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AGENCE NATIONALE DE LA RECHERCHE

ANR



**AGENCE
INNOVATION
DÉFENSE**

LIS

LABORATOIRE
D'INFORMATIQUE
& SYSTEMES



BOMBYX

Intelligent listening real-time sonobuoys
network for whale-ship collision mitigation,
environmental awareness & anthropophony
in Pelagos Sanctuary

2014-2029

DYNI team LIS CNRS Univ Toulon

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CNS PELAGOS
2021 - CORSE

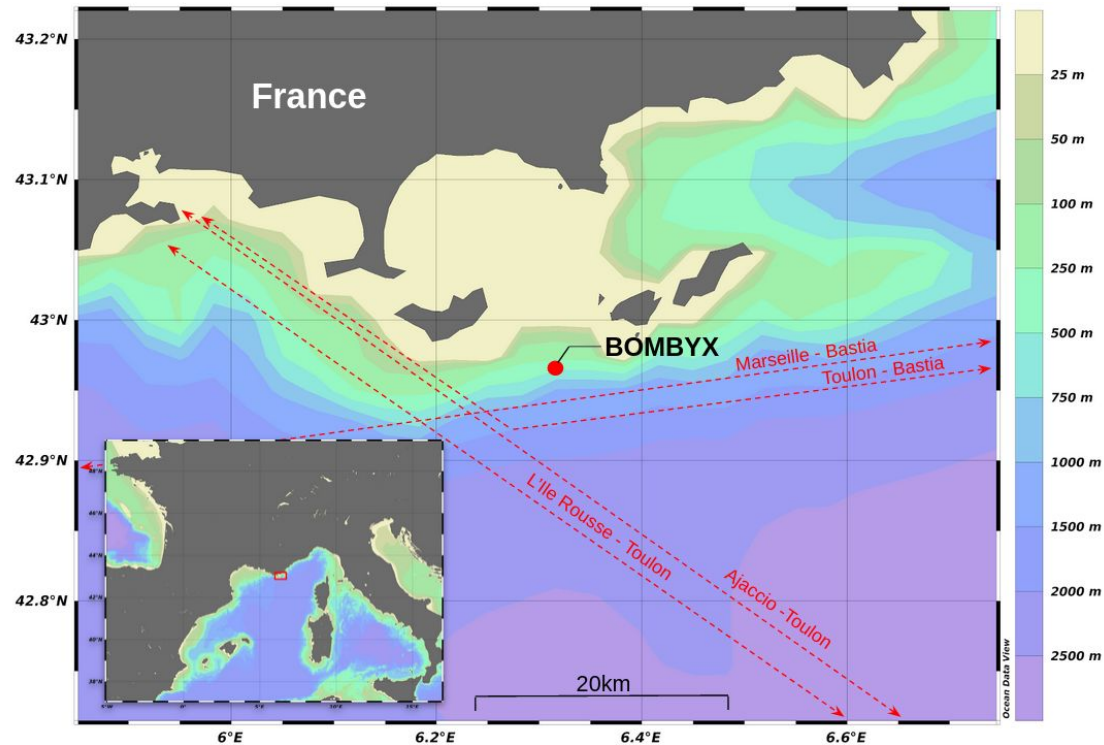
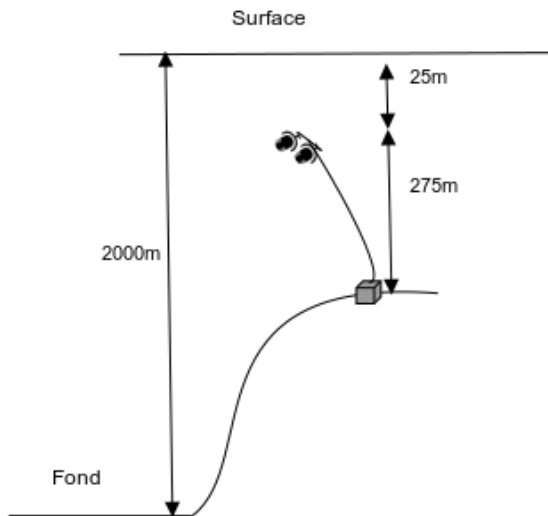
BOMBYX1 : 2015-2018

The first long term stereo Monitoring of Sperm Whales



The BOMBYX 2015-2018

- Bombyx station, stereophonic
- 25 m of depth
- Env 2700 hours of recordings, stereo
- Detection of sperm whale clics on Bombyx
- Data for future training



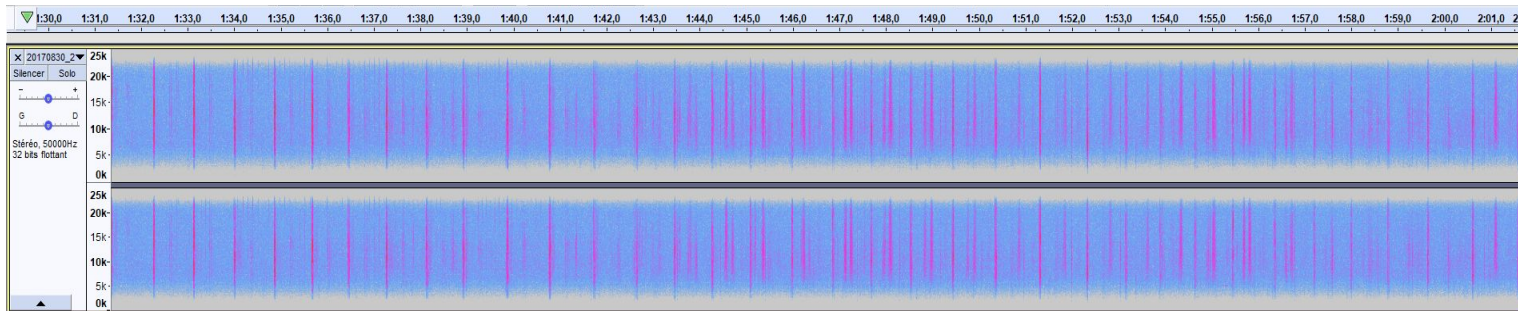
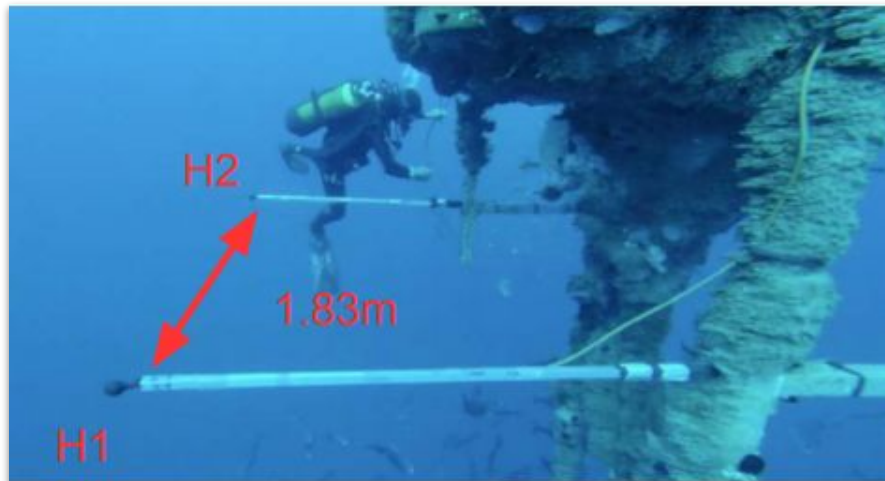
Bombyx 1

Data :

- Sparse recording from 2014 to 2018
- 2 channels (2 meters wide)
- 50kHz
- 25m deep hydrophones
- No annotation

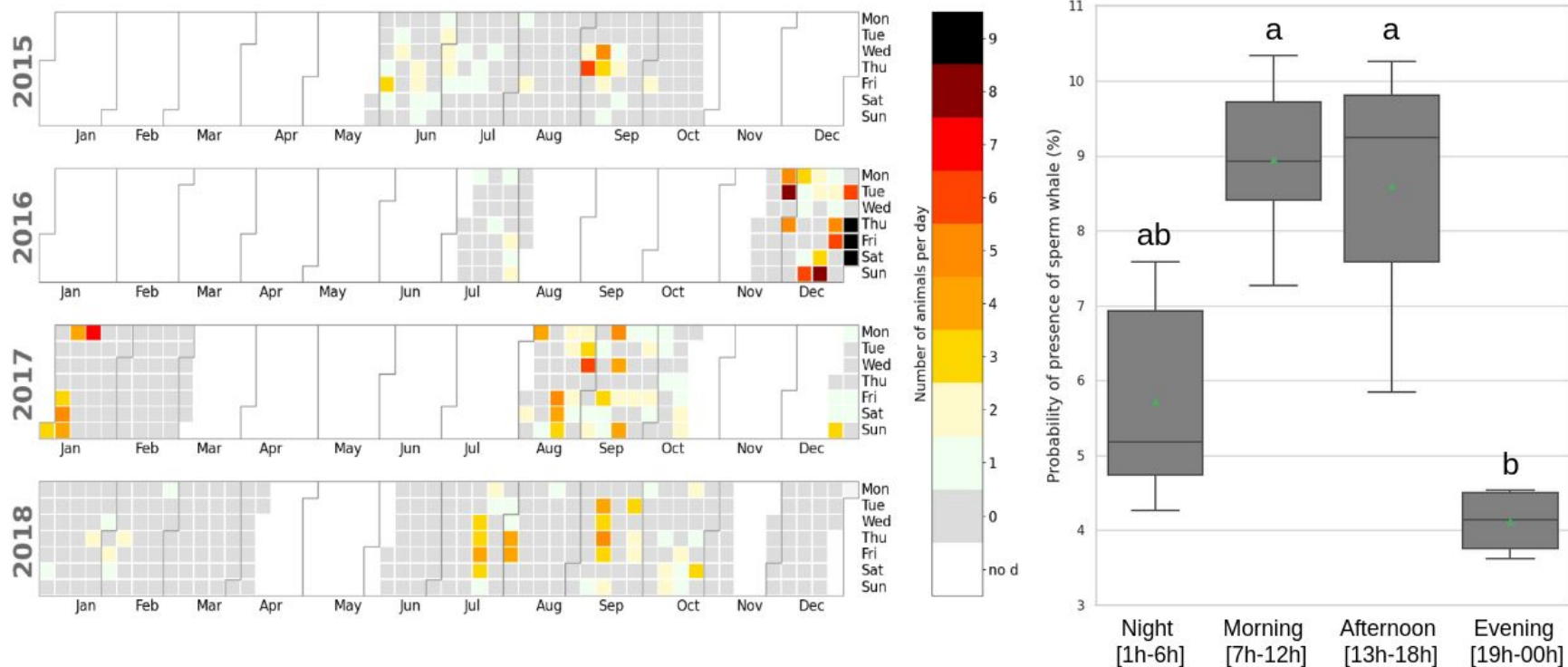
Objective :

- Noise robust sperm whale and fin whale detections



a) The BOMBYX 2015-2018 = Sperm whale detections

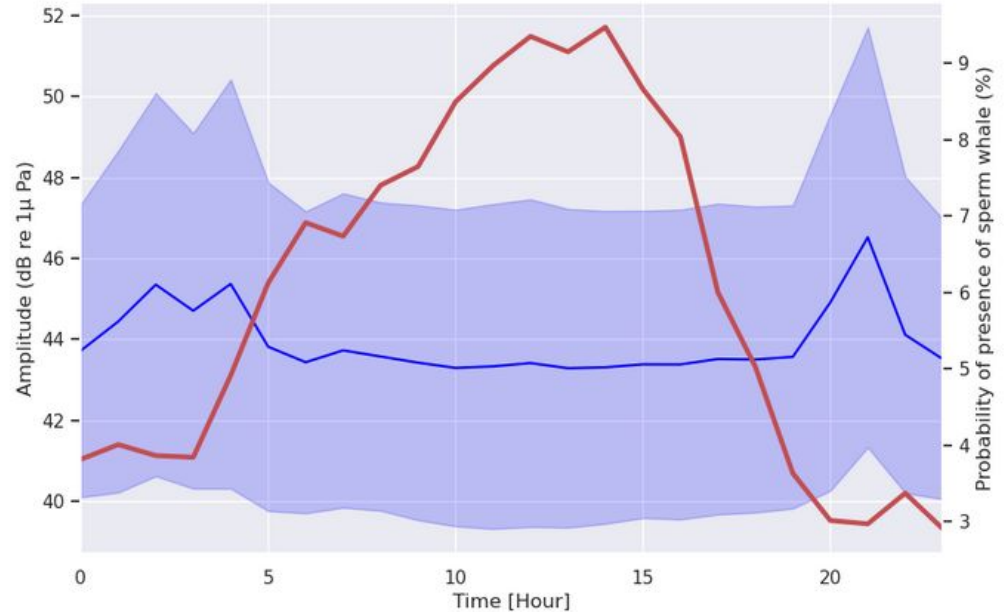
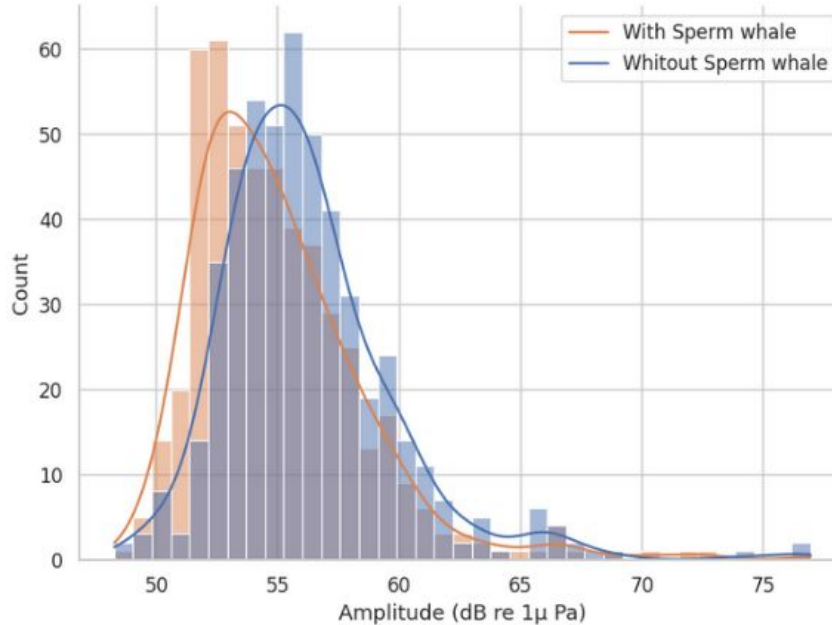
Sperm whale acoustic detection and background noise



Left: Number of detected sperm whales per day during the 4 years of recordings (white region: no recording). Right: Mean of the probability of presence for each period of the day.

The BOMBYX 2015-2018

Sperm whale acoustic detection and background noise

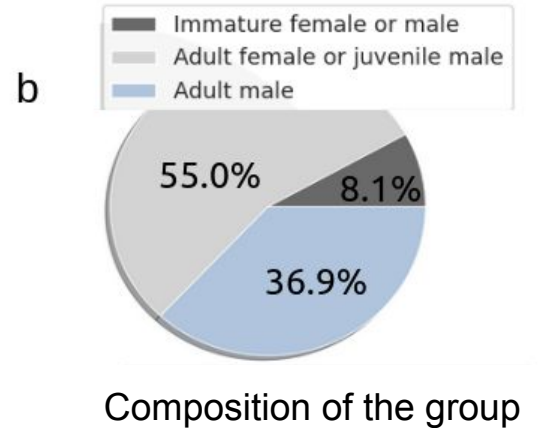
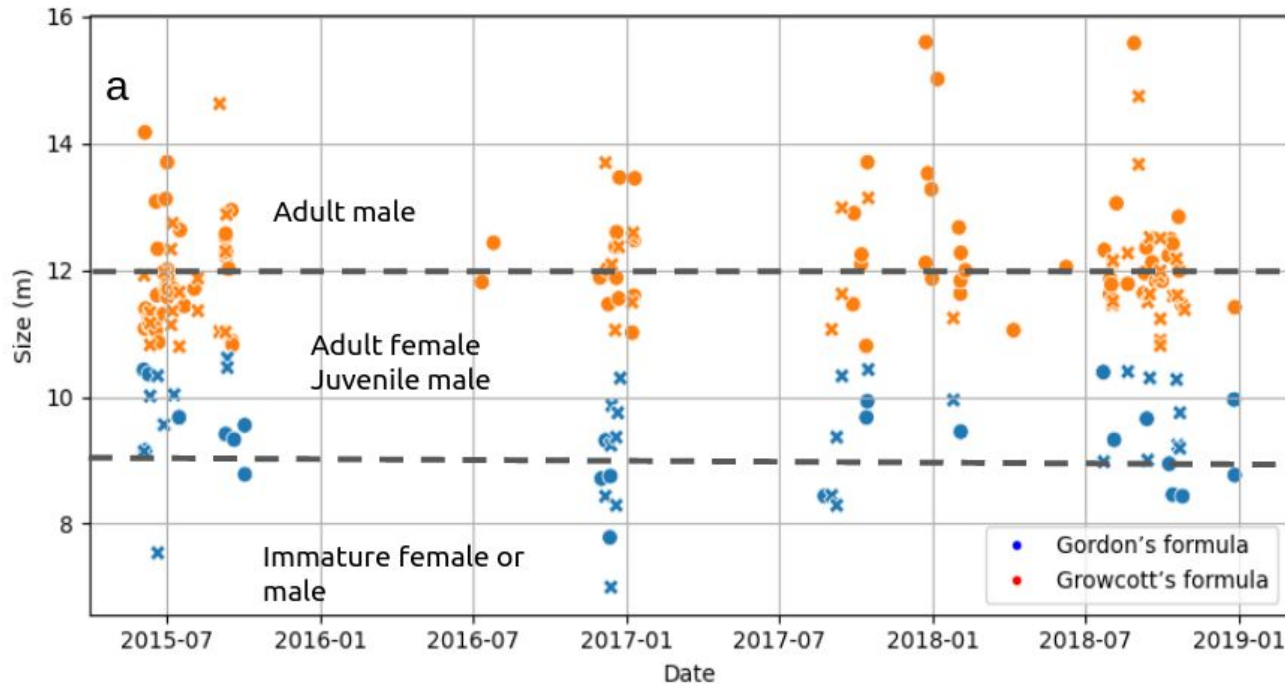


(Left) Distribution of the amplitude for the octave 12800 Hz according to presence/absence of sperm whales.

(Right) Superposition of dial pattern of amplitudes for the octave 12800 Hz and probability of presence of sperm whales.

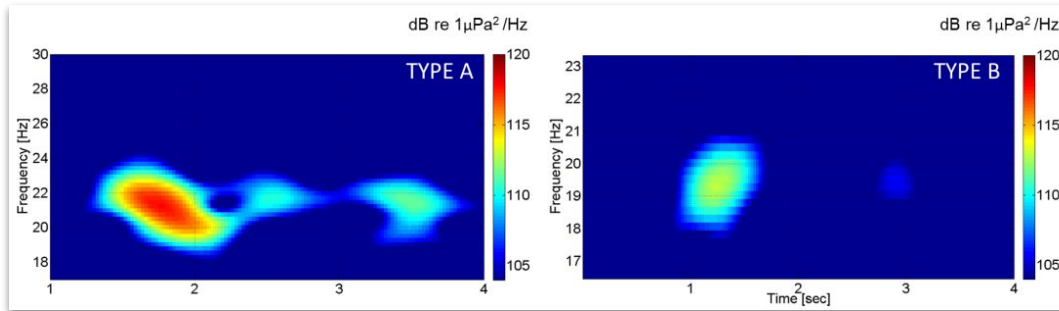
The BOMBYX 2015-2018

Sperm whale Interpulse Interval (IPI) and size measurement



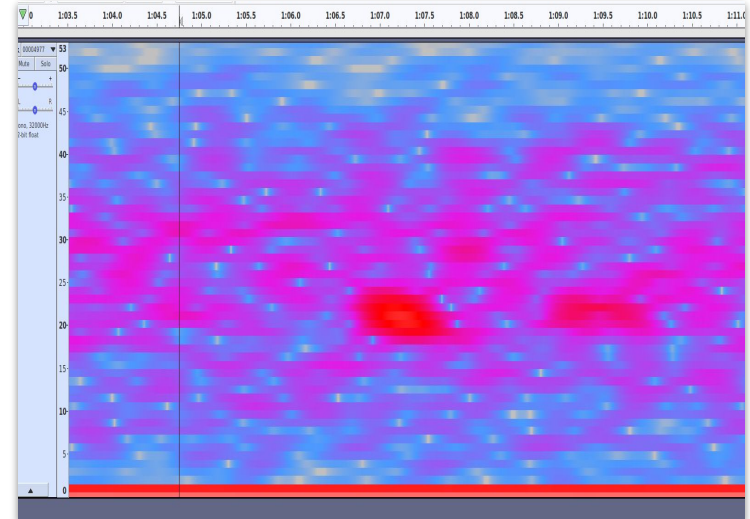
Sperm whales density: density of sperm whales in the area was 1.69 whales/1,000 km²

b) Fin whale pulse detection (low frequency, 20 Hz)



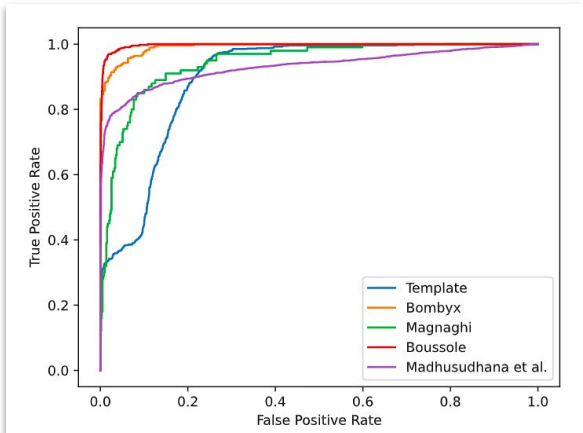
*Monitoring fin whale (*Balaenoptera physalus*) acoustic presence by means of a low frequency seismic hydrophone in Western Ionian Sea - EMSO site. Gianni Pavan*

- Centroid frequency : 20Hz
- Bandwidth : 5-7Hz
- Length : 1sec
- Periodicity : 15-40sec

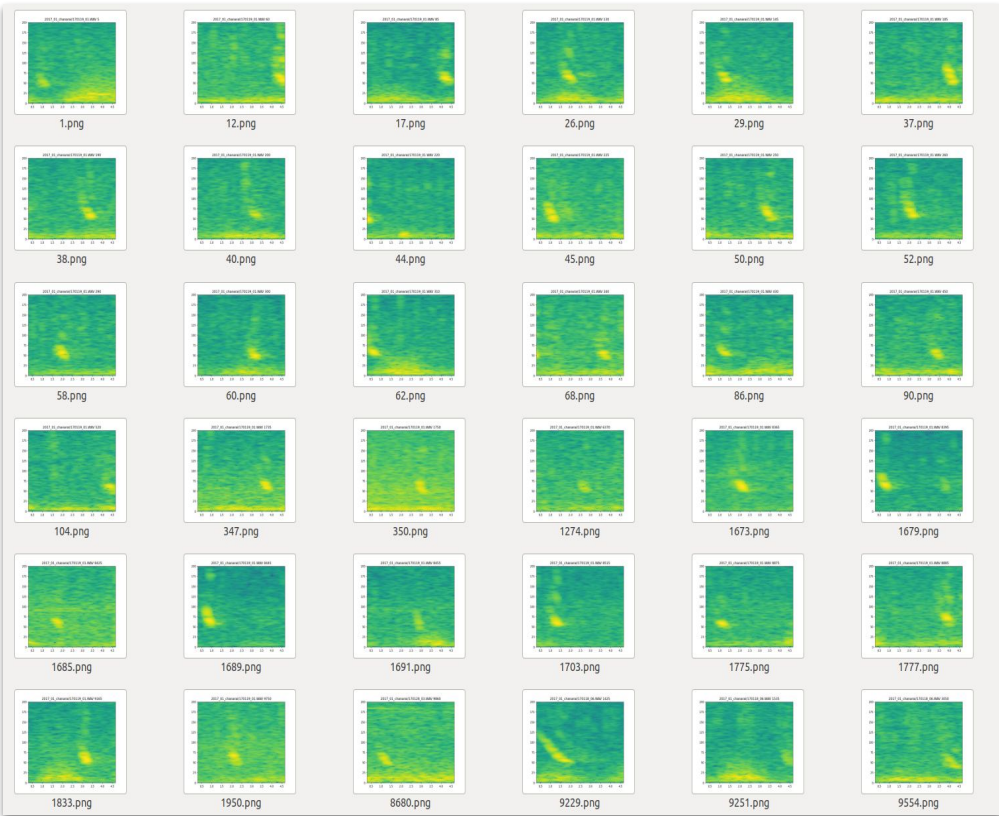


Sample from sonobuoy Boussole 2009 dataset

Low Frequency event classification : Fin whale pulse detection



Sample of high predictions over Chilian dataset (rec. Patris, Malige, Glotin 2017, Chanaral, Humbold loop...)



- Sampling frequency = 200Hz
 - STFT (winsize=256, hopsiz=16)
 - Mel (128 features from 0 to 100Hz)
 - Log
 - Conv 128 - 512
 - Conv 512 - 512
 - Conv 512 - 1
 - MaxPool
- Conv = batch norm, depthwise conv, dropout, Relu*

Fin whales of the Med. sea

Song structure

[In submission-Scientific Report] Temporal evolution
of the Mediterranean fin whale songs (first author)
Catch up on the litterature of fin whale songs

Compilation of CNN detections into songs

Discrimination of pulse types (GMM on centroid freq)

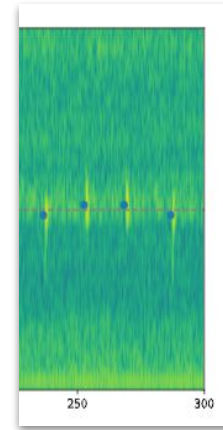
Difficulty to fin the write metric for it

Inter-annual trend of IPI

Intra-annual trend of centroid frequency

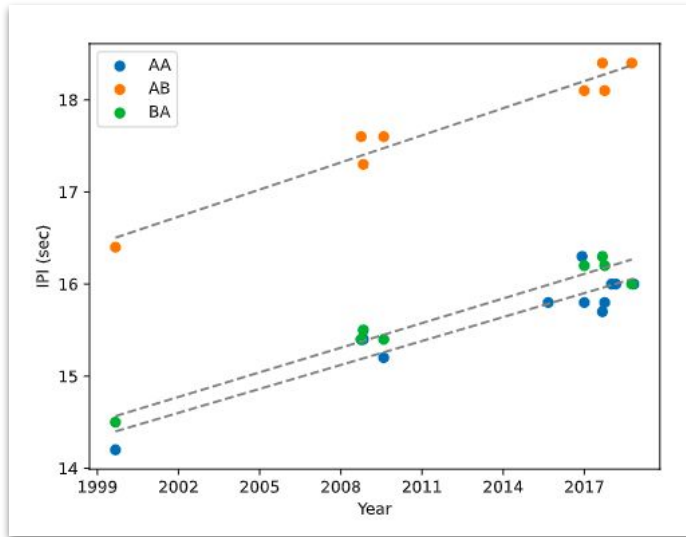
Comparison of CNN with baseline

AUC 93 agains AUC 95 of Madhusudhana et al. (2021)

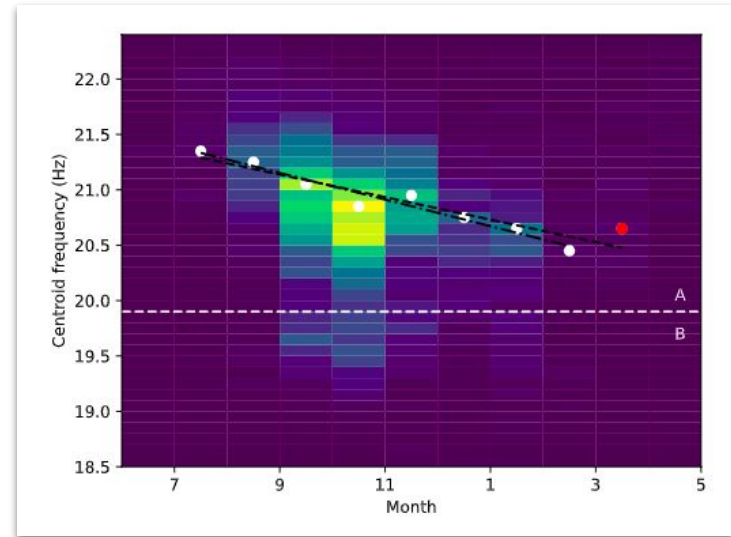


Temporal evolution of Mediterranean fin whale pulses

Result of Fin whale on **Bombyx1** from 2015 to 2018, IPI and frequency analyses



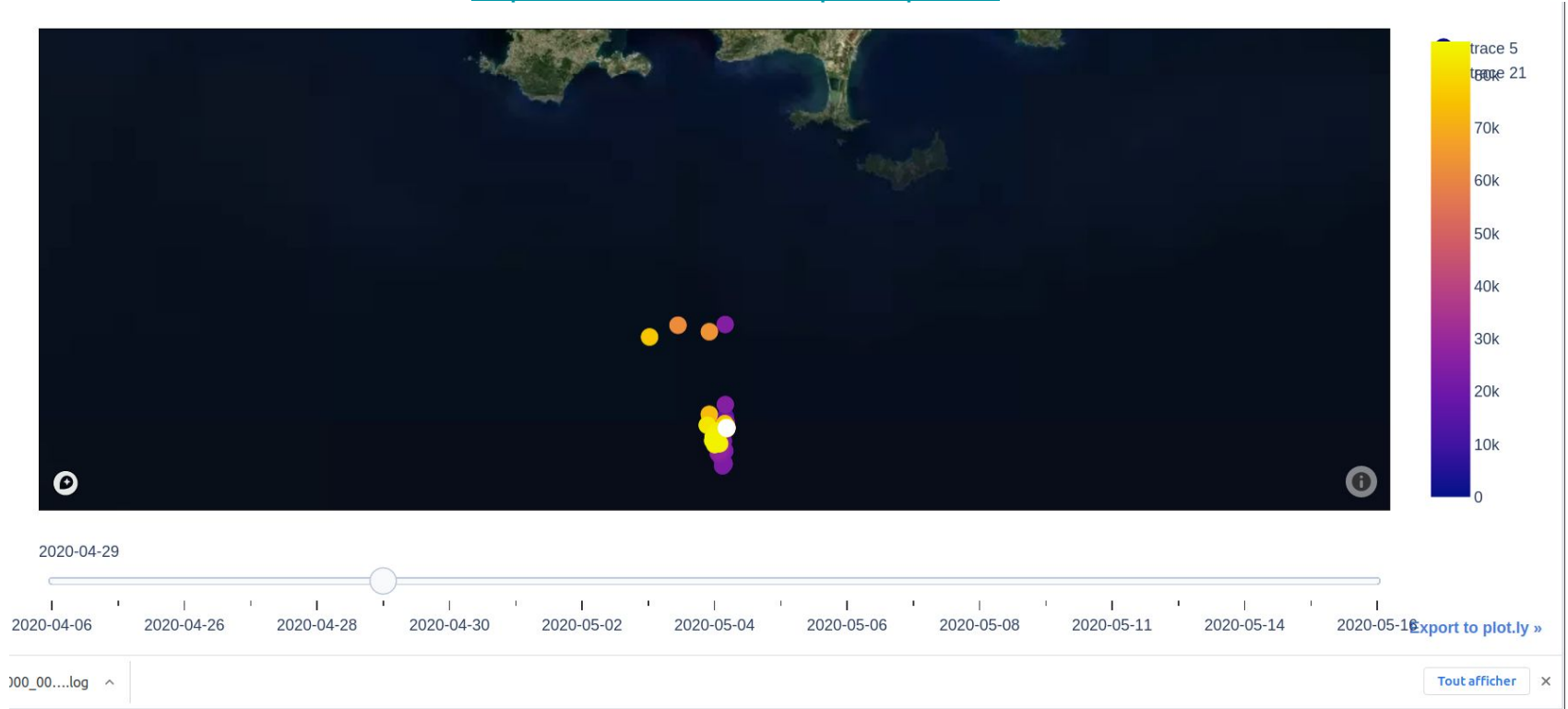
Yearly increase of the stereotypical IPIs by 0.1sec/year



Seasonal decrease of the centroid frequency by 0.1Hz/month

Other application on KM3 / south Giens Tracking Fin Whale with KM3 (Neutrino detector), 3 hydrophones, from april to may 2020

<http://sabiiod.univ-tln.fr/pub/bp.html>



Embedding these detection algorithms
into Bombyx2 Sonobuoy
Low power solutions

Embedded AI Bombyx2 - Analog wake-up

- Background noise estimation
- >8kHz Energy thresholding
- State Machine consistency validation
- 75% AUC on Bombyx 1
- Ultra low power **12.5 μ A**

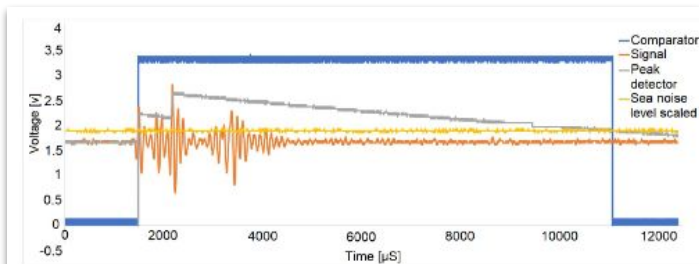


Fig. 7. Clicks of cetacean (Pm) with ULP processing, acquired on real signals (High-pass filtered input signal (orange), V_{Ref} (yellow), click envelope (grey), output of the comparator (blue)).

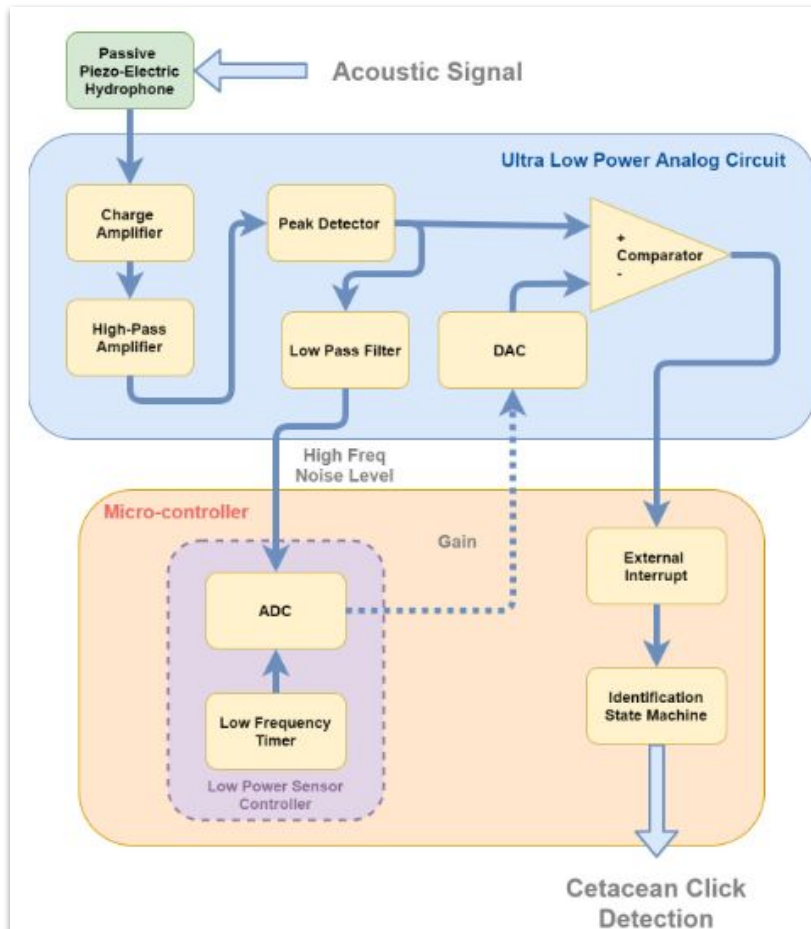
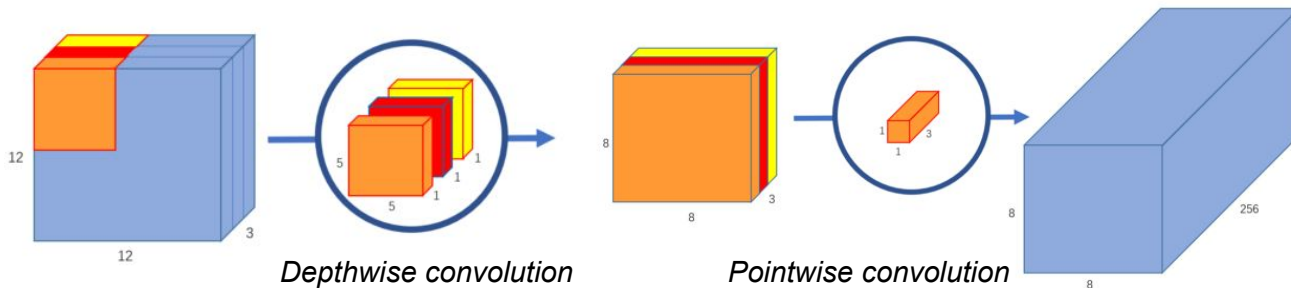


Fig. 4. Block diagram of the detector of a train of pulses of a Sperm Whale.

Embedded AI

Depthwise separable convolution, decimated CNN



Conv : $5 \times 5 \times 3 \times 256$

DW Conv : $5 \times 5 \times 3 + 3 \times 256$

	# parameters	# mutliplications
Traditionnal	272×10^3	309×10^6
Depthwise	11×10^3	13×10^6

- Conv 64 - 512
- Conv 512 - 512
- Conv 512 - 1

Embedded AI Into Low power micro-processor (PIC)

Analyse pour 5 secondes de signal

	Fin Whale	Sperm Whale
Sampling rate	200 Hz	50 kHz
Spectrogram size	128 x 46	64 x 974
Spectrogram computation time	0.2 sec	4.5 sec
Forward pass time	0.5 sec	2.1 sec



PIC 32MZ by Microchip

Bombyx 2

Low complexity CNNs

	params type	# params	poids params	# mutliplikations
Depthwise	float32	11K	54Ko	13 M
Quantized	int8	272K	1.1Mo	309 M

- Sampling frequency = 50kHz
- STFT (winsize=512, hopsize=256)
- Mel (64 features from 2 to 25kHz)
- Log
- Conv 64 - 64
- Conv 64 - 64
- Conv 64 - 1
- MaxPool

Conv = batch norm, depthwise conv, dropout, Relu
Valid AUC = 0,93

Sperm whale binary classifier

- Sampling frequency = 200Hz
- STFT (winsize=256, hopsize=16)
- Mel (128 features from 0 to 100Hz)
- Log
- Conv 128 - 512
- Conv 512 - 512
- Conv 512 - 1
- MaxPool

Conv = batch norm, depthwise conv, dropout, Relu
Valid AUC = 0,90

Fin whale binary classifier

Bombyx 2

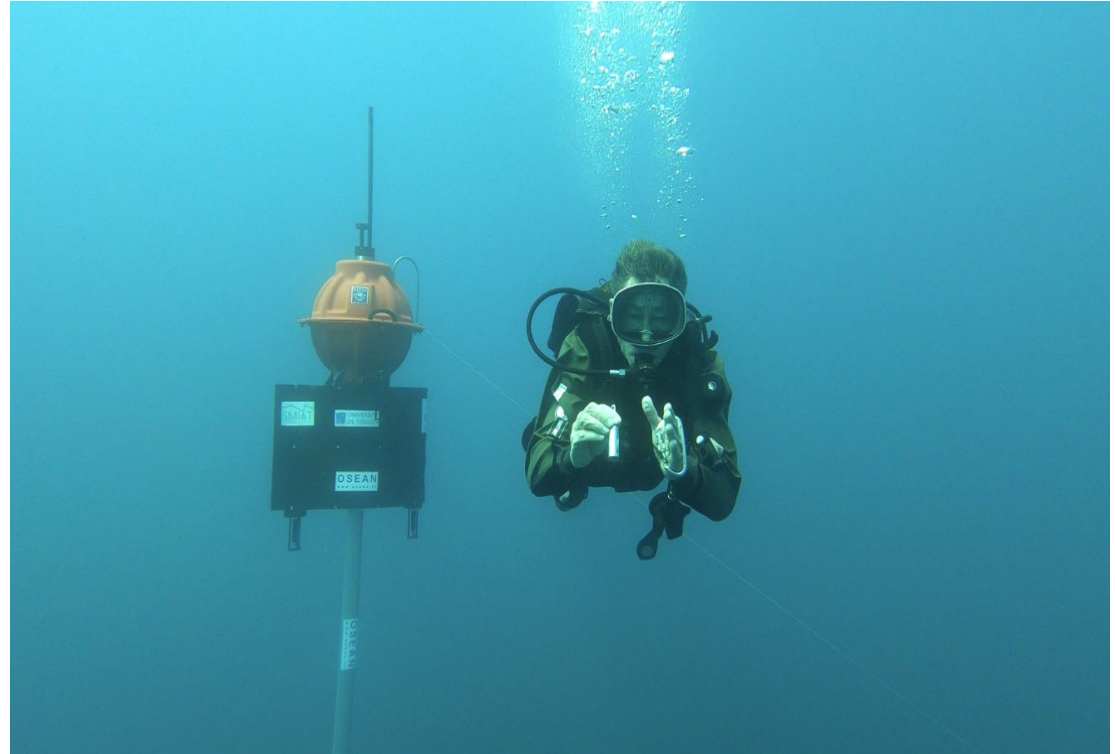
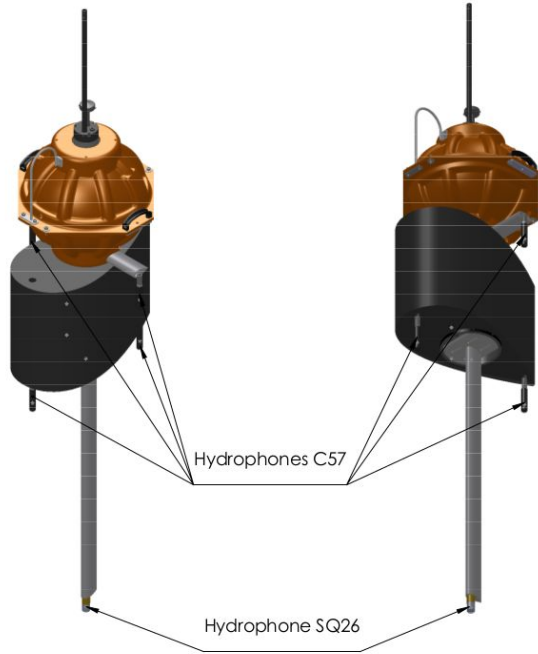
Accomplished :

- Hyper-parameter search / optimization for the **low power analog detector**
- Training of low complexity (11k params) **CNN for sperm whale detection** (0.92 valid AUC), using data from Bombyx 1
- **Gathering of a multi-source dataset** of fin whale calls Iteratively
- Training of low complexity **CNN for fin whale detection** (in progress)
- Implementation of the forward pass in C to be embedded on the buoy

Perspectives :

- Tests forward pass with fixed point parameters
- Fine tuning of **CNN for fin whale detection** until satisfying results
- **Optimize operational scenario** for best durability / utilisability compromise
- Validation of the **C implementation on PIC**
- Preparation of the data to be uploaded via 4G (detection times, pulse samples)
- Ex-situ **localization using TDoAs**

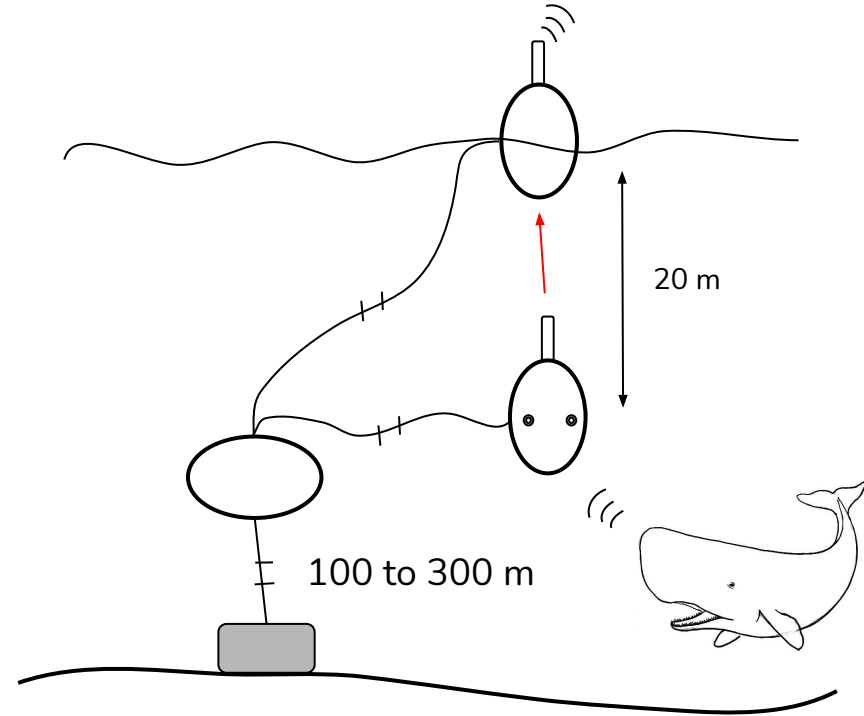
BOMBYX 2 : pentaphonic with surface real-time alert transmission



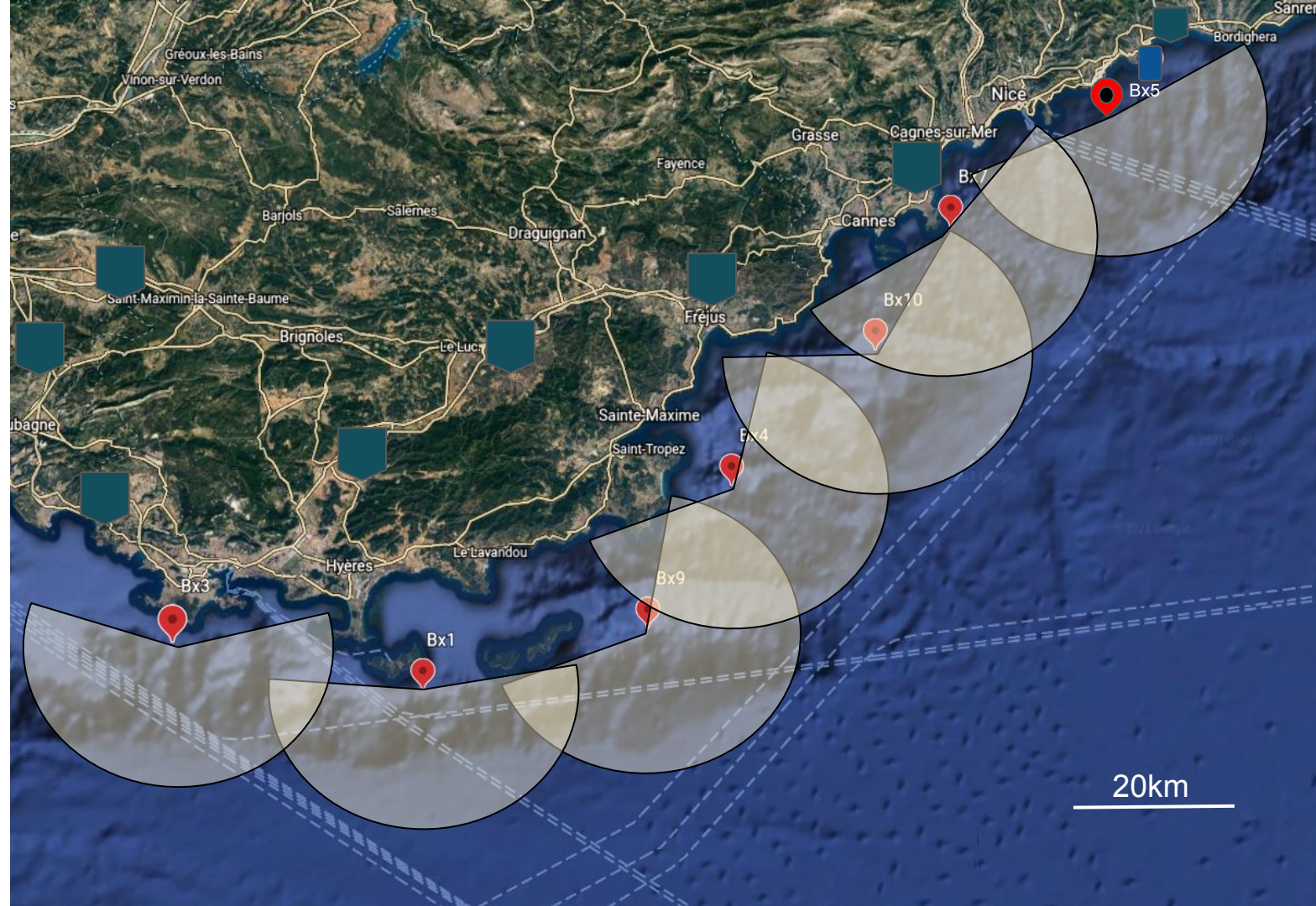
Application to Online AI Bombyx 2

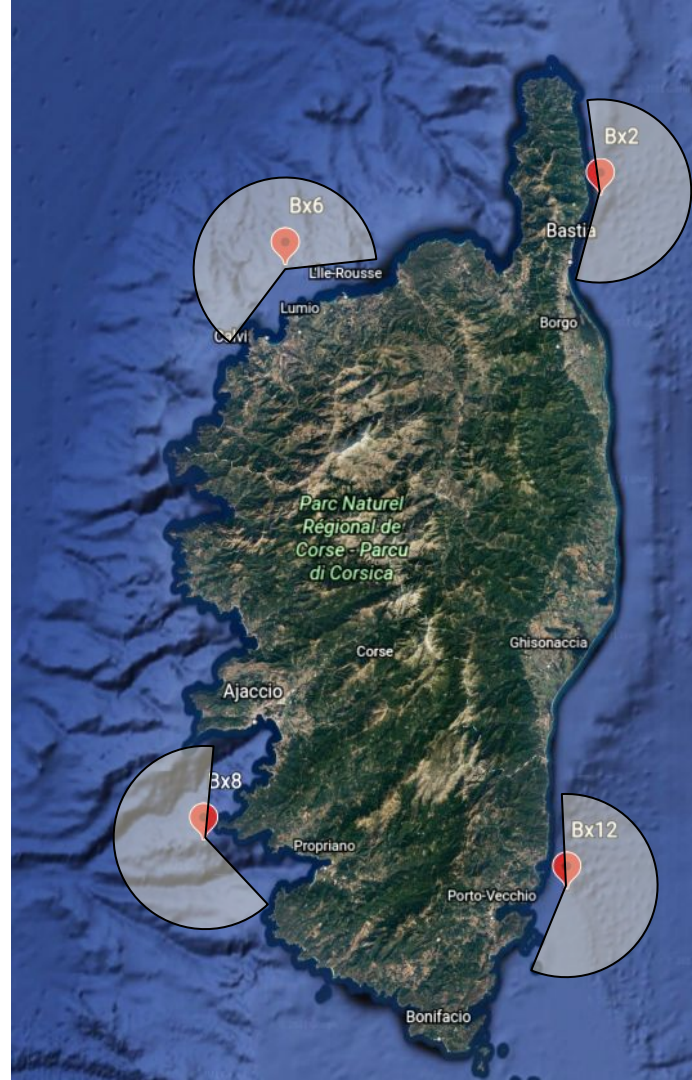
4G emission to LIS,
PELAGOS, PREMAR,
REPCET

- To be placed in 2022
 - South of Port-Cros Island and Cape Corsica
- Floatability variation system
 - 20m deep recording and surface 4G communications
- Alert system for sperm whale and fin whale presence
 - Mitigate ship strikes risk
- 5 hydrophones
 - Azimuth and distance estimation
- Battery powered (approx. 6 month)
- PIC32-Mz microprocessor



**Deployment of Bombyx2 in GIAS program (2)
and further CPER, LIFE,... 2021-26**





Installation in Port-Cros begin november 2021, in Cap Corse mid nov. 2021

Thank you

Questions ?

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