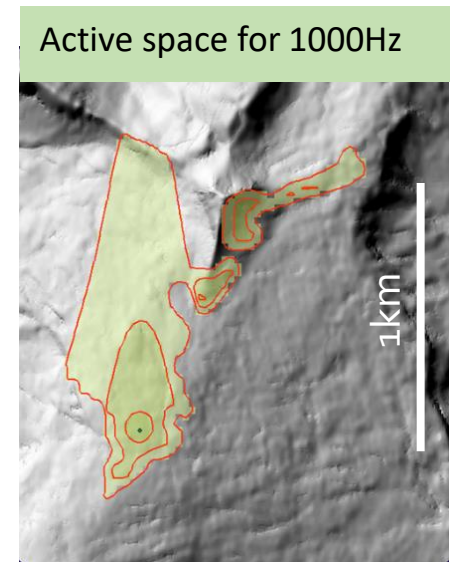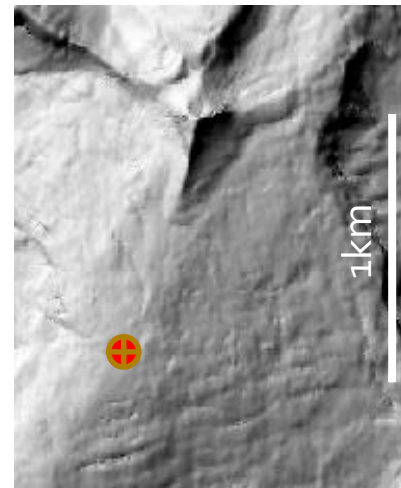
I. Modeling the active spaces

■ **Spread Gis**   an ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting   *(SE Reed, JL Boggs & JP Mann, 2012)*

Ski resort of Flaine (Haute-Savoie, France).
Here at 2500m lives a population of Rock Ptarmigan

Active space for 1000Hz

Topography
the source location
environmental condition

Propagation of frequency
bands 1000 Hz

What happens to the Rock Ptarmigan's song ?

I. Modeling the active spaces

- Propagation experiments

Ski resort of Flaine (Haute-Savoie, France).
Here at 2500m lives a population of Rock Ptarmigan

I. Modeling the active spaces

- ## Propagation experiment

Ski resort of Flaine (Haute-Savoie, France).
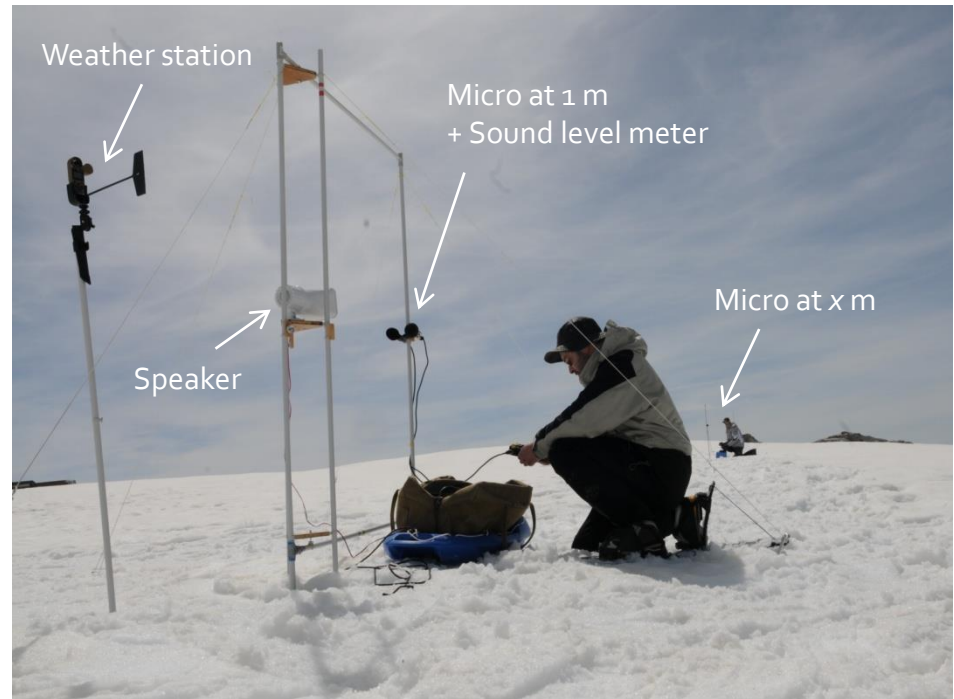Here at 2500m lives a population of Rock Ptarmigan
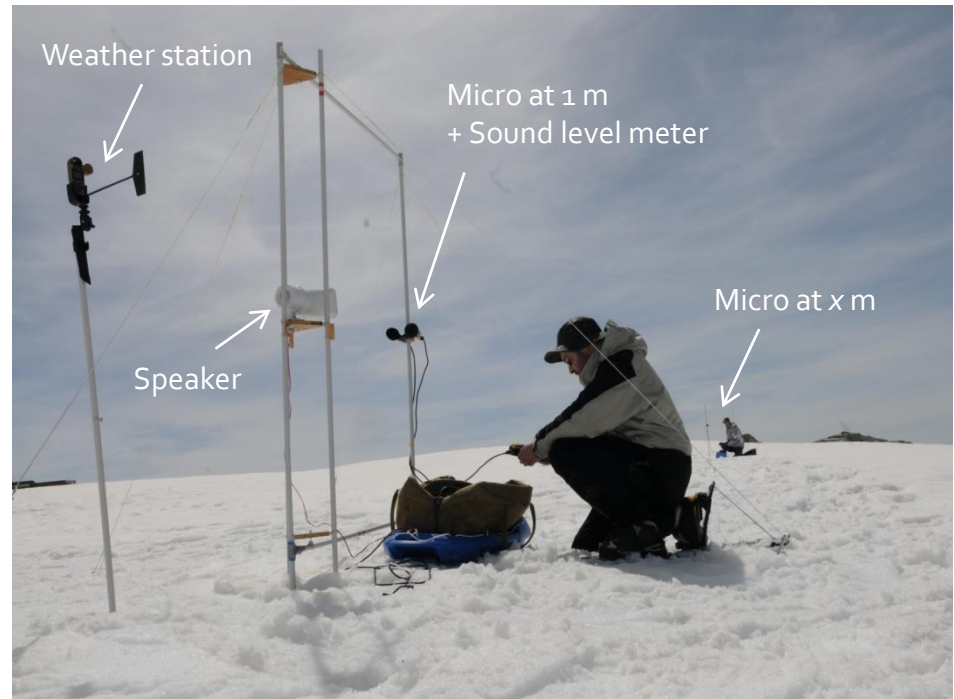

-Sound Level Meter Class 1 NL-52   (dB Z,   100 ms Lp)
-The amplifier used was a TBA 1905 with horn **s**peaker 8 Ohm
-ME 62 omni-directional microphone for K6 condenser microphone
-ZOOM H6 24bit (sampling frequency 41kHz)
-Kestrel 4500 Weather Meter |

I. Modeling the active spaces

- ## Propagation experiment

Ski resort of Flaine (Haute-Savoie, France).
Here at 2500m lives a population of Rock Ptarmigan

Weather station

Micro at 1 m
+ Sound level meter

Speaker

Micro at *x* m

Ptarmigans vocalizations and constant 1000Hz signals were broadcast towards three directions and recorded at 1, 25, 50, 100, 200, 300, 400 and 600m.

I. Modeling the active spaces

- ## Propagation experiment

Ski resort of Flaine (Haute-Savoie, France).
Here at 2500m lives a population of Rock Ptarmigan
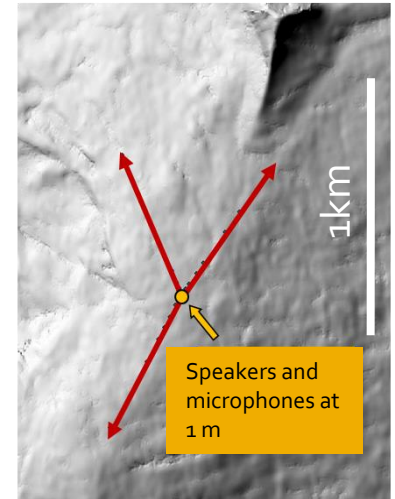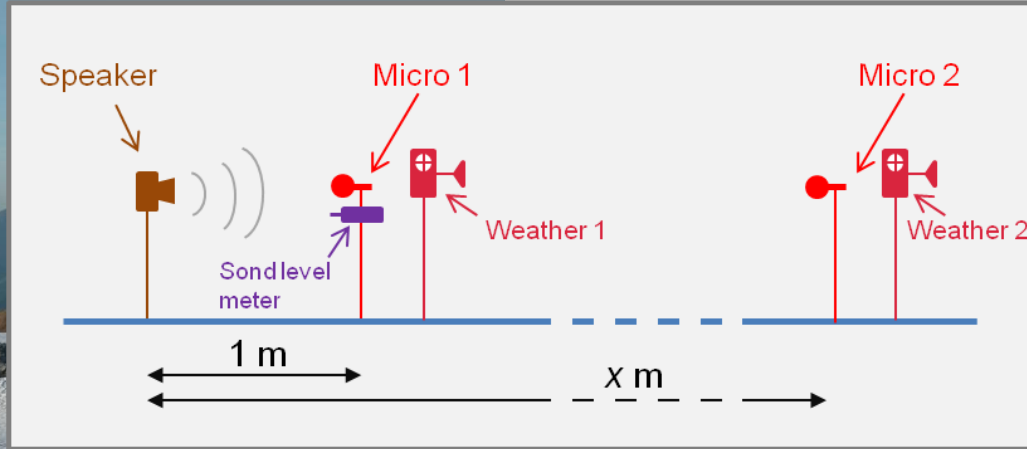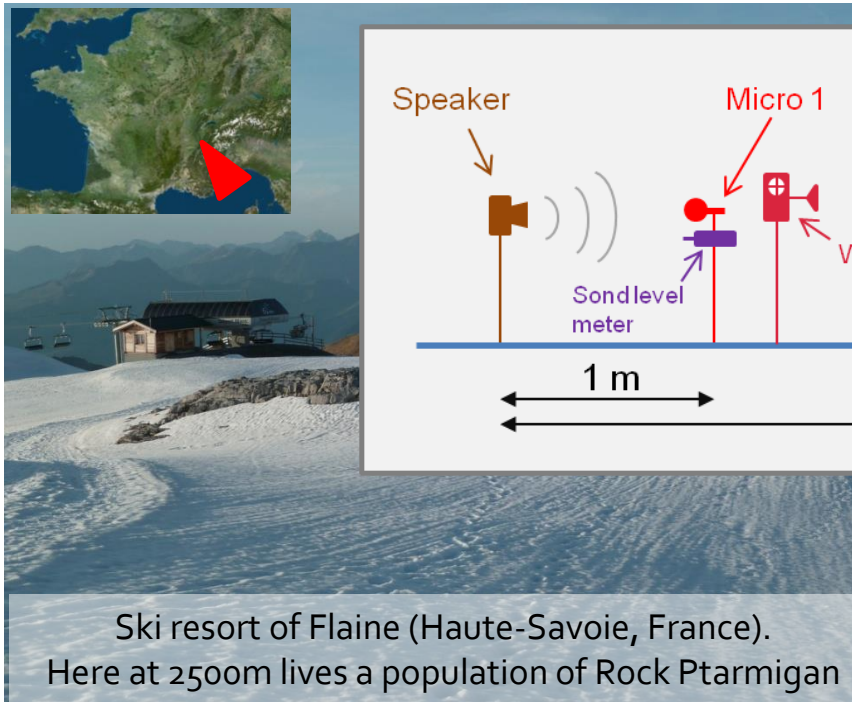
Ptarmigans vocalizations and constant 1000Hz signals were broadcast towards three directions and recorded at 1, 25, 50, 100, 200, 300, 400 and 600m.

I. Modeling the active spaces

- ## Propagation experiment

SOUNDTRACK

1000 Hz

Ptarmigan song

Amplitude

100dB

Time (s)

5 repetitions,
7 distances,
3 directions,

Nb of pulses

Ampli F1 / Ampli F2

1st group of pulses

2dd group of pulses

3rd group of pulses

F_2

F_1

Amplitude

Frequency

Time (s)

Signal/noise of 1st group
=RMS(group 1) /
RMS(noise)

Envelope du groupe 1

Envelope of noise

Time (s)

3 parameters
-Signal-to-noise ratio
1st group of pulses [log]
-Estimated number of pulses
-Amplitude ratio of the two
frequency peaks

Ptarmigans vocalizations and constant 1000Hz signals were broadcast towards three directions and recorded at 1, 25, 50, 100, 200, 300, 400 and 600m.
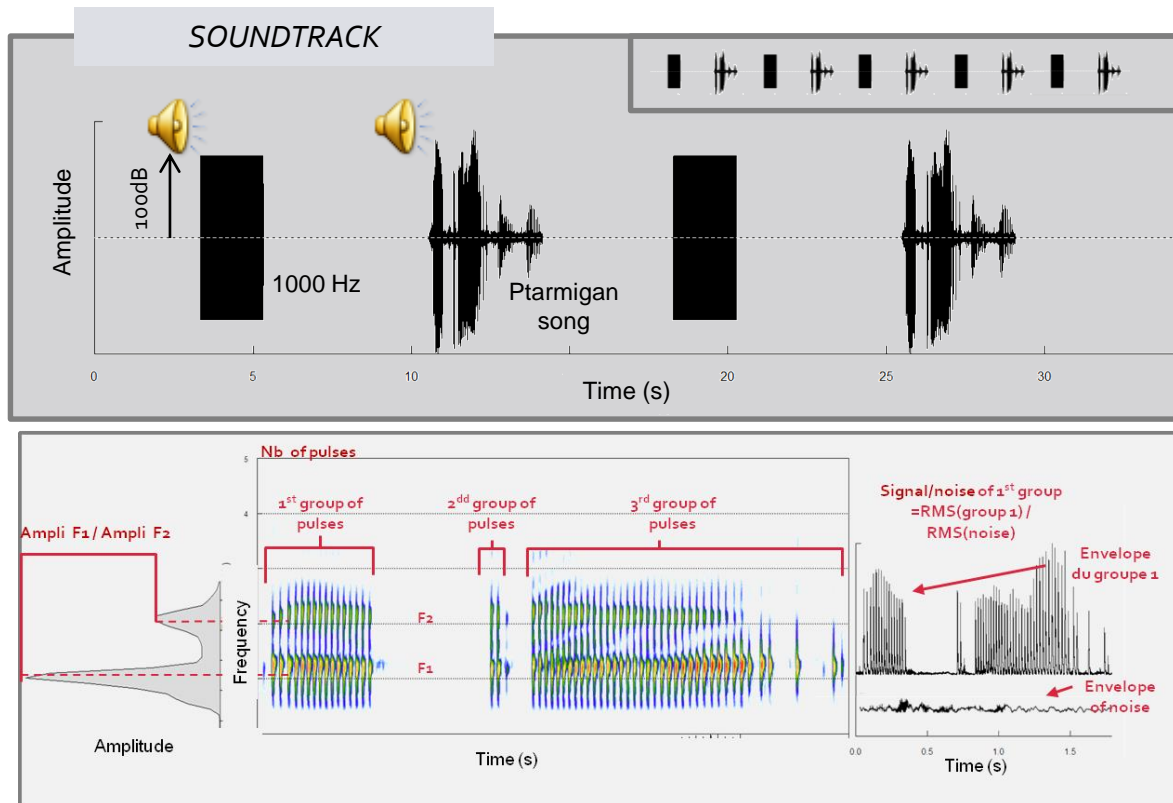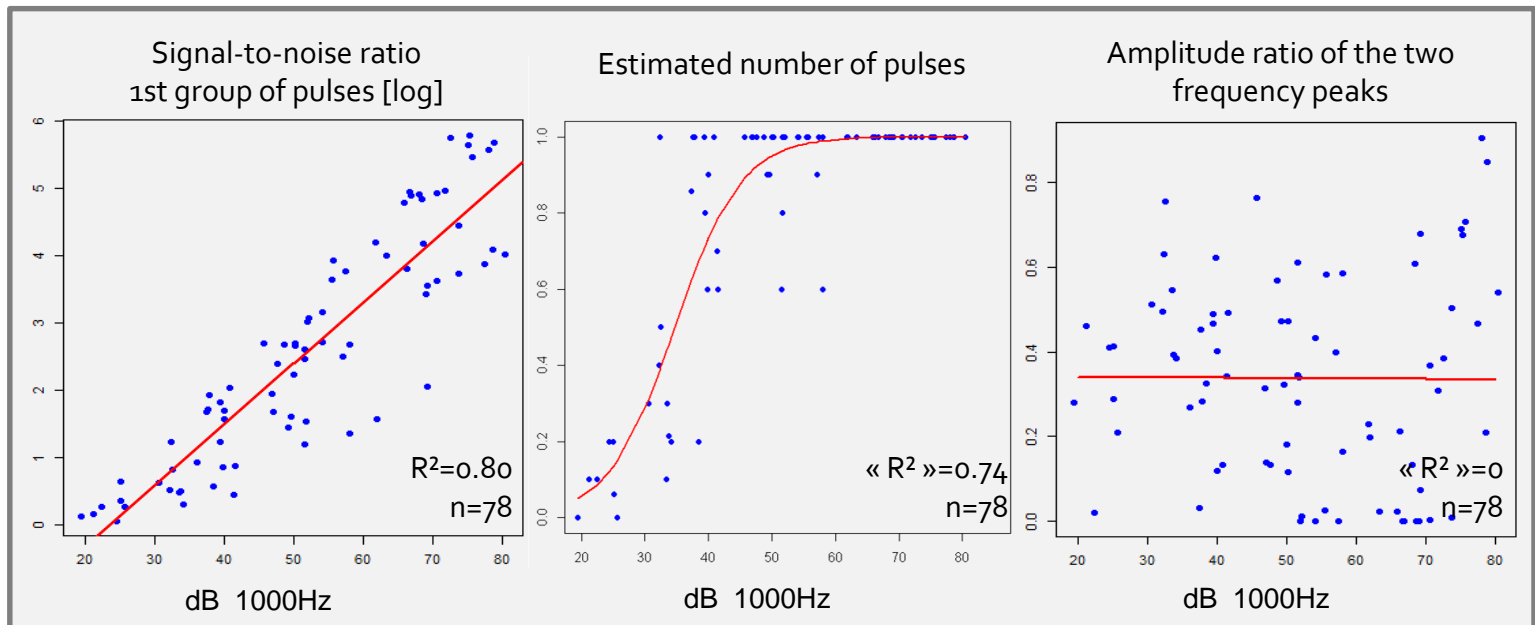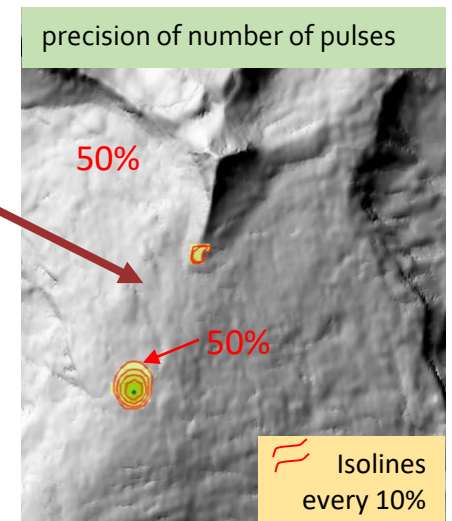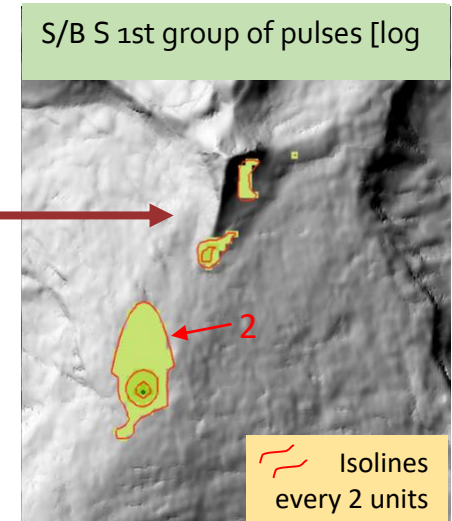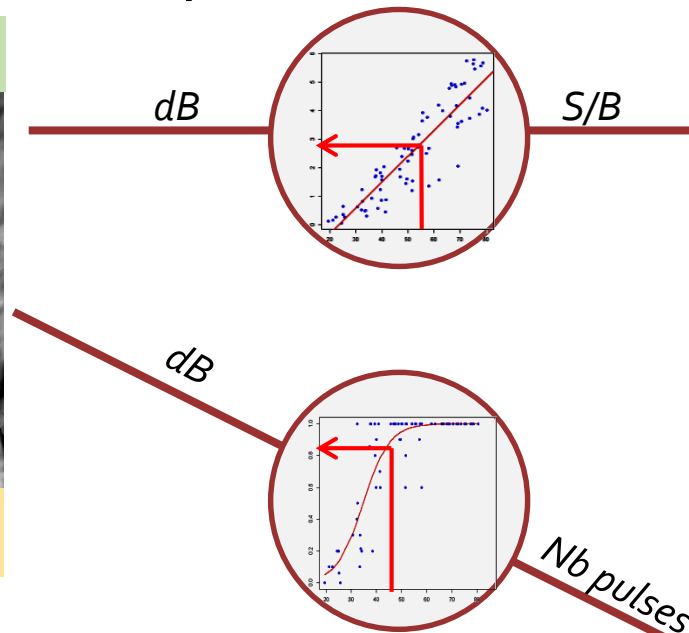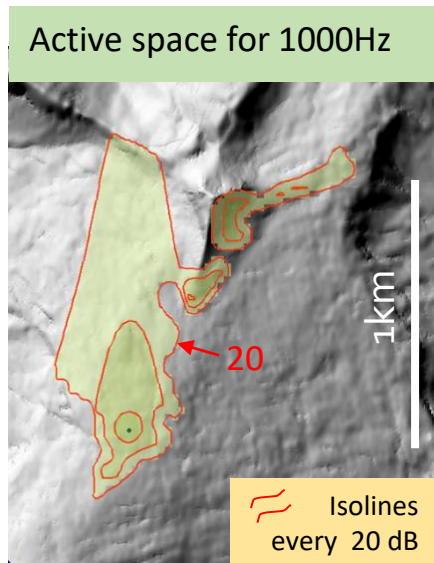
I. Modeling the active spaces

- ## Relationship between parameters degradation and 1000Hz degradation

  - The "glm" function of the R stat package
  - Depending on the shape of the point cloud, the link function used was the identity function (classical linear model), the logit function (logistic model) or the log function (Poisson model).
  - The coefficient of determination R^2 was calculated to estimate the quality of the models.

relations between the degradation of 1000Hz (in abscissas) and the degradation of the acoustic parameters (in ordinate).

Modeling the active spaces

Active space for 1000Hz

Isolines every 20 dB

dB

S/B

S/B S 1st group of pulses [log

2

Isolines every 2 units

dB

Nb pulses

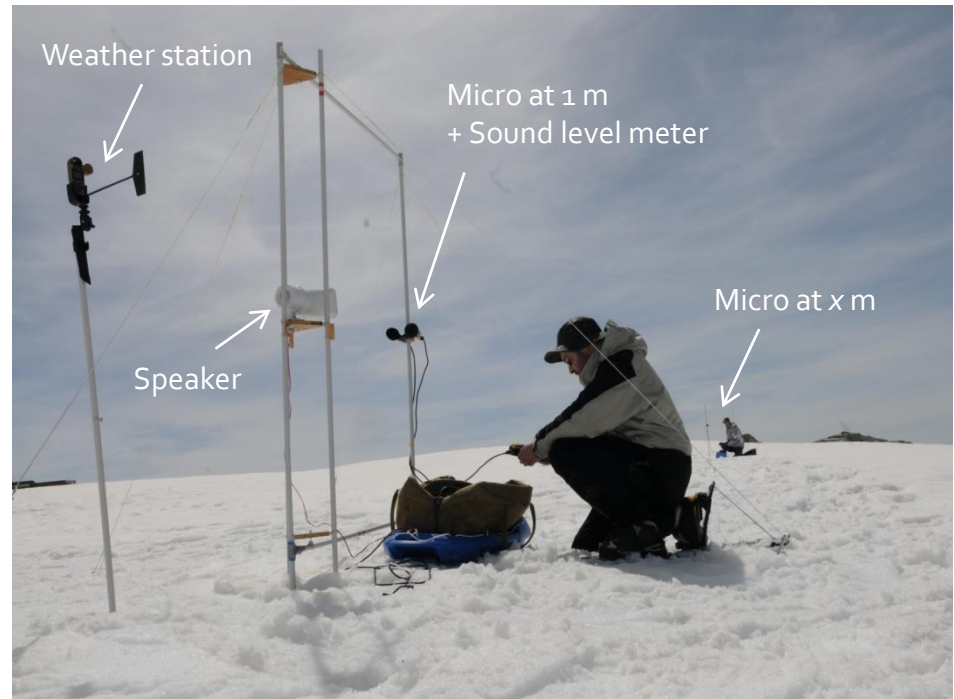precision of number of pulses

50%

50%

Isolines every 10%

→For most parameters, a relationship can be established with a 1000Hz signal, and thus their modeled propagation.
→The parameters of Ptarmigan's song do not all propagate in the same way.
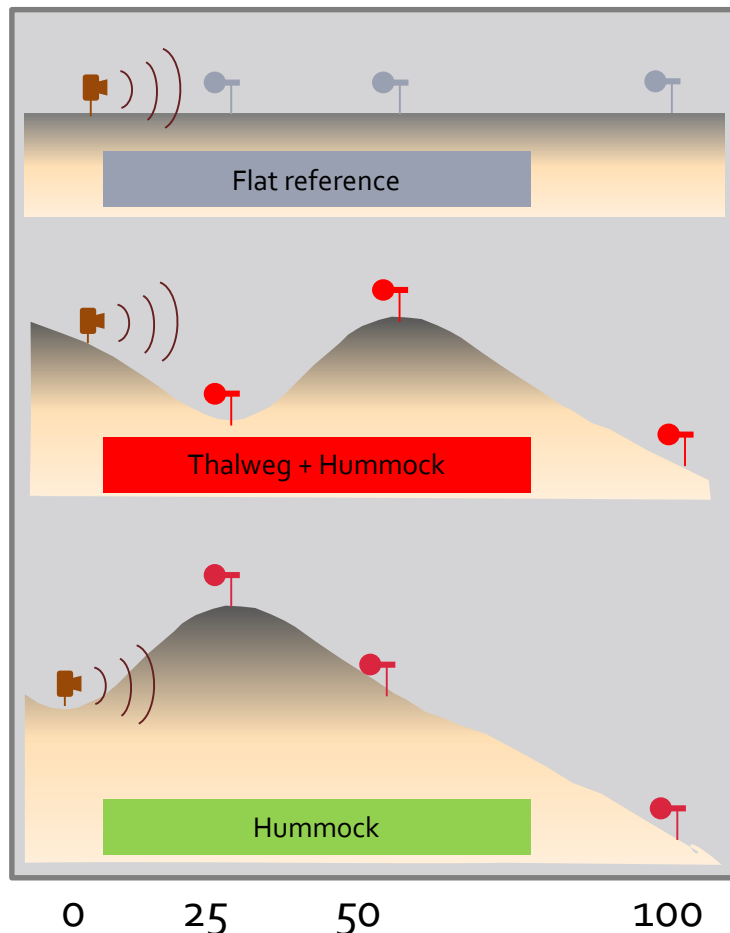→Macro variation: active space is not circular

- Propagation experiment

Ski resort of Flaine (Haute-Savoie, France).
Here at 2500m lives a population of Rock Ptarmigan

Weather station

Micro at 1 m
+ Sound level meter

Micro at *x* m

Speaker

II. Test of the micro variations of landform

- ## Propagation experiment

Flat reference

Thalweg + Hummock

Hummock

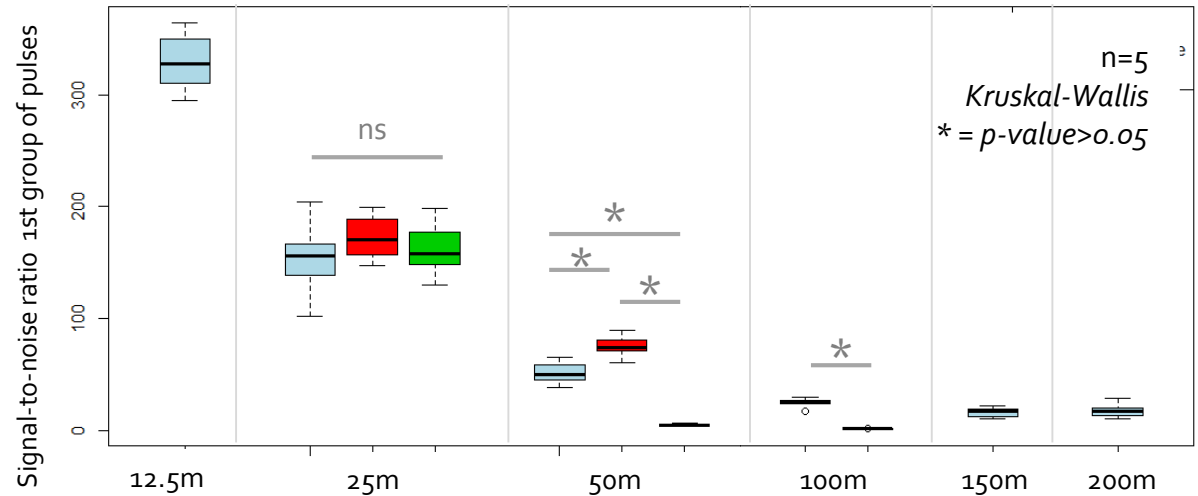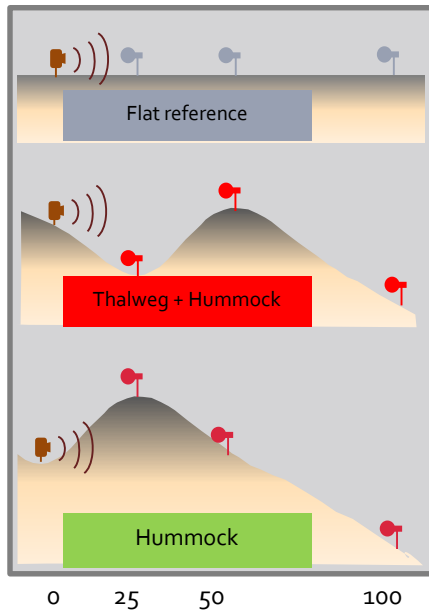0   25   50   100

-3 ways of short distance propagation

-Hummock hight of 6m

- Microphone: 25, 50 and 100m.
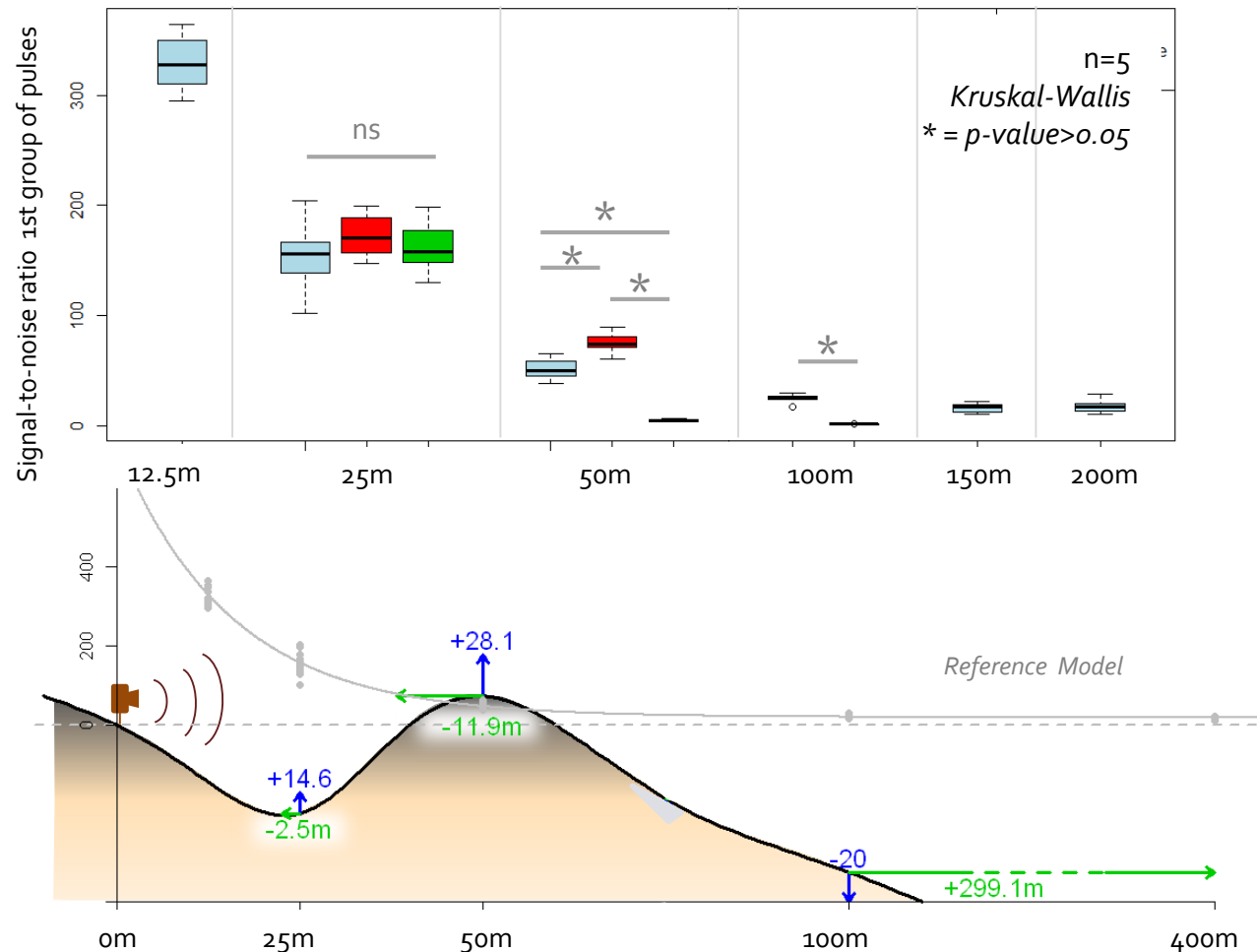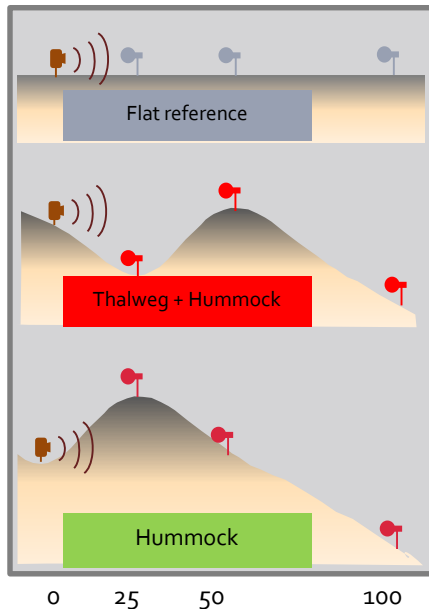
-same acoustic parameters of the studied singing

- degradation of the parameters according to the profile?
(Kruskal-Wallis at every distance)

→ All the parameters take significantly different values on the uneven paths compared to the flat reference

The degradation of the S / N ratio on the reference channel and its model (GLM) are indicated in light gray ("reference model").
The blue arrows give the difference of the value of the S / N ratio between the model and the average of the measurements with relief.
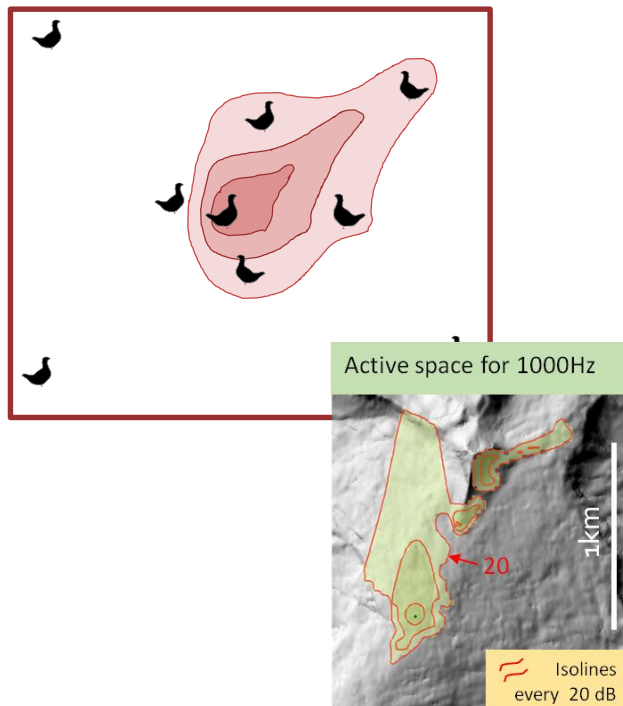The horizontal green arrows give the distance to go to adjust the value to the model
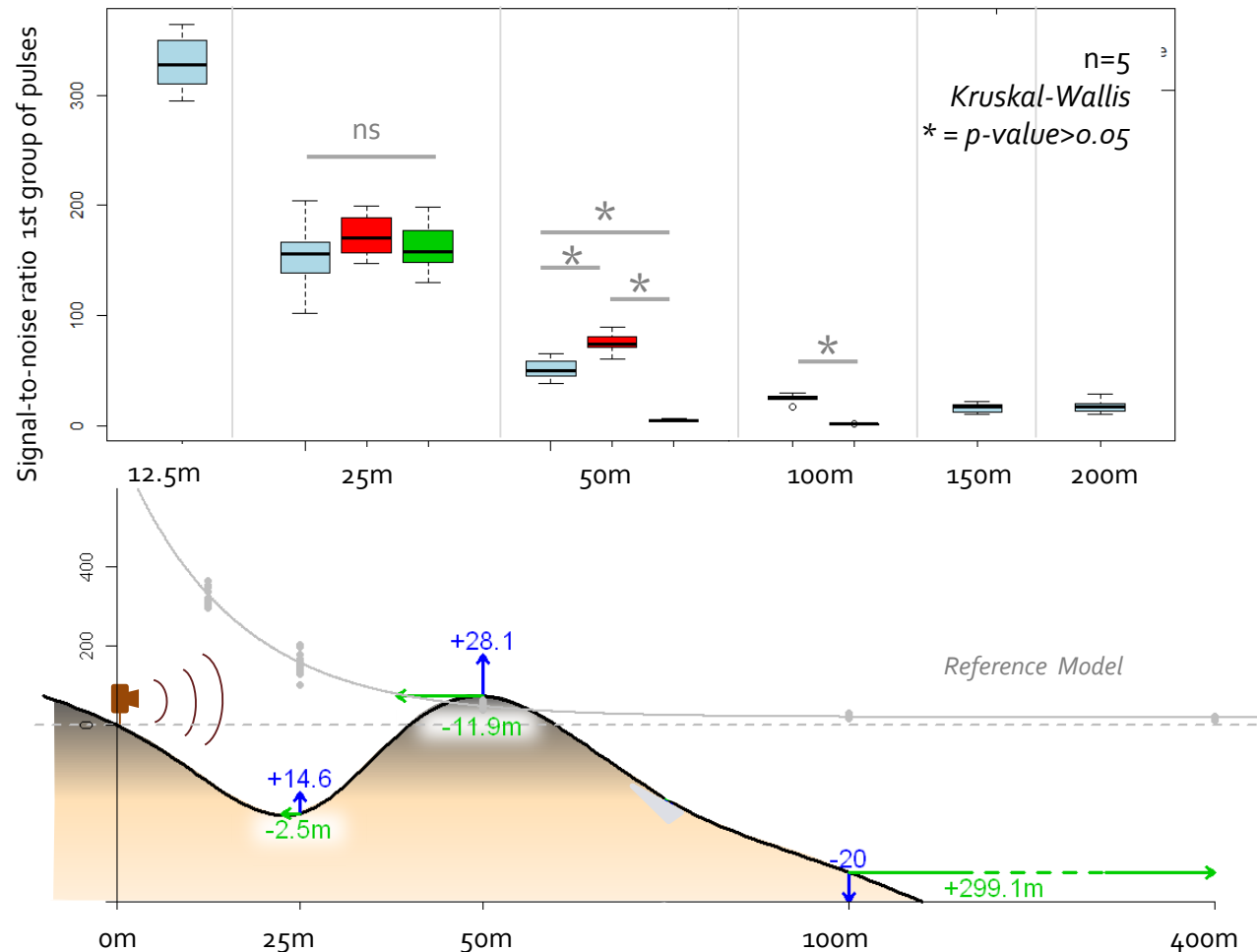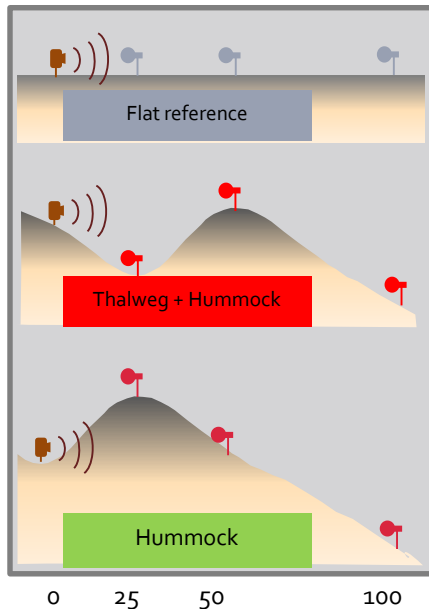
The hummock causes an accelerated degradation of the acoustic parameters of the song, equivalent to a distance of 3 hundred meters between the transmitter and the receiver.
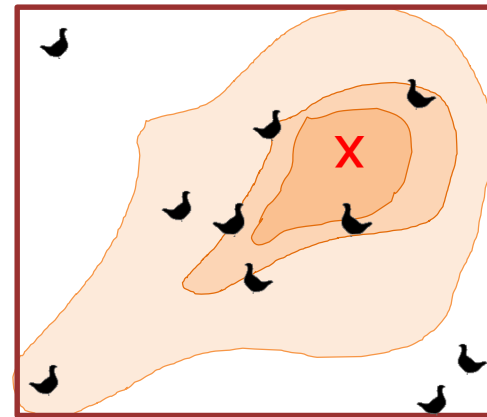
- Active and detection space

Active space= "effective" area of the signal

Detection space = Detectability area of a signal

Active space for 1000Hz

20

1km

Isolines every 20 dB

→ Modeling the detection space of an observer point

■ Spread Gis   ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting   *(SE Reed, JL Boggs & JP Mann, 2012)*

-Modeling the active space for a large number of points

-A grid of points is created on the study area (they were taken every 100m to be precise enough while keeping a reasonable calculation time)

-Concanetation of all active space for each detection threshold (ArcGIS, "model builders")
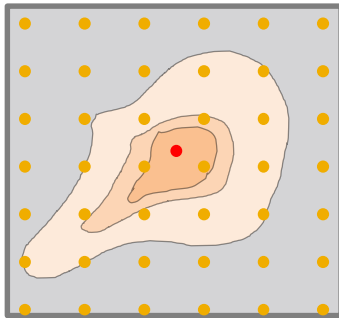
-The contour lines are represented

- ## Spread Gis   ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting   *(SE Reed, JL Boggs & JP Mann, 2012)*

-Modeling the active space for a large number of points

-A grid of points is created on the study area (they were taken every 100m to be precise enough while keeping a reasonable calculation time)

-Concanetation of all active space for each detection threshold (ArcGIS, "model builders")

-The contour lines are represented

- ## Spread Gis

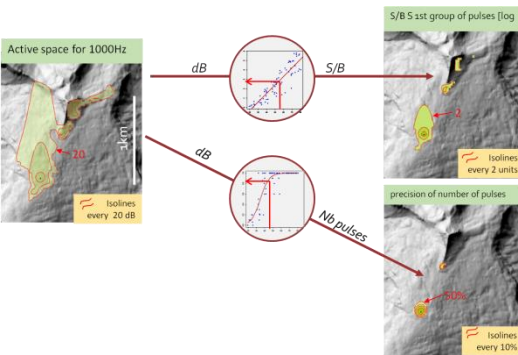| Active space for 1000Hz	dB of 1000Hz	S/B S 1st group of pulses [log	Precision of number of pulses

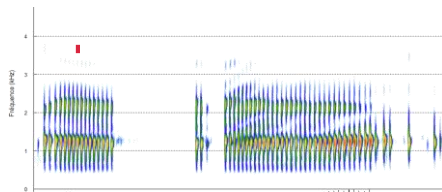the red curves indicate a constant level of the parameter.

→ It is clear that they do not delimit circular surfaces.

→ the active space and the detection space are slightly different
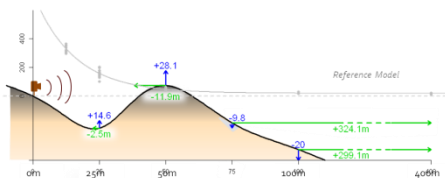
Discussion conclusion

• The active spaces of a bird's song can be modeled as long as the relationships between the acoustic parameters and a constant signal are established.
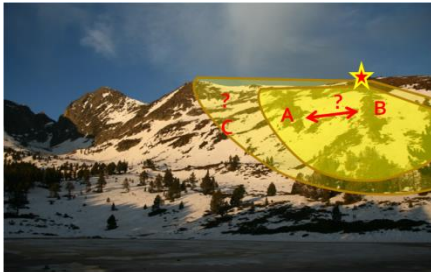

• The parameters of a Ptarmigan's song do not all propagate in the same way.

• The relief (and any obstacle micro and macro relief) strongly modifies the shape of the active and detection spaces.

Discussion conclusion

- ## Censusing

•Take into account the reality of acoustic propagation in the calculation of the listening surface or the probability of detection during censusing.
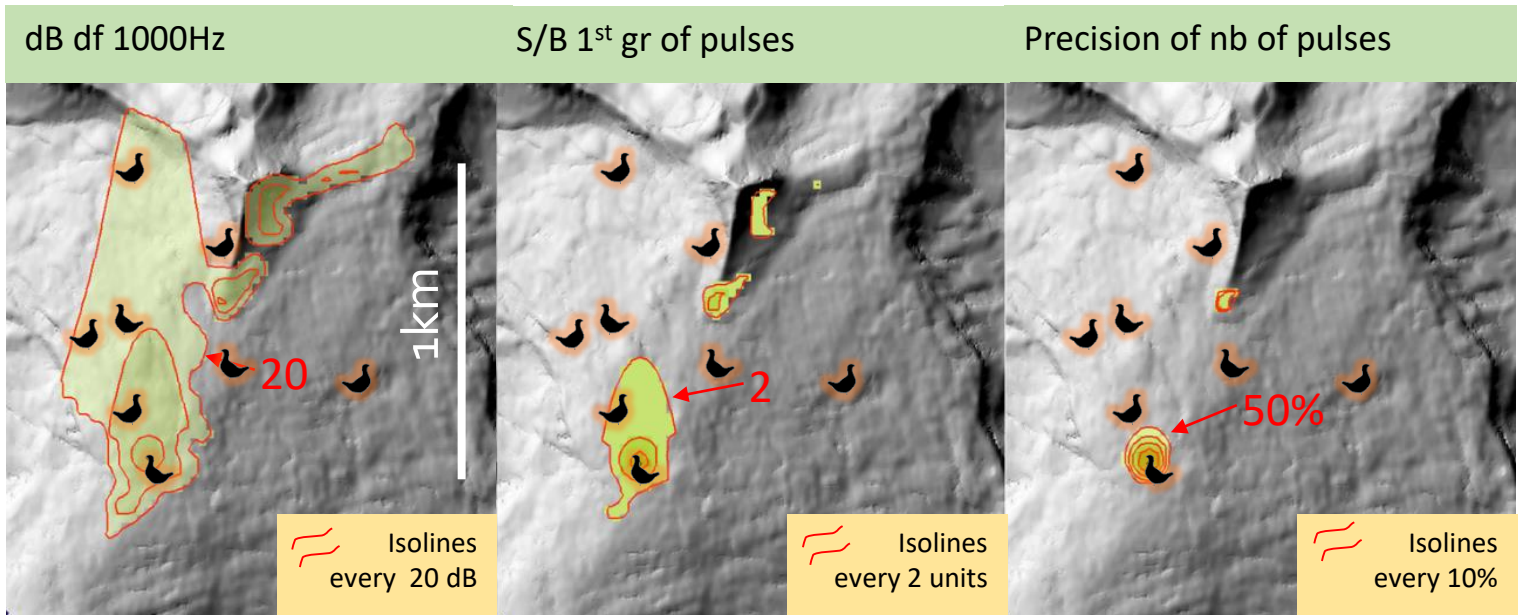
•Use the concept of detection space for the human ear, to specify the area covered by each participant

•Estimate the area of double counting between different listening stations

Discussion conclusion

- ## Network communication

| dB df 1000Hz	S/B 1ˢᵗ gr of pulses	Precision of nb of pulses

-There are consequences on the transmission of information (few parameters likely to carry information do not propagate the same way)
-There are consequences on the organization of the network communication
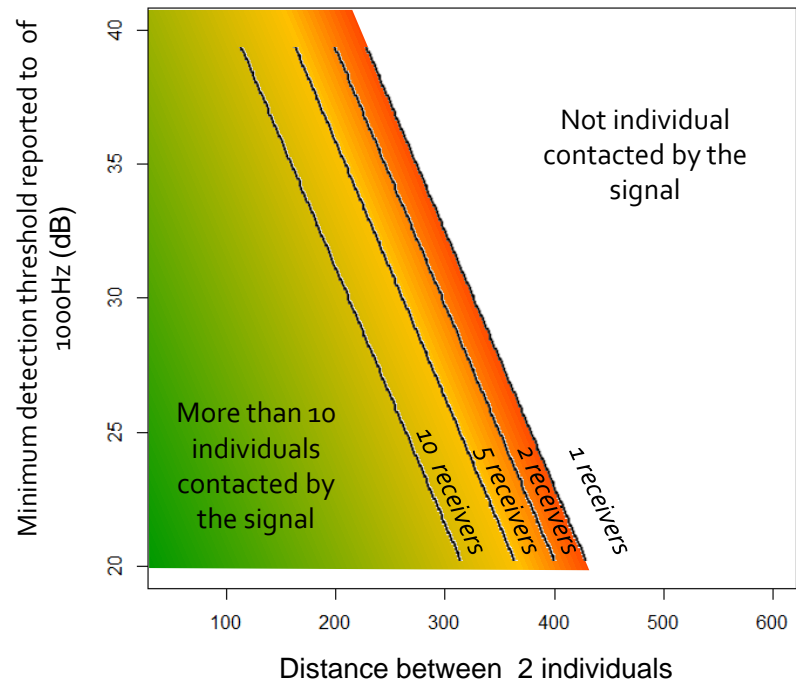
Discussion conclusion

- ## Network communication

Simulations of populations with variable density and distribution
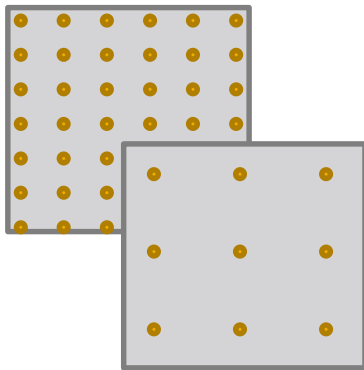
100 to 2.8 individuals / km²

distances of 100m to 600m between individuals, which is realistic for our pop

The average number of individuals in the detection space was recorded (by a Model Builder in ArcGIS).
A generalized linear model (GLM with a fish law) was then constructed to explain this number as a function of density and minimum threshold.

Discussion conclusion

- ## Network communication
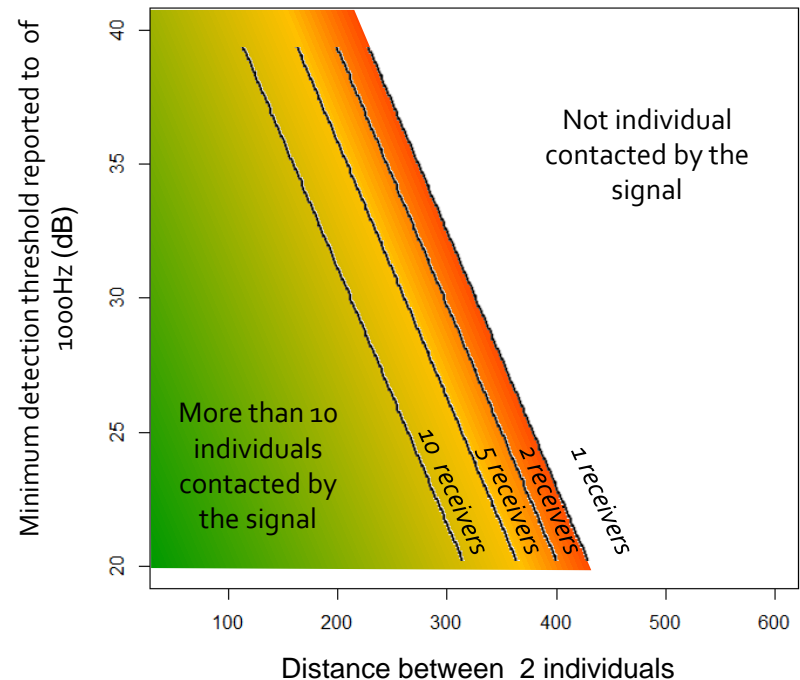
An individual transmitter is unlikely to be heard by at least two receivers if they do not fly

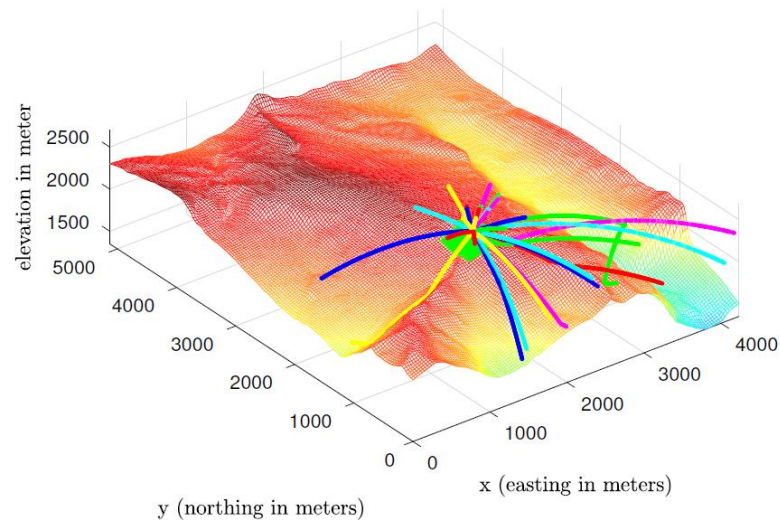# Current project and prospects

- ## Collaboration :   D.DRAGNA & S. OLLIVIER

Laboratoire de Mécanique des Fluides et d'Acoustique - UMR 5509

L. Berger :Master internship,

3D Ray tracing approach

- Collaboration :   D.DRAGNA & S. OLLIVIER

Laboratoire de Mécanique des Fluides et d'Acoustique - UMR 5509

L. Bereger :Master internship,

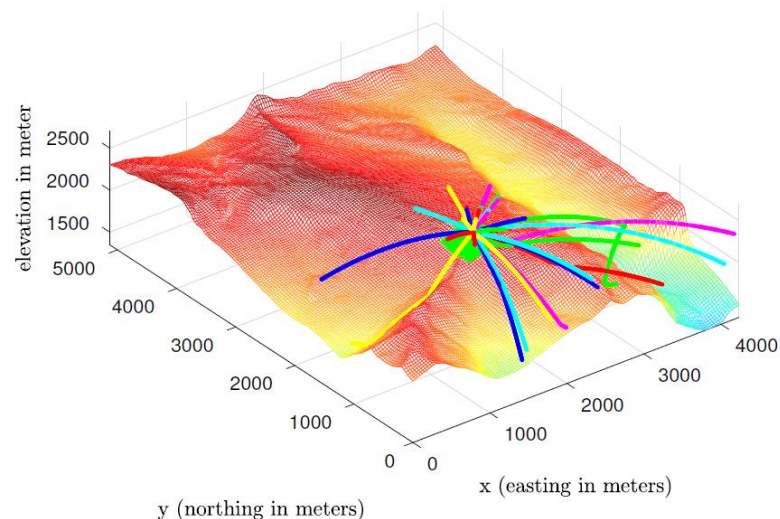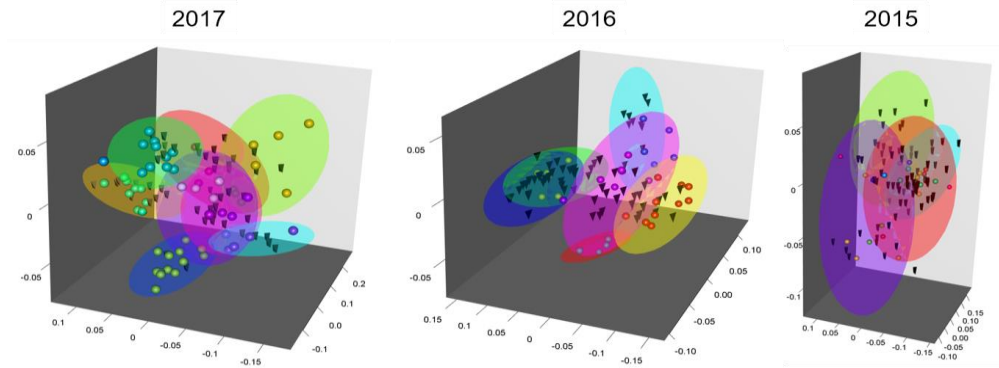• Best and more precise model of active and detection space
• Having the signals after propagation to analyze information loss
• Model the active space of the information and not only of the structure

Current project and prospects

- ## Individual signature
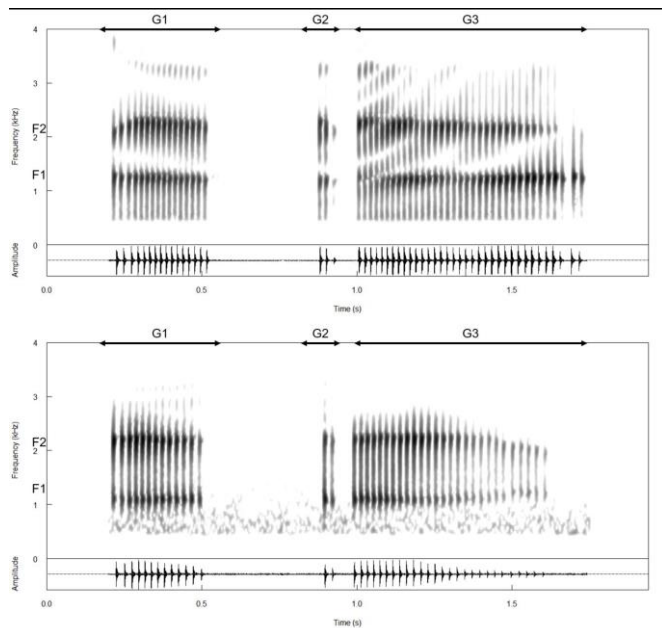
-Extraction song and parameters
-wavelet continuous transform (Morlet wavelet R package)
-Discrimination with powered partial least squares discriminant analysis (PPLS-DA; "pls" R package)
-Classification unsupervised classification method (high dimensional data clustering HDDC)

(PhD of T Marin-Cudraz)

Current project and prospects

- ## Individual signature
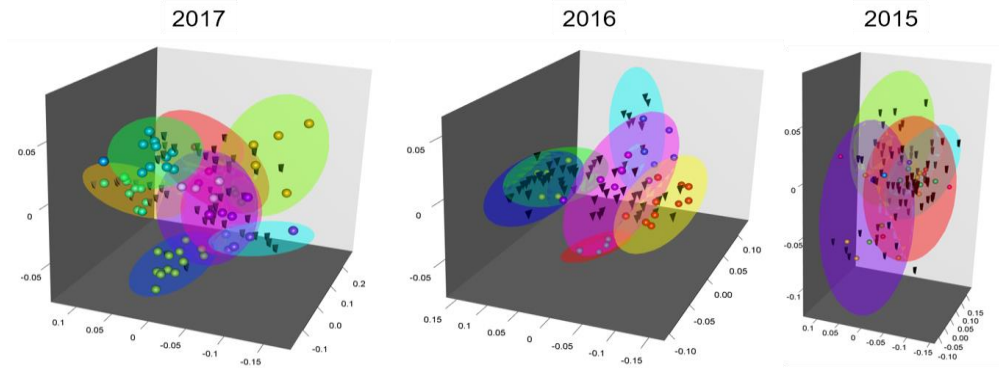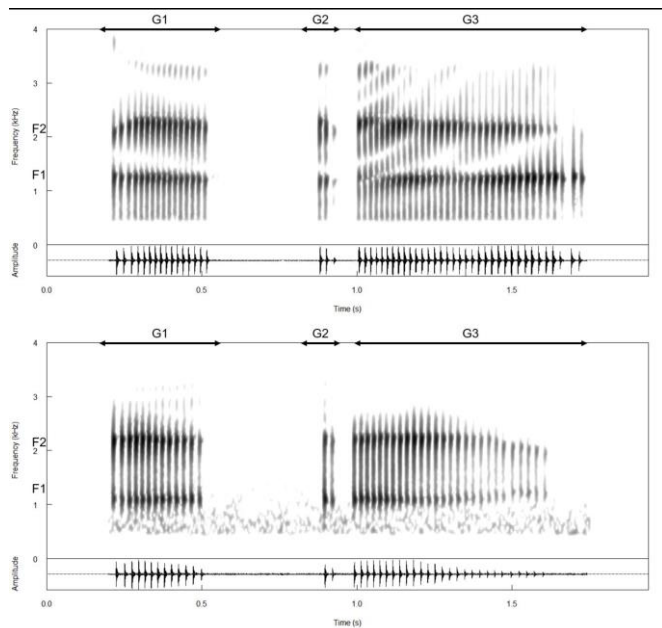
→ Develop and test an alternative censusing approach based on bioacoustics and compared it with the already existing point count protocol.

(PhD of T Marin-Cudraz)

Current project and prospects

- *automatic acoustic recorder*

-Vocalizations phenology
-Automatic censusing
-locate and track vocalizations
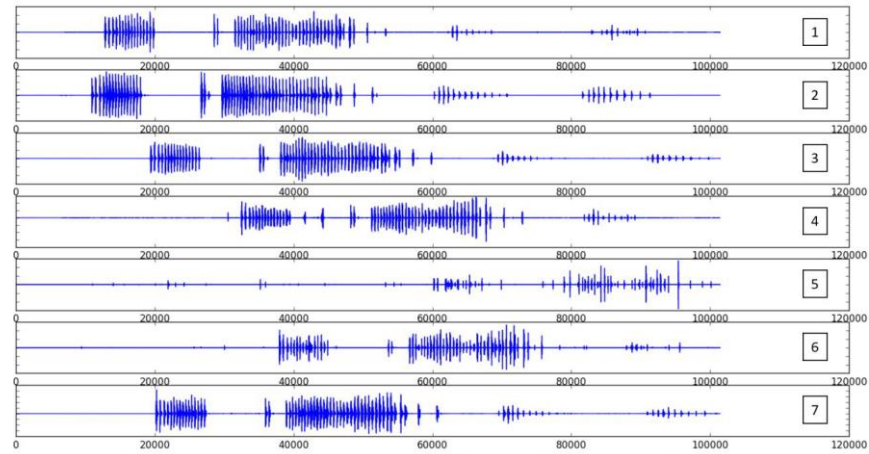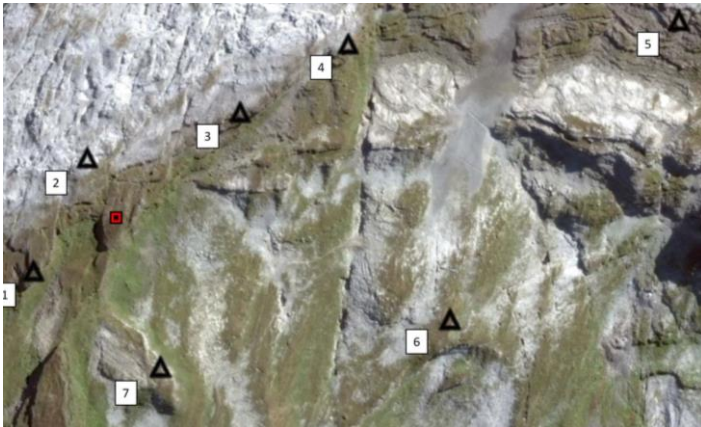-Source localization by acoustic triangulation

→ Surond the source (Mennill DJ. 2011)

Current project and prospects

- *Travel and territory of the male*

10g GPS solar Tags
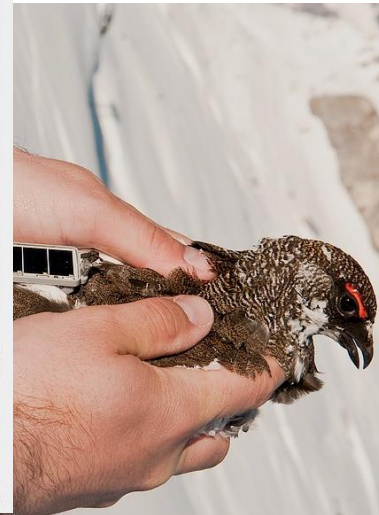
Current project and prospects
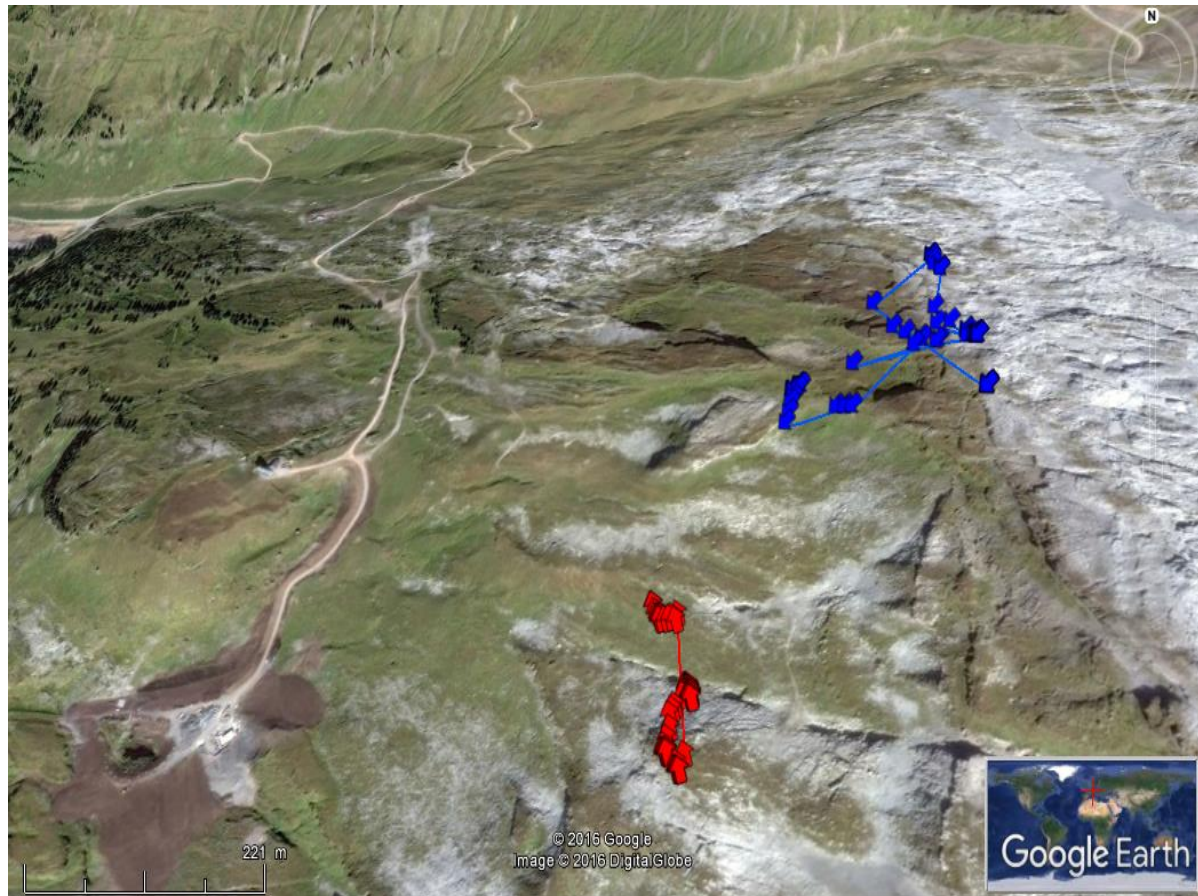
- Travel and territory of the males

- **Travel and territory of the males**

© BD Topo IGN 2015

Légende
- ○ Positions GPS Barbe Bleue 04.06.2016 (sans burst)
- ○ Positions GPS Ravanel 04.06.2016 (sans burst)
- ● Positions GPS Ravanel 03.06.2016 (sans burst)
- ● Positions GPS Barbe Bleue 03.06.2016 (sans burst)
- ▲ Emplacements des balises acoustiques
- — Transports câblé
- — Routes
- Bâtiments
- ☀ Sommets
- Zone recouverte de végétation

Echelle :
0   25   50   100 Mètres
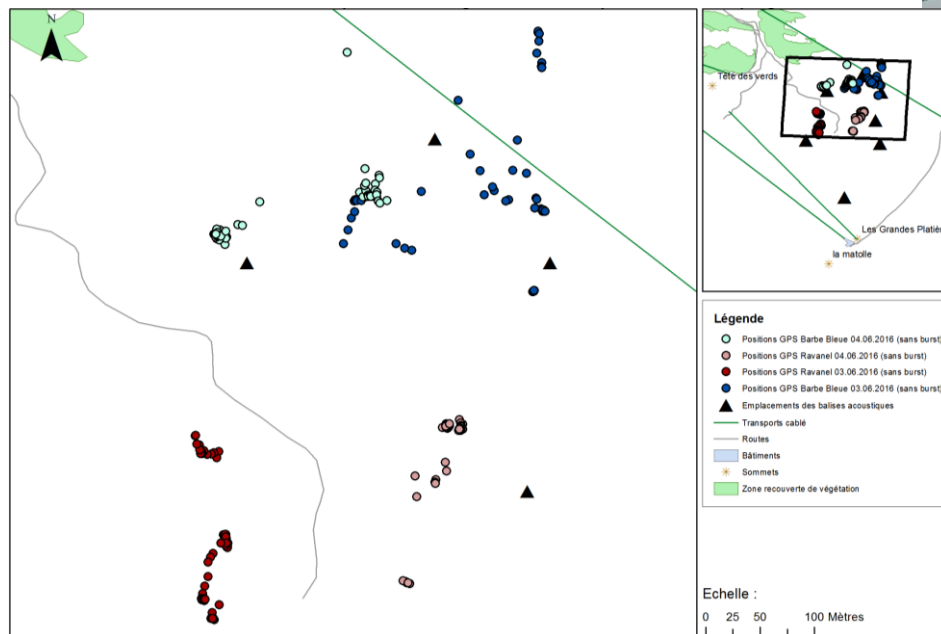
Current project and prospects

- Space-time investigation of acoustic communication networks :Global and dynamic active space with spatial and temporal active spacs

thank you for your attention

I. Modeling the active spaces

relations between the degradation of 1000Hz (in abscissas) and the degradation of the acoustic parameters (in ordinate). at. average sound leve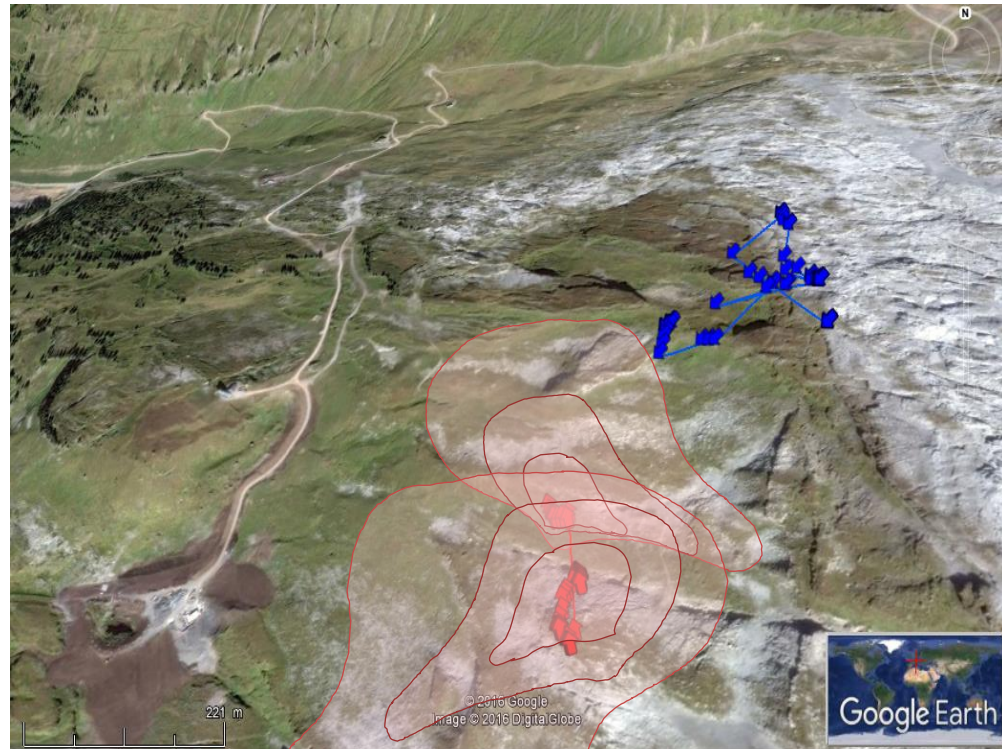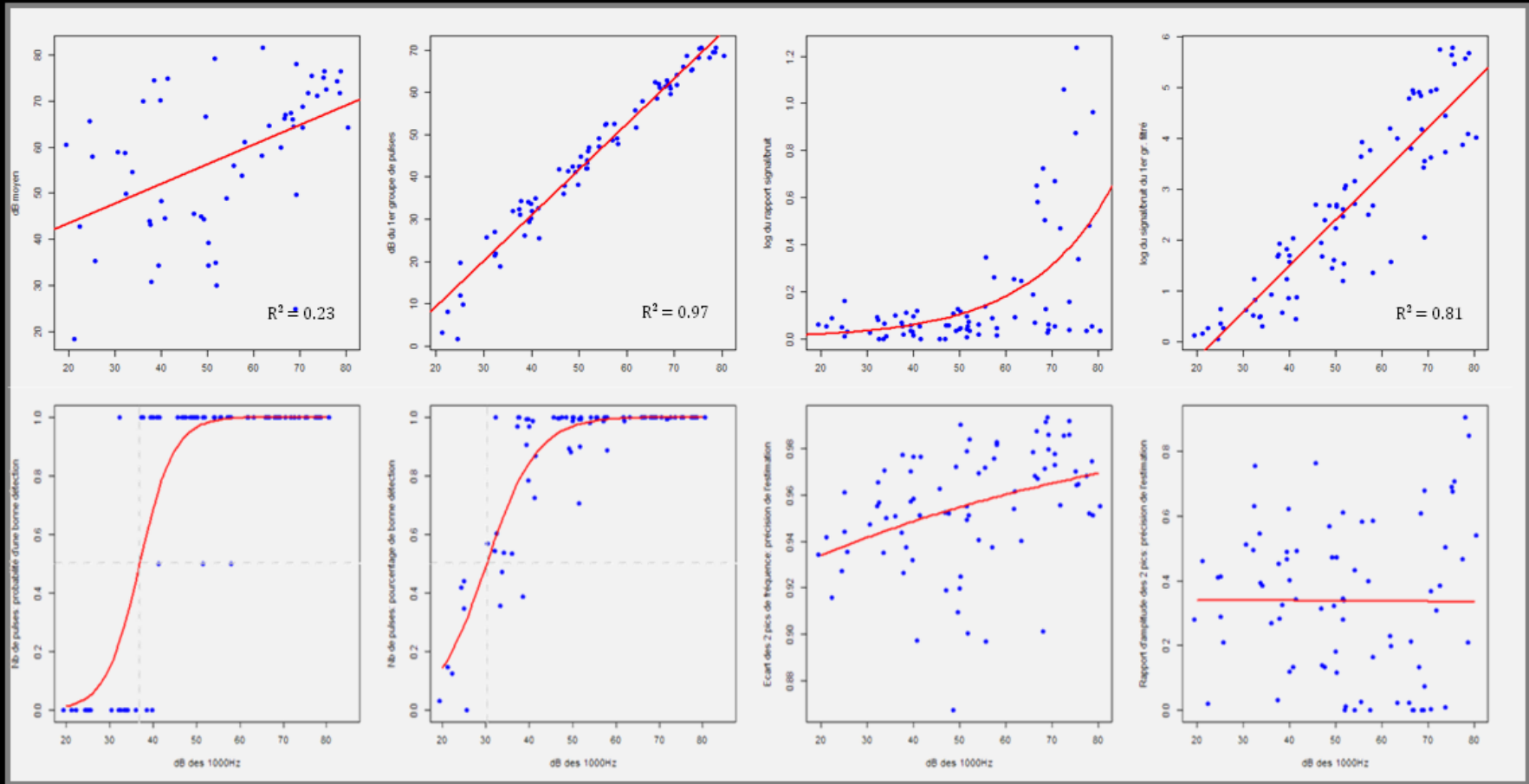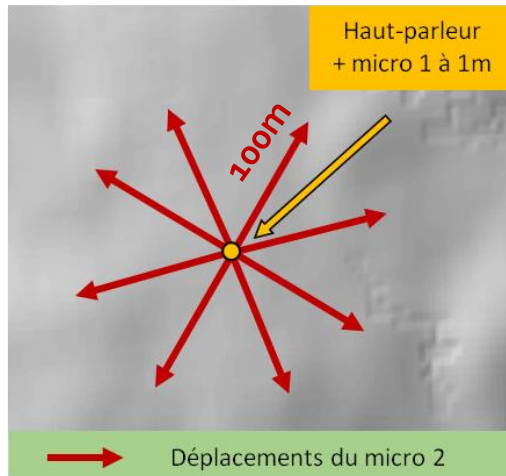l of the song (linear relation). b. sound level of the first part of the filtered song (linear relation).c. logarithm of the signal-to-noise ratio of the song (exponential relation, GLM with Poisson's law). d. logarithm of the signal-to-noise ratio of the first part of the song (linear relation). e. probability of good detection of the number of pulses that is to say coding success / failure (logistic relationship). f. precision of the estimation of the number of pulses (logistic relation). g. accuracy of the estimate of the difference between the two singing frequency peaks (logistic relationship not significant). h.accuracy of the estimate of the amplitude ratio between the two singing peaks (logistic relationship not significant).

2) Le relief et vent → les espaces actifs

Le vent rend les espaces actifs du chant de Lagopède non circulaires

- 8 voies de propagation courte distance

- micro : 12.5, 25, 50 et 100m

- 3 paramètres acoustiques du chant étudiés

- dégradation des paramètres en fonction de l'intensité et de la direction du vent? (GLM)
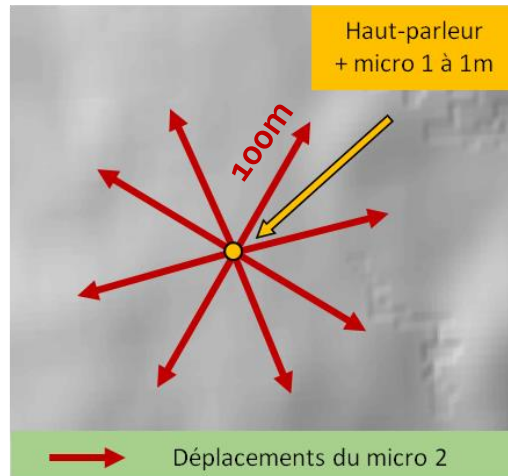
Haut-parleur + micro 1 à 1m

100m

Déplacements du micro 2

2) Le relief et vent → les espaces actifs

Le vent rend les espaces actifs du chant de Lagopède non circulaires

Haut-parleur
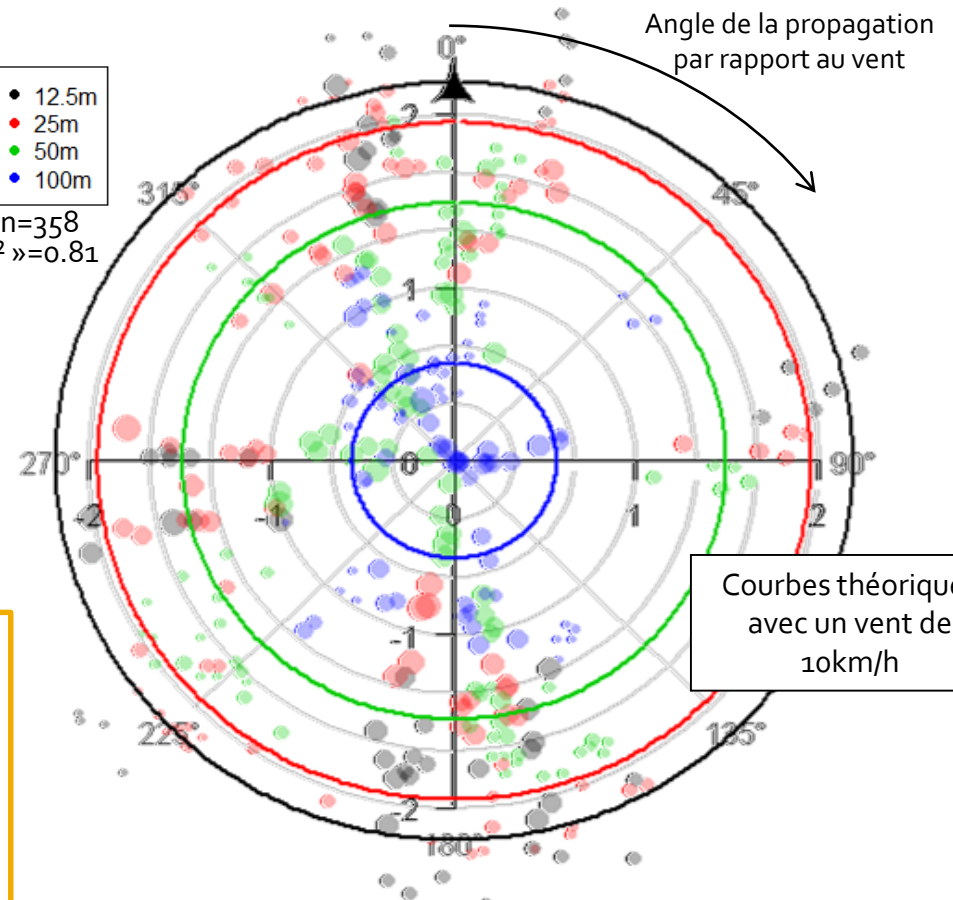+ micro 1 à 1m

100m

Déplacements du micro 2

- 12.5m
- 25m
- 50m
- 100m

n=358
« R² »=0.81

- Thématique de recherche

- Projet lagopèdes

- Espaces actifs et de détection

Angle de la propagation par rapport au vent

Courbes théoriques avec un vent de 10km/h

→ La direction du vent a peu d'influence sur la forme des espaces actifs.

→ L'intensité du vent diminue la surface de propagation dans la plupart des cas.

Signal/Bruit du 1er groupe de pulses [log]
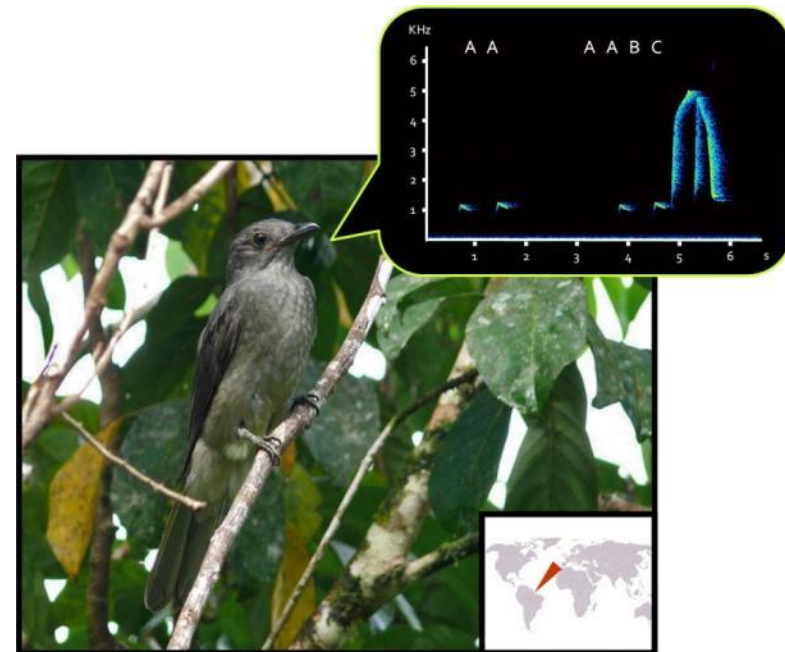Angle : direction de la propagation par rapport au vent
Taille des points: intensité du vent (5-20km/h)

Vocal communication in a lek

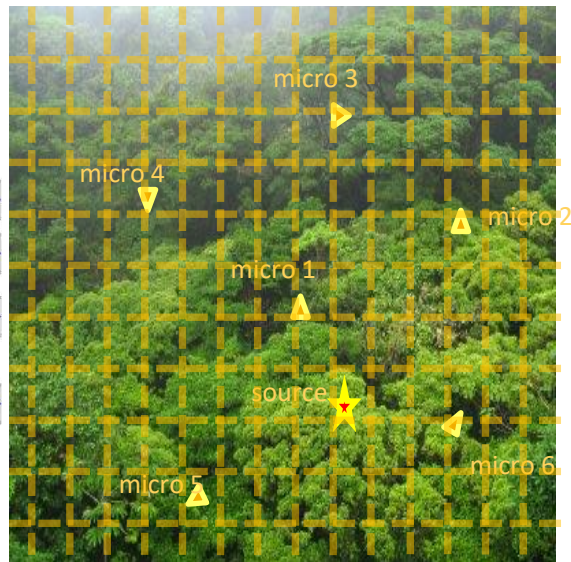aggregation of males gathered to
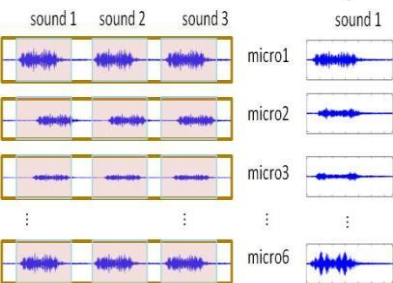engage in competitive displays

The screaming piha

Space-time investigation of acoustic communication networks
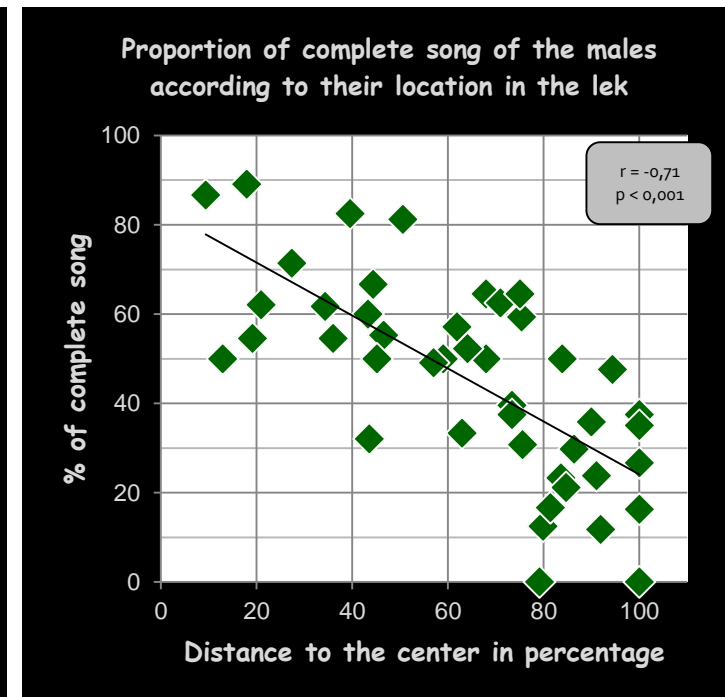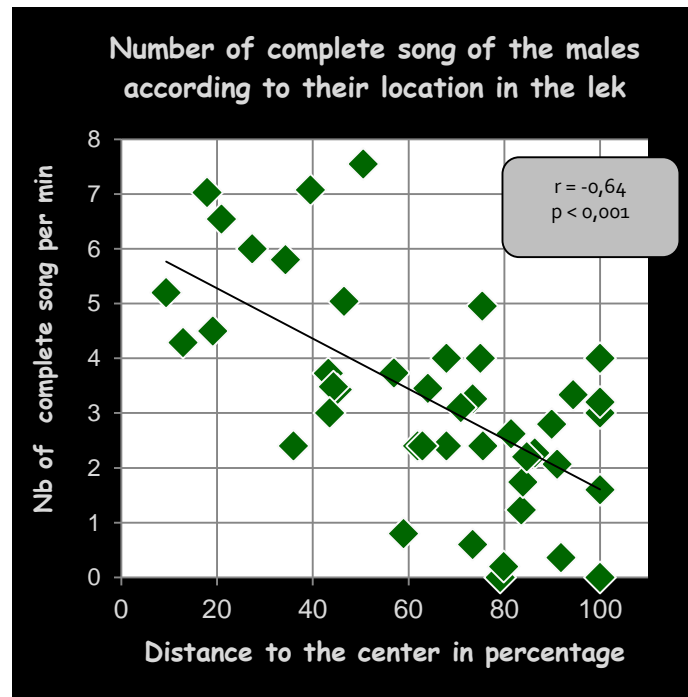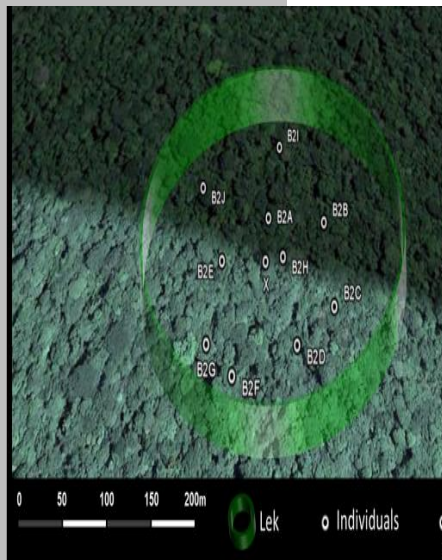

Pass band filtering and vocalisation extraction

sound 1   sound 2   sound 3   sound 1

micro1
micro2
micro3
micro6

micro 3

micro 4

micro 2

micro 1

source

micro 5

micro 6

Huetz C. & Aubin T. 2012. In
"Sensors for Ecology"

Space-time investigation of acoustic communication networks

- Vocal activity and type of vocalizations of individuals in the lek according to their location

Number of complete song of the males according to their location in the lek

r = -0,64
p < 0,001

Nb of complete song per min

Distance to the center in percentage

Proportion of complete song of the males according to their location in the lek

r = -0,71
p < 0,001

% of complete song

Distance to the center in percentage
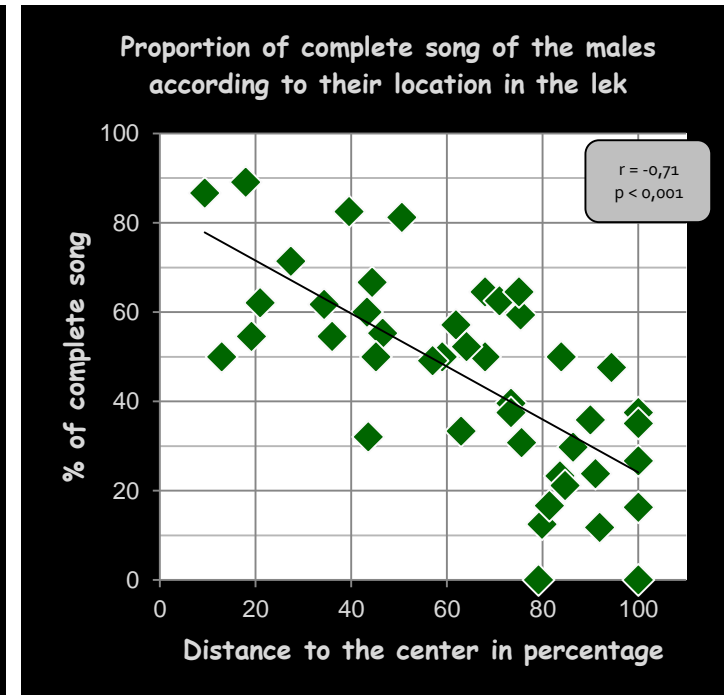
Individuals on the center of lek → sing more
→ produce more complete song

Vocal interactions in the lek depend on the dominance-subordination relationships

Space-time investigation of acoustic communication networks

• Vocal activity and type of vocalizations of individuals in the lek according to their location

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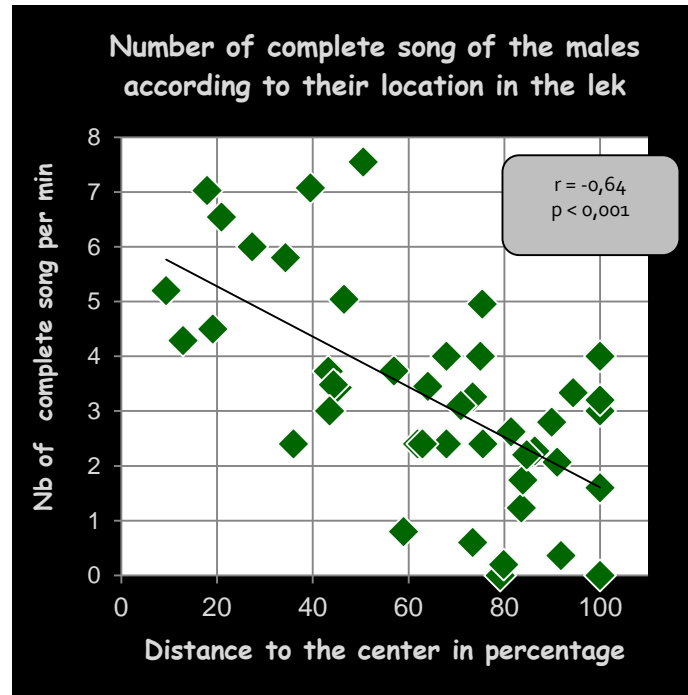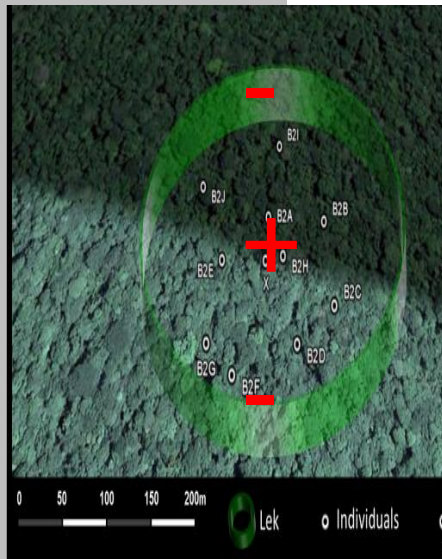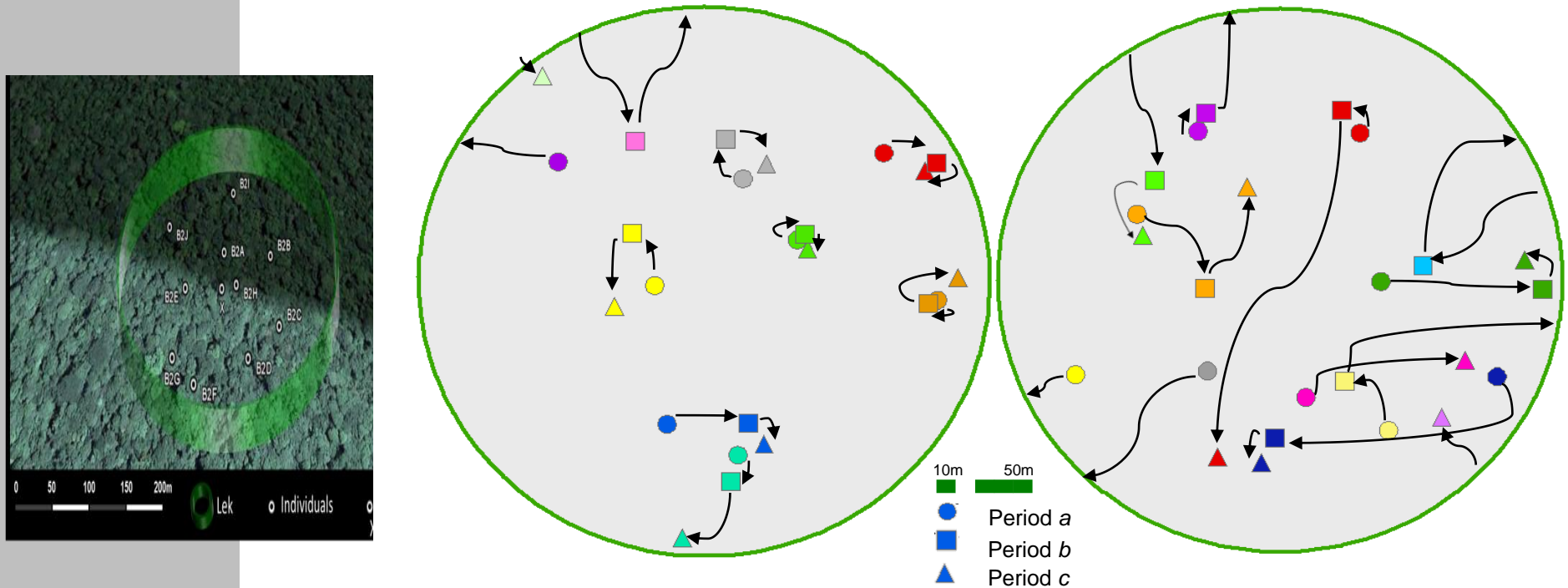Individuals on the center of lek   → sing more
                                    → produce more complete song

Vocal interactions in the lek depend on the dominance-subordination relationships

Space-time investigation of acoustic communication networks

•The dynamic of two leks.

The composition remain relatively stable during a whole year

A higher turn-over could disrupt the social order of lek and causes troubles in spatial stability.