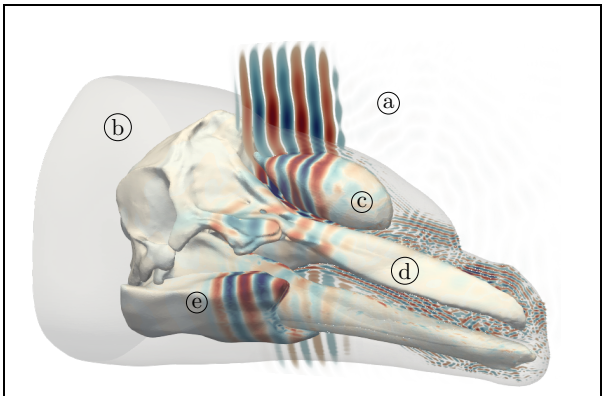
SILENCE (**S**ustainable **I**mpact of underwater **L**oud **E**nvironmental **N**oise on **C**etacean **E**cholocation)

(Prof. Lapo Boschi)

Today, human activities that take place in seas and oceans (e.g., shipping, wind farms, seismic exploration) are quickly expanding. An important by-product of the growth of ocean economy is underwater noise pollution: loud sounds that propagate through water at long distances, and are becoming dominant in marine soundscapes worldwide. Noise pollution is known to disrupt marine life, but quantitative knowledge of its extent and effects is still limited. Research is needed to provide policy makers with guidelines, crucial to taking advantage of marine resources in a sustainable way. Noise pollution models must include precise information not only on how noise is generated and propagates, but also on its impact on specific marine species. **The proposed Ph.D. thesis addresses the impact of noise on marine mammals**, and in particular on the sound localization system of toothed whales.

Behavioral experiments show that toothed whales localize and echolocate sound with extreme accuracy. It has been established that other mammals can tell whether a sound comes from above or below, in front or behind them solely because of their pinna, or external ear, whose complex structure filters it in different ways depending on the angle at which it reaches the head. Dolphins have no pinnae, and **the mechanism by which they can tell the elevation of a sound source is unknown**. Yet they localize sound more accurately than most other species. This ability is essential to their survival, and likely to be severely hindered by noise: it is crucial to understand how dolphins localize sounds to understand **how underwater noise affects them, and how its effects can be mitigated**.



Numerically modelled propagation of a 40 kHz sound wave through the head of a common bottlenose dolphin, incl. (a) water, (b) soft tissues, (c) the melon, (d) the skull, (e) mandibular fat bodies. Different colours stand for different values of particle velocity along the vertical axis. (Carlos Garcia, Lapo Boschi and co-workers, Journal of the Acoustical Society of America*, 2026.)*

The Ph.D. candidate will contribute to identifying the dolphin's functional "internal pinna" – a hypothesized anatomical filter analogous to the mammalian pinna – by combining high-resolution tomographic anatomy with advanced wave propagation models originally developed for seismology. They will simulate wave propagation through 3D head geometries and use machine learning to correlate acoustic features with spatial localization performance, testing whether a single structure or distributed anatomy mediates directional filtering.

The proposed research bridges numerical modeling, acoustics, biomechanics, and comparative anatomy, offering new insights into evolutionary adaptation in marine mammals. If an internal pinna is identified, it will reveal a unique solution to a universal sensory challenge. If not, this will imply that the cetacean brain performs unprecedented signal processing, redefining our understanding of neural computation. Beyond fundamental discovery, the thesis contributes to quantifying how anthropogenic noise degrades localization performance, providing data-driven metrics for marine conservation policy and directly supporting the UN **Sustainable Development** Goals (SDG 14: Life Below Water).

Relevant scientific collaborations:

- Prof. **Jean-Marie Graïc**, Department of Comparative Biomedicine and Food Science, UNIPD (neuroanatomy)
- Prof. **Daniel Remondini**, Department of Physics, UNIBO (machine learning)

- Prof. **Heiner Igel**, Department of Earth and Environmental Sciences, Ludwig-MaximiliansUniversity Munich (numerical modeling of wave propagation)
- Dr. **Stefan Catheline**, Laboratory of Therapeutic Applications of Ultrasound, Lyon (biomechanics)
- Dr. **Léonard Seydoux**, Institut de physique du globe de Paris (machine learning)

Available funds:
The proposer Prof. Lapo Boschi is the coordinator of the **PRIN-PNRR project** SWIM (aSsessing the Impact of offshore Wind turbines on Marine mammals in the Adriatic sea), and a co-investigator of the SEASOUNDS (Innovative marine soundscape characterization to effectively mitigate ocean and sea noise pollution) **doctoral network funded by the European Union**. (Besides the available funds, the doctoral candidate will benefit from SEASOUNDS activities, e.g. workshops). In addition, the proposer has recently submitted research grant proposals to CARIPARO (*Ricerca Scientifica di Eccellenza 2026*) and Human Frontier Science Program (https://www.hfsp.org/funding/hfsp-funding/research-grants) and plans to submit another proposal to the EU SYNERGY program.