LE BRUIT EN MER

DU DÉVELOPPEMENT DES ACTIVITÉS MARITIMES

À LA PROTECTION DE LA FAUNE MARINE

Marittimo FEDER GIAS

REGION SUD

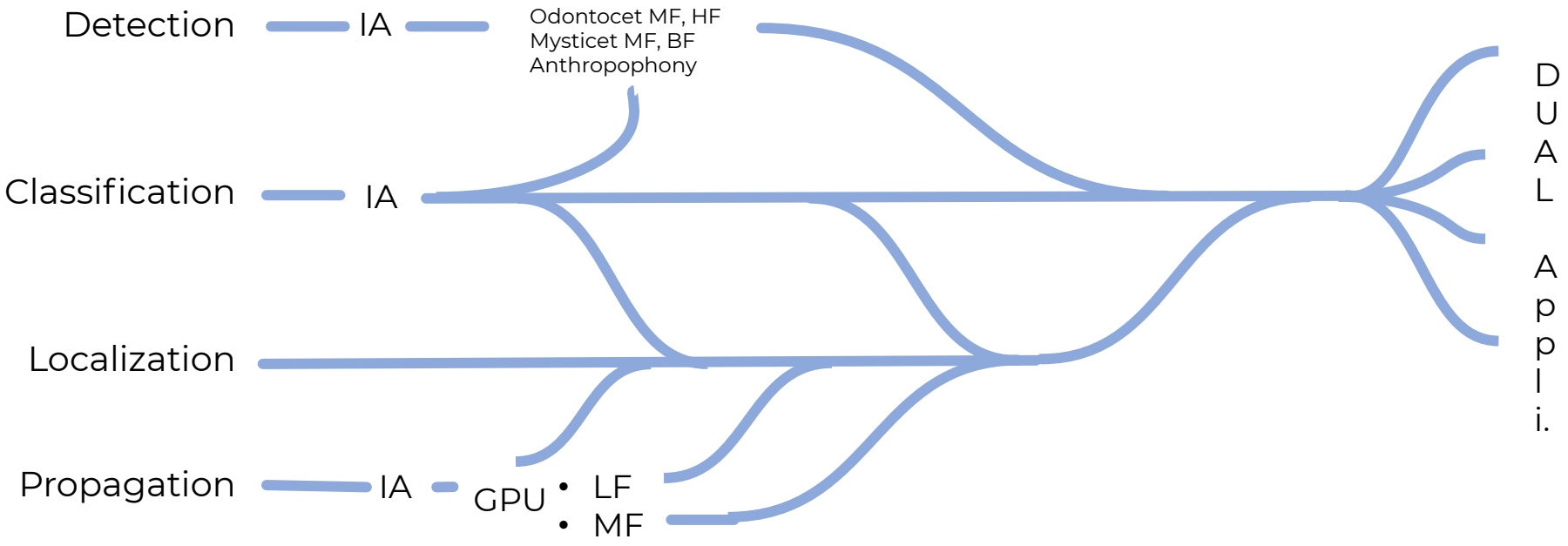
Chaire IA "ADvanced underSea Intelligent Listening"

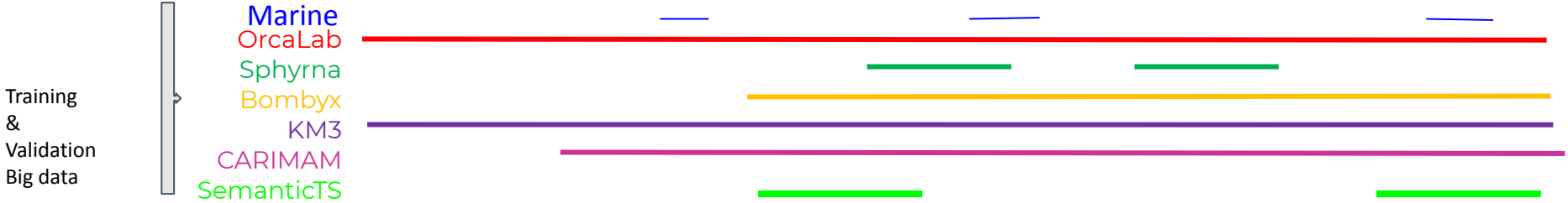
Dyni Team LIS CNRS et al.

Glotin Hervé

glotin@univ-tln.fr

In collaboration with OrcaLab, Gianni Pavan, Osean, D. Bonnet et al

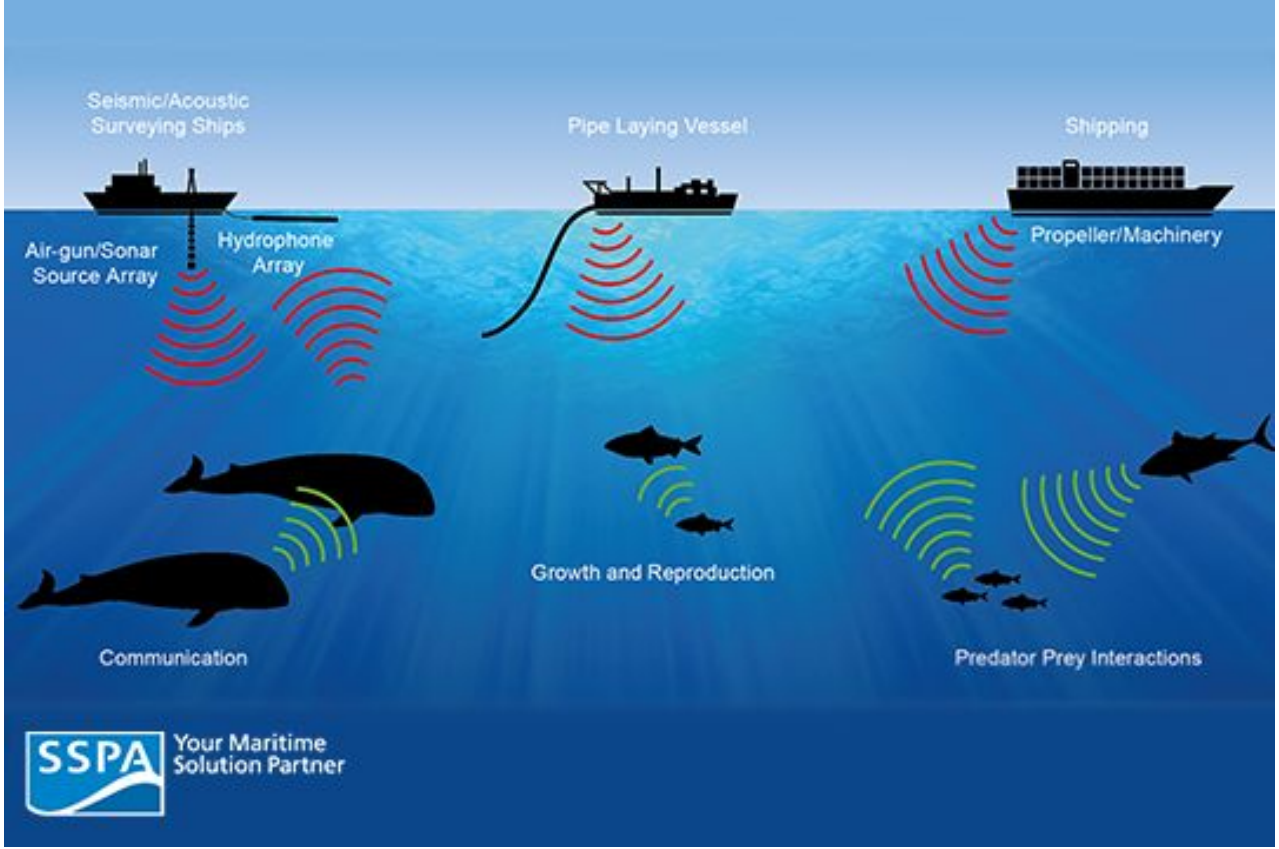

Detection
IA
Odontocet MF, HF
Mysticet MF, BF
Anthropophony
Classification
IA
Localization
Propagation
IA
GPU
• LF
• MF
DUAL
Appli.


Training
&
Validation
Big data
Marine
OrcaLab
Sphyrna
Bombyx
KM3
CARIMAM
SemanticTS

Anthropic Pressures In The Sea

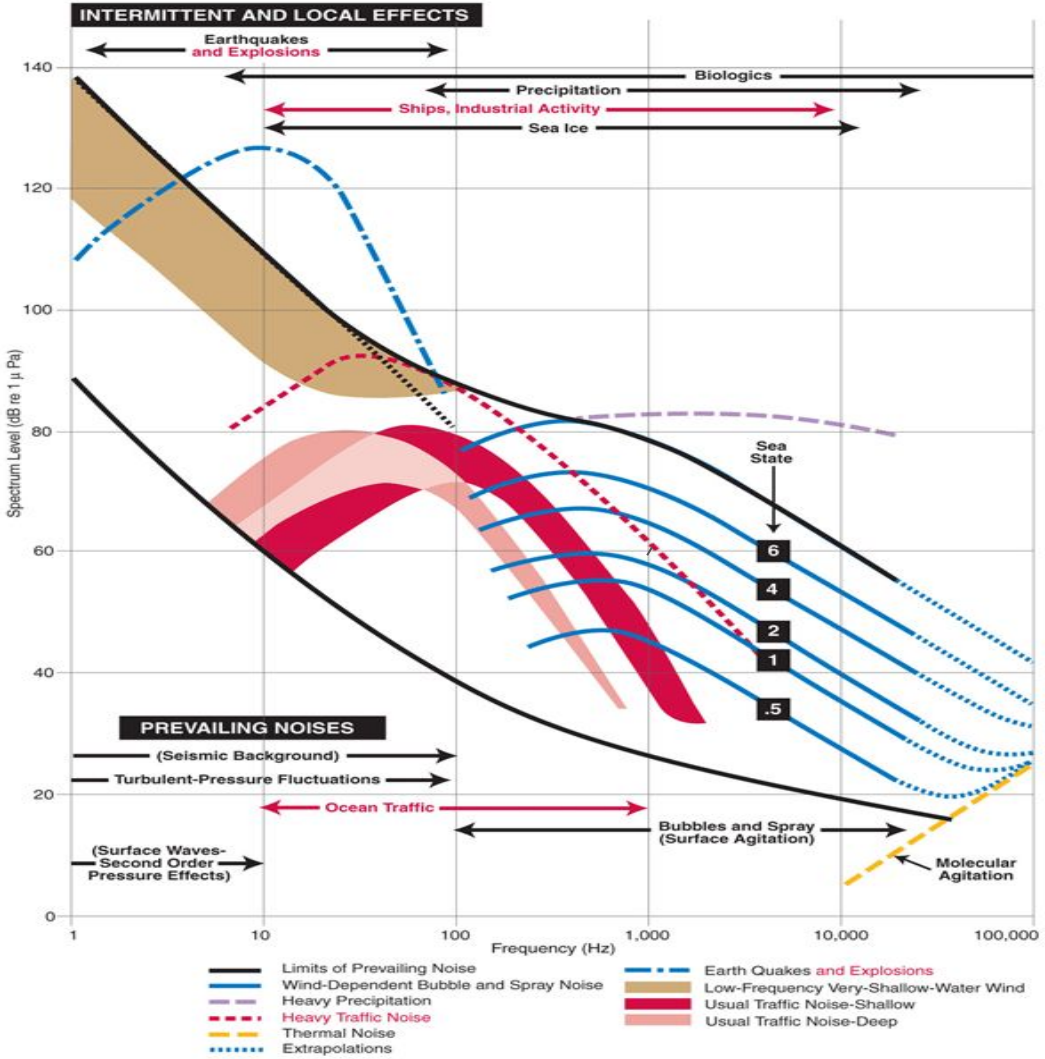
Noise Sources & Impacts

4 June 2021

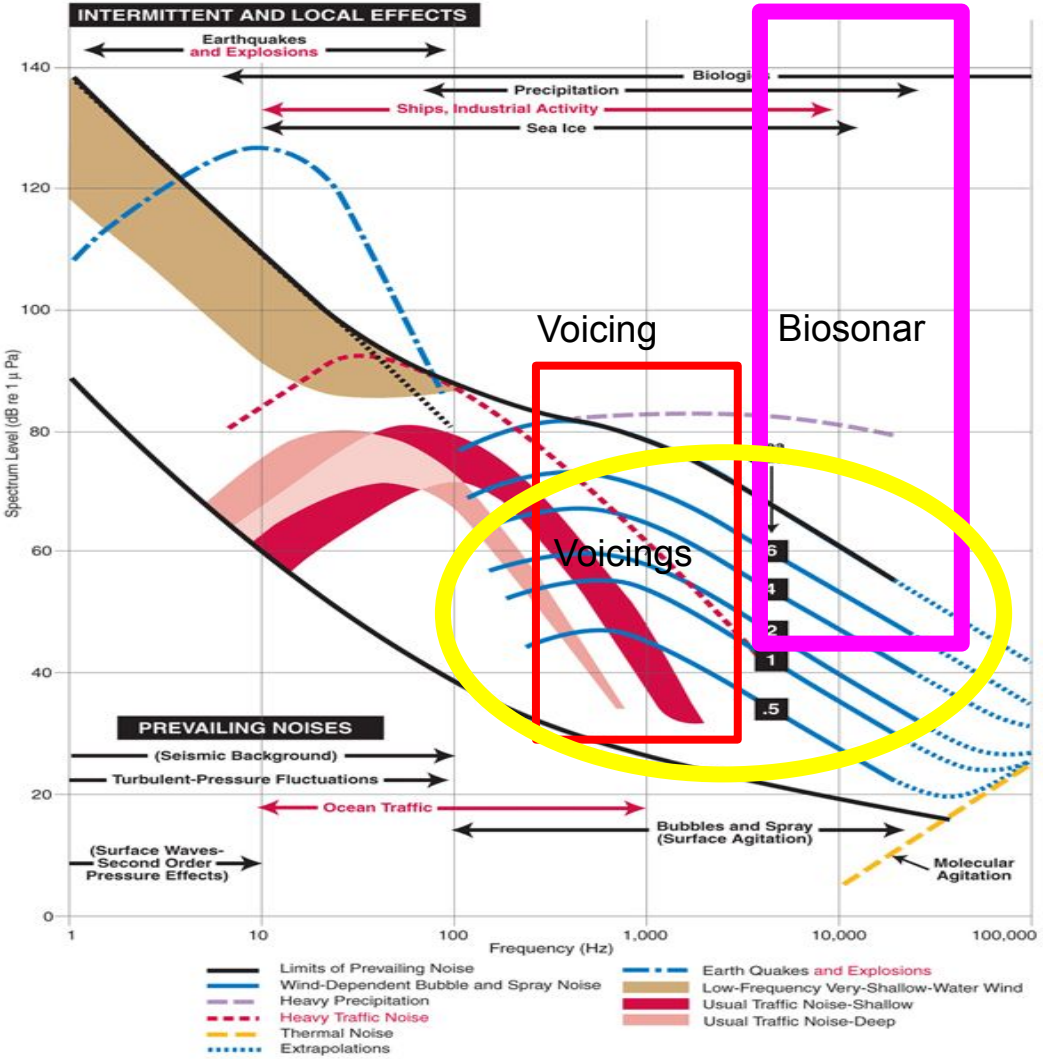


Anthropogenic underwater noise is continually changing. New waterborne technologies can be modeled so that new designs are optimized to reduce impact on marine life. Still, All forms of underwater radiated noise caused by human activities must be continuously measured in-situ.

dB level


INTERMITTENT AND LOCAL EFFECTS
Earthquakes and Explosions
Biologics
Precipitation
Ships, Industrial Activity
Sea Ice
Spectrum Level (dB re 1 μ Pa)
140
120
100
80
60
40
20
0
Sea State
6
4
2
1
.5
PREVAILING NOISES
(Seismic Background)
Turbulent-Pressure Fluctuations
Ocean Traffic
Bubbles and Spray (Surface Agitation)
(Surface Waves-Second Order Pressure Effects)
Molecular Agitation
1
10
100
1,000
10,000
100,000
Frequency (Hz)
Limits of Prevailing Noise
Wind-Dependent Bubble and Spray Noise
Heavy Precipitation
Heavy Traffic Noise
Thermal Noise
Extrapolations
Earth Quakes and Explosions
Low-Frequency Very-Shallow-Water Wind
Usual Traffic Noise-Shallow
Usual Traffic Noise-Deep

dB level



But noises are sometimes covering more...

Some work in the Research Station to Monitor Orca Behavior and Anthropophony : OrcaLab

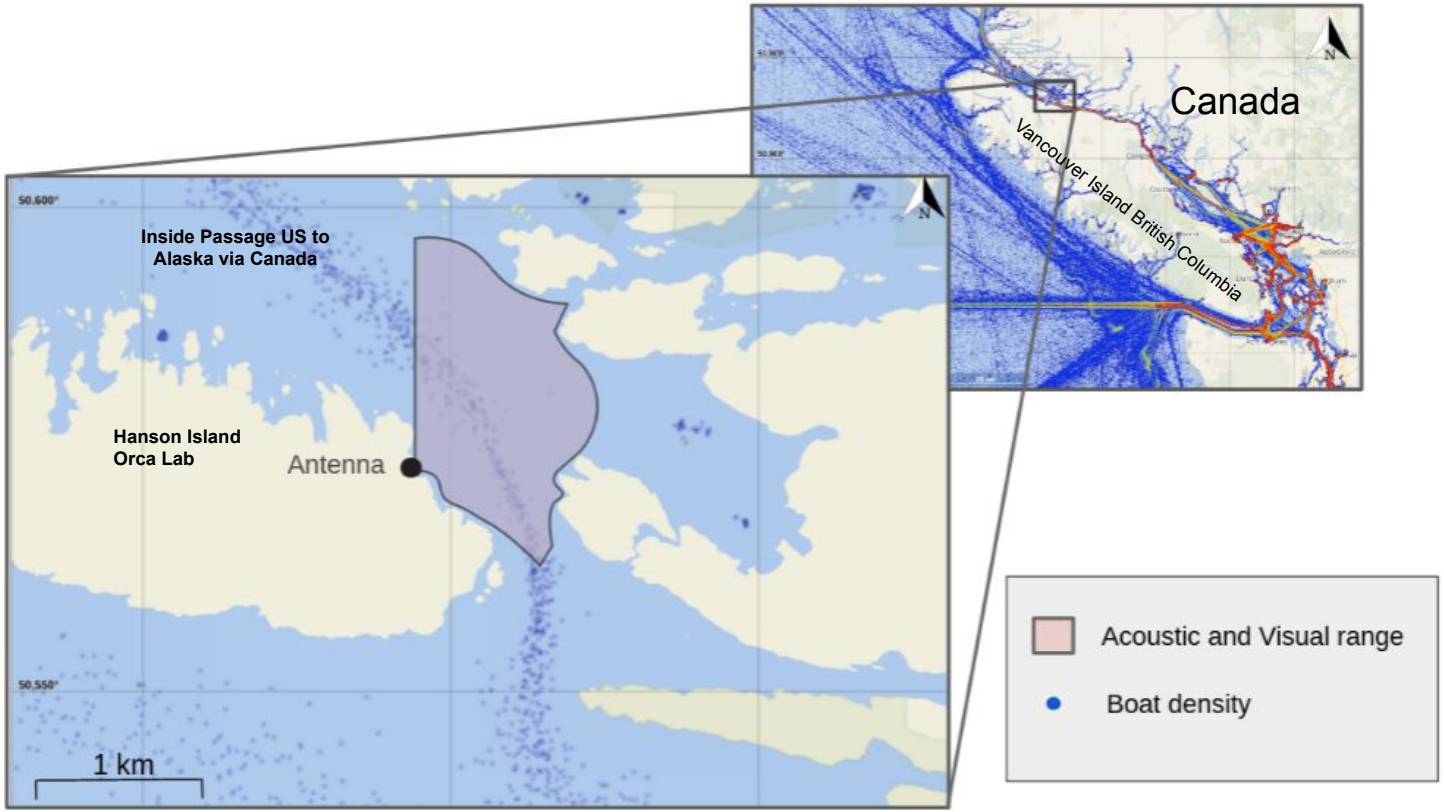
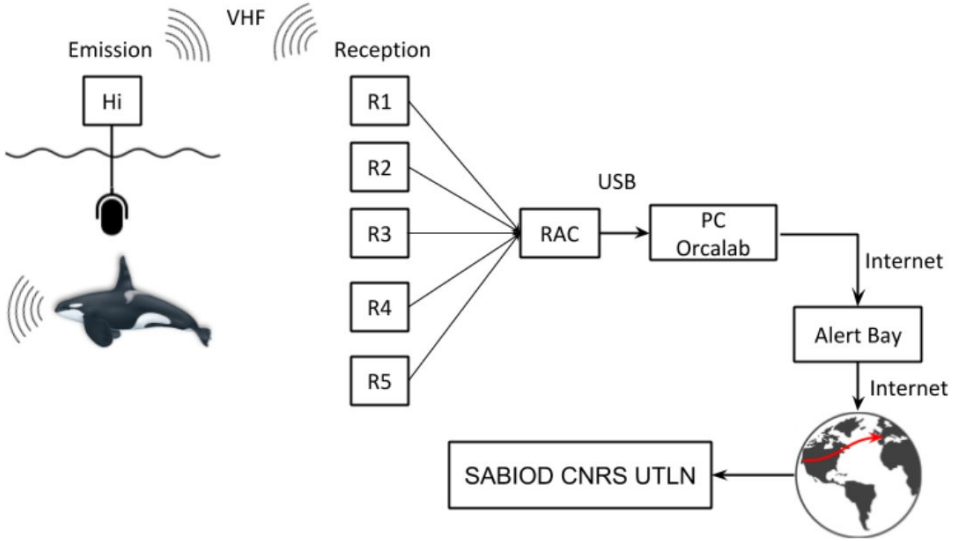
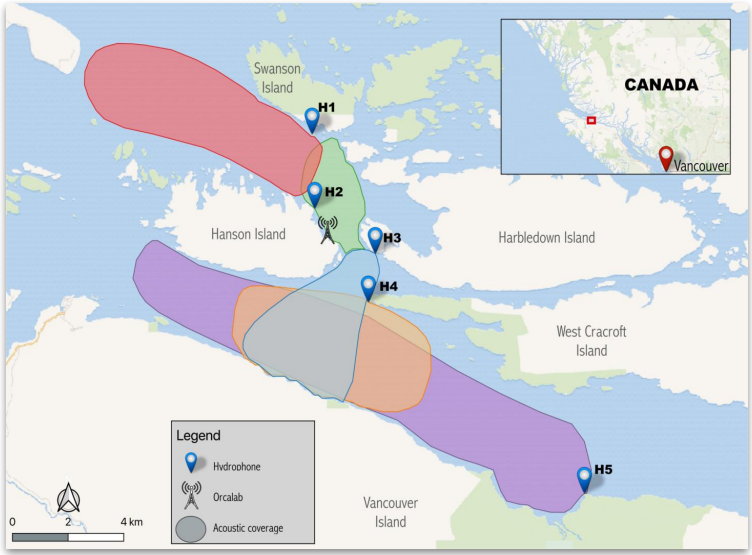


Figure S3. Map of viewing and listening ranges, covering an area of approximately 5km^2 with a possible audio and visual azimuthal estimate of Orcas passages and the Boat density (source: Vessel-Finder). The ferry recorded the 11th of August followed this path.

Orca Vocalization Detection
Context - OrcaLab

- Northern resident orcas community
- In situ observatory since 1970
- 5 Hydrophones (recording at 22kHz)
- Full time recording since 2015 (50 TB)





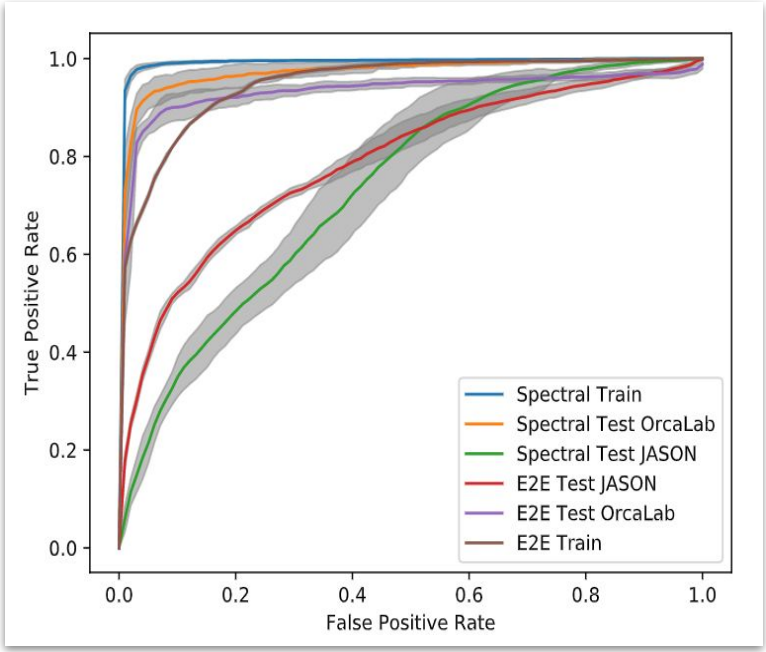
Hydrophone layout in Johnstone Strait

Orca Vocalization Detection
Models' Performances

Averaged over 10 runs

Spectral Model			
	Precision	Recall	AUC
Training	0.91 ± 0.017	0.97 ± 0.005	0.99 ± 0.001
Test OrcaLab	0.91 ± 0.105	0.90 ± 0.044	0.98 ± 0.010
Test JASON	0.51 ± 0.04	0.87 ± 0.030	0.74 ± 0.027

End-to-end Model			
	Precision	Recall	AUC
Training	0.63 ± 0.004	0.87 ± 0.002	0.95 ± 0.002
Test OrcaLab	0.50 ± 0.019	0.96 ± 0.005	0.94 ± 0.008
Test JASON	0.63 ± 0.023	0.70 ± 0.032	0.79 ± 0.010

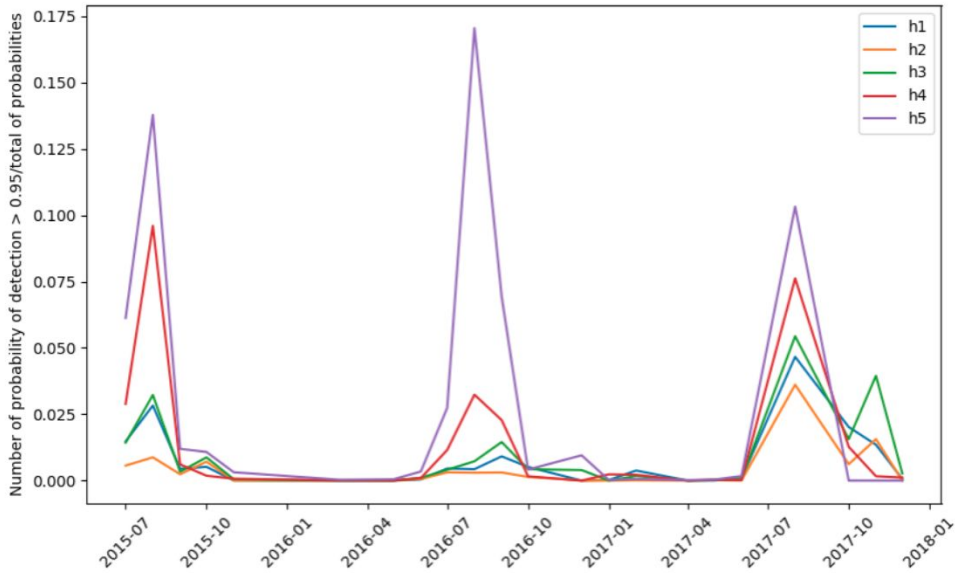


Recieving operator curve

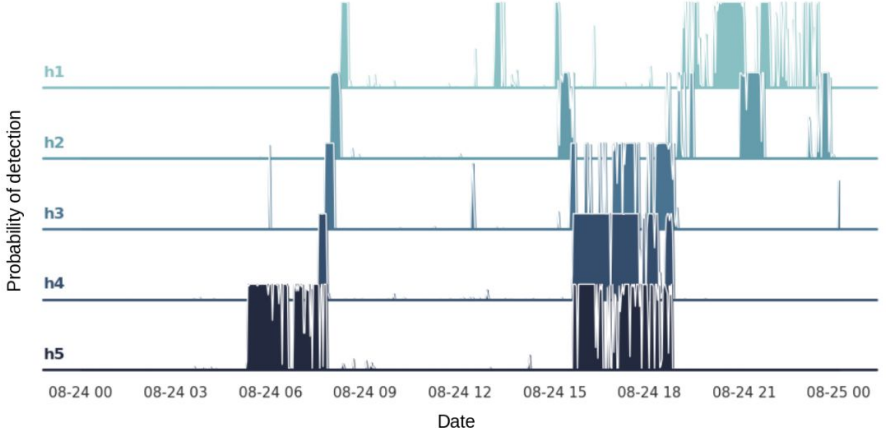
Best et al. 2020, IJCNN

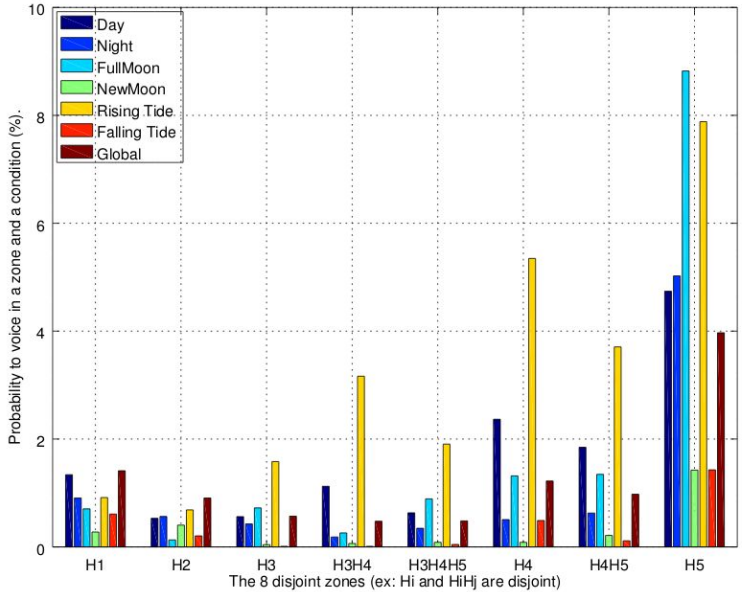
Orca Vocalization Detection
First Results

- Run over 3 years (2015 to 2017)
- Over 420k detected vocalizations



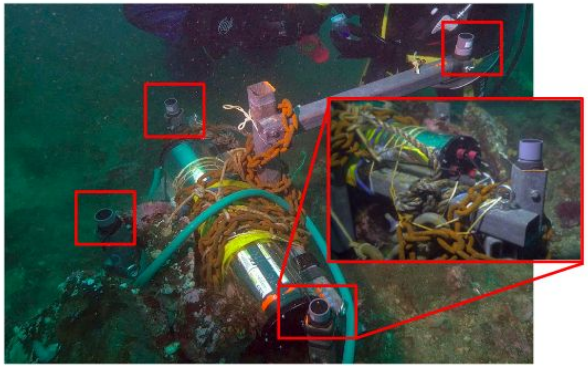
Probability of vocalization detection through time

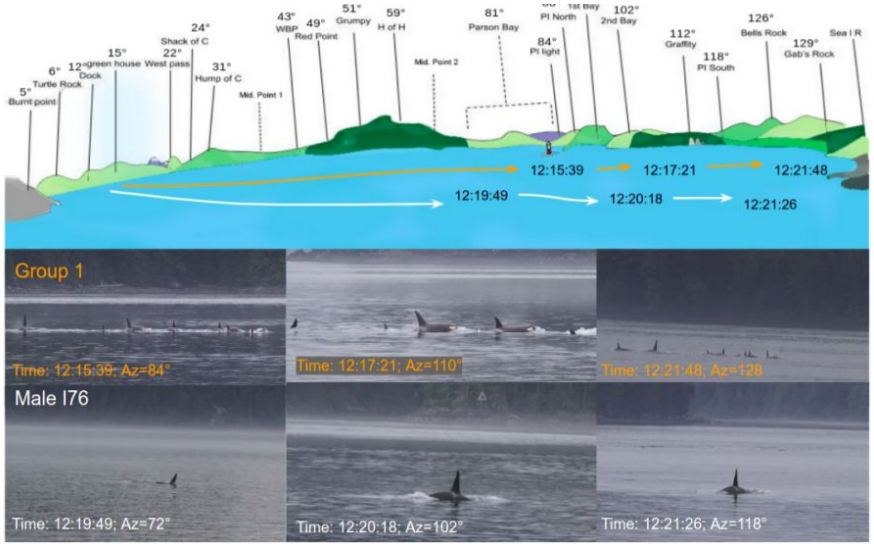


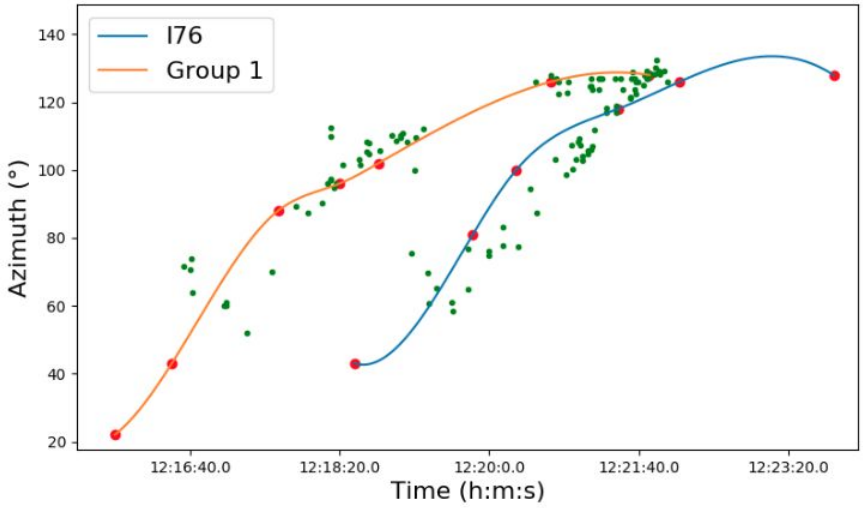


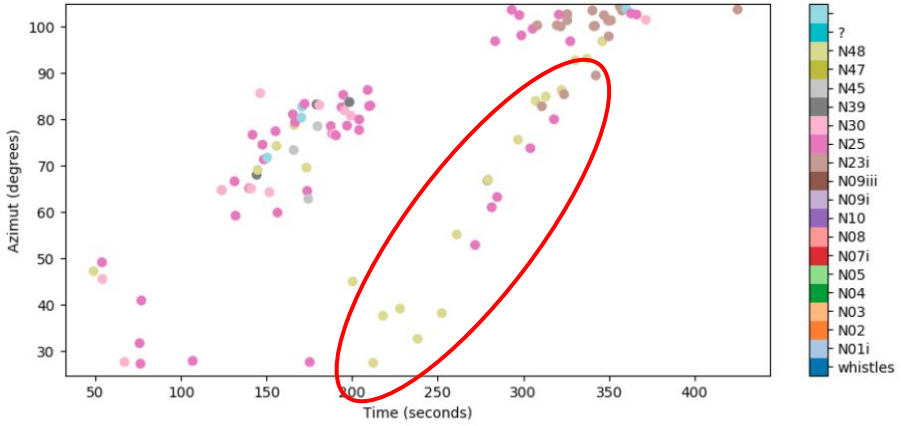
Best et al. 2020, IJCNN; Poupard et al. Ocean 2019

Individual separation and identification of orcas calls in the wild: Individual signature learning ?









Poupard et al, in Sub

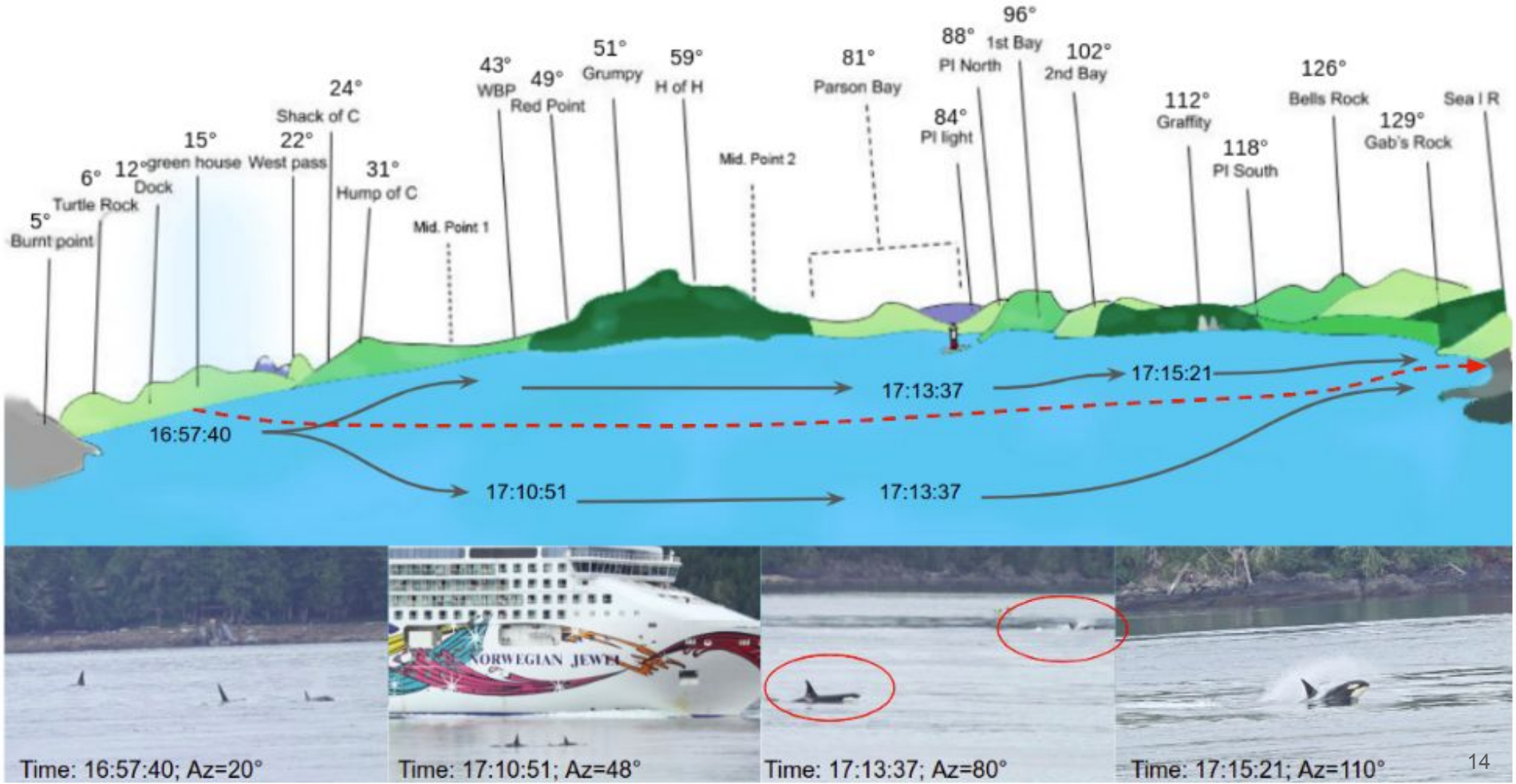
Example

The Cruise Ship Norwegian Jewel Passage close to the Orcalab Array

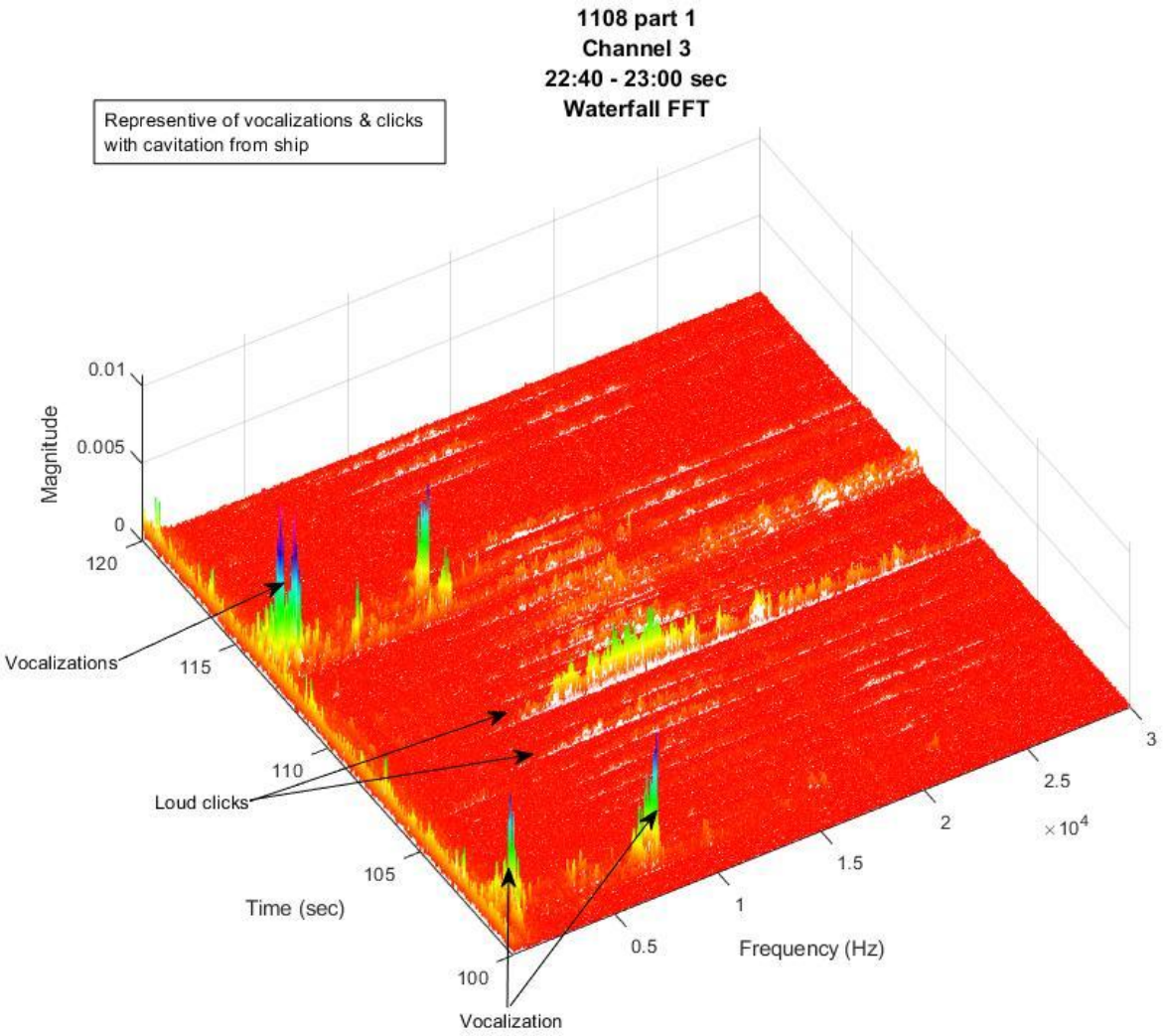
Azipod noise characterisation

(CPA 700 Meters)

Interferences with Orca Vocalizations and Clicks


5°
Burnt point
6°
Turtle Rock
12°
Dock
15°
green house
22°
West pass
24°
Shack of C
31°
Hump of C
Mid. Point 1
43°
WBP
49°
Red Point
51°
Grumpy
59°
H of H
Mid. Point 2
81°
Parson Bay
84°
PI light
88°
PI North
96°
1st Bay
102°
2nd Bay
112°
Graffity
118°
PI South
126°
Bells Rock
129°
Gab's Rock
Sea l R
16:57:40
17:10:51
17:13:37
17:13:37
17:15:21
Time: 16:57:40; Az=20°
Time: 17:10:51; Az=48°
Time: 17:13:37; Az=80°
Time: 17:15:21; Az=110°

Clicks
& voicings into
usual noise



Norwegian Jewel is powered by a diesel-electric propulsion system comprising five MAN - B&W 12V48/60B diesel engines providing power to two Azipod thrusters. The system is variably rated at 75,000 kilowatts (100,000 hp), and 39,000 kW (52,000 hp). This gives the cruise ship a maximum speed of 25.6 knots (47.4 km/h; 29.5 mph).

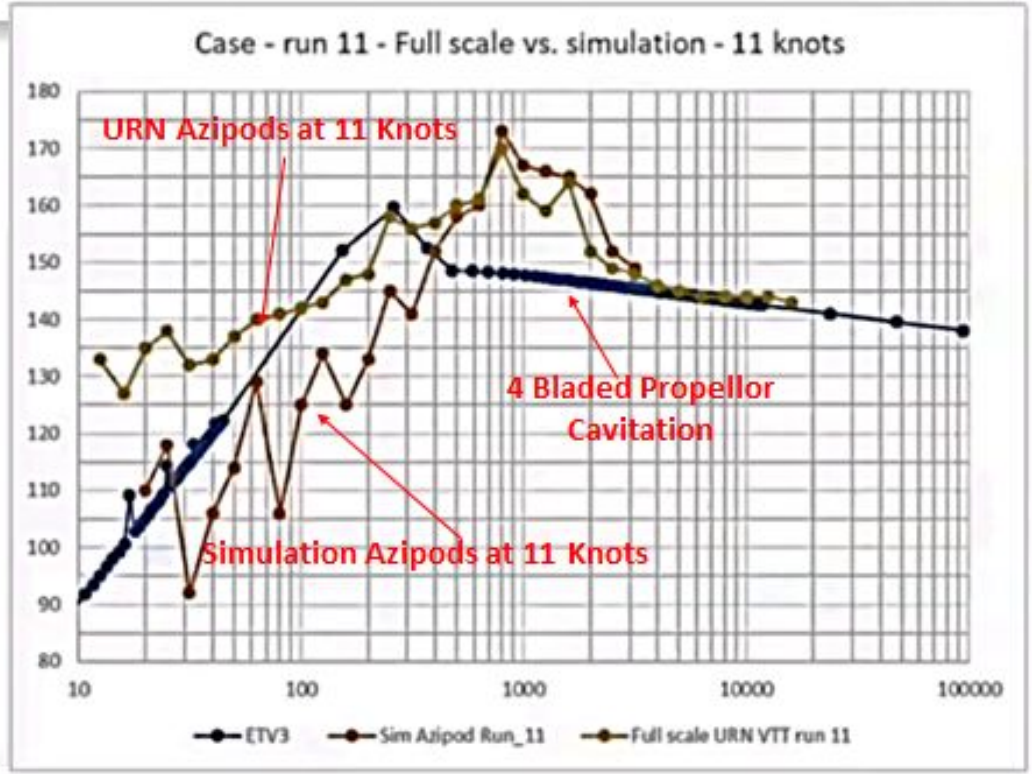
Laid down: 28 October 2003
Launched: 12 June 2005
Length: 294.13 m (965 ft 0 in) oa, 263.5 m (864 ft 6 in) pp
Speed: 25.6 knots (47.4 km/h; 29.5 mph)

The Norwegian Jewel appeared to be following existing Canadian regulations regarding speed in waters known to have Orcas present.

Case Polaris IB – 11 knots

- Azipod rating: 1500kW / 134RPM
- The magnetic noise simulation catch well the main peaks – 800Hz and 1600Hz.
- Propeller noise simulation match with hump center frequency location and magnitude.
- There is cavitation on the blades, because the inception speed is lower than 11 knots.
- The total noise curve measured during trial contains all noise sources.
- ABB analysis focus on propeller and magnetic noise peaks.

- To Conclude: Current ABB URN simulation method is able to predict noise emission with high accuracy.



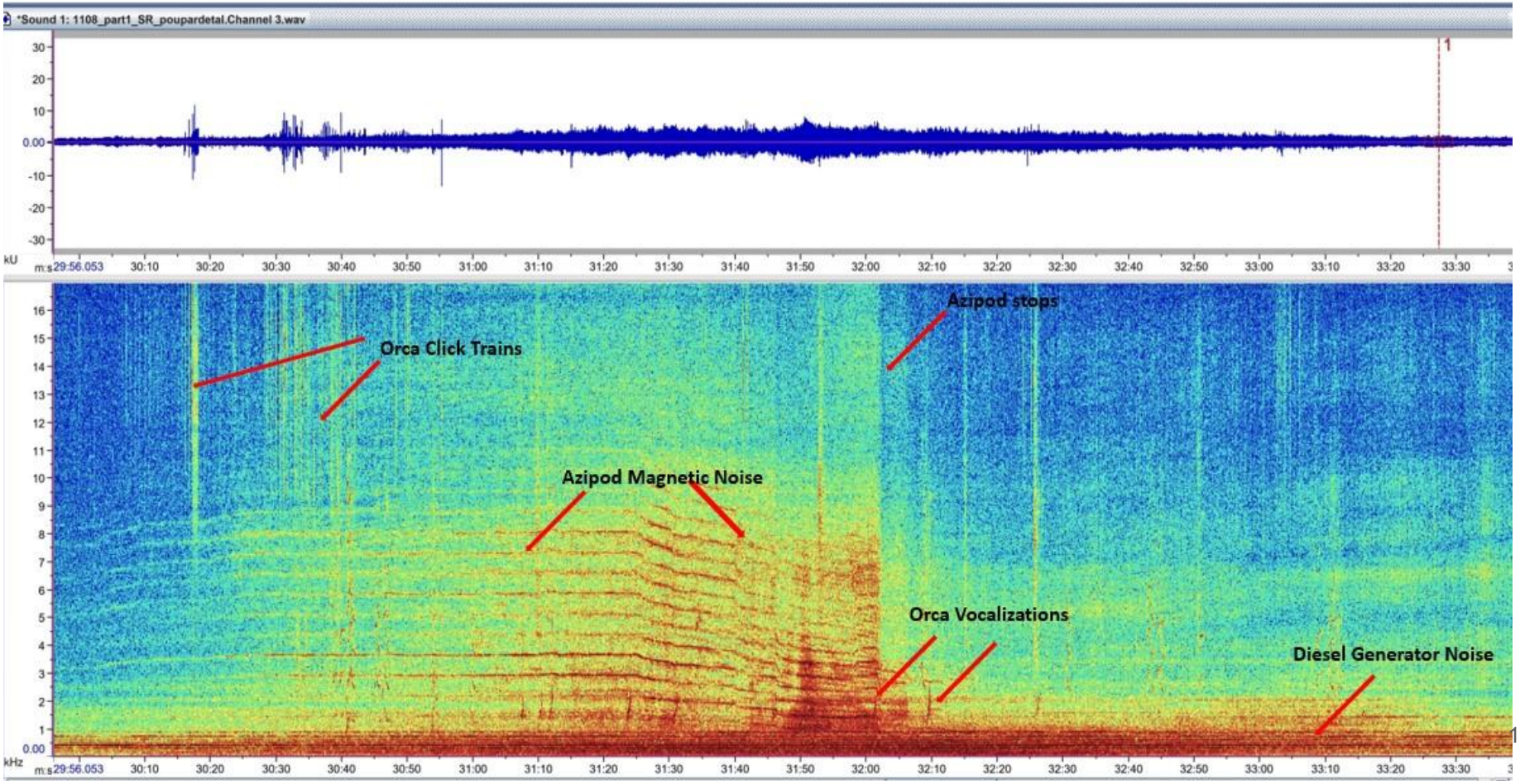
Radiated Noise Test (URN) of Icebreaker Polaris 2020, off Helsinki

ABB

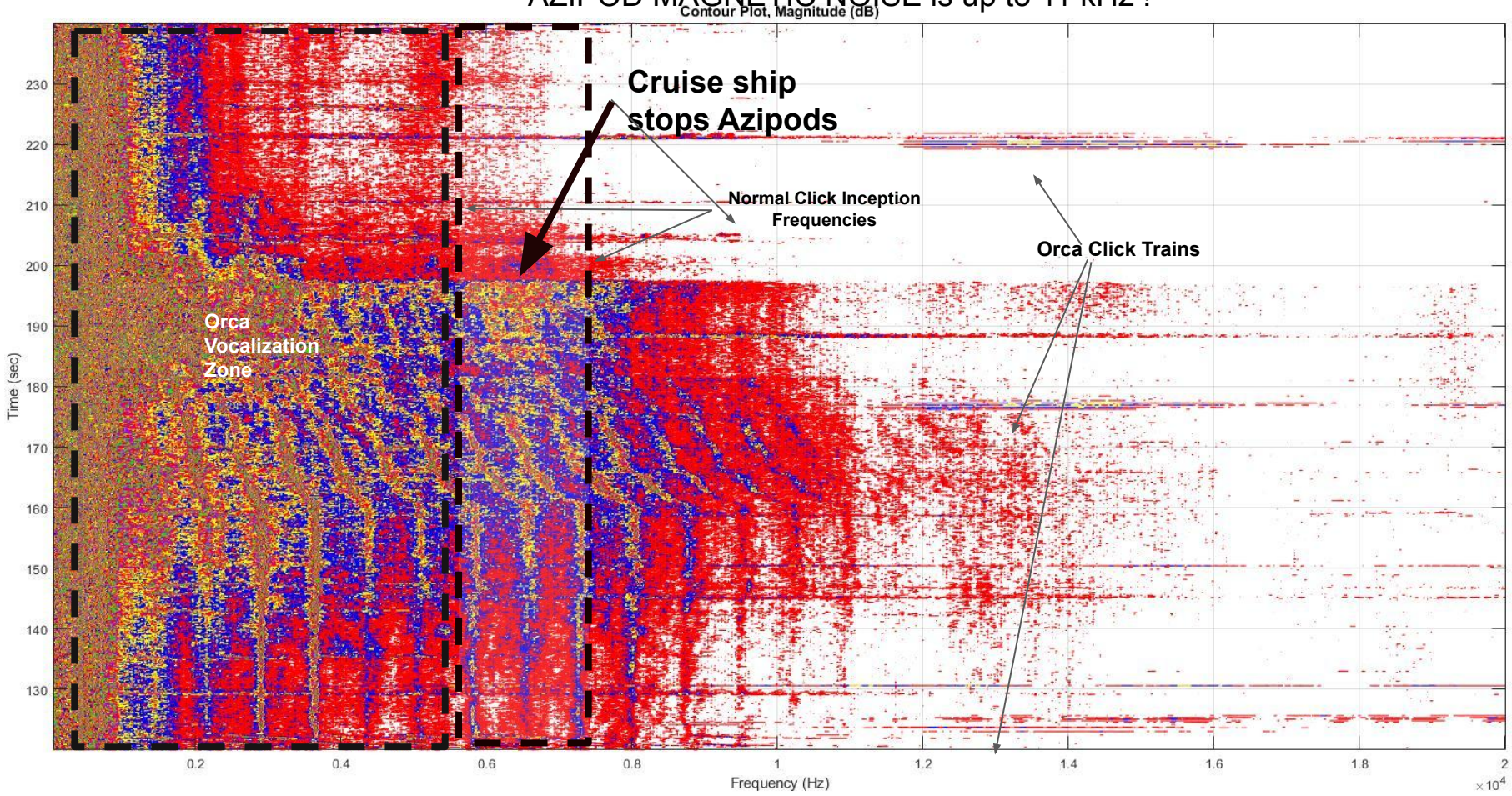
The Norwegian Jewel has 75 Megawatt Power

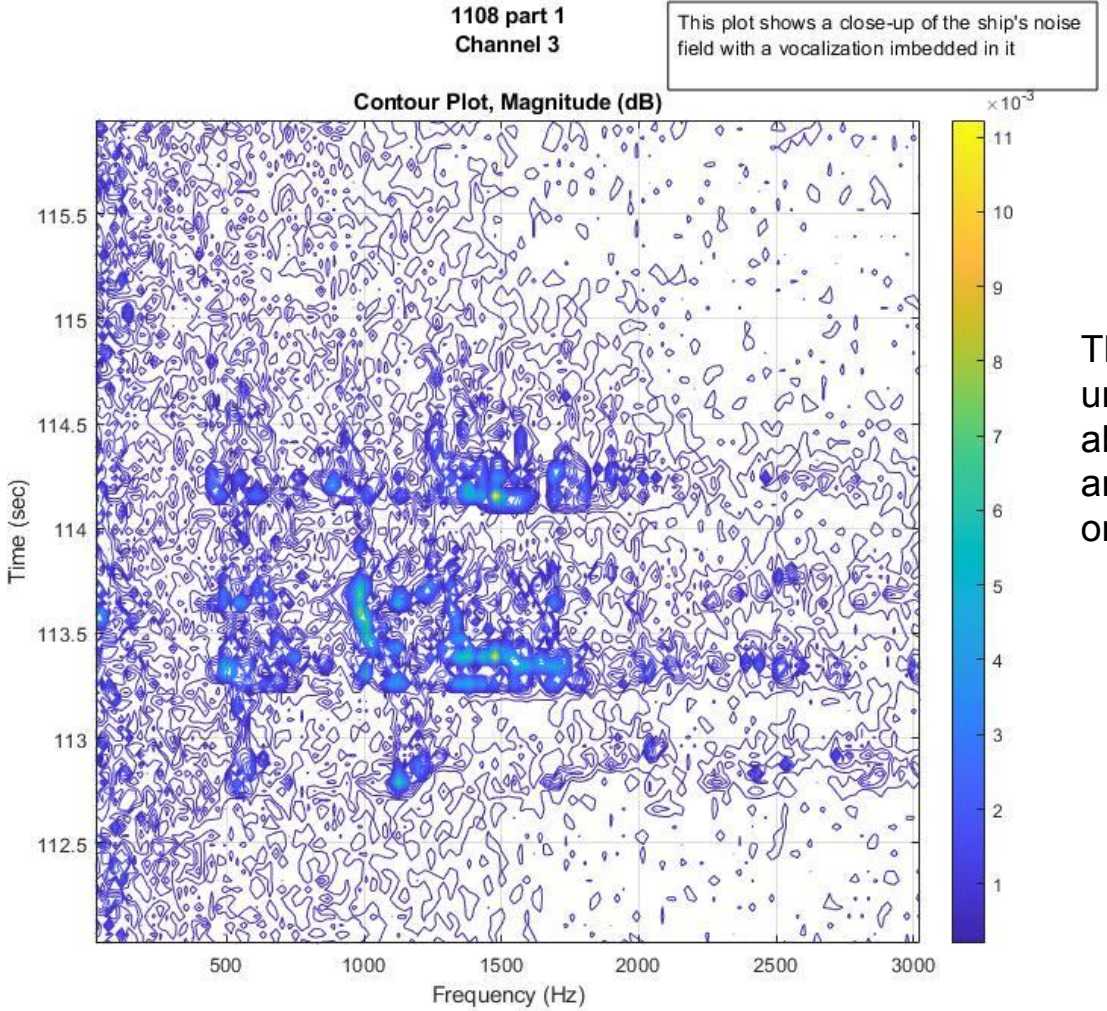
Cruise Ship CPA

Underwater Radiated Noise with Orcas Present

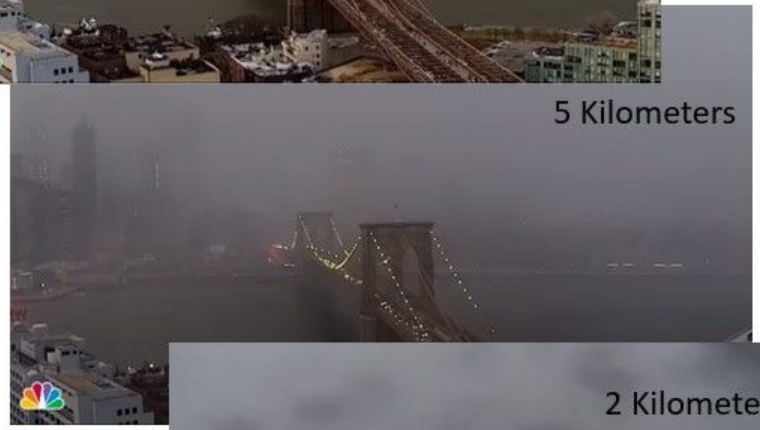


AZIPOD MAGNETIC NOISE is up to 11 kHz !

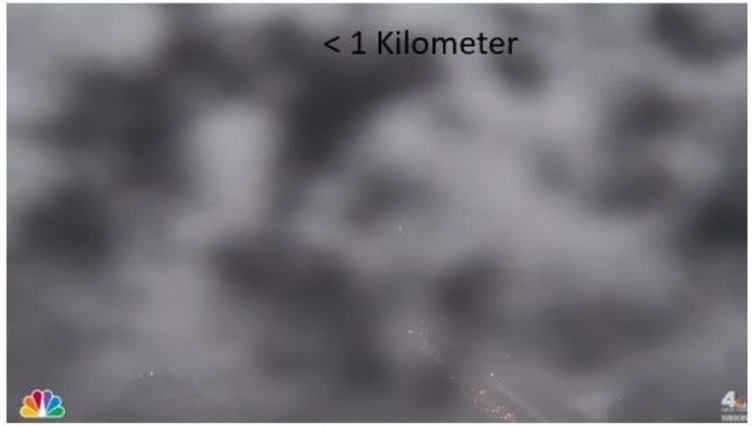




The ship's machinery dominated the underwater acoustic noise field up to about 1800 Hertz The bright lines are the acoustic signature of and orca's vocalization



Orcas use sound to see. The underwater soundscape is profoundly impacted by manmade noise. The frequency (pitch) and amplitude of this anthrophony degrades Orca's ability to adequately "see" its environment.



Summary

Generally the relative amplitude of clicks versus ambient is 20-35 dB above background.
Vocalizations are between 9 and 14 dB above background.
At the approximate maximum acoustic CPA we measured the ship at 21.3 dB above ambient. This is a broadband measure and is just before the Azipod propulsion shuts down

When the ship is still several kilometers from the Orca there is evidence that Orca vocalizations are impacted. As the ship closes inside one kilometer, specific machinery noise increases to the point where it is doubtful the Orca can communicate well or use echolocation.

There is an urgent need to perform quantitative radiated noise measurements on various classes of ocean going vessels to better understand the true impact they may have on Cetaceans in general but especially on Odontoceti.

The scope of such a program will require national support.

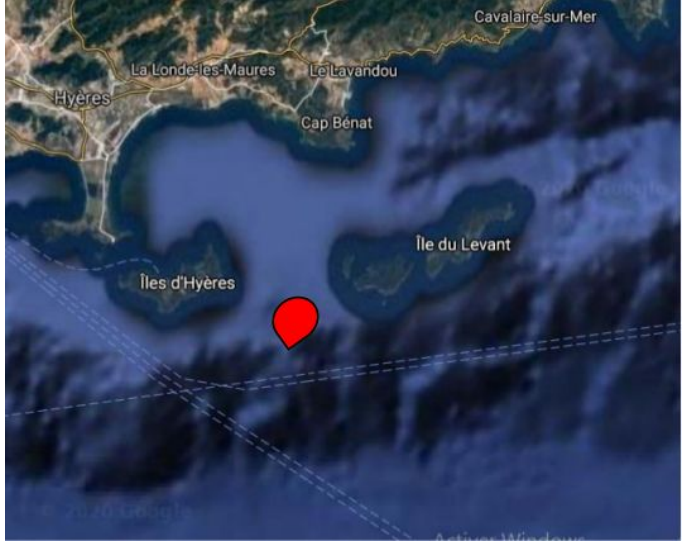
The American Bureau Of Shipping (ABS) has issued ***GUIDE FOR THE CLASSIFICATION NOTATION UNDERWATER NOISE AND EXTERNAL AIRBORNE NOISE MAY 2021.***
Excerpt from Introduction:

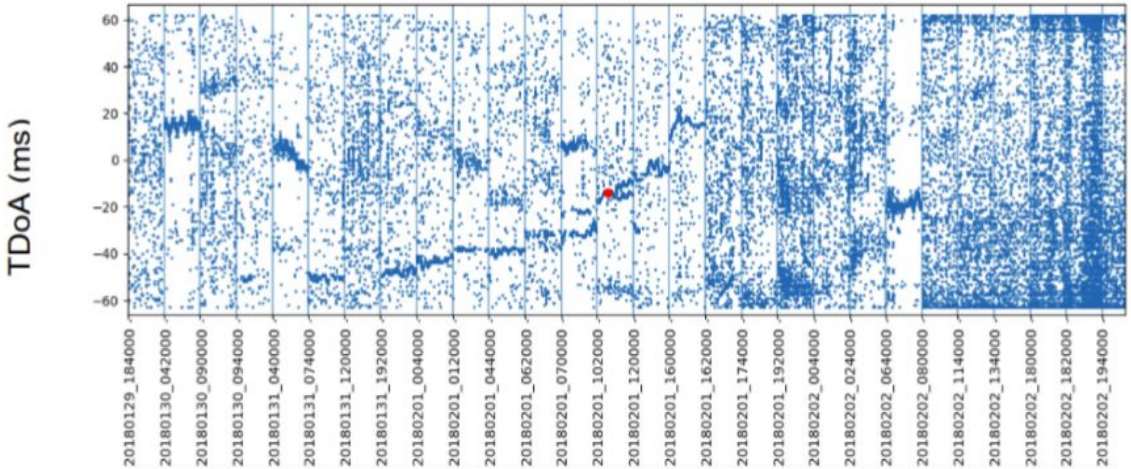
> ***Introduction (1 May 2021)***
> *The impact of underwater ship noise on marine life as a result of the global increase of vessel numbers, vessel size, and propulsion power has recently become an emerging issue in the marine industry. Ships generate underwater noise over a broad range of low frequencies, particularly from the propeller, machinery, and hull movements. The radiated underwater noise poses a potential threat to marine mammal behavior and/or induces stress responses as it may interfere with their hearing of natural signals for communication, feeding, socializing, prey detection, and orientation in the water. Historically, underwater radiated noise from commercial vessels was not a key area of consideration in ship design and construction. However, efforts have been made by international regulatory bodies such as IMO and the EU to minimize the adverse effect of underwater radiated noise from commercial vessels on marine mammals (see, for instance, IMO MEPC.1/Circ.833; EU MSFD 2008/56/EC). Noise emitted by vessels to the surrounding environment is becoming a concern in many port areas, especially those close to residential areas. Noise sources on vessels, such as engine ventilation, can be loud and travel significant distances. Around-the-clock operation of vessels berthed at the port also poses an additional challenge, since the emitted airborne noise causes nighttime disturbance of nearby residents. All these can have a negative impact on the well-being and health of the residents living in the proximity of a port.*

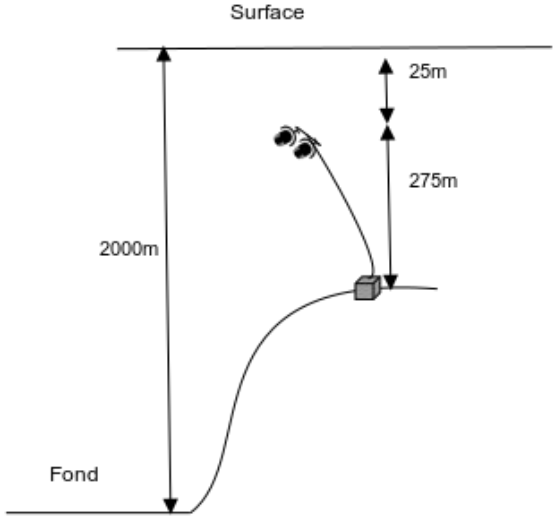
BOMBYX1 - 2015 2018

The BOMBYX station

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







BOMBYX1 effort and detection of Physeter

-

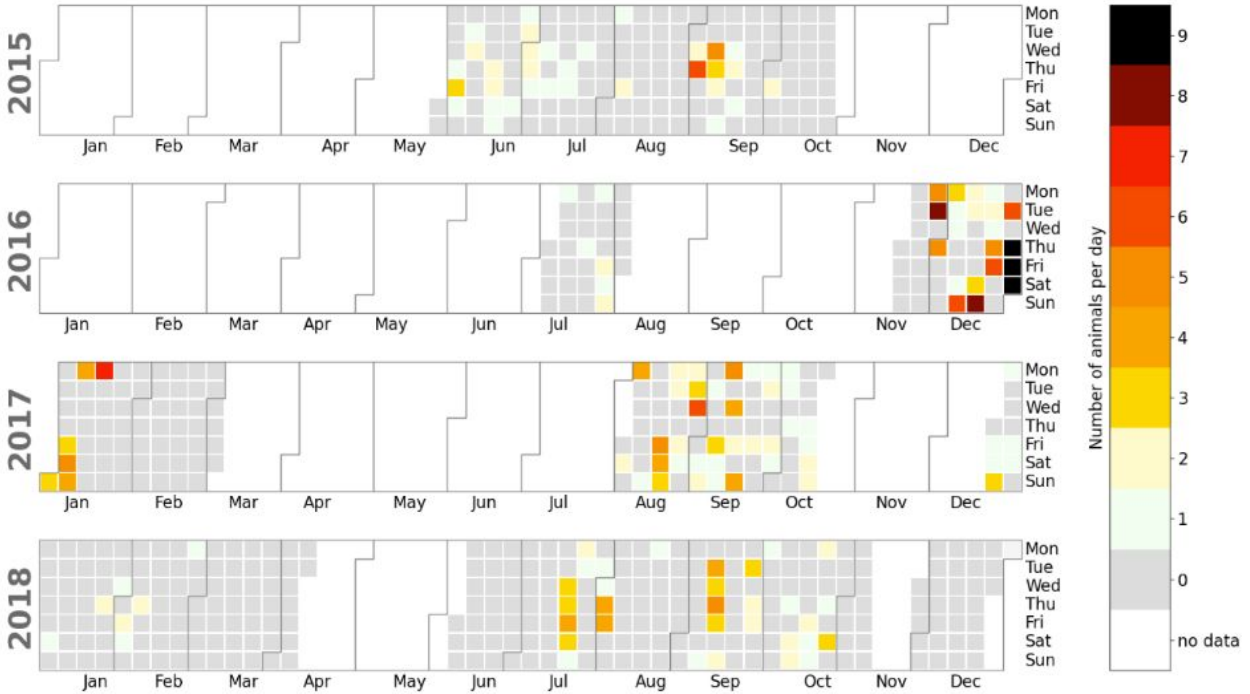
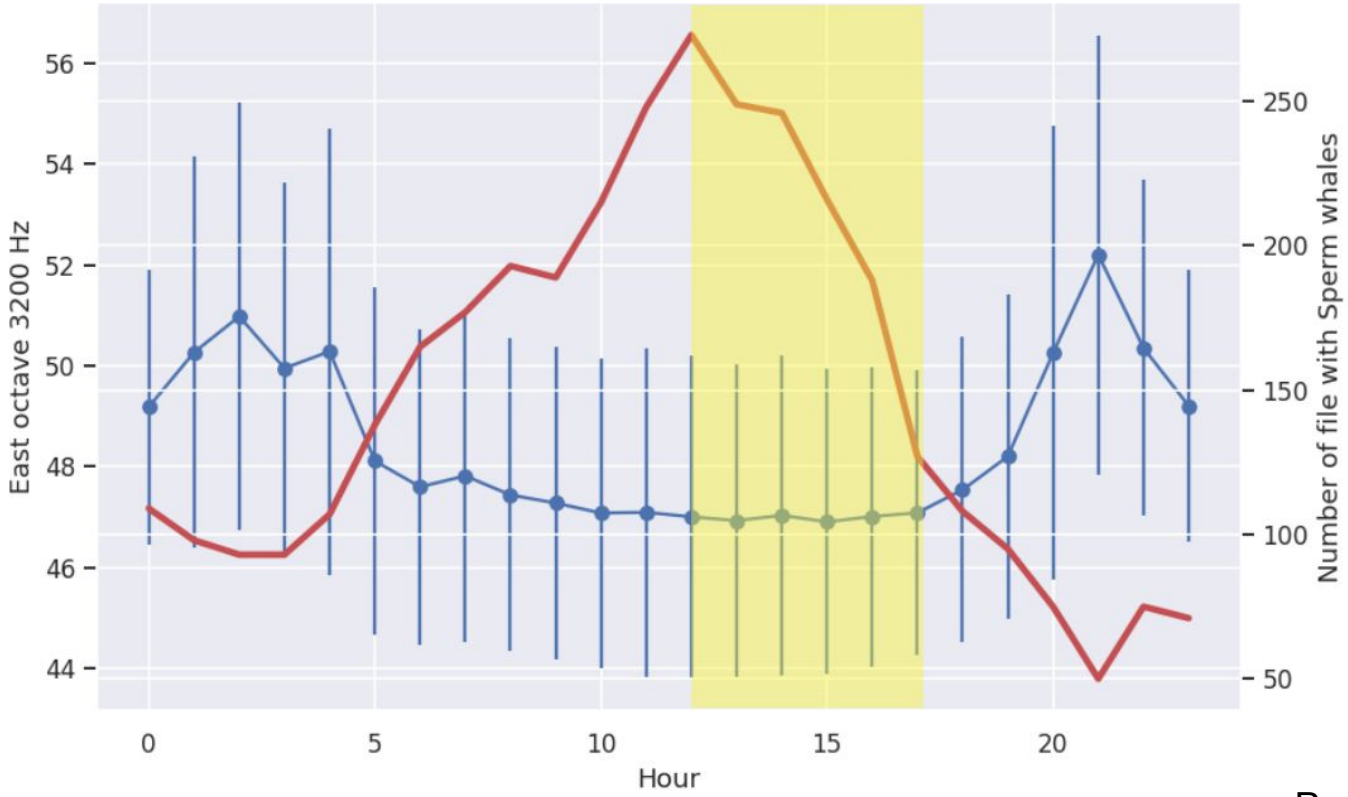


Figure 1. Number of animal per day during the 4 years of recordings

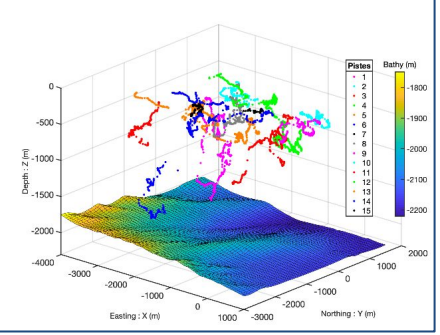
Summary of Bombyx1 : Physeter avoid traffic noise !

dB level re 1uPa



Count of whale detections (#file)

Poupard et al. 2021



FONDATION PRINCE ALBERT II DE MONACO

Explorations de Monaco
Monaco Explorations

ACCOBAMS

SEA PROVEN

UNIVERSITÉ DE TOULON

SMIoT
Scientific Microsystems for Internet of Things

SABIOD.ORG
Scaled Acoustic Biodiversity
Mastodons Big Data

Toulon Univ. LSIS CNRS
DYNI

cnrs

Etho-acoustics of Megafauna

from short 4D mobile hydrophone array, and lock down effect

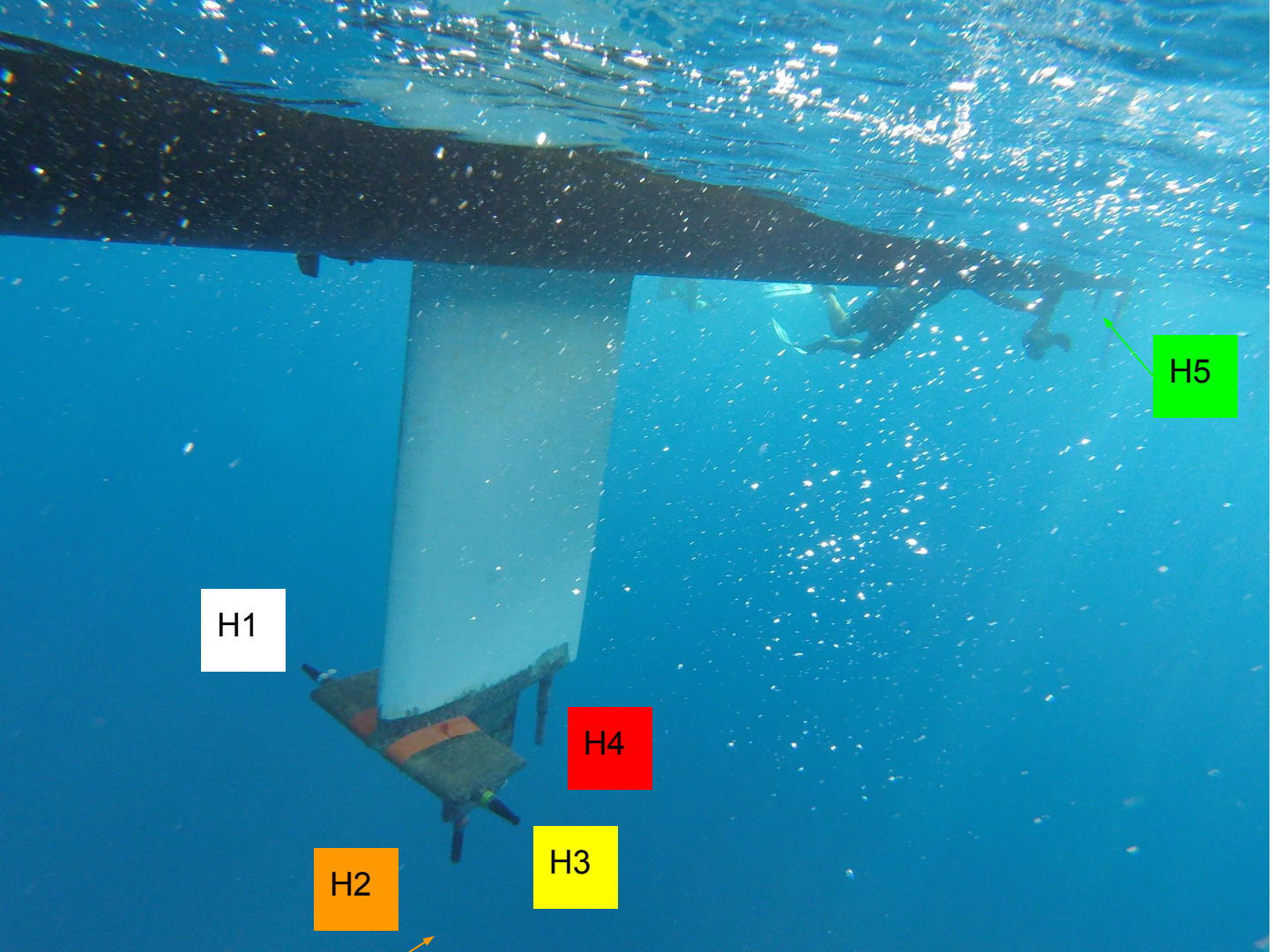
The ASV Sphyrna

ALV Sphyrna (SeaProven)

Polynesian Design, 20 m, Stable

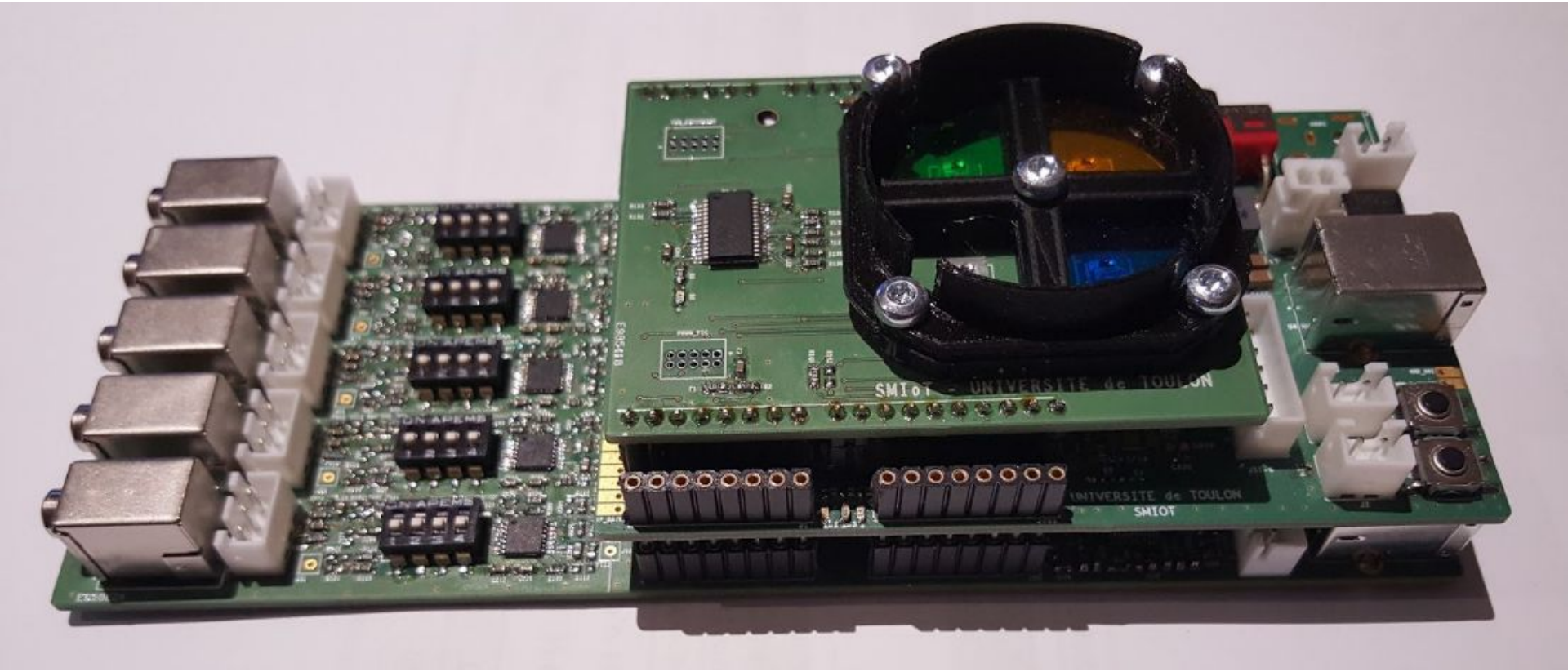
Hydrodynamic, Low acoustic print

1 t. useful charge.



The 5 hydros fixed under the keel of the ASV.

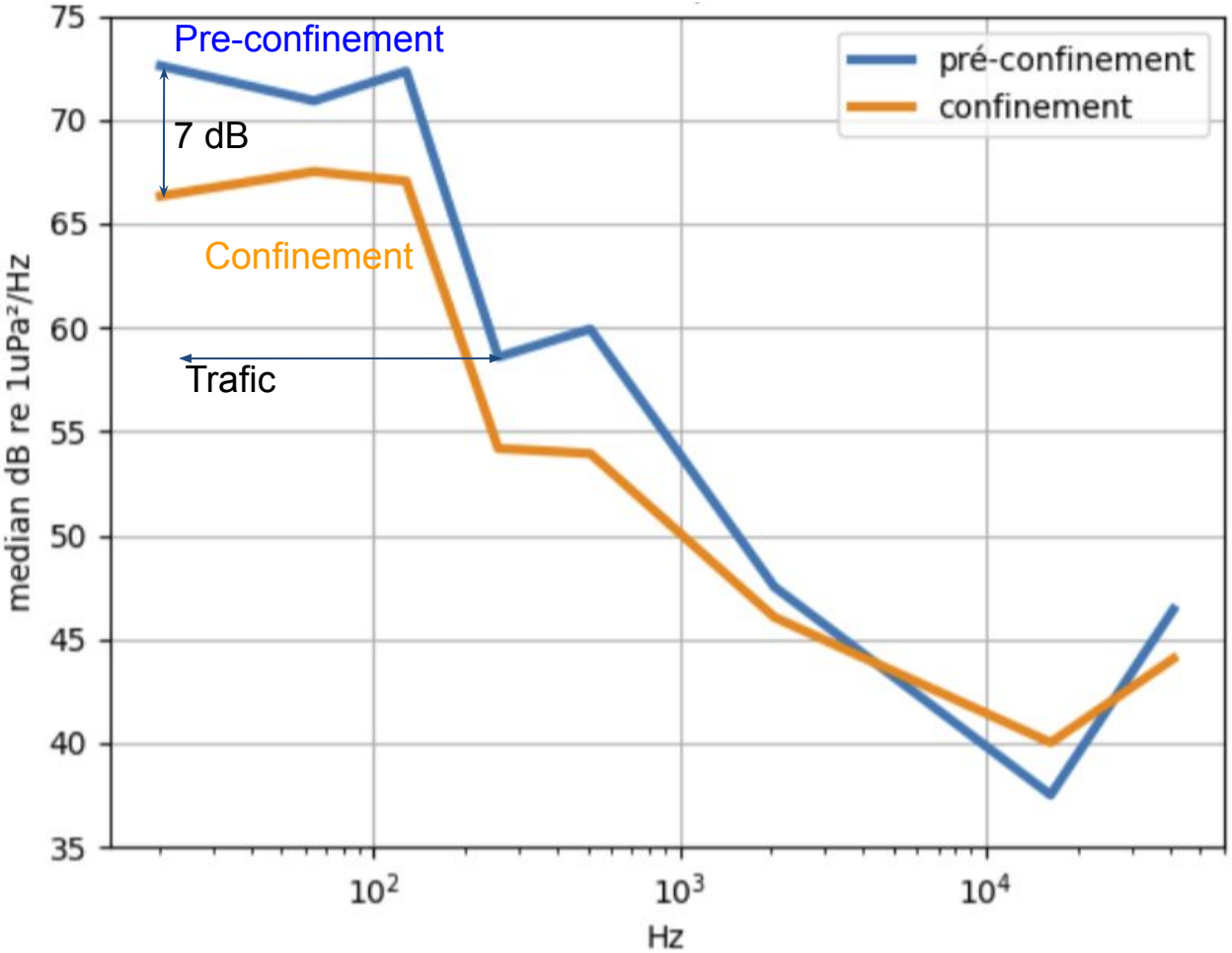
The JASON sound card from univ. Toulon, SMIoT, allowing 5 x 1 mHz Sampling rate + luxmeter, into the drone



Sphyrna Odyssey :
From October 2019 to March 2020 (before lock down) + April to May 2020 (lock down)
Map of the dB level for 20 Hz octave before lock down

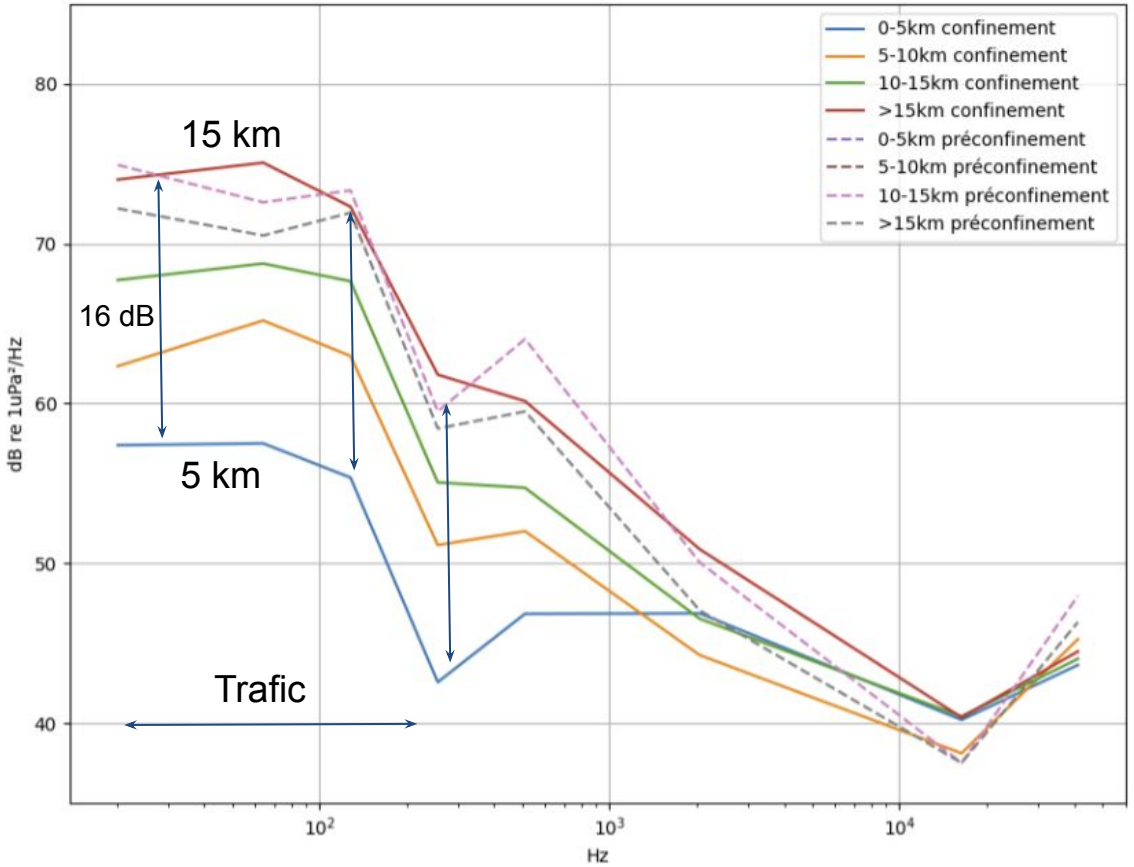
octave 20Hz

Covid effect



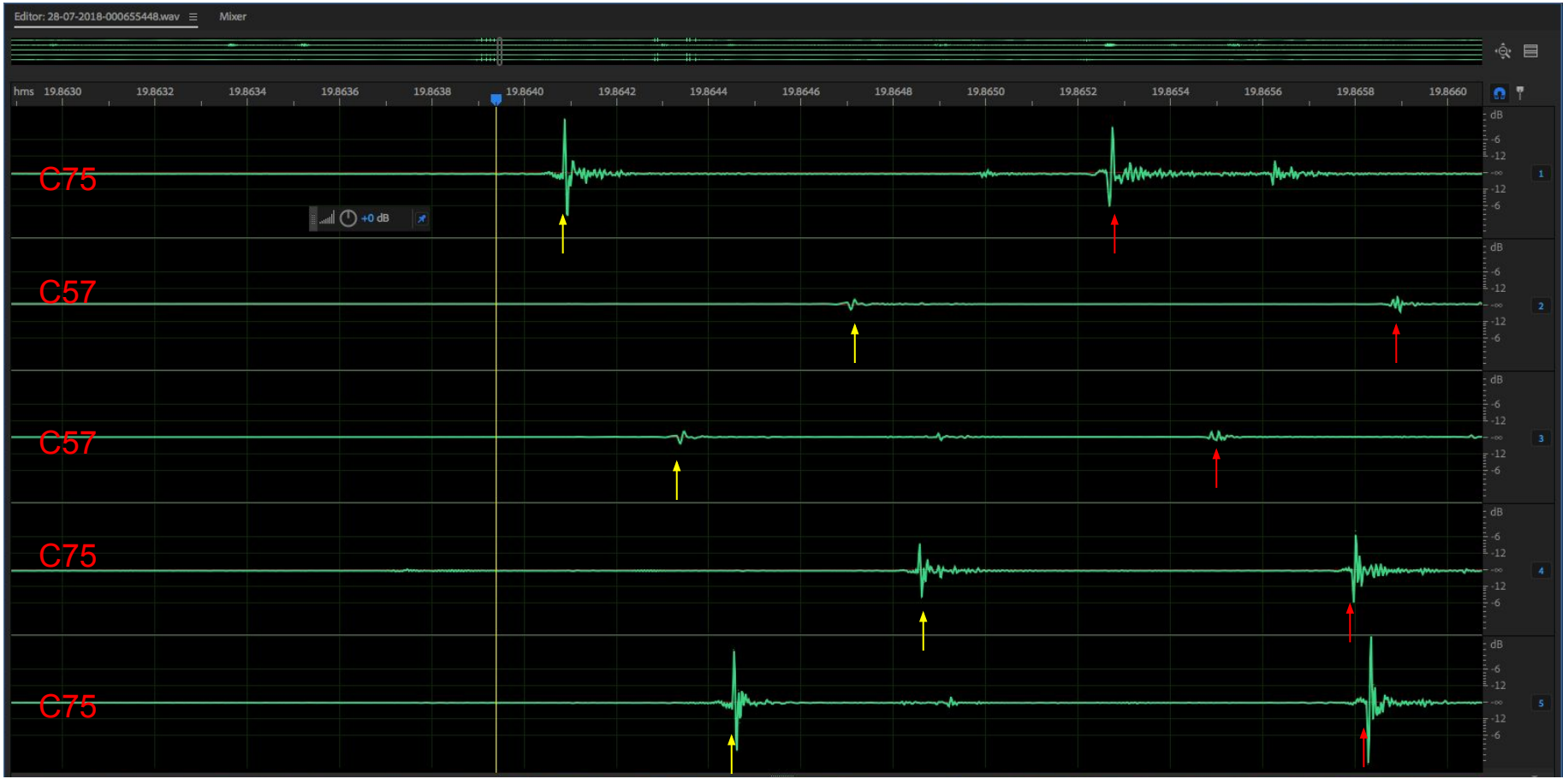
Medium of minimum dB levels, hourly, for each octave during (blue) vs out (orange) lock down

Effect of the Coast distance
& of the lock down

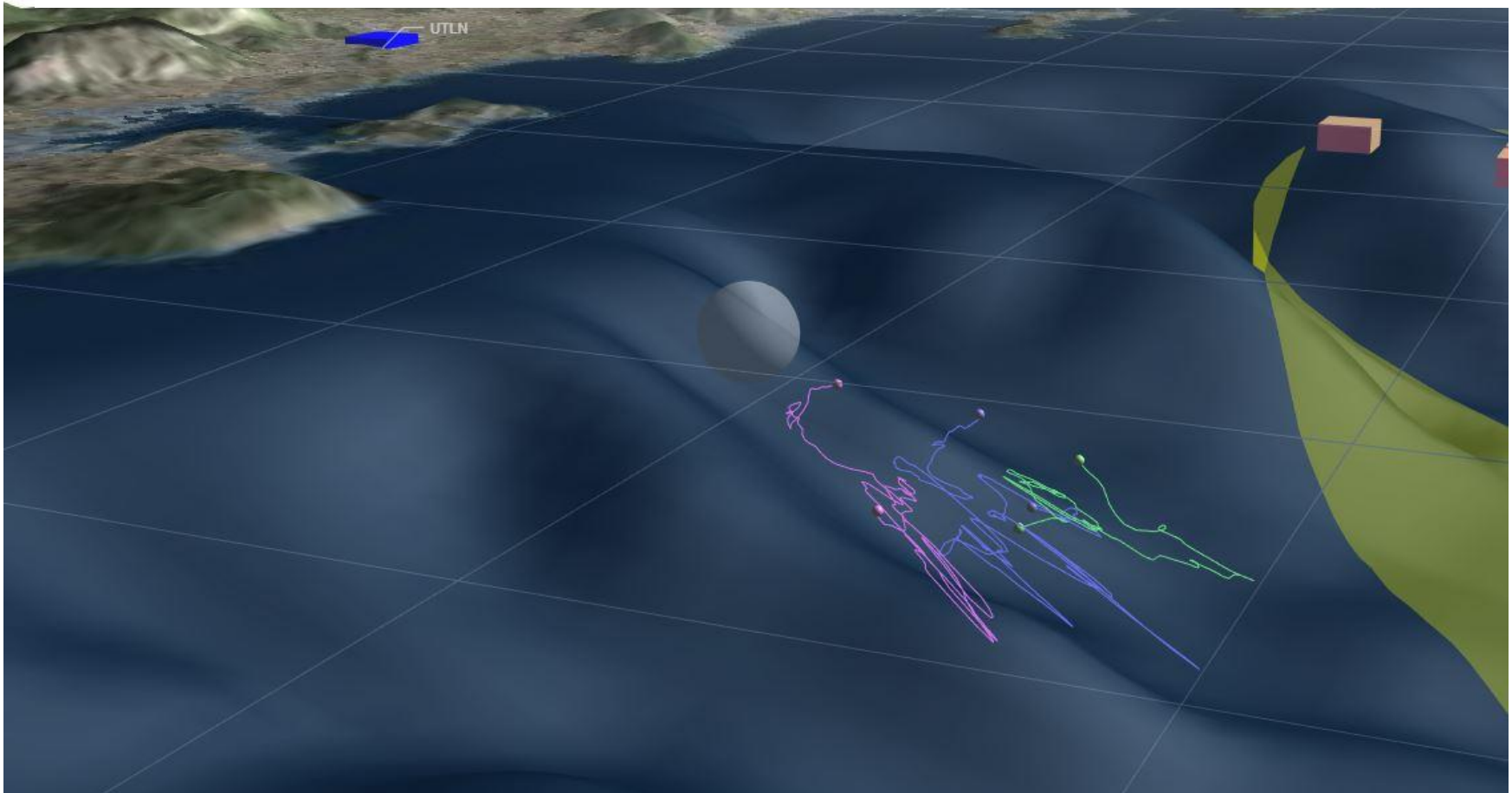


Medium of minimum dB levels for each octave during vs out lock down according to distance to the coast

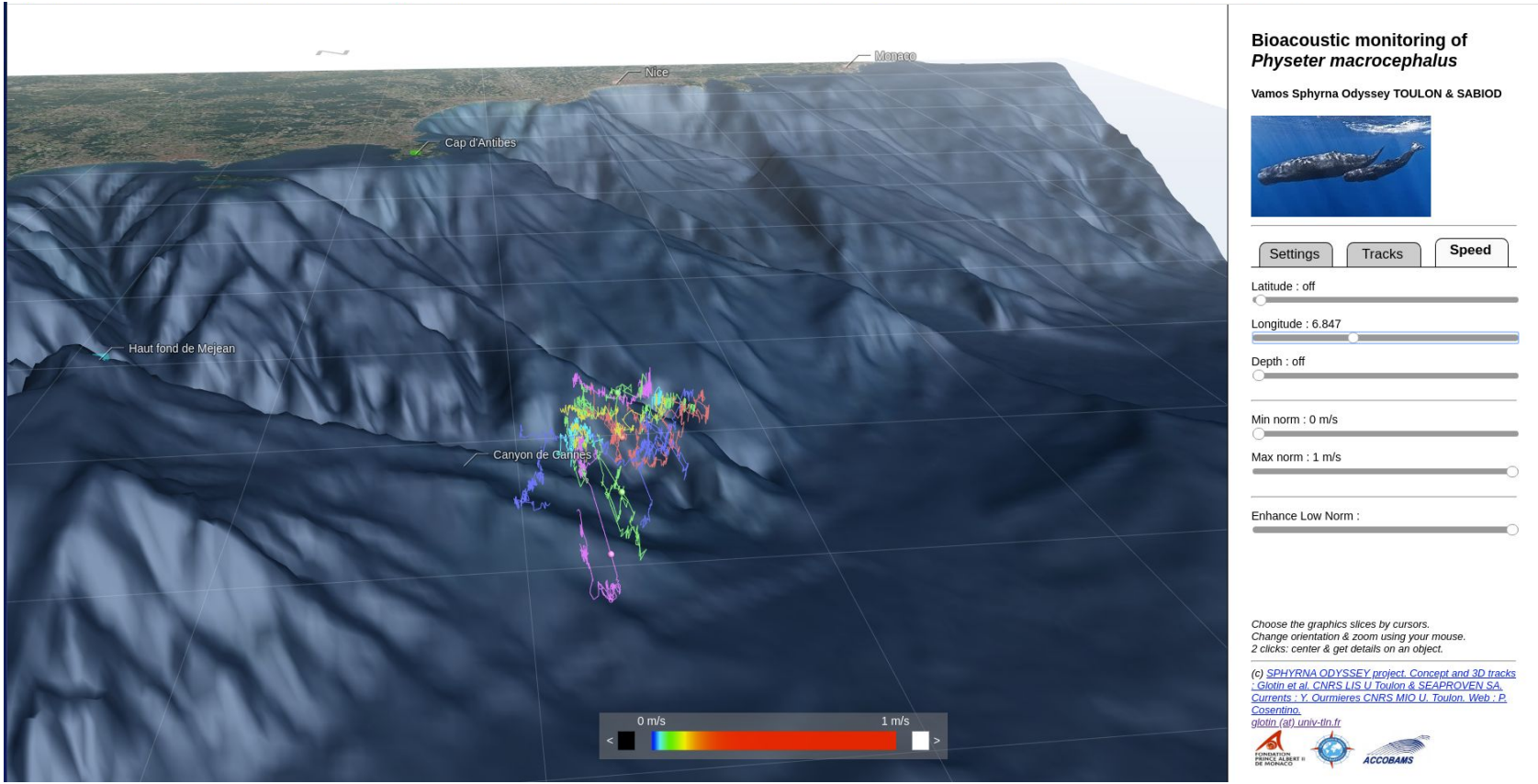
Clear dolphin clicks, TDOA measures, recorded on 5 channels, Chan 1, 4, 5 = gain x 4, Chan 2, 3 = gain 1/2



August 2018, 1 Physeter, 3 tracks, 50 minutes each, down to -1000 m



January 2020, South of Antibes



https://sabiod.lis-lab.fr/pub/SPHYRNA/3D/current_norm/

Matching poursuit & tracking 3D

Missions Sphyrna 2018, 2020, 2021…

Bio-Multistatisme ?

=> corpus & AI

Det Class Loc & Propagation joints

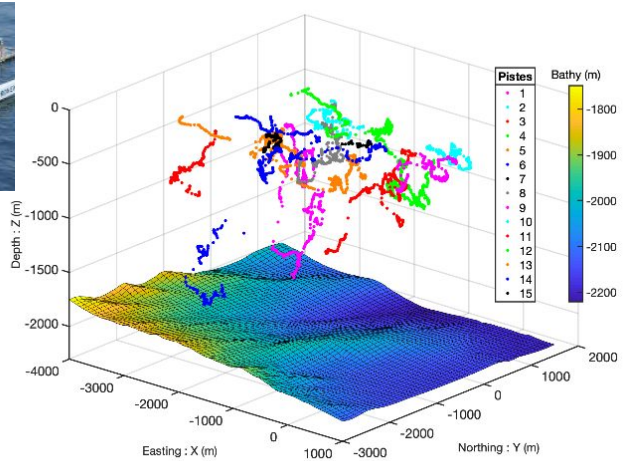
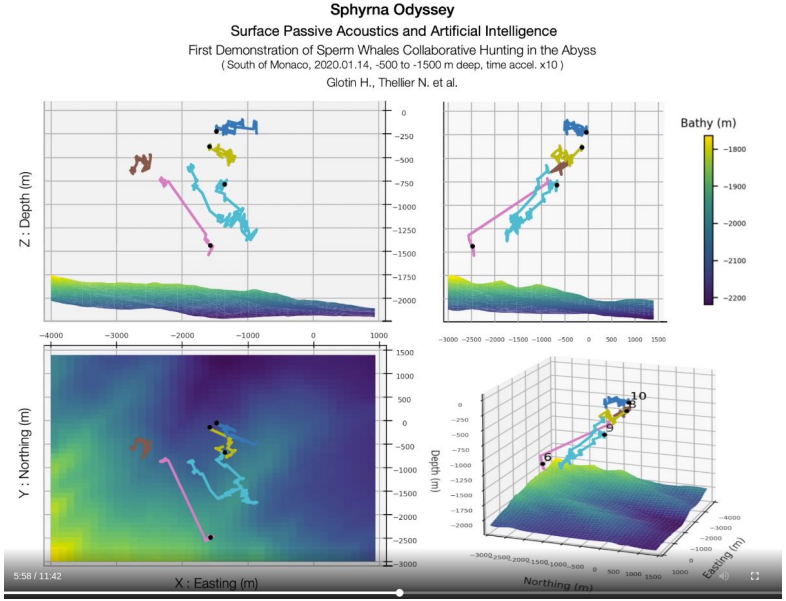
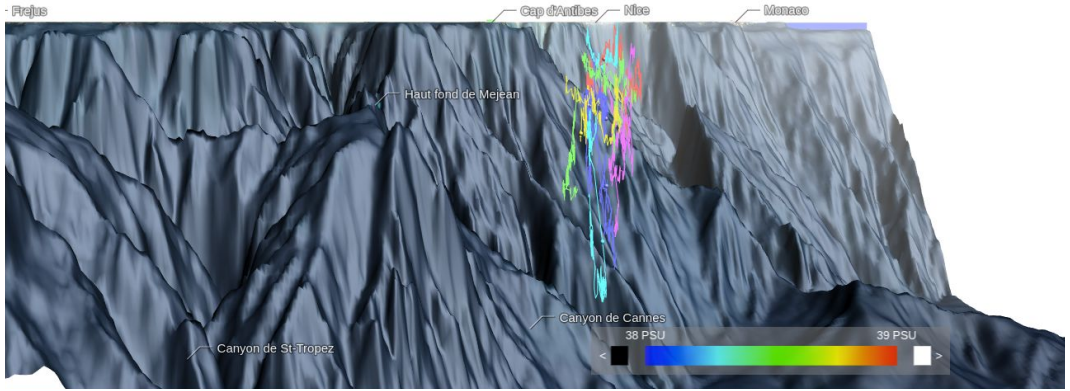


Figure 3.1: Traces 3D des déplacements des 15 pistes (record entier)





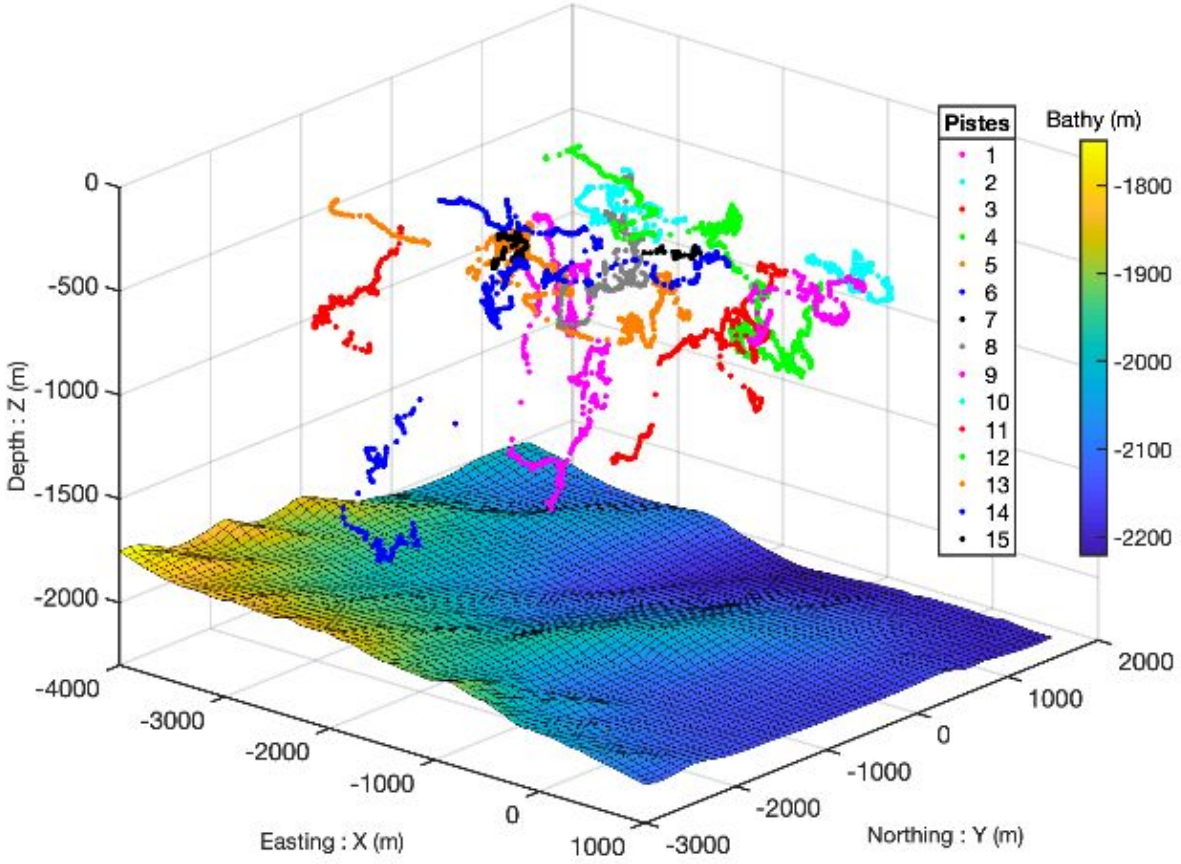
14 january 2020, 6 Physeters : Alliance = coordination up to 500m

http://sabiod.univ-tln.fr/pub/SPHYRNA/Sphyrna_Odyssey_3DAbyssalAlliance20200114Monaco.mp4

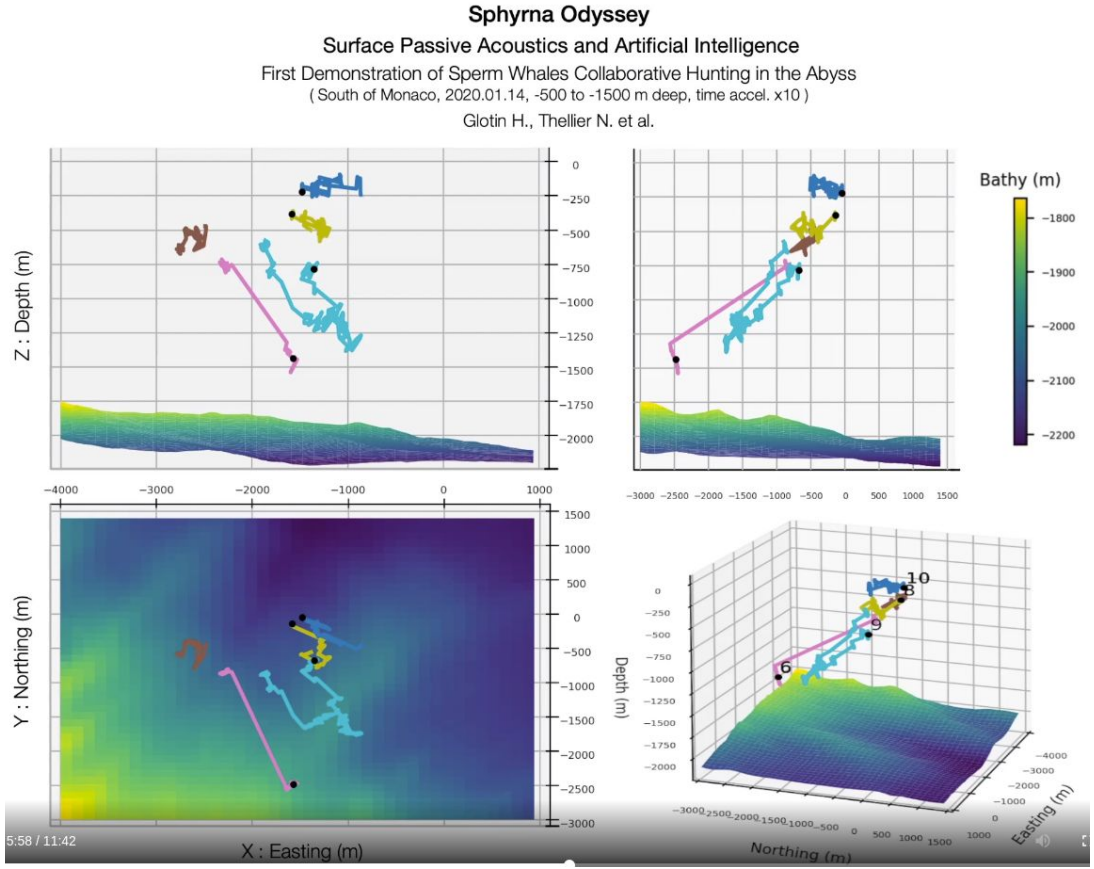
Correlation between the tracks : Alliance

Coincidences of the beams of the biosonars

They Collaborate May need Silence to do so.

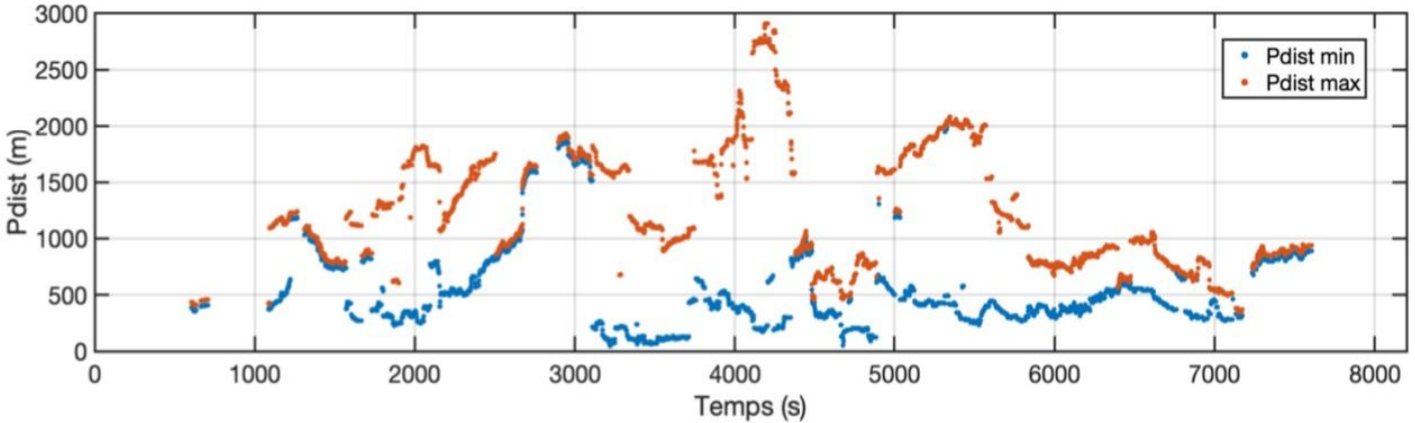


Dynamic visualisation of the tracks :
https://sabiod.lis-lab.fr/pub/SPHYRNA/3D/SO_Glotin_Thellier_etal_PhyseterAlliance_Monaco_20200114_3DtracksX_Y_Z.mp4



Ethoacoustics : Inter track distances

1 minute time window, computation of distance between each pair of tracks



→Majority Pdist min @ 400-500 m, in agreement with the travel of the click and its echo :

Emission @ 180 dB allow a two way travel of 430m :

Echo Energy Equation $EE = S - 40 \log(R) - 2\alpha(f)R + 20 \log(d)$

New criteria for TSL ?

More results in 3D visualisations with currents

Trajectories :
http://sabiod.lis-lab.fr/pub/SPHYRNA/3D/SO_Glotin_Thellier_etal_PhyseterAlliance_Monaco_20200114_3DtracksX_Y_Z.mp4

Trajectories and norm of the current :
https://sabiod.lis-lab.fr/pub/SPHYRNA/3D/current_norm

Trajectories and thermocline :
https://sabiod.lis-lab.fr/pub/SPHYRNA/3D/temp

Trajectories and halocline :
https://sabiod.lis-lab.fr/pub/SPHYRNA/3D/salt

Demo of the map : https://sabiod.lis-lab.fr/pub/SPHYRNA/radio/20201029_FranceInter_TerreauCarre_Glotin_1h/Sphyrna_Odyssey_courant_halocline_3D_aveclestrajectoires_20200114.mp4

Conclusion

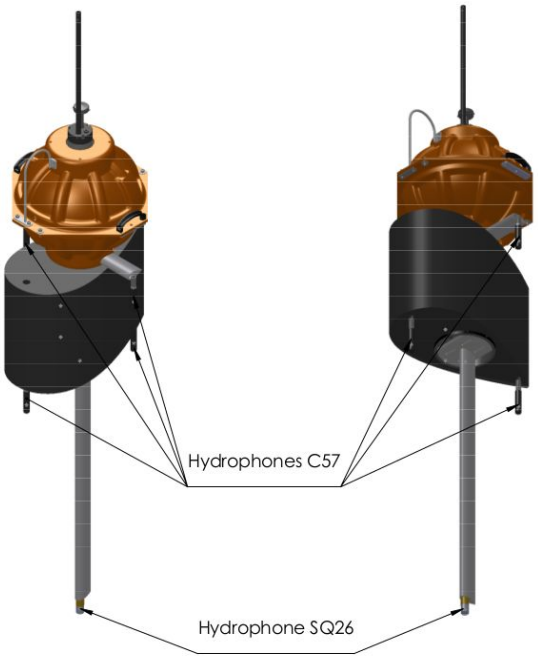
Evidences of soundscape variation during Covid19.
First 3D tracking of group of Physeters from small mobile surface antenna.
First demonstration of Alliance of cachalots.

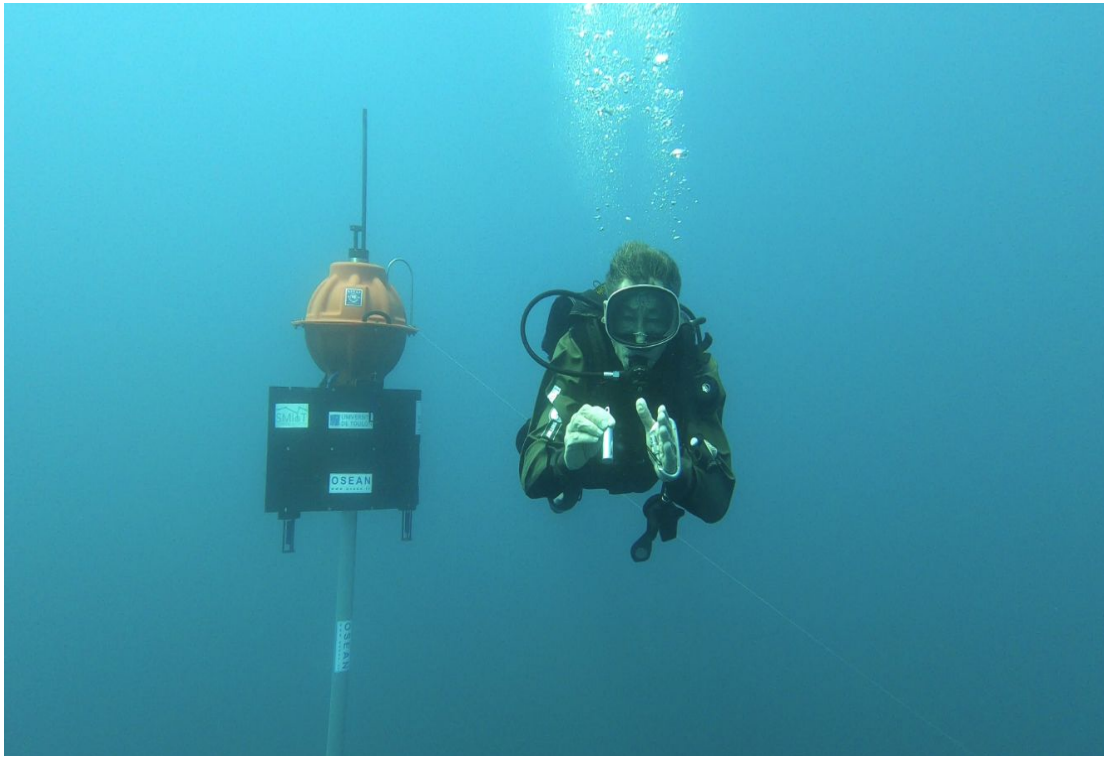
Perspectives : Ethoacoustics of the Abyssea, correlation to current, oceanic front, halocline, thermocline, size / age of the individuals, success of predation in group versus alone, interaction in 3D with boat trafic …

Real Time sonobuoy with the same technology (3D) is being deployed in Toulon and Corsica in GIAS MARITTIMO Project for anti-collision

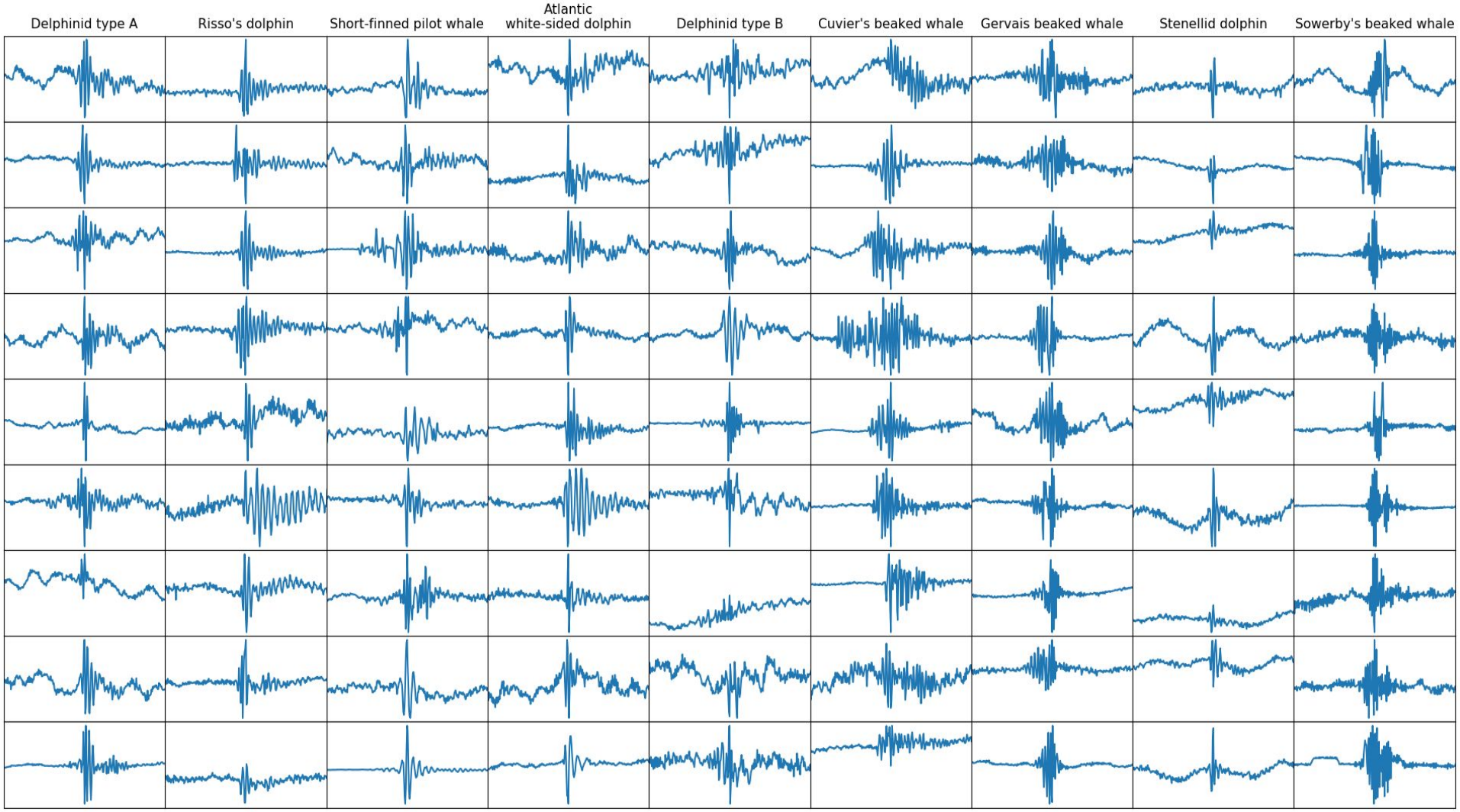
We thank ACCOBAMS, FAP2, EDM for their grants,
SEAPROVEN for its strong effort
and PNPC/Pelagos for logistic support

BOMBYX2 : pentaphonic with surface real-time alert transmission



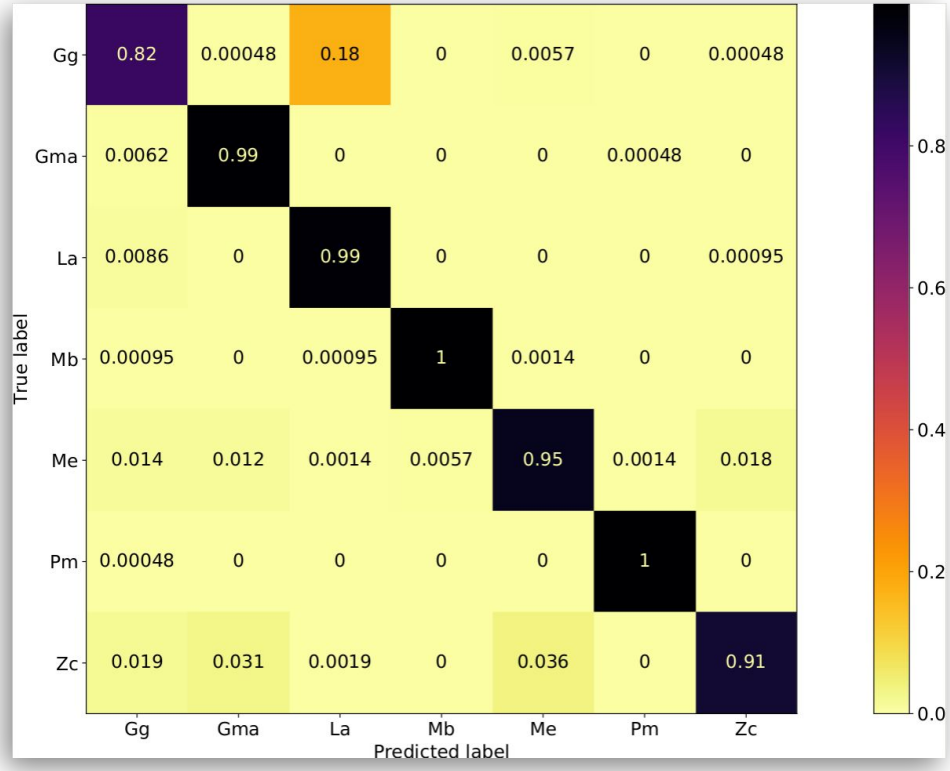


GIAS MARTTIMO Glotin et al 2018-2021, coll OSEAN, SMIoT


Delphinid type A
Risso's dolphin
Short-finned pilot whale
Atlantic white-sided dolphin
Delphinid type B
Cuvier's beaked whale
Gervais beaked whale
Stenellid dolphin
Sowerby's beaked whale

Neural network raw wav classification (Ferrari et al 2020)

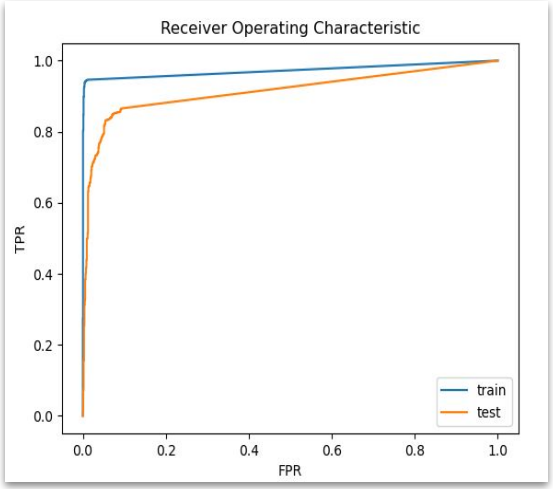
Accuracy = 95.1 % on the 7 classes



Ferrari et al. 2020

Embeded AI into BOMBYX
Bombyx 2 - CNN for Physeter

- **Convolutionnal neural network validation**
  - Relatively low compleity (~10k parameters)
  - Input : Mel-scaled spectrum between 2kHz and 25kHz
  - 98% AUC train, 93% AUC test
- **Azimuth and distance estimation**
  - Click onset recording using the analog detector
  - 50ns time resolution
  - All hydrophones pointing downwards
  - Integration of the triangulation of multiple pulses

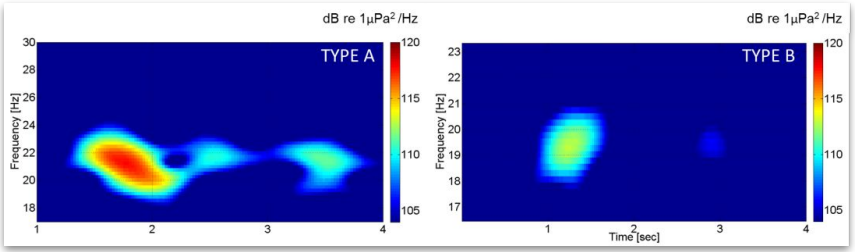


- Sampling frequency = 50kHz
- STFT (winsize=512, hopsize=256)
- Mel (64 features from 2 to 25kHz)
- Log
- Conv 64 - 64
- Conv 64 - 64
- Conv 64 - 1
- MaxPool

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

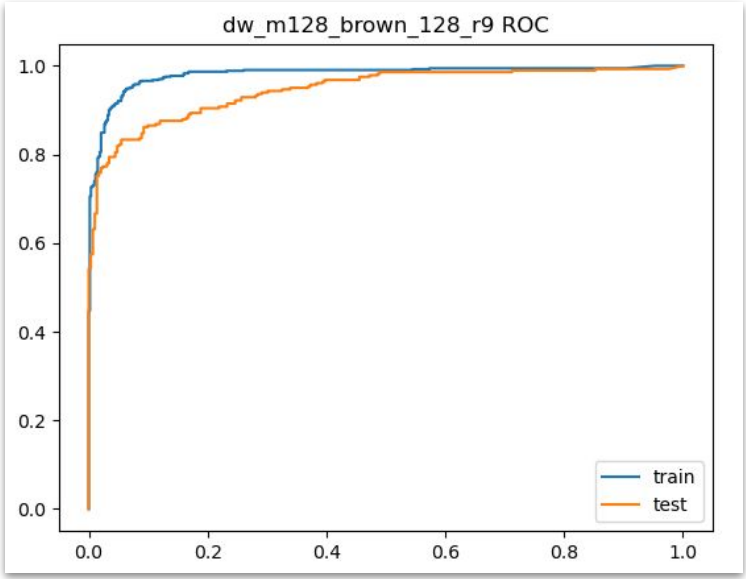
Best et al. 2020

Fin whale pulse detection
Context - Fin whale pulse



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

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

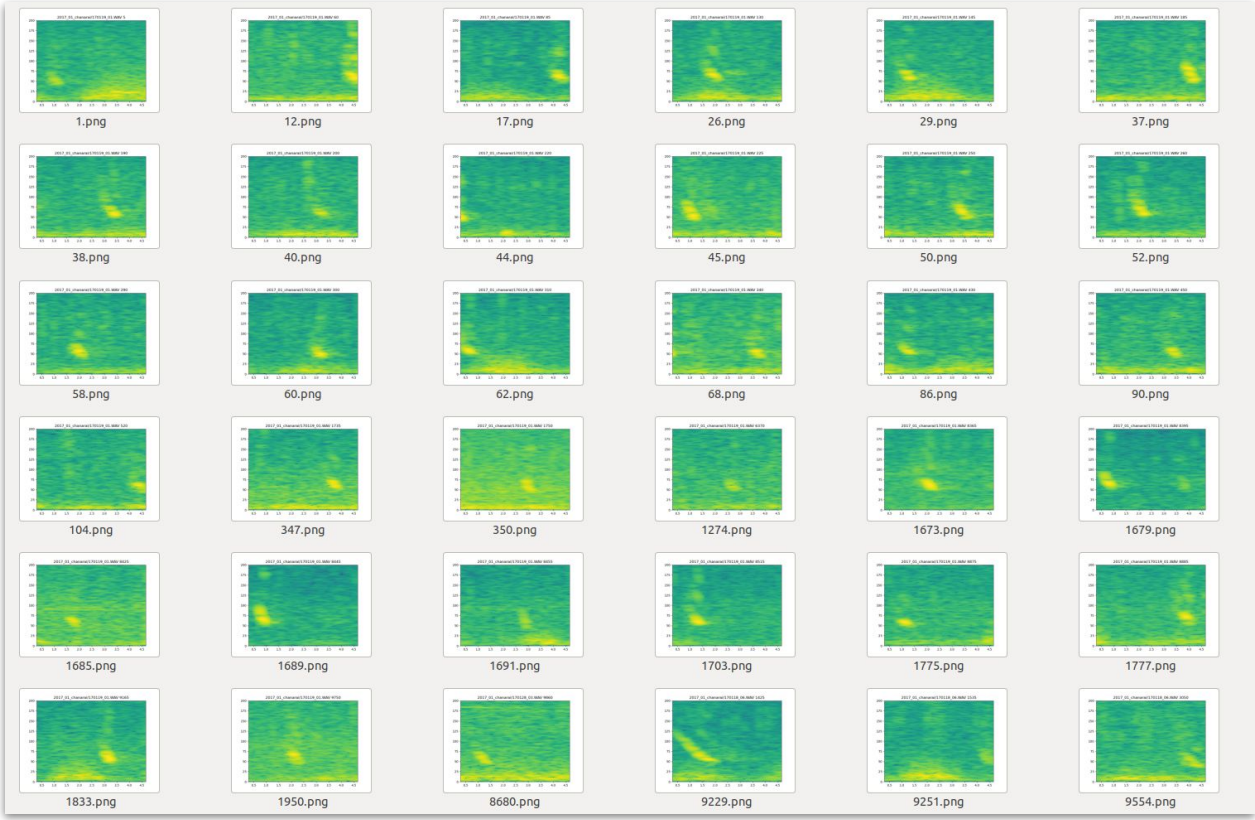


Best et al. 2020

Low Frequency event classification : Fin whale pulse detection

Application to new datasets

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



Best et al 2021

JASON 2015-2020 :: QHB http://sabiod.org/pub/QHB.pdf

A NOVEL LOW-POWER HIGH SPEED ACCURATE AND PRECISE DAQ WITH EMBEDDED ARTIFICIAL INTELLIGENCE FOR LONG TERM BIODIVERSITY SURVEY

Valentin Barchasz[1,2,3] **Valentin Gies**[1,2] **Sebastián Marzetti**[1,2] **Hervé Glotin**[1,3]

[1] Université de Toulon, INPS, SMIoT, France
[2] Université de Toulon, Aix Marseille Univ. CNRS, IM2NP, Marseille, France
[3] Université de Toulon, Aix Marseille Univ. CNRS, LIS, DYNI, Marseille, France
valentin.gies@univ-tln.fr, glotin@univ-tln.fr, http://smiot.univ-tln.fr

ABSTRACT

Acoustic monitoring is a key feature for studying biodiversity. Recent works on very high frequency animal sounds open new insights and challenges on biodiversity survey. In order to set a scaled monitoring, and to cover most of the frequencies of the present species, a novel multi-channel ultra high velocity recorder has been designed, called Qualilife HighBlue. This paper presents its architecture and characteristics. One of its most innovative features is an always-on ultra-low power wake-up, triggering recordings when temporal and/or spectral interesting events are detected. For this task, shallow neural networks are embedded for advanced pattern detection, as

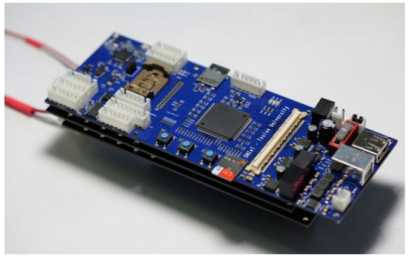


Figure 1. QHB plugged to 2 daughter-boards.

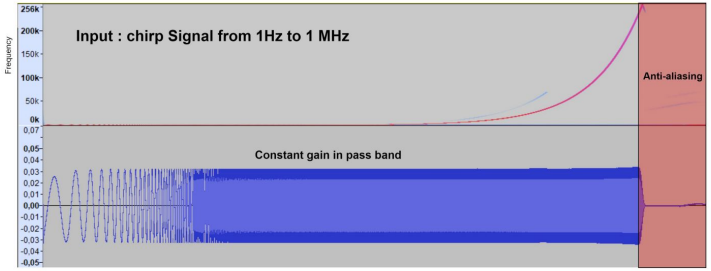
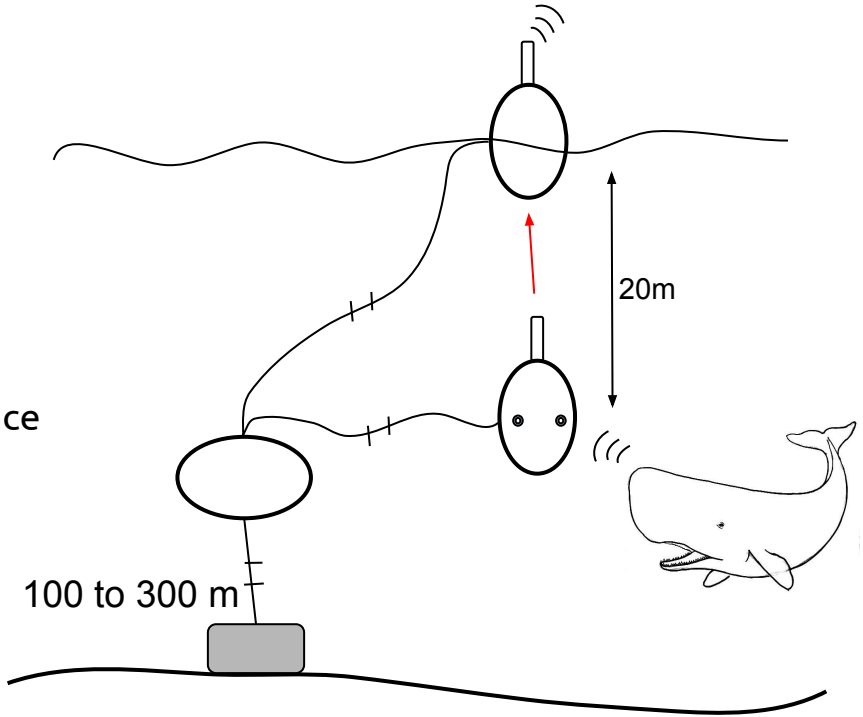


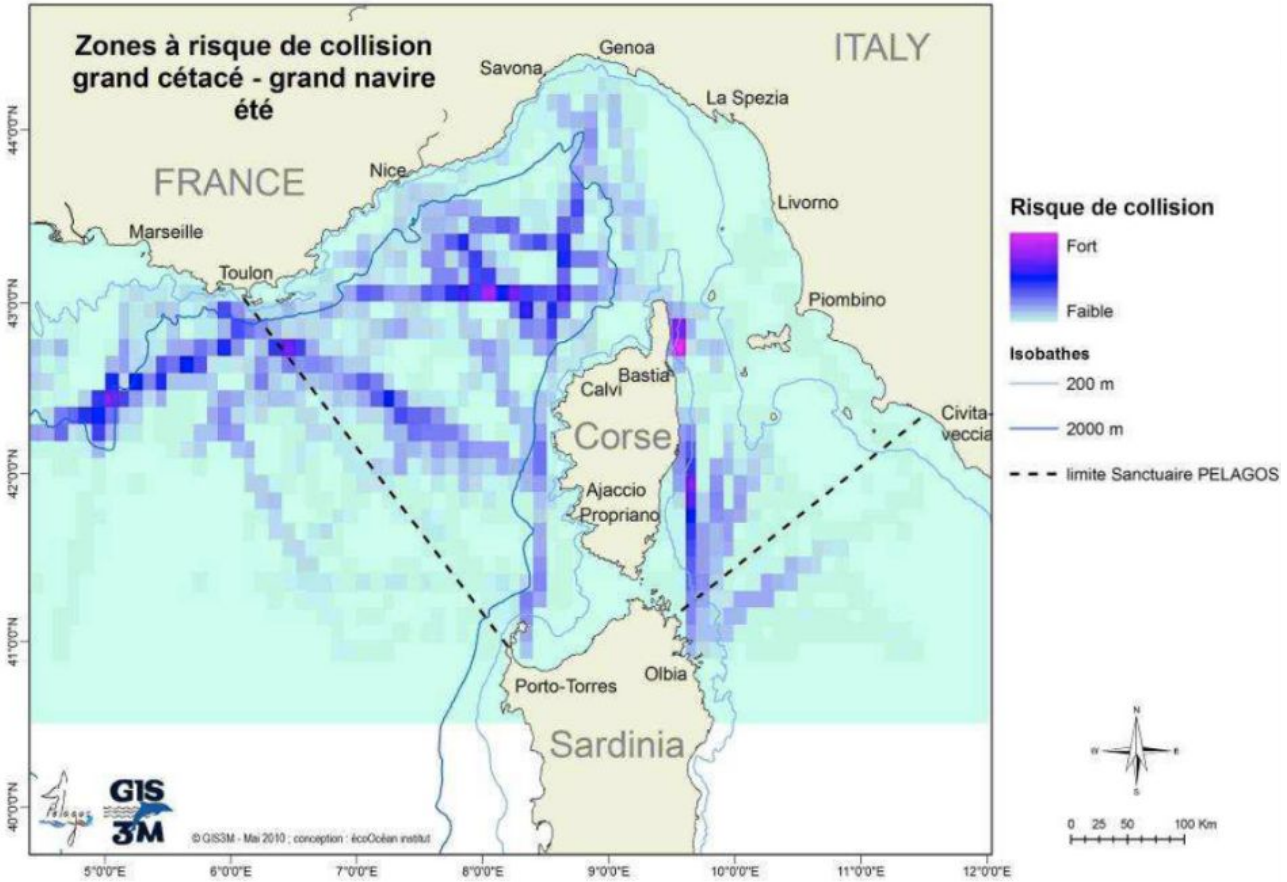
Figure 5. Spectrogram and signal of a chirp test from 1 Hz to 1 MHz recorded on QHB.

Application to Online AI
Bombyx 2

- To be placed in 2021
  - 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

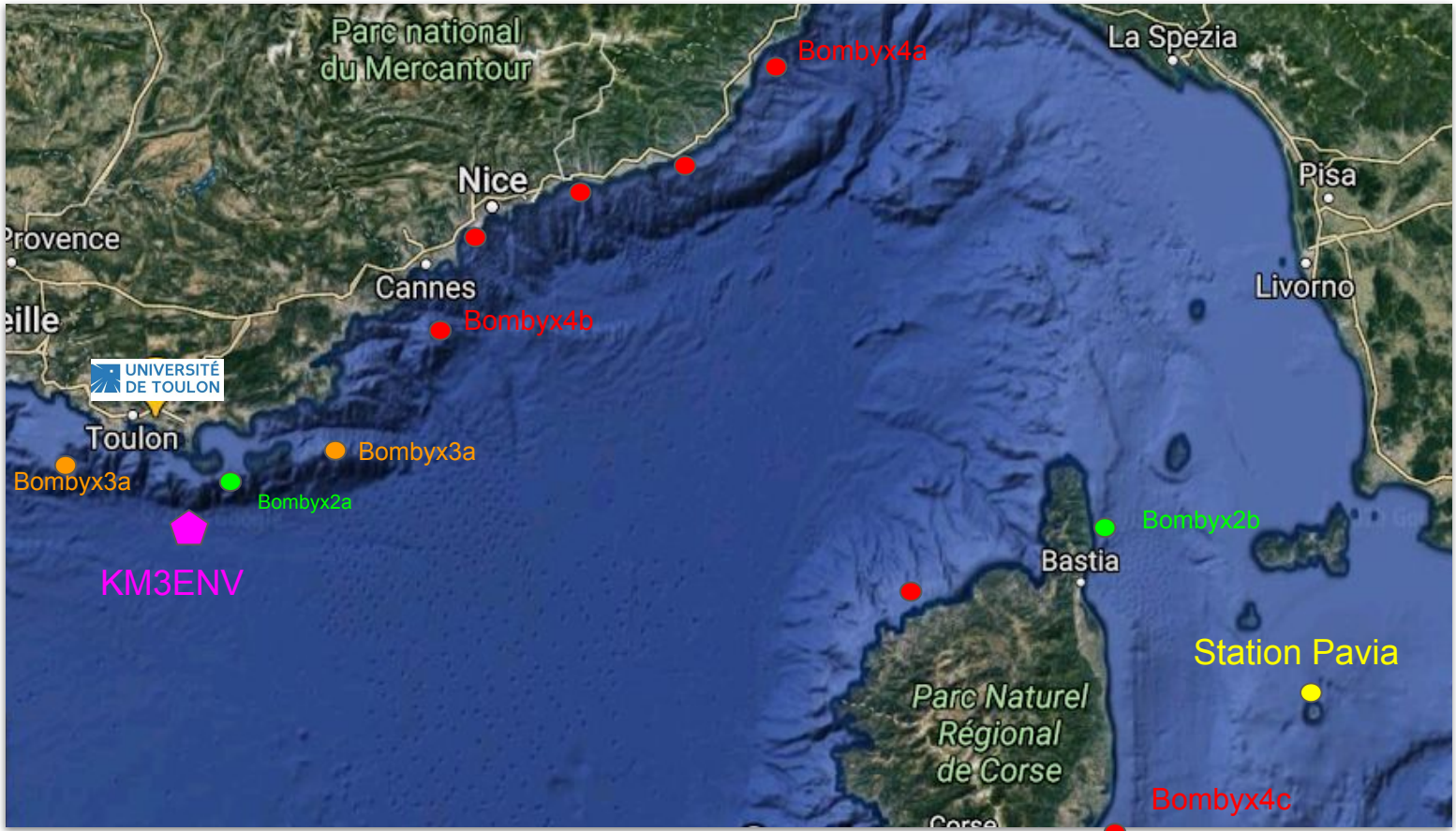


Collision Risks Ship-Megafauna



Perspective à 2 ans : Institut / Fondation IA et Bioacoustique

observer les Canyons profonds de 2500m et leurs habitants en 3D



Bombyx2 = GIAS 2018-26 ; Bombyx3 = APOG 2021-26 ; Bombyx4 = GIAS2 2021-2026 ; stations UTLN / Pavia

Application to Caribbean 2019-21+

- 20 stations SMIoT UTLN / IM2NP / LIS
- 256 Fe * 3 weeks
- 500 Go x 10 sessions x 20 stations
- Data analysis DYNI
  20 espèces

Some of recent publications

Ferrari, Glotin, Marxer, Asch (2021) Classification of Marine Mammal Clicks by Raw Audio Multiscale Hierarchical Convolutional Neural Network and a Study of Learned Representation, submitted to JASA

Poupard, Symonds, Spong, Glotin (Submitted to Scientific Report Nature 2021) Evidences of Intra-Group Orca Call Rate Modulation Using A Small-Aperture Four Hydrophone Array.
https://assets.researchsquare.com/files/rs-116685/v1_stamped.pdf

Barchasz, Gies, Marzetti, Glotin (2020) A novel low-power high speed accurate and precise DAQ with embedded artificial intelligence for long term biodiversity survey, Eu. Forum Acusticum
http://sabiod.univ-tln.fr/pub/QualiHighBlue_DAQ_FA2020.pdf

Best, Ferrari, Poupard, Paris, Marxer, Symonds, Glotin (2020) Deep Learning and Domain Transfer for Orca Vocalization Detection. In International joint conference on neural networks. IEEE IJCNN,
https://hal.archives-ouvertes.fr/hal-02865300/document

Ferrari, Glotin, Marxer, Asch (2020) End to end raw audio deep learning of transients, application to bioacoustics, Eu. Forum Acusticum https://hal.archives-ouvertes.fr/hal-03078665/document

Ferrari et al. (2020) 3D diarization of a sperm whale click cocktail party by an ultra high sampling rate portable hydrophone array for assessing individual cetacean growth curves, Eu. Forum Acusticum
https://hal.archives-ouvertes.fr/hal-03078655/document

Ferrari et al. (2020) DOCC10: Open access dataset of marine mammal transient studies and end-to-end CNN classification, in 2020 International Joint Conference on Neural Networks (IJCNN). IEEE
https://hal.archives-ouvertes.fr/hal-02866091/document

Marzetti, Gies, Barchasz, Best, Paris, Barthelemy, Glotin (2020) Ultra-Low Power Wake-Up for Long-Term Biodiversity Monitoring, in proc. IEEE IoTAIS

Poupard, Best, Ferrari, Spong, Symonds, Prevot, Soriano, Glotin (2020) From massive detections and localisations of orca at orcalab over three years to real-time survey joint to environmental conditions in Eu. Forum Acusticum

Ferrari (2020) Study of a Biosonar Based on the Modeling of a Complete Chain of Emission-Propagation-Reception with Validation on Sperm Whales, Phd Thesis, Université Picardie Jules Verne, (dir Glotin & Asch)
https://hal.archives-ouvertes.fr/tel-03078625/document

Poupard (2020) Contributions en Méthodes Bioacoustiques Multiéchelles: Spécifiques, populationnelles, individuelles et comportementale, Phd Thesis, Université de Toulon (dir Glotin Soriano Lengagne)
http://sabiod.univ-tln.fr/pub/poupard/cv/m_poupard_phd_08012021.pdf

Glotin, Thellier, Best, Poupard, Ferrari, et al. (2020) Rapport Mission Sphyrna Odyssey : Découvertes Ethoacoustiques de Chasses Collaboratives de Cachalots en Abysse & Impacts en Mer du Confinement COVID19
,http://sabiod.univ-tln.fr/pub/SO1.pdf