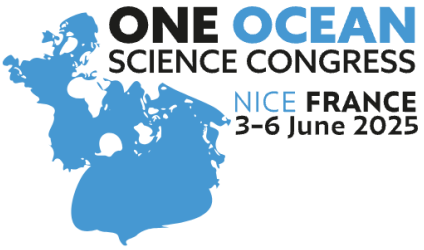

Artificial Intelligence for Marine Biophony & Anthropophony surveys

Chairman : Hervé Glotin (CNRS LIS, CIAN) - Org. : H. Glotin and Louise Freyburger (PNPC)

Booklet of the abstracts

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https://one-ocean-science-2025.org/ https://sdgs.un.org/conferences/ocean2025/about-unoc-2025

Summary

Integrating drone passive acoustics with eDNA for marine mammals distribution studies

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The "Sphyrna Odyssey 2019-2020" mission combined passive acoustic monitoring and environmental DNA (eDNA) to monitor marine mammals in the Mediterranean, focusing on areas impacted by heavy marine traffic. Sphyrna autonomous vessels, equipped with hydrophones, provided real-time detection of vocalizing species [1], while eDNA sampling from surface waters captured genetic traces over larger spatial areas, including busy shipping lanes [4].

Acoustic monitoring provided real-time data on vocalizing species, while eDNA detected species even in the absence of vocalizations, though factors like ocean currents and DNA degradation influenced results [3]. Both methods identified eight cetacean species, revealing higher densities along continental slopes, submarine canyons, and areas with significant shipping traffic. This study highlights the value of integrating acoustic and genetic methods to understand cetacean presence and distribution, crucial for conservation in high-impact regions [2].

[1] Glotin, H., Spong, P., Symonds, H., Roger, V., Balestriero, R., Ferrari, M., ... & Dakin, T. (2018) Deep learning for ethoacoustical mapping: application to a single Cachalot long term recording on joint observatories in Vancouver Island. *The Journal of the Acoustical Society of America*, *144*(3), 1776-1777

[2] Glotin H., Thellier N., Best P., Poupard M., Ferrari M., Vieira S., Giés V., ... Sarano F., Benveniste J., Gaillard S., de Varenne F. (2020) Sphyrna-Odyssey 2019-20, Découvertes Etho-acoustiques de Chasses Collaboratives de Cachalots en Abysse & Impacts en Mer du COVID19, http://sabiod.org/pub/SO1.pdf, 197p, Univ. de Toulon, CNRS

[3] Collins, R. A., Wangensteen, O. S., O'Gorman, E. J., Mariani, S., Sims, D. W., & Genner, M. J. (2018). Persistence of environmental DNA in marine systems. *Communications Biology*, *1*(1), 185

[4] Ficetola, G. F., Miaud, C., Pompanon, F., & Taberlet, P. (2008). Species detection using environmental DNA from water samples. *Biology letters*, *4*(4), 423-425

PolarPod-Perseverance in Arctic listening with AI to the Old World Symphonia

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Cetacean interspecies communication remains a mystery. In some fjords of the Norwegian Arctic the concentration of their prey increases due to climate change, then also the megafauna concentration, resulting in accelerating competition and species interactions. We then aim to analyze this unknow cocktail party combining simultaneously several sources : *Orcinus orca (Oo)* * *Megaptera novaeangliae (Mn)* * *Balaenoptera physalus (Bp)* * *Physeter macrocephalus* (Pm) * Landscape.

This is an incredible opportunity to analyse for the first time these pristine soundscapes during the short season of these whale runs. It has been related in the end of the XIXth century that such whale concentration was frequent. But since the whale industry, only Oo were present. It is only since 2010 that gradually other species have investigated again this area, including recently the Pm (nov. 2023).

Then the Center of Artificial Intelligence in Natural Acoustics (CIAN) [2] deployed its mobile acoustic laboratory on the PolarPod-Perseverance vessel. With its length of 42m, this exploration sail propulsion vessel is the future for CO2 balance, as well as for acoustic studies in dynamic conditions. Versatility and oceanographic skills of Perseverance are perfectly suited for this type of acoustic mission.

We deployed a small array, Manta-1, based on our custom hydrophones and AI embedded electronic sound card. Manta-1 was used for transects by sail propulsion having a neutral impact on acoustics. We also deployed a fixed pentaphonic array and a long array. It resulted in a complex and novel corpus of whale cocktail parties that has been processed by AI listening algorithms of CIAN [1]. We then model the nictemeral acoustic cycles of each species and we test the 6x2 hypotheses of inter-species positive interactions (foraging collaboration), and negative interactions (competition).

[1] ADAPREDAT, R Report, MITI CNRS, Glotin et al, (2024) https://sabiod.lis-lab.fr/pub/ADAPREDAT/AAPSanteEnvironnement2022.2_Rapportfinal_GLOTIN_FJORD3D_202403.pdf
[2] https://cian.univ-tln.fr

Whale Way: a joint audio and photold Physeter m. mid term survey in Pelagos

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The population of sperm whales, *Physeter macrocephalus*, classified as “Endangered” in the Mediterranean Sea by the IUCN, is threatened by human activities, even in the Pelagos sanctuary dedicated to them. Marine traffic, the densest in the world, is one of the main threats both by:
- noise pollution which profoundly disrupts echolocation and communication, essential to the life of this large cetacean;
- collisions, the primary source of unnatural mortality for large cetaceans: 15% of the sperm whales we observed are injured by collisions (see photo).

In order to reduce the threats weighing on this very small population (a few hundred individuals), the Longitude 181 association has been carrying out, since 2022, jointly with CIAN, a study program (Whaleway expeditions) aimed at determining, both the preferred areas of presence, and the impact in these areas of anthropogenic noise on sperm whale activity. The method is based on a catalog of visual and acoustic (IPI) identity cards which allows the regular recapture of identified individuals, and on 3D acoustic recordings which allow the sperm whale to be positioned in the water mass, “click by click”, during hunting dives, with a precision never before achieved to date. Not only does this study open up a better understanding of social interactions in the night of the abyss (concerted hunting), but these daily (up to 4 consecutive days), monthly and annual recaptures allow us to draw up a detailed map of individual movements (see map) and relative area fidelity. Cross-referencing with other available catalogs reveals a mean recapture rate of around 2.5.

As a result, it is possible to compare this mapping to the movements of ships, thanks to their AIS, and to measure very finely the adaptation and disturbance caused by these anthropogenic aggressions. Ultimately, the aim is to make zoning proposals in the Pelagos sanctuary to request measures to preserve sperm whales.

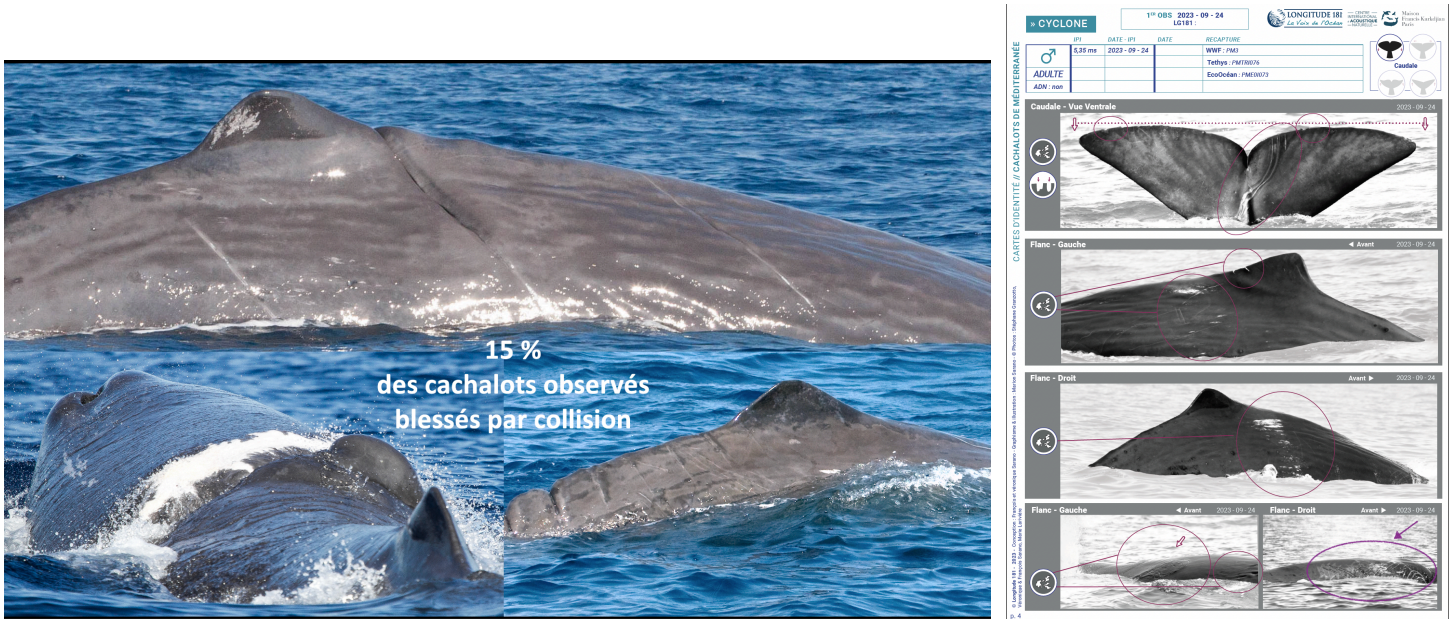

Fig 1 : (Left) 15% of the sperm whales we observed are injured by collisions.
(Right) Identity card of a sperm whale: morphological characteristics, IPI, recaptures.

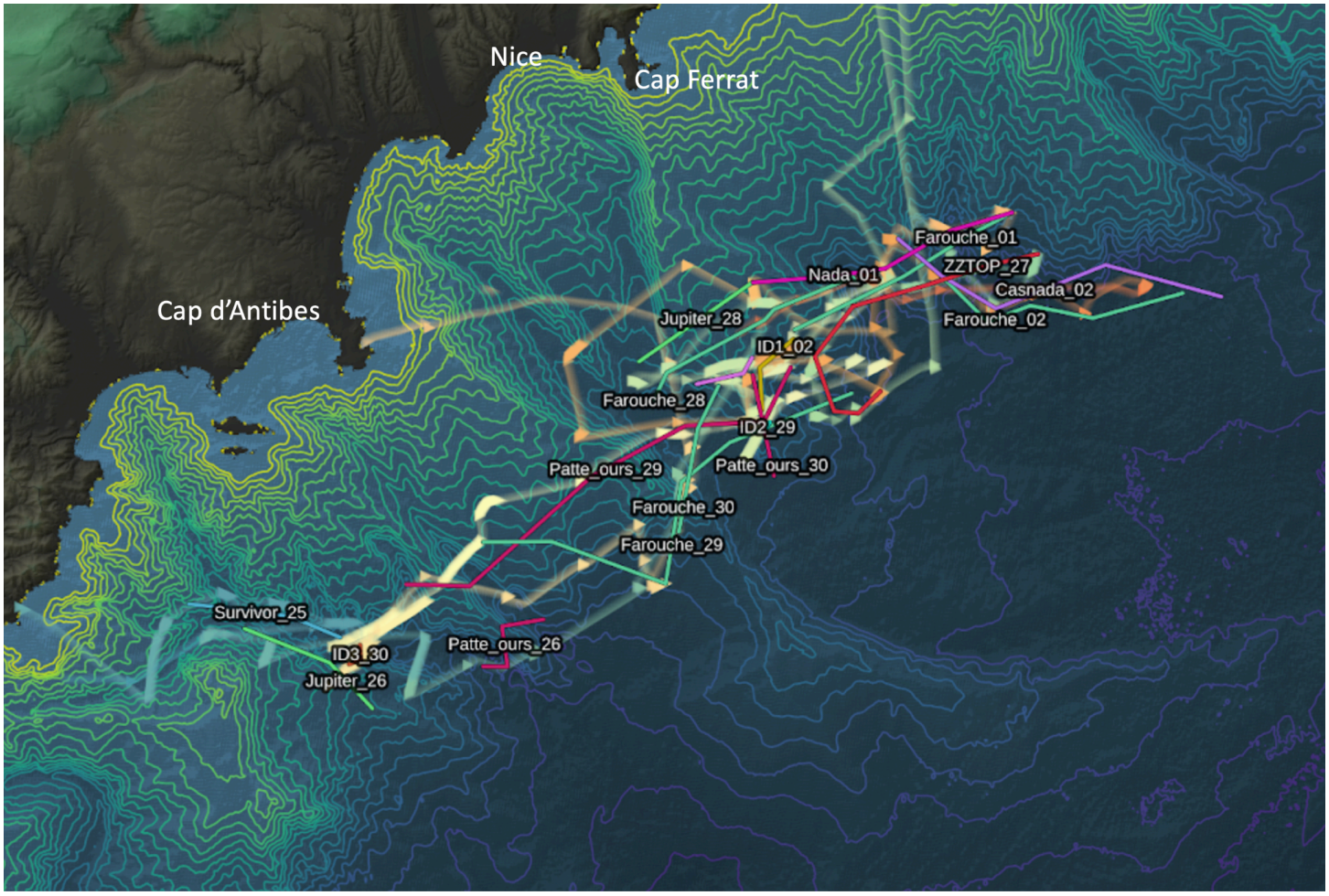

Fig 2: Effort of observation and sperm whale detections during several hours South Antibes

References

H. Glotin et al, (2024): Bilan d'une décennie d'observations des grands cétacés en milieu anthropisé Nord Pelagos: BOMBYX, KM3Env, et antennes mobiles JASON. Programme de recherche triennal Pelagos 2021 – 2024 CIAN - DYNI LIS CNRS - Université de Toulon. 150.

Rendell L, Frantzis A. (2016): Mediterranean Sperm Whales, Physeter macrocephalus: The Precarious State of a Lost Tribe. In: Notarbartolo Di Sciara G, Podestà M and Curry BE, editors. Mediterranean Marine Mammals Ecology and Conservation. Advances in Marine Biology, Vol 75. Oxford: Academic Press; 2016. p. 37–74.

Frantzis A, et al (2019): Shipping routes through core habitat of endangered sperm whales along the Hellenic Trench, Greece: Can we reduce collision risks? PLoS ONE 14(2): e0212016. https://doi.org/10.1371/journal.pone.0212016

Sarano V. et al, (2022): Underwater photo-identification of sperm whales (Physeter macrocephalus) off Mauritius. Marine Biology Research, https://doi.org/10.1080/17451000.2022.2040737

How autonomous diving platforms can help gather large amounts of high-quality sound measurements both in space and throughout the water column

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a) Akvaplan Niva - Tromso - Norway

With the continuous increase of human activities at sea, predicting noise propagation from a given source is paramount to understanding the potential extent of its effects on the marine environment. Sound propagation models serve this purpose. These are complex modeling frameworks which account for both the physics of sound traveling in water as well as some environmental parameters which may affect it. However, in-situ sound measurements are required for validating such models, particularly at large distances from the source, where predictions can deviate largely from reality.

Traditionally, such measurements are obtained from hydrophones placed on installations (buoys, landers) at fixed depths which do not allow verification of the vertical propagation of sound. In this study, a hydrophone was mounted on a mobile uncrewed platform (Slocum glider from Teledyne) which was moving up and down the water column as well as at different distances from the sound source during a full scale industrial seismic survey.

The dBSea sound propagation model was used to predict sound levels from the seismic source and the measurements were used for validation. An array of simulations was performed to test which model settings best aligned with the data, with particular focus on the vertical propagation properties. This exercise gave insight on which areas of the model tend to either over- or underestimate sound levels and showed how autonomous diving platforms can help gather large amounts of high-quality sound measurements both in space and throughout the water column.

Megafauna survey in Acorez : perspectives with Bombyx Sonobuoy

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Monitoring soundscapes provides data for several purposes, such as research and management. Marine megafauna, especially cetaceans, have been monitored at the Azores archipelago using the BOMBYX system, composed of 4 hydrophones. Besides recording biological sounds, anthropogenic noise was also recorded, due to the close location of shipping routes at SE of São Jorge island.

There are 28 species of cetaceans seen in the region, but the most frequent and more expected to be recorded are: Sperm whale, Bottlenose dolphins, Risso's dolphins, Common dolphins, Striped dolphins, Spotted dolphins, Blue whales, Fin whales, Sei whales, Humpback whales, Short-finned pilot whales, False killer whales, Cuvier's beaked whale, Mesoplodon densirostris, Mesoplodon bidens, Northern Bottlenose whales. There could also be records of Bryde's whale, Minke whale, Mesoplodon europaeus, Mesoplodon mirus, Pygmy sperm whale, Dwarf sperm whale.

The BOMBYX EUROPAM sonobuoy is equipped with real time transmission and powered by solar panels. With a small size, only 1m high, it supports a 1 m diameter acoustic antenna, that allows to diarize the different sources, anthropic and biophonic, in azimuth and elevation. It aims to monitor the interactions of the megafauna against anthropic pressure. It includes a real time species identification, and can thus alert on some risk of collision. We will present the overview of the Bombyx Surveys.

Tursionet: detecting bottlenose acoustic interactions in the Pelagos sanctuary with small-scale fisheries - acoustic and detection processing

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The Tursionet project, funded by the Pelagos Initiative hosted by the Prince Albert II of Monaco Foundation, aims to study the acoustics interactions of bottlenose dolphins with different types of fishing gear from small-scale fisheries in the coastal waters in the Pelagos Sanctuary, a Marine Protected Area for marine mammals located in the Northwestern Mediterranean between France, Italy, and Monaco [1].

Several hydrophones have been deployed along the Ligurian coast near different types of static fishing gear (e.g. gillnets and pots) to monitor the acoustic interactions of bottlenose dolphins interacting with the nets and evaluate their frequency and possible impact.

The acoustics data collected will also be used to create an automated system to detect and signal the acoustic activity of dolphins to speed up the analysis for future works. Among the vast vocal repertoire of bottlenose dolphins [2], echolocation trains and final buzzes have been the most recorded and are thus the perfect candidate to build an automatic system of detection and classification. As in most automated systems, the data stream must go through several processing steps before it is fed into the classification system. In the present study, we investigate different preprocessing and feature extraction methods and test their advantages, disadvantages, and feasibility according to the classification system used.

This study aims to be a benchmark for the future and a table of discussion between different groups to find an optimal framework for the processing of acoustic signals of cetaceans, a crucial step in the pipeline of automated systems of cetacean bioacoustics.

[1] Tursionet project: https://www.tursionet.eu/en/

[2] Jones, B., Zapetis, M., Samuelson, M. M., & Ridgway, S. (2019). Sounds produced by bottlenose dolphins (*Tursiops*): a review of the defining characteristics and acoustic criteria of the dolphin vocal repertoire. *Bioacoustics*, *29*(4), 399–440 https://doi.org/10.1080/09524622.2019.1613265

Ambiguity function of highly defined biosonar of Marine Mammals compared to Chiroptera

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Cetaceans use methods based on acoustic signals to perceive the environment (echolocation)[1][2] and communicate due in part to the low visibility in this environment [3]. Studying these acoustic signals enables us to identify and understand these animals better. There are different methods to describe an acoustic signal, one of which involves using transformations to represent signal variations according to time and amplitude modulations [4]. These representations are called time-frequency representations (TFR). However, the TFR method usually used (by short-time Fourier transform) [5] to study cetaceans is not suitable for all types of emitted signals.

We shown here that the Ambiguity Function (AF), is a representation that provides information of transient signals in terms of Doppler and time delay [6]. This representation is used as input for an autoencoder, to analyze the latent space. The results obtained support the hypothesis that there are characteristics within the animal's click that are linked to its behavior and its age/sex. This work opens the door to more advanced analyses such as the ability to monitor populations, differentiate juveniles, males, and females, and improve our knowledge of these cetaceans, which are still little known to the general public.

[1] Griffin, D. R. (1944). Echolocation by blind men, bats and radar. Science.
[2] Griffin DR (1958) Listening in the dark, 2nd edn. Cornell University, New York.
[3] Au, W. (1993). The Sonar of Dolphins Springer, New York, pp. 32, 41–46, 66–70, 148–152.
[4] Sejdić, E., Djurović, I., and Jiang, J. (2009). Time–frequency feature representation using energy concentration: An overview of recent advances. Digital signal processing, 19(1):153–183.
[5] Allen, J. (1977). Short term spectral analysis, synthesis, and modification by discrete fourier transform. IEEE Transactions on Acoustics, Speech, and Signal Processing, 25(3):235–238.
[6] Max, J. (1987). Méthodes et techniques de traitement du signal et applications aux mesures physiques. vol. 2: Appareillage, méthodes nouvelles, exemples d'applications. Paris: Masson.

Physeter m. distribution in oceanography conditions and high maritime traffic areas

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The Pelagos Sanctuary, a key marine protected area in the northwestern Mediterranean Sea, serves as an habitat for the sperm whale (*Physeter macrocephalus*) [1,2]. Investigating the oceanographic conditions within this region is pivotal to understanding the species' spatial and temporal distribution, ecological habits, and foraging strategies. Oceanographic parameters such as sea surface temperature, salinity gradients, current dynamics, and primary productivity play a fundamental role in shaping prey availability and the whales' habitat use [3].

The region's complex bathymetry, characterized by submarine canyons and steep continental slopes, creates localized upwelling zones that enhance trophic interactions [4]. Long-term monitoring of these conditions is essential to assess the impact of environmental variability and anthropogenic stressors, including climate change and marine traffic, on sperm whale populations. These insights are critical for refining conservation strategies and advancing sustainable management of the Pelagos Sanctuary as a biodiversity hotspot.

[1] Notarbartolo-Di-Sciara, G. (2014). Sperm whales, Physeter macrocephalus, in the Mediterranean Sea: a summary of status, threats, and conservation recommendations. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *24* (S1), 4-10.

[2] Poupard, M., Ferrari, M., Best, P., Glotin H. (2022). Passive acoustic monitoring of sperm whales and anthropogenic noise using stereophonic recordings in the Mediterranean Sea, North West Pelagos Sanctuary. *Sci Rep* **12**, 2007.

[3] Azzellino, Arianna & Gaspari, Stefania & Airoldi, Sabina & Nani, B.. (2008). Habitat use of cetaceans along the continental slope and adjacent waters in the western Ligurian Sea. Deep Sea Research Part I: Oceanographic Research Papers. 55. 296-323. 10.1016/j.dsr.2007.11.006.

[4] M-C. Fabri, L. Pedel, L. Beuck, F. Galgani, D. Hebbeln, A. Freiwald (2014). Megafauna of vulnerable marine ecosystems in French Mediterranean submarine canyons: Spatial distribution and anthropogenic impacts, Deep Sea Research Part II: Topical Studies in Oceanography, Volume 104, Pages 184-207, ISSN 0967-0645.

Spiking Neural Network for cetacean survey

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Cetacean surveys are important to assess the state of marine biodiversity, but are energy and time consuming. In the past years, Passive Acoustic Monitoring (PAM) became a key element of these surveys since it allows the obtention of information about cetaceans hidden deep beneath the water surface [1].

However, processing all the audio files acquired during the PAM campaigns remains time and energy consuming, and there is a need for an automated and low power process for cetacean sounds classification [2].

Spiking Neural Network (SNN) could be one of the possible solutions to this challenge [3]. We present a simple SNN architecture for transient marine mammal sounds classification, which, together with an analog artificial cochlea model, could be used to make an embedded neuromorphic ultra-low power sound classification device.

[1] Zimmer, W. M. (2011). *Passive acoustic monitoring of cetaceans*. Cambridge University Press.

[2] Bittle, M., & Duncan, A. (2013). A review of current marine mammal detection and classification algorithms for use in automated passive acoustic monitoring. In *Proceedings of Acoustics* (Vol. 2013, pp. 1-8). Victor Harbor, SA: Australian Acoustical Society.

[3] Baek, S., & Lee, J. (2024). Snn and sound: a comprehensive review of spiking neural networks in sound. *Biomedical Engineering Letters*, *14*(5), 981-991.

Line gain for long term environmental survey

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The complexity of artificial intelligence (AI) raises significant challenges in developing embedded detection systems [1,2], particularly in terms of power consumption [3]. In contrast, biological auditory perception addresses these issues efficiently [4]. Drawing inspiration from biological primitive extraction in the auditory system [5], we present a new method for drastically reducing energy required for acoustic signal processing and classification. This method could also be applied to more general problems. To assess the efficiency of the proposed algorithm, experiments were conducted using the Google Speech Command Dataset [6], focusing on 4 and 8 classes with added noise. Mimicking the structure of the cochlea, system training starts with 64 analog primitives, which are pruned sequentially, retaining only the most relevant ones for classification. This pruning relies on a novel neural network layer called "Line Gain." Results demonstrate that the proposed algorithm significantly reduces total energy consumption by 82%, while maintaining comparable accuracy levels (greater than 90%). Applications are then conducted on whale voicings. Perspectives are given in the context of low power budget detectors as subsea monitoring to assess long term anthropophony and biophony.

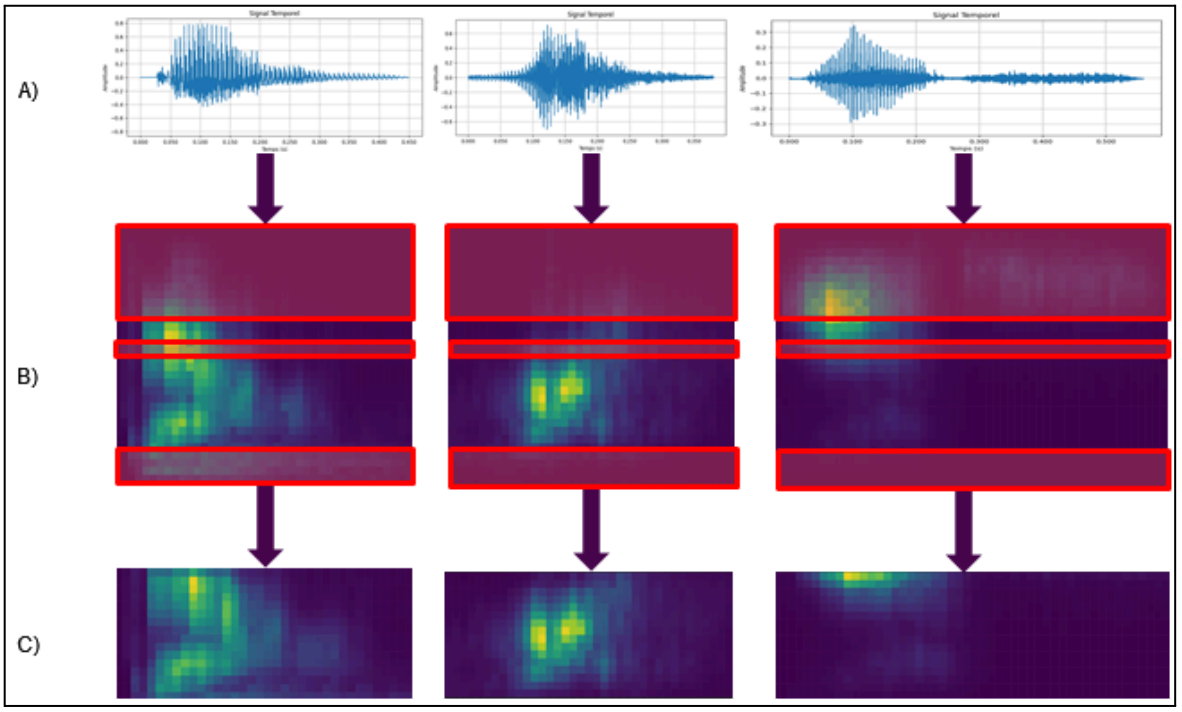

Fig.: example of 3 voicings. (Top) the wave form. (Middle) the cepstrogram. (Bottom) our compression

[1] M. Miah and G. Wang, Keyword spotting with deep neural network on edge devices, IEEE Int. Conf. Electronics Information & Emergency Communication 2022
[2] M. Shah, S. Arunachalam, J. Wang, D. Blaauw, D. Sylvester, H.-S. Kim, J.-s. Seo, and C. Chakrabarti “A fixed-point neural network architecture for speech applications on resource constrained hardware” Jour. Sig. Proc. Sys. V90,05 2018
[3] B. Liu, Z. Wang, W. Zhu, … , W. Ge, An ultra-low power always-on keyword spotting accelerator using quantized convolutional NN & voltage-domain analog switching network-based approximate computing, IEEE Access 10.1109/ACCESS.2019.2960948 V7, 2019
[4] S. Marzetti, V. Gies, V. Barchasz, H. Barthélemy H. Glotin Comparing analog and digital processing for ultra low-power embedded artificial intelligence, IEEE Int. Conf. Internet of Things & Intelligence Sys. 2022
[5] B. Marin, L. Cerna, Signatures of cochlear processing in neuronal coding of auditory information, Journal Mol Cell Neurosci. 2022
[6] P. Warden “Speech commands: A dataset for limited-vocabulary speech recognition” arXiv 1804.03209 2018

SeGaMas : Serious Game for Marine Mammals Survey

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Studying cetaceans is a complex task, due to the inaccessibility of the marine environment and low visibility. Passive acoustics is a very promising non-invasive solution. Nowadays, detection and classification of recorded species are carried out automatically and with good accuracy, in particular using AI methods. However, using such methods to locate animals is still imprecise, due to the lack of ground truth data on their actual movements.

To overcome this, we are working on the creation of a complete model of acoustic scenes, called SeGaMas (Serious Game for Marine (mammals) Survey). This model includes the generation of realistic cetacean trajectories, inspired by [1] and [2], the regular emission of a biophonic signal, and a ray-tracing model to reconstruct the signal arriving at the sensor. As inputs, the model receives bathymetric, oceanographic and ambient noise data. As output, it provides animal trajectories, the received signal and the paths taken by this signal.

These simulated data are then used to create a “click sequences to trajectories” AI model, capable of reconstructing the trajectory of a sound source from a simple recording thanks to advanced IA techniques such as Transformer NN [3] . Therefore, we’ll define adapted loss functions, as E_p(f(U(p))) where p is the generated path distribution, and U the controls (sensor positions, sensibilities…). They will also be useful in the study of cetacean perceptions, and to better design and position our sensors.

[1] Parrott et al (2010). *3MTSim: An agent-based model of marine mammals and maritime traffic to assist management of human activities in the Saint Lawrence Estuary, Canada*.

[2] Chouchane et al (2012), EvoCOP 2012: *Splitting method for spatio-temporal sensors deployment in underwater systems*

[3] Vaswani, A. (2017). Attention is all you need. Advances in Neural Information Processing Systems.

Analysis of sperm whale (*Physeter m.*) dialogues, click by click, an ethoacoustic approach

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Off Mauritius, expeditions are conducted to study the 'Irène Gueule Tordue' clan of sperm whales by collecting behavioural, acoustic and genetic data [1,2]. The innovative Opale tool, developed by SMIot and LIS DYNI [3], is equipped with five hydrophones and two GoPro cameras, passively records high-definition interactions among sperm whales, providing unique observations. This ethoacoustic study focuses on dyadic interactions, characterised as 'confrontational play' between immature males, marked by the emission of a series of 'staccato' clicks. These 'confrontational plays' are specific to immature males, underlining the originality of this study, which requires long-term observations and a distinction between the sexes of the individuals involved. Each click is automatically detected and annotated, then assigned to its emitter, even when click trains overlap, using click separation and direction of arrival estimation methods [4,5], while exploring specific click characteristics.

These techniques allow precise differentiation of vocalisations for each individual. By analysing these vocal exchanges, the study aims to decode the social role of clicks in the communication and group dynamics of sperm whales, while deepening our understanding of their social structure. This approach provides a detailed view of socio-acoustic behaviours within a matrilineal unit [6], increasing our knowledge of sperm whale society and communication modes, and thus supporting conservation efforts for this vulnerable species.

We acknowledge our interdisciplinary team composed of CIAN with LIS UTLN, Institute d'Alembert, Longitude 181 and the Indian Ocean Marine Life Foundation, as well as the Mauritian authorities for their support.

[1] Sarano V., Sarano F., Girardet J., Preud'homme A., Vitry H., Heuzey R., Sarano M., Delfour F., Glotin H., Adam O., Madon B. & Jung J-L (2022): Underwater photo-identification of sperm whales (Physeter macrocephalus) off Mauritius.Marine Biology Research, https://doi.org/10.1080/17451000.2022.2040737

[2] Sarano F., Girardet J., Sarano V., Vitry H., Preud'homme A., Heuzey R., Garcia Segarra A M, Richard G., Tixie P., Guinet C., Delfour F., Glotin H., Adam O. & Jung JL (2021) : Kin relationships in cultural species of the marine realm: case study of a social group of sperm whales (Physeter macrocephalus) off Mauritius Island, Indian Ocean. Royal Society Open Science 8: 201794. https://doi.org/10.1098/rsos.201794

[3] Glotin, H., and al. (2024). OPALE: a super resolution audiovisual mobile antenna for cetacean ethoacoustical researches. DCLDE 2024, Rotterdam. https://cian.lis-lab.fr

[4] Ferrari, M. (2020). Study of a biosonar based on the modeling of a complete chain of emission-propagation-reception with validation on Sperm Whales, PhD, University of Picardie Jules Verne. Sciences Technologie et Santé (ED 585), codir Asch and Glotin

[5] Zimmer, W.M.X. (2013). Range estimation of cetaceans with compact volumetric arrays. The Journal of the Acoustical Society of America, 134(3), 2610. doi:10.1121/1.4817892

[6] Whitehead, H. (2024). Sperm whale clans and human societies. Royal Society Open Science, 11 (231353). https://doi.org/10.1098/rsos.231353

Sotalia g. dolphin long term survey by deep learning

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The Guiana dolphin (*Sotalia guianensis*), commonly known as estuarine dolphin is one of the ten dolphins in great danger of extinction, currently classified as "near threatened" in the IUCN Red List of Threatened Species (IUCN, 2019). Indeed this species has restricted global distribution [1] as it is only found across the South-Western Atlantic OceanCentral and South America coast and is notably resident of the Guiana coastline. Due to its sedentary nature, Guiana dolphins are vulnerable to its habitat degradation and fall easily victim to bycatch in gillnets [2]. Monitoring population activity and assessing anthropogenic impacts are therefore fundamental for conservation. Since 2021, a long-term survey has been deploying multiple hydrophones and deep learning techniques for the automatic detection of Guiana dolphin vocalization. This study aims to compute the repertoire of Guiana dolphin whistles by clustering signal patterns [3,4] in relation to daily routines, highlighting the influence of tidal cycles. These identified patterns can then be associated with behavioral tendencies, environmental factors, or anthropogenic pressures, thus gives a proxy for the assessment of anthropic pressure on this species. Furthermore with the beginning of shoreline pile driving at one of the three monitoring stations in 2023, the survey allows to simultaneously observe the effects of pile driving on dolphin behaviors and site presence, assessing the human influences on this endangered species.

[1] Borobia, Monica & Siciliano, Salvatore & Lodi, Liliane & Hoek, Wyb. (2011). Distribution of the South American dolphin Sotalia fluviatilis. Canadian Journal of Zoology. 69. 1025-1039. 10.1139/z91-148

[2] Almeida, Inaê & Percequillo, Alexandre & Rollo, Mario. (2024). Surviving the Tide: Assessing Guiana dolphin persistence amidst growing threats in a protected estuary in South-eastern Brazil. Journal for Nature Conservation. 82. 1-9. 10.1016/j.jnc.2024.126713

[3] P Best, H Glotin, S Paris, R Marxer, (2024) Deep audio embeddings for vocalisation clustering, PLoS ONE, e0283396

[4] M Poupard, P Best, JP Morgan, G Pavan, H Glotin (2024) A first vocal repertoire characterization of long-finned pilot whales (Globicephala melas) in the Mediterranean Sea: a machine learning approach, Royal Society Open Science 11 (11), 231973

Subsea source range estimation based on Neural Network

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Access to the 3D tracks of sperm whales is required to assess the impact of anthropophony on their diving behavior. Passive acoustic and the time difference of arrival (TDoAs) are methods commonly used to localize the source of the clicks, although require a large number of hydrophone arrays [4] or are imprecise. While azimuths and elevations are readily assessed via TDoAs with a single antenna [1,2,5], radius estimation is challenging for small arrays with respect to the Cramer Rao Bound [1,5]. We therefore exploit other relationships between TDoAs, radius and frequency difference of arrival (FDoAs) [3]. In order to solve such systems, deep learning models have been trained with supervised learning and generated dataset to enable radius estimation using a single relationship while combining observables of different natures (i.e. TDoAs and FDoAs). The model achieves a 10% error in radius estimation in most cases. This neural network model has also been tested on fieldwork data with small arrays and gives promising biodiversity monitoring.

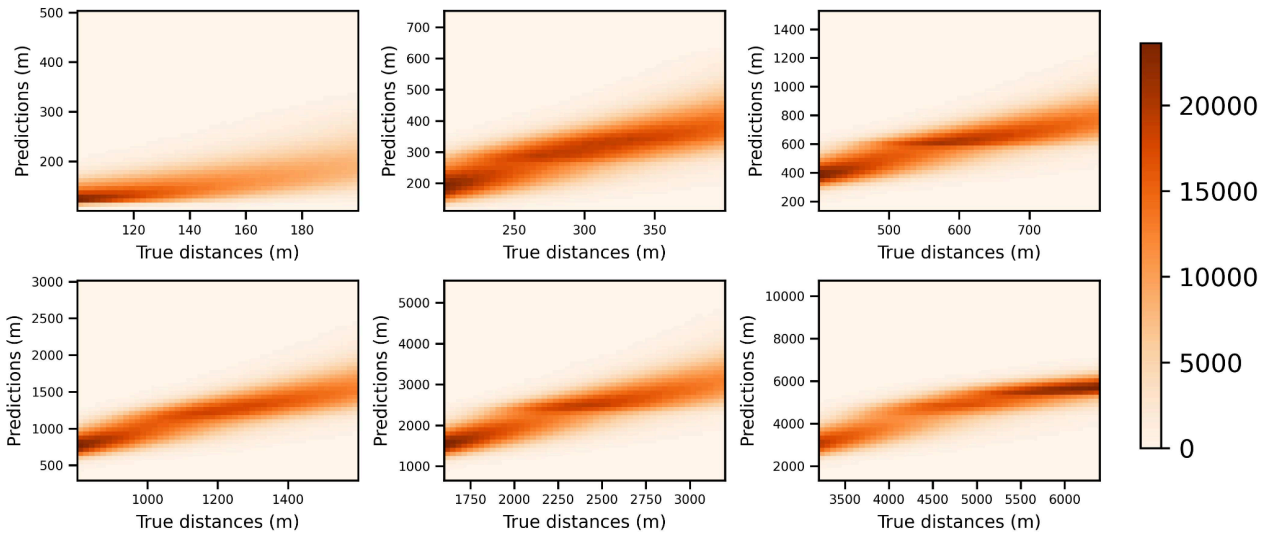

Fig : Example of neural network model predictions for generated sources range between 100m and 6400m of small hydrophone array.

[1] Bénard-Caudal, F. Giraudet, P. Glotin, H. (2010) Whale 3D monitoring using astrophysic NEMO ONDE two meters wide platform with state optimal filtering by Rao-Blackwell Monte Carlo data association, *Applied acoustics* 71 11 994-999

[2] Giraudet, P., Glotin, H. (2006). Real-time 3D tracking of whales by echo-robust precise TDOA estimates with a widely-spaced hydrophone array. *Applied Acoustics*, *67*(11-12), 1106-1117.

[3] Glotin, H. Mishchenko, A. Giraudet, P. (2015) Contraintes conjointes de différences temporelles et effet Doppler multibandes pour la séparation, caractérisation et localisation de sources sonores par acoustique passive. Patent FR14 54539.2015

[4] Nosal, E. M., & Frazer, L. N. (2006). Track of a sperm whale from delays between direct and surface-reflected clicks. *Applied Acoustics*, *67*(11-12), 1187-1201.

[5] Zimmer, W. M. (2013). Range estimation of cetaceans with compact volumetric arrays. *The Journal of the Acoustical Society of America*, *134*(3), 2610-2618

Fin whales and sperm whales acoustic behaviors in the Mediterranean sea anthropophony

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The ever-increasing anthropogenic activities pose considerable threats to cetaceans including vessel collisions and acoustic pollution potentially leading to acoustic masking, behavioral changes and/or physical damages. Using long term passive acoustic monitoring over 6 years (2015 to 2024), we aimed to explore the impact of anthropophony on sperm and fin whales in Pelagos sanctuary (Port-cros and Monaco, Northwestern Mediterranean Sea) as part of the Europam project (1).

Automatic detections of cetaceans revealed the year-round acoustic presence of sperm whales, with no particular agenda. A discernible daily pattern was identified with higher detections during morning and afternoon hours (7am to 6pm). Fin whales were mainly detected in autumn and winter. Ambient noise calculations revealed strong anthropogenic activity between 10am and 6pm in summer in the low- and medium-frequency bands in Monaco (Figure). Levels in autumn and winter are lower, except for low-frequency raking noises that warrant further investigation, as they may hinder the detection of fin whales. Analyses of 2015-2018 recordings have shown a significantly lower acoustic activity of sperm whales under high levels of anthropogenic noise (2). Ongoing investigations aim to validate this trend in 2022-2023. Comparisons will be made with areas less impacted by marine traffic, such as Northern Norway [3]. This research will help reveal patterns of presence and behavior of cetaceans species in response to varying levels of anthropogenic noise.

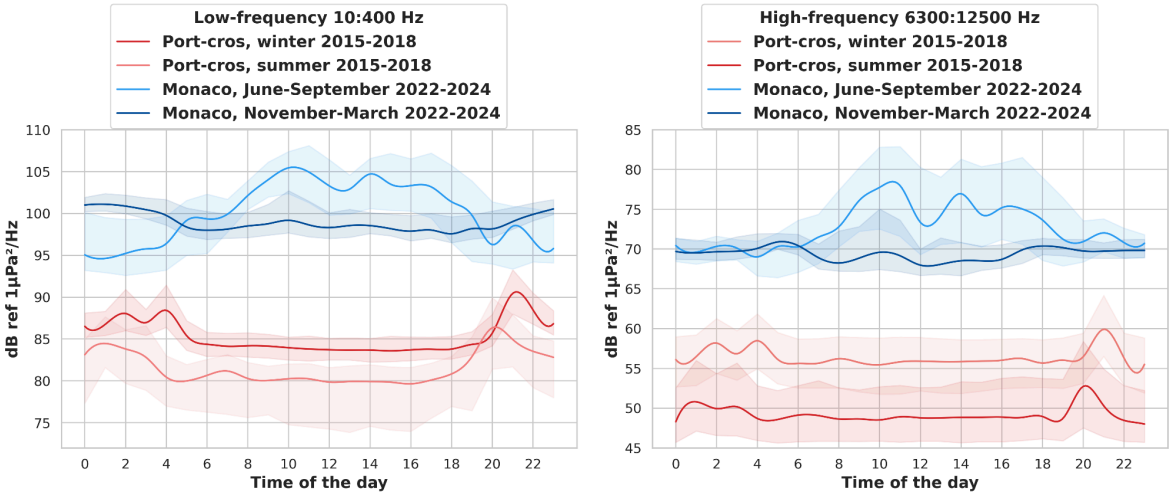

Fig. : Ambient noise estimation in Port cros (red) and Monaco (blue) during summer (light color) and winter (dark color) period for low-frequency (10:400Hz left) representing mainly maritime traffic and medium frequency (6500:12500Hz, right).

[1] Projet Europam 2023-2026. https://bioacoustics.lis-lab.fr/europam/
[2] Poupard, M., Ferrari, M., Best, P., Glotin H. (2022). Passive acoustic monitoring of sperm whales and anthropogenic noise using stereophonic recordings in the Mediterranean Sea, North West Pelagos Sanctuary. *Sci Rep* **12**, 2007.
[3] ADAPREDAT, R Report, MITI CNRS, Glotin et al, (2024)

(* previously presented at DCLDE 2024)

Organisation of the session

6th June session 10, “ AI for Marine Biophony & Anthropophony surveys “

7 Oral presentations :

OOC2025-1445 : PolarPod-Perseverance in Arctic listening with AI to the Old World Symphonia
--> 775893

OOC2025-1569 : Whale Way: a fine Physeter m. audiovisual survey
--> 775904

OOC2025-1174 : Megafauna survey in Acorez : perspectives with Bombyx Sonobuoy
--> 775959

OOC2025-1479 : Integrating passive acoustic and environmental DNA to understand cetacean presence and distribution
--> 775920

OOC2025-1562 : Ambiguity function of biosonar cetaceans from HD observations and their automatic classification
--> 775949

OOC2025-1241 : Tursionet: detecting bottlenose acoustic interactions in the Pelagos sanctuary with small-scale fisheries. Aspects of acoustic data-preprocessing and detection techniques
--> 776134

OOC2025-1425 : How autonomous diving platforms can help gather large amounts of high-quality sound measurements both in space and throughout the water column
--> 775896

7 Poster presentations :

OOC2025-1564 : SeGaMas : Serious Game for Marine Mammals Survey
--> 775942

OOC2025-1161 : Analysis of sperm whale (Physeter macrocephalus) dialogues, click by click, an ethoacoustic approach
--> 775955

OOC2025-1109 : Physeter and oceanography conditions in high maritime traffic areas
--> 775905

OOC2025-1152 : Guiana Dolphin long term survey by deep learning
--> 775950

OOC2025-1568 : Line gain for long term environmental survey
--> 775939

OOC2025-1165 : Spiking Neural Network for cetacean survey
--> 775923

OOC2025-1119 : Subsea source range estimation based on Neural Network
--> 775954