Integrating acoustic and genetic methods to assess cetacean distribution with the Autonomous Surface Vehicles “Sphyrna”: a multimodal study of oceans by acoustics, eDNA, and satellite images

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ONE OCEAN SCIENCE CONGRESS
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First missions in PELAGOS SANCTUARY

Protecting our marine ecosystems is one of the great challenges of our time.

Our Sphyrna Odyssey campaigns, initiated in 2018 by Sea Proven and the University of Toulon, which carry out field projects around the world, in order to increase their knowledge. The data collected help ensure the resilience of marine ecosystems while improving the livelihood of coastal communities and maintaining biodiversity.

2018, Sphyrna Odyssey launches its first expedition leading to the realization of the first passive 3D trajectory of cetaceans via the use of an autonomous electric ship.

2019, the second edition aimed to assess the impact of noise pollution due to human activities. The study of scientific surveys has led to the proposal of solutions to reduce the risk of collisions between cetaceans and ships.

2020, the last "**Quiet Sea**" exploration benefited from unique acoustic conditions as it was conducted during the lockdown period, resulting in high quality data collection.

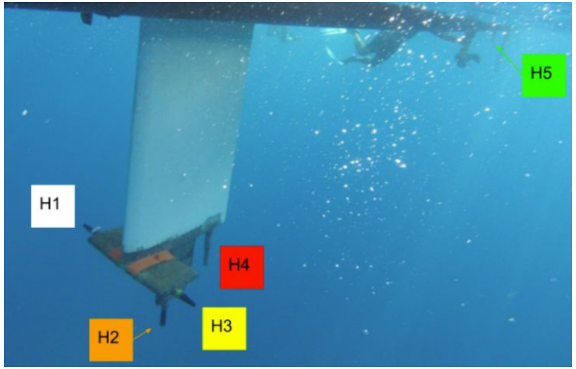
Goals, motivation, methodology

- Passive Acoustics : one of the **most efficient approaches for biodiversity monitoring** at long term and in wide fields
- We developed efficient **novel instrumentations and methods**
- Application of the methods on two domains : **cetacean ecosystem and cultural transmission**.
- We deploy different passive acoustic platforms to characterize how the acoustic space is partitioned among animals and determine **singing activity dynamics in space and time**.
- We aim to innovate in research in **cultural evolution in communication systems** mediated by sound and investigate Acoustic Niche Partitioning in Marine soundscapes.
- Within the **AI Chair for Bioacoustics**, ADSIL LIS CNRS, we **extend methods and applications to various species and ecosystems, to assess biodiversity and anthropic pressures**

Transects by Autonomous Laboratory Vessels: *Sphyrna Odyssey mission*

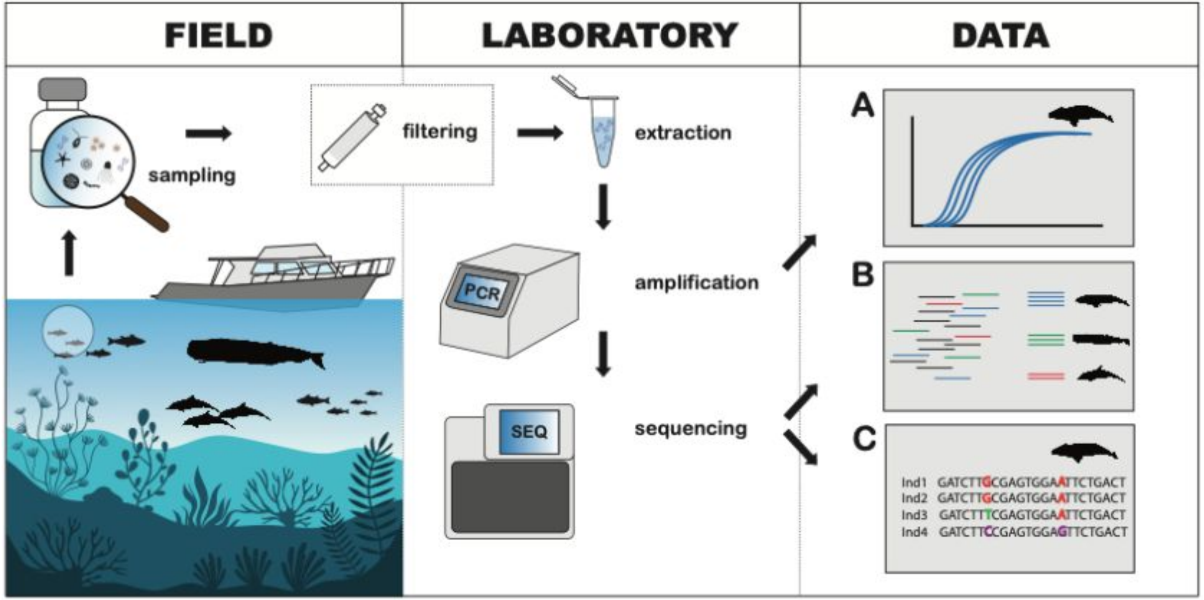
Sphyrna - Autonomous Laboratory Vessel

- ➢ The Sphyrna Odyssey oceanographic missions are mainly dedicated to the **bioacoustic monitoring of cetaceans** and to the detection of their **vocal productions** (codas, whistles, vocalizations) - emitted in various frequency ranges -, from the two Sphyrna (Autonomous Laboratory Vessel - ALV), - each equipped with 5 hydrophones (H1 to H5) for acoustic surveys.



The acoustic antenna

eDNA methodology



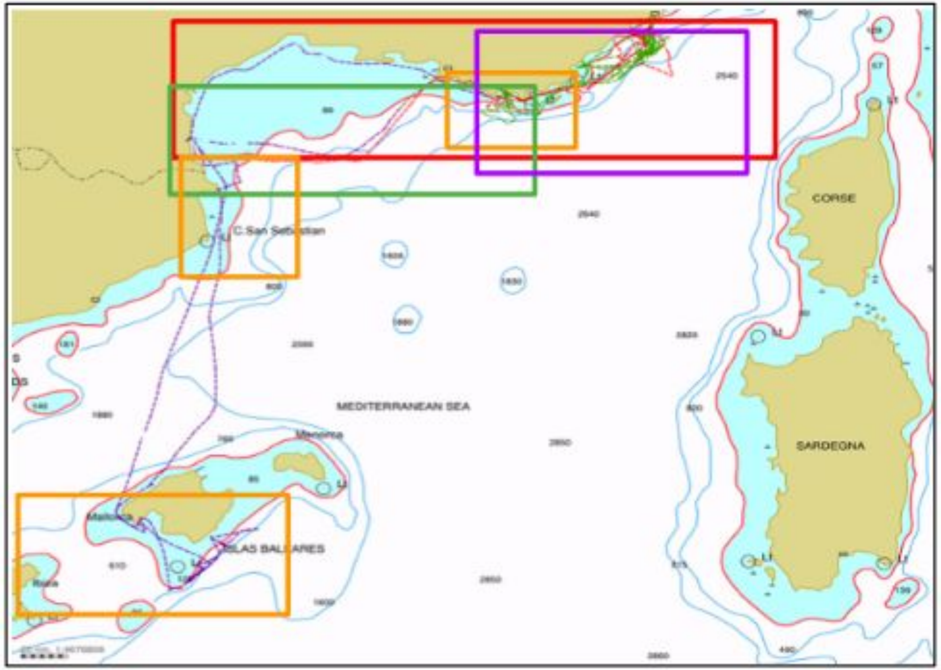
A schematic overview from eDNA sampling to sample processing collected in the field and data generation options. The "DATA" panel explains methods commonly used to detect the presence of cetaceans with eDNA, including A) determination of the presence of target species DNA with e.g. qPCR, B) metabarcoding for species detection and community inference, and C) SNP identification and haplotype sequencing for population genetics (Székely et al., 2022).

Sphyrna Odyssey 2019-2020 mission

Passive acoustic, eDNA sampling, and visual observation during.

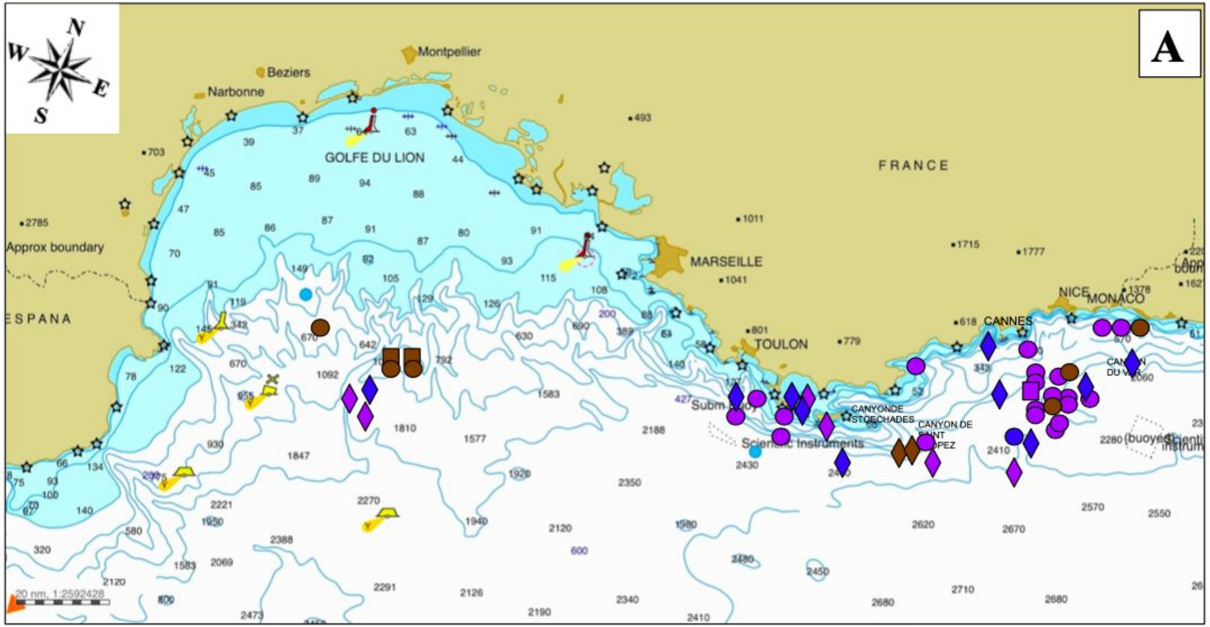
Each campaign area is represented with a distinct color.

Acoustic drift recordings refer to the passive monitoring of underwater acoustic environments using autonomous vessels equipped with hydrophones.



Campaign Areas	Dates	Sampling Types
Campaign 1	25/09/2019 - 31/10/2019	Acoustic drift recordings, Visual observation
Campaign 2	25/11/2019 - 20/12/2019	Acoustic drift recordings, Visual observation
Campaign 3	08/01/2020 - 08/03/2020	Acoustic drift recordings, eDNA sampling, Visual observation.
Campaign 4	23/04/2020 - 10/05/2020	Acoustic drift recordings, eDNA sampling, Visual observation.

Results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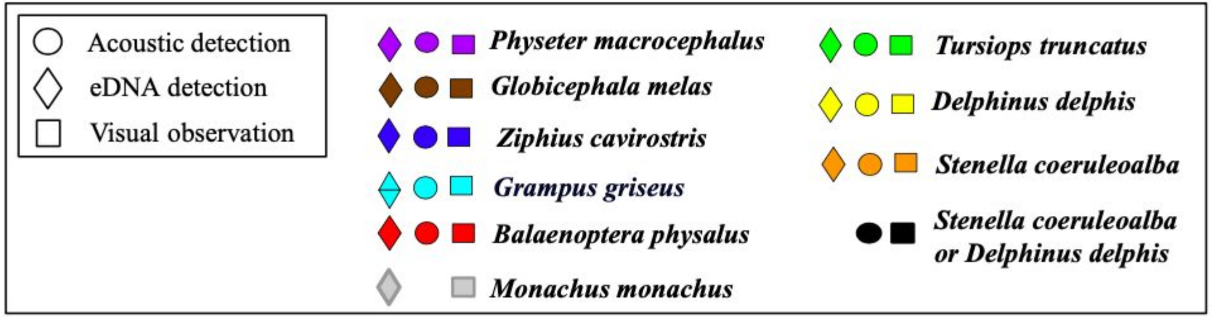
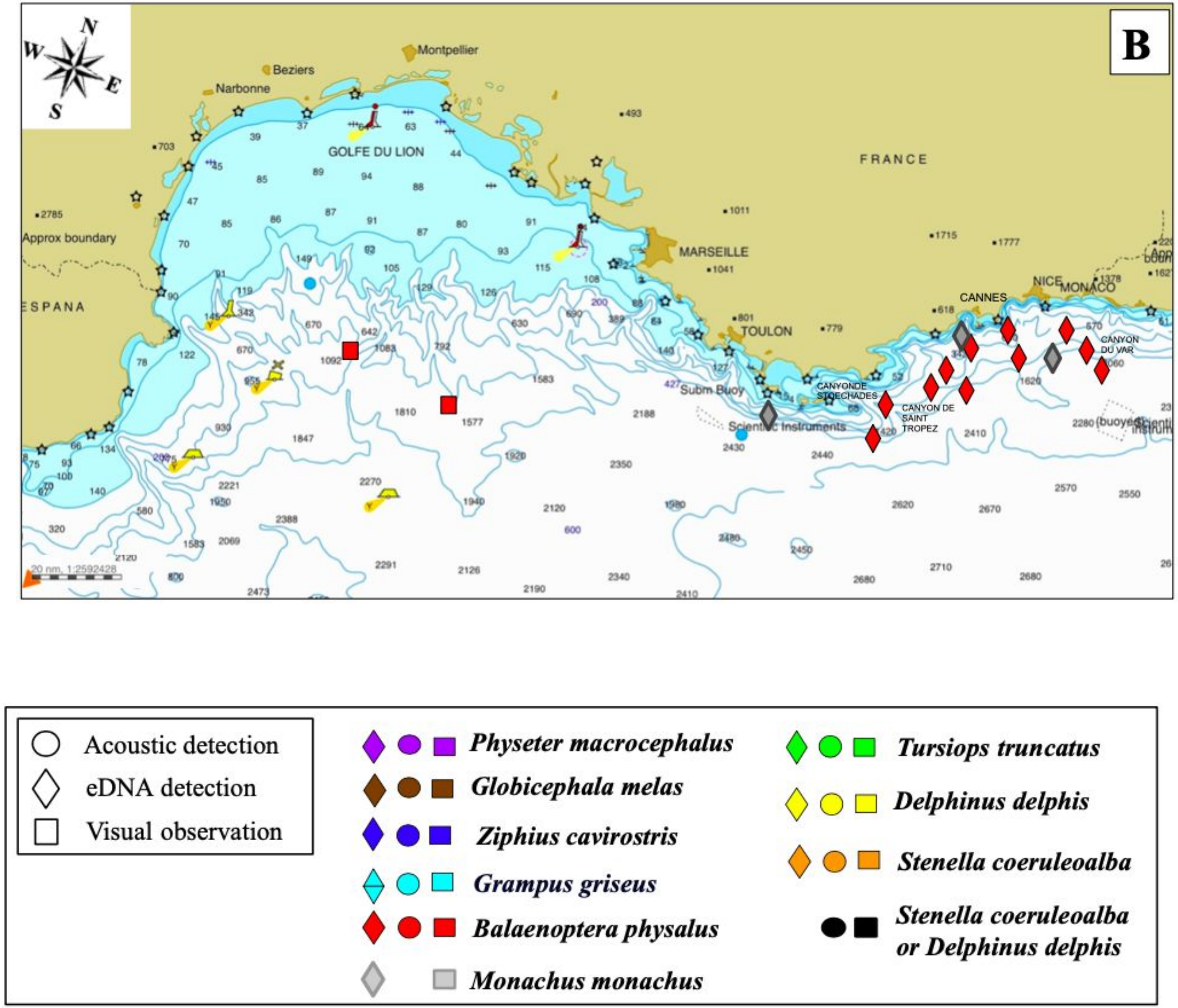

Acoustic detection
eDNA detection
Visual observation
Physeter macrocephalus
Globicephala melas
Ziphius cavirostris
Grampus griseus
Balaenoptera physalus
Monachus monachus
Tursiops truncatus
Delphinus delphis
Stenella coeruleoalba
Stenella coeruleoalba or Delphinus delphis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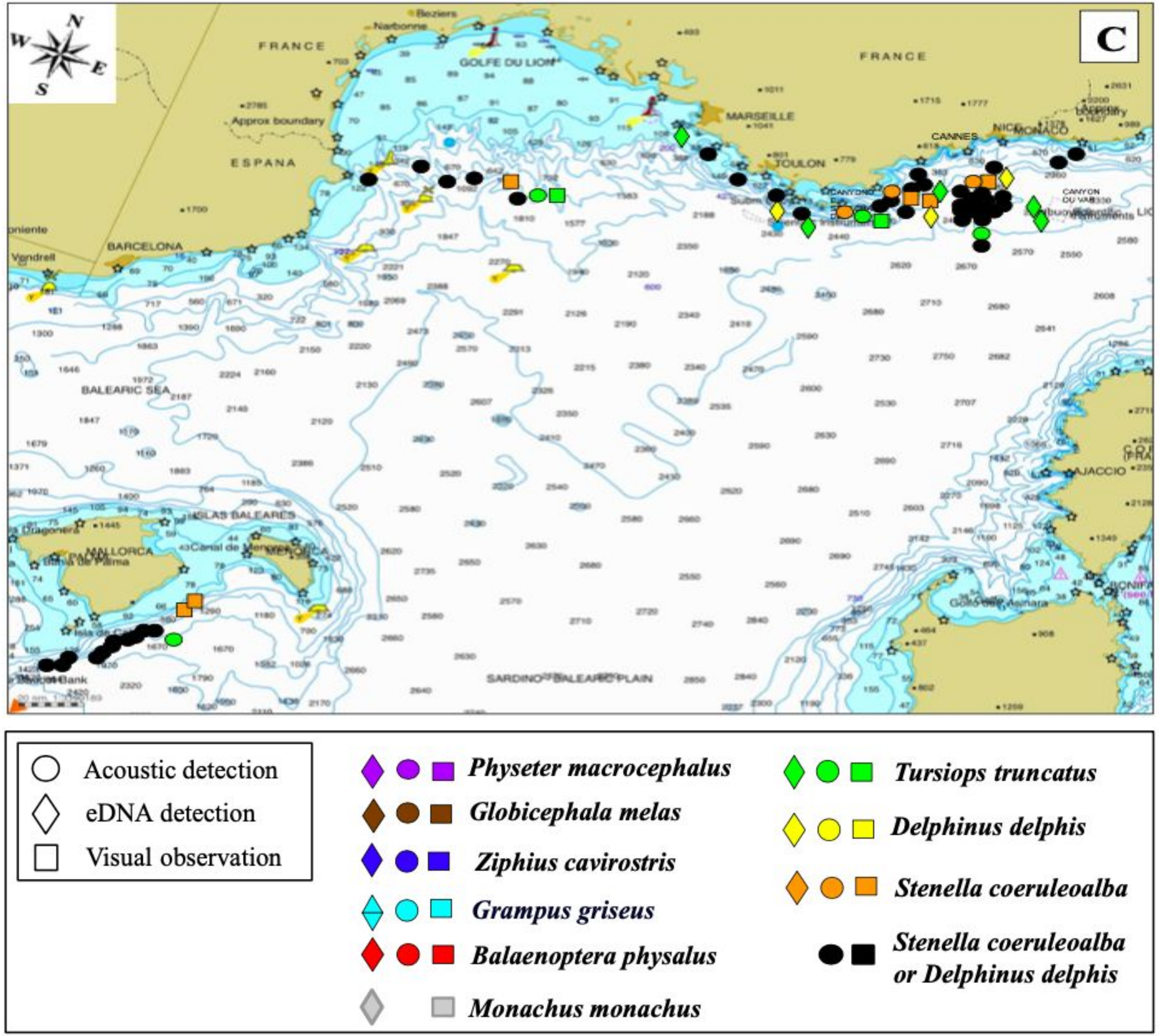

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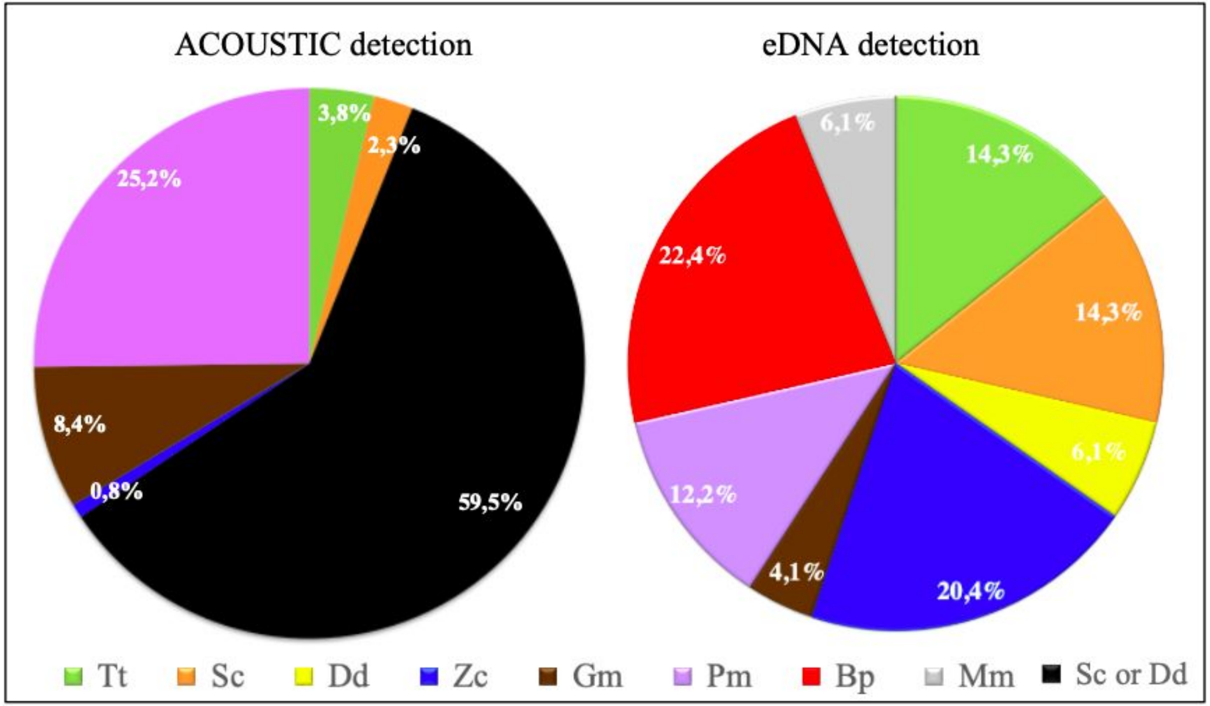
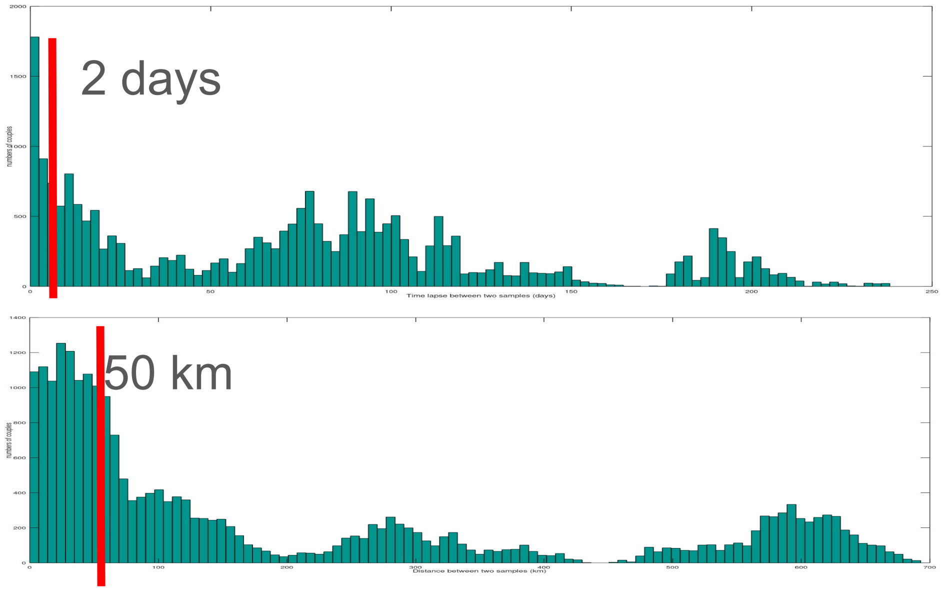


Detection frequency of species estimated by the acoustic method on 119 samples (left) and by the eDNA method on 33 samples (right). eDNA detected all eight species: *Balaenoptera physalus* (Bp), *Stenella coeruleoalba* (Sc), *Delphinus delphis* (Dd), *Tursiops truncatus* (Tt), *Grampus griseus* (Gg), *Globicephala melas* (Gm), *Ziphius cavirostris* (Zc), *Physeter macrocephalus* (Pm), and *Monachus monachus* (Mm). Passive acoustics detected five cetacean species: *Stenella coeruleoalba* (Sc), *Tursiops truncatus* (Tt), *Globicephala melas* (Gm), *Ziphius cavirostris* (Zc) and *Physeter macrocephalus* (Pm). The *Stenella coeruleoalba* (Sc) or *Delphinus delphis* (Dd) category includes acoustic signals for which the specific delphinid species could not be determined.

➢ Mutual information analysis

Top : Distribution of pairwise temporal distances (*dT*) between measurements (in days). A threshold of 2 days was applied to define timely co-occurrences, representing measurements within the same time period or proxy.

Bottom : Distribution of pairwise spatial distances (*dR*) between measurements (in kilometers). A threshold of 50 km was applied to define spatial co-occurrences, representing measurements within the same locality or proxy.



➢ Results of the Mutual Information between spatio temporal distributions of eDNA with (visual+acoustic) detect.:

- For (dT=2 days and dR=50 km), significant differences in mutual information (MI) values were observed.
- At the local scale (dR=50 km), the mutual information between eDNA and acoustic/visual detections was low.

- Conversely, at the basin scale (dR>50 km), MI was substantially higher, indicating greater concordance between the two detection methods.

➢ Conclusion

The combination of acoustic and eDNA methods allows for a better understanding of marine biodiversity depending on current dynamics in the area and the geography of the area.

This study demonstrated that only at a large scale, the acoustic and visual detections, and eDNA detections, share mutual information.

However, at a local level (less than a distance of 50 km), this mutual information between the two modalities is weak.

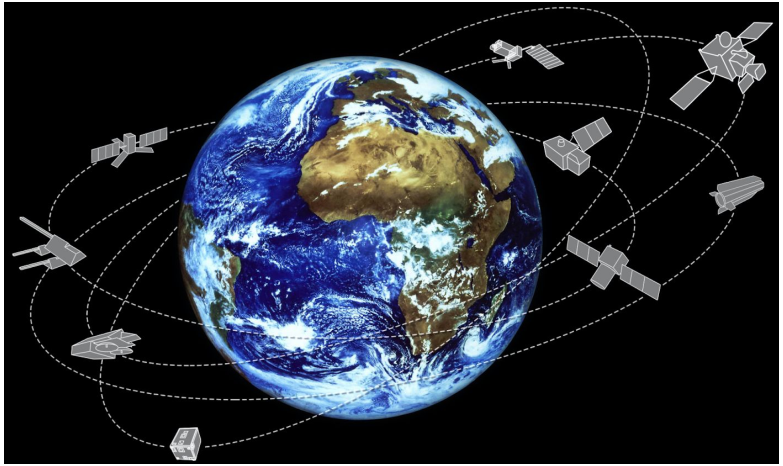
For large dynamic basins, the complementarity of these modalities at small scales, it seems, is not relevant. But for small dynamic basins, the complementarity of these modalities at a large scale can generate relevant information.

To maximize their complementarity, distinct and consecutive campaigns of eDNA sampling followed by acoustic detections could be considered. These strategies would optimize the positioning of acoustic devices, whether they are marine surface drones, fixed devices, or drifting buoys, based on the key zones identified by eDNA.

In conclusion, integrating acoustic and eDNA approaches represents a significant advancement in non-invasive cetacean monitoring. Although improvements are needed, this methodology offers an opportunity to better understand and protect marine ecosystems. The potential applications of this approach extend beyond the Mediterranean, paving the way for similar initiatives in other marine ecosystems.

➢ Perspectives

One of our objective is to **correlate spatial and surface observations to assess the marine environment and cetacean populations** in order to finely study cetacean behavior (life cycles) as a function of **oceanographic structures, bathymetry and environmental parameters**.

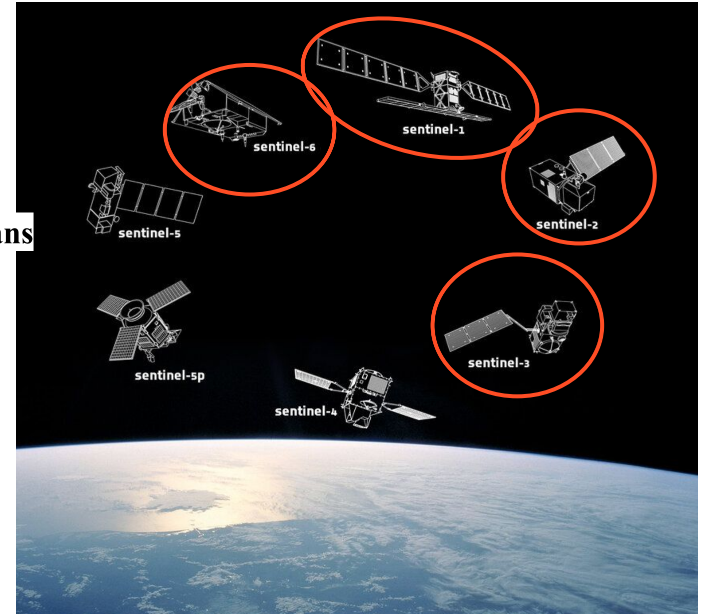


Spatial and surface correlation

➢ We complement the acoustic measurements with **chemical parameter** capture to gain a better understanding of the **distribution of living organisms in their environment**.

➢ Satellite observations and metadata

➢ The European Space Agency (**ESA**) and the European Copernicus program provide a **unique monitoring of the environment**.



Ocean observation satellites will allow us to determine the **favorable conditions for cetaceans** (*bathymetry, currents, chemical and biological variables*):

❑ **Sentinel-1**: provides **images of the sea surface**, current measurements

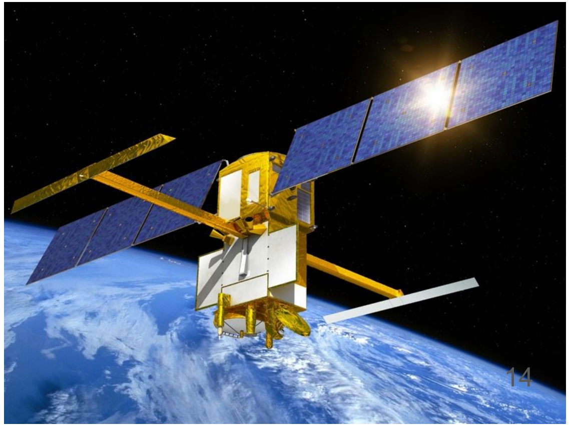
❑ **Sentinel-2**: **chlorophyll distribution**, sediment content, turbidity, bathymetry and pollution of coastal waters

❑ **Sentinel 3**: temperature, water color, chlorophyll, plankton blooms and wind speed: **Monitoring marine pollution and biological productivity**

❑ **Sentinel-6:** ocean currents, wind speed and wave height

❑ Satellite "**SWOT**" (Surface Water Ocean Topography) - **improved resolution, powerful and innovative**- : measure waves, currents and sea level, mesoscale ocean circulation

➢ Evaluate the effects of ocean circulation on marine life, ecosystems cetacean distribution and water quality.



➢ Next Missions : Gascogne golf (Eolian farm surveys) & french Polynesia (megafauna surveys)

Acknowledgments

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