Saturn

Developing Solutions for Underwater Radiated Noise

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SATURN Project

Research Newsletter

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Image courtesy TSI

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SATURN's newsletter is designed and edited by Amy Dozier (MaREI University College Cork).

WWW.SATURNH2020.EU

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Measuring vessel noise in deep and shallow water

Roberto Yubero
TSI

In SATURN's second year, the TSI team was busy preparing for underwater radiated noise (URN) tests to be undertaken in November 2022. These tests were performed to measure the underwater noise produced by a vessel — following different testing procedures for deep and shallow waters — with the objective of better understanding how to monitor underwater noise from ships.

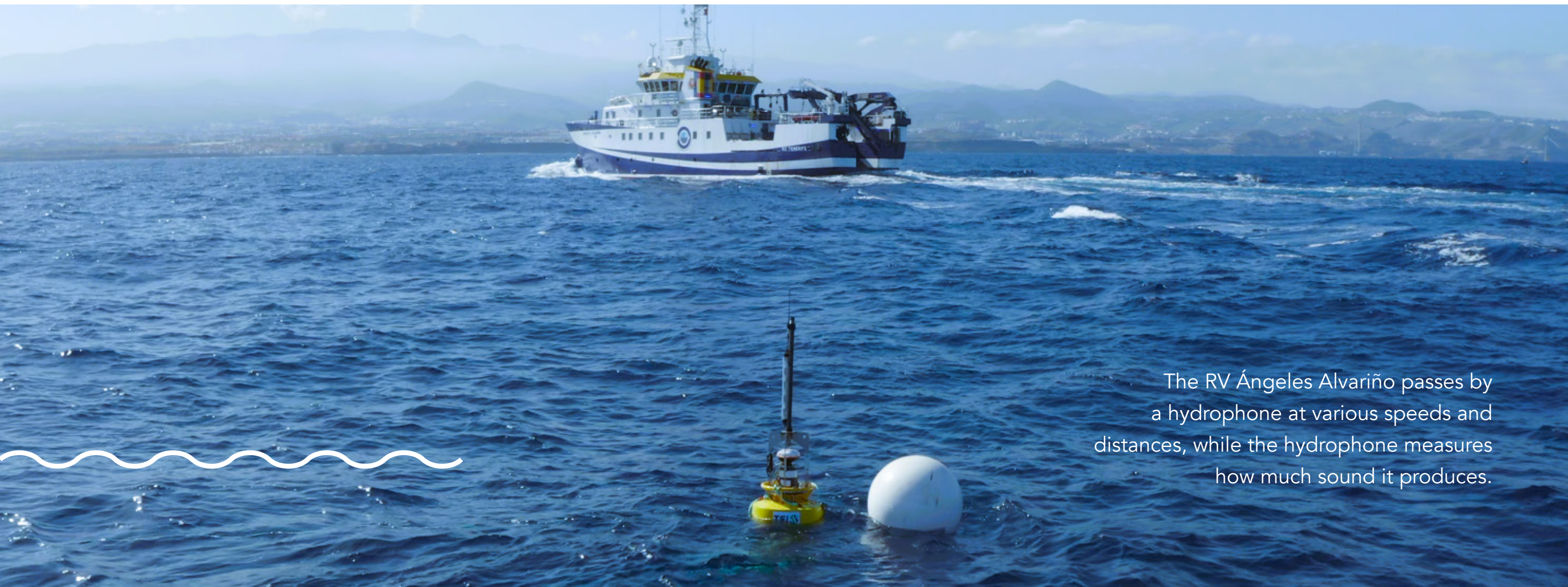
To reach this goal, TSI compared different available procedures to select the best way to measure vessel underwater radiated noise, studying the instrumentation deployment, test execution, and post-processing methodologies for several international standards and classification societies. The outcome of this study was gathered in an internal project report published in April 2022. Meanwhile, the TSI team worked on tuning up the testing equipment in controlled and real environments (laboratory, pool, hydrodynamic channel, and San Juan Reservoir, Madrid). Anticipating the enormous amount of data from the URN measurements, TSI also developed software to ease and speed up both the validation of each run and the post-processing of the measured data.

In November 2022, the URN tests took place for eleven consecutive days in the Canary Islands, Spain. These tests we performed according to a selection of the previously studied standards and class notations procedures to characterise the vessel noise signature in deep and shallow waters. Tests included the execution of the first international standard to measure vessel

What is Underwater Radiated Noise?

Underwater radiated noise or **URN** is a generic term that is broadly understood to mean the acoustic energy in the form of sound and vibration that radiates outward from vessels into and through the medium in which they are operating.

There are multiple sources of sound and vibration from a vessel which together form a complex signature covering a wide range of sound levels and frequencies. Sound signatures vary considerably between different vessel types and also fluctuate in response to different operating conditions.



The RV Ángeles Alvariño passes by a hydrophone at various speeds and distances, while the hydrophone measures how much sound it produces.

noise in shallow waters, still in development: the ISO 17208-3.

During these tests, a communication buoy and a set of hydrophones (underwater microphones) were prepared each day and deployed at sea. The location of the hydrophones was continuously monitored by the communication buoy's GPS. The vessel passed close to the buoy at different distances and speeds to measure how much sound it produced. At the end of each day, the communication buoy and hydrophones were recovered, and the recorded data was downloaded onboard the research vessel. While the tests were occurring, we had the opportunity to record a whole day of tests with drone footage, showing how these measurements are performed. Don't miss it!

This test campaign produced a tremendous amount of data (more than 270 measurements producing around 150GB of data) that will be processed to obtain the vessel's acoustic signature. To do so, TSI will use their recently developed processing software. Results will come very soon!

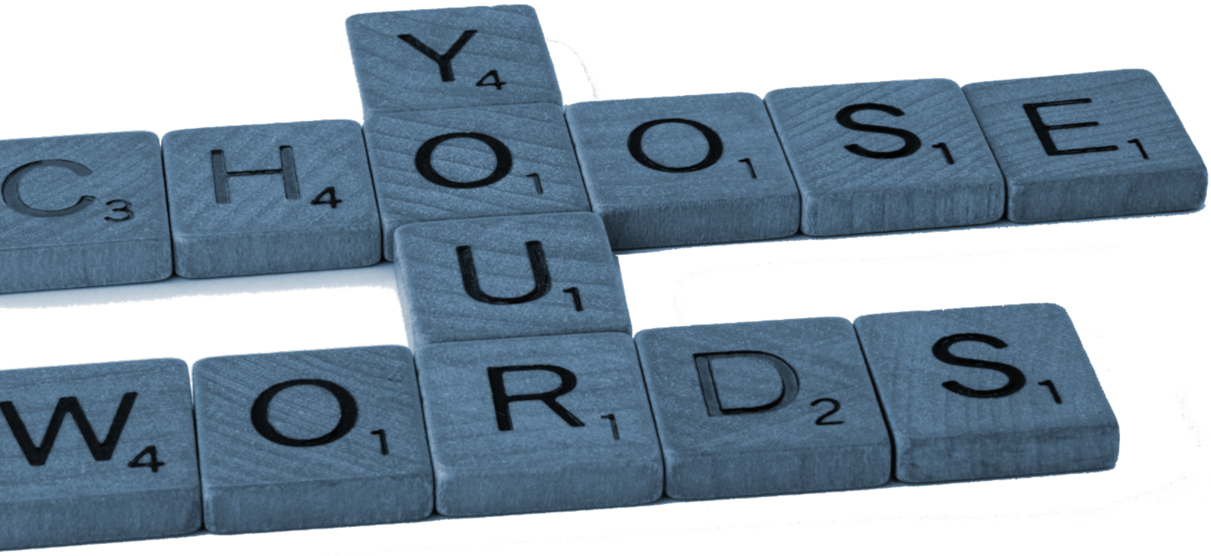
Above

A communication buoy and a set of hydrophones (underwater microphones) were prepared each day and deployed at sea. The location of the hydrophones was continuously monitored by the communication buoy's GPS.

Video: Quantifying Vessel Noise

Left

Watch a video showing drone footage of the underwater radiated noise tests with explanatory captions on [our website](#) *or* [YouTube channel.](#)



Terminology *Matters*

Michael Ainslie
JASCO Applied Sciences

U.S. President William Howard Taft once said, "Don't write so that you can be understood, write so that you can't be misunderstood." A prerequisite for exchanging scientific ideas without misunderstanding is a common interpretation of the terms used in the discourse. And not only science can fall victim to misaligned terminology; dire consequences can occur in practical life.

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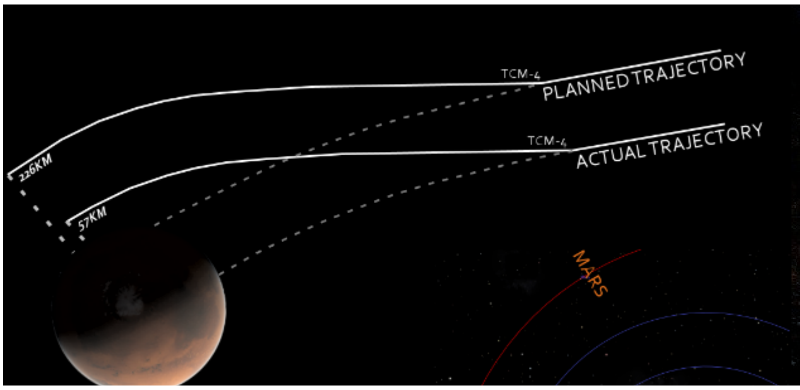
>
> *U.S. President William Howard Taft*

In 1628 a Swedish warship sank on her maiden voyage, having capsized due to instability, because two teams involved in the construction defined the foot (the unit of length) in two different ways. Today we have the International System of Units (SI) and the International System of Quantities (ISQ) to safeguard us against similar disasters, but we still find ways of losing a spacecraft by choosing not to follow international standard units (Mars Climate Orbiter), or having to redesign a bridge already under construction whose spans would otherwise not have met due to the lack of an international standard for sea level (Laufenburg Hochrheinbrücke).

Acousticians took heed of Taft's advice, and the first international standard for underwater acoustical terminology (ISO 18405:2017 Underwater acoustics – Terminology) was published in in 2017, followed three years later by ISO 80000-8:2020 Quantities and units – Acoustics, which consolidated 1 μPa as the international standard reference value of



Left

Actual and planned trajectories of the Mars Climate Orbiter in 1999; the orbiter was 25 km too close to survive.

Right

The modern Hochrheinbrücke in Laufenburg belies the mishap in its design.

Below

Selected terms and their definitions from the second draft (August 2022) of the SATURN Terminology Standards.

underwater sound pressure in the ISQ. ISO 80000 (ISQ) and ISO 18405 define basic terms like 'sound', 'sound pressure', 'sound pressure level', 'sound exposure level', 'decidecade', 'source level' and 'soundscape' (Ainslie et al., 2021). And yet there remains a lack of key terminology needed for characterisation of vessel sounds and impact assessment and mitigation of underwater radiated noise from ships.

Building on the firm foundation provided by the ISQ and ISO 18405, a SATURN work package team led by JASCO and supported by BV, DNV, IBL, PLOCAN, TNO, and UPC is developing standard terminology for the project. Examples of the wide scope of this effort can be drawn from general underwater acoustics ('acoustic near field'), underwater bioacoustics ('acoustic habituation'), vessel acoustics ('radiated noise level', 'structure-borne sound') and sound mapping ('temporal observation window'). And spirited academic debate about the meaning of 'source level' is nowadays replaced by snappy discussion on Twitter.

The first draft, issued in August 2021, was circulated internally. The resulting feedback led to an improved second draft published twelve months later, which has become the SATURN project workhorse and was adopted by the EU technical group on underwater noise (TG Noise) for its guidance on threshold values announced in November 2022 . The final project standard is scheduled for publication in October 2024 and will include, among further expansions, new terminology for particle motion.

While there is much good news to report, there are setbacks too. The ISQ definition of the decibel (dB) was withdrawn in 2019 amid lack of agreement, leaving undefined the most widely used unit in acoustics. JASCO is supporting the International Electrotechnical Commission (IEC) to fill this important gap with a new standard IEC 80000-15 Quantities and units – Logarithmic and related quantities, presently under development. Meanwhile SATURN is left with the choice to wait for IEC to issue its new standard, or develop its own definition of the dB. The times of capsizing warships and missed bridge crossings may hopefully be behind us, but there is still drama in standardisation.

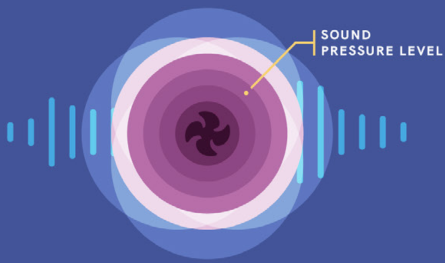
acoustic near field	spatial region between a source and its acoustic far field **notes:** See 'acoustic far field' (ISO 18405, entry 3.3.1.1). In the acoustic near field, the direct-path sound pressure amplitude does not vary inversely with distance from the source.
acoustic habituation	relative persistent waning of a response as a result of repeated acoustic stimulation which is not followed by any kind of reinforcement **notes:** The term 'habituation' is sometimes misused to describe observed moderations in responses to human disturbances, which should be referred to as increasing tolerance to a disturbance stimulus. 'Habituation' can also mislead policymakers by leading to conclusions that particular human activities (e.g., shipping) have neutral or benign consequences for wildlife, but no response is not necessarily indicative of no impact. See also Thorpe (1963), p61 **source:** Bejder et al 2009
structure-borne sound	sound that propagates via elastic deformation in a solid structure,
temporal observation window	interval of time within which a statistic of the sound field is calculated or estimated **source:** ADEON terminology standard [5] **notes:** Examples of statistic include rms sound pressure, peak sound pressure, and sound pressure kurtosis. An example is rms sound pressure calculated using a temporal observation window of 1 min.

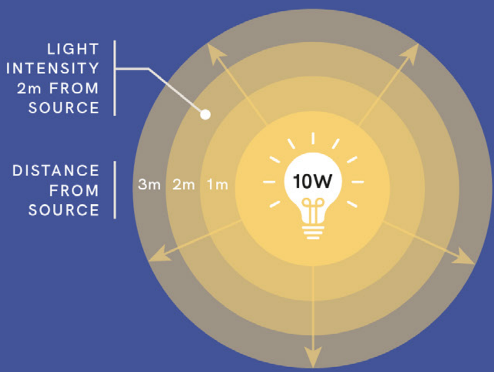
New Infographic on Underwater Sound Terminology

In underwater acoustics, ‘source level’ and ‘sound pressure level’ are expressed in decibels (dB), but represent different physical quantities whose values are not comparable. Our new infographic created by **Amy Dozier** (UCC) and **Michael Ainslie** (JASCO) shines a light on these sometimes confused terms using light as a helpful analogy. For more details on this subject, see [Ainslie, Halvorsen and Robinson (2022), A Terminology Standard for Underwater Acoustics and the Benefits of International Standardization].

View, download, or share the infographic at [https://www.saturnh2020.eu/resources-1/underwater-acoustics-infographic].

Using the Right Terminology to Measure Underwater Sound





Light: Power vs Intensity

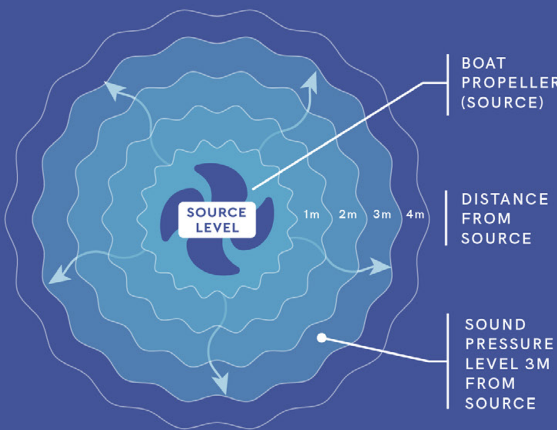
Every light bulb has a set amount of power it emits (in this example, 10 watts). Power is a property of the light source (the light bulb) and is expressed in units of watts (W).

The intensity of the light varies with distance from the light bulb and quantifies the amount of light at a camera lens or your eye. Intensity is expressed in units of watts per square metre (W/m2).

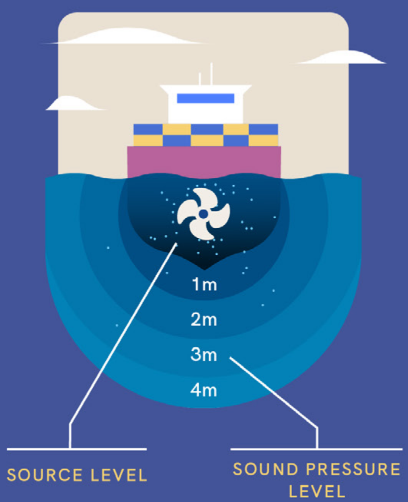
The same idea is true with sound, but the terminology is slightly different.

Sound: Source Level

Imagine a boat’s propeller making sound as it moves underwater. The propeller has a sound power (like the light bulb) but the property of the source most widely used in underwater acoustics is source level, not sound power. Source level is a property of the sound source (the propeller), and is expressed in units of decibels (dB). The reflection of sound from the sea surface means there is no simple relationship between sound power and source level.



Source level is closely related to ‘sound power’, which is a property of an underwater object equal to the rate at which sound energy is emitted from that object. Sound power and source level are properties of the acoustic source and are independent of distance from the source.



Sound Pressure Level

The intensity of the sound varies with distance from the source (just like light). It is represented by the quantity sound pressure level, which is the amount of sound at a specific location in space (e.g. 3 metres from the source). The sound pressure level (SPL) quantifies the amount of sound at a hydrophone (underwater microphone) or your ear. Like source level, sound pressure level is expressed in units of decibels (dB). However, even though source level and SPL are expressed in the same unit (dB), they represent different physical quantities whose values are not comparable. In particular, source level is *not* the sound pressure level at 1 m.

Left

View more resources on [our website]. More infographics will be developed this year from our Communications team!

Uncovering the Effects of Ship Noise on Pilot Whale Populations in Tenerife

Marín, O., Arranz, P., Johnson, M. and Aguilar de Soto, N

BIOECOMAC Lab

University of La Laguna

We are excited to share with you the latest findings from our ongoing research at the BIOECOMAC lab at the University of La Laguna (ULL) in the Canary Islands, Spain. Over the past year, we have been utilizing cutting-edge techniques such as passive acoustic methods (PAM) and analyzing maritime traffic data to gain a deeper understanding of the sounds that are most harmful to cetaceans in the area. Additionally, we have been utilizing drone images to study short-finned pilot whale (*Globicephala macrorhynchus*) populations in the Teno-Rasca special area of conservation on the island of Tenerife. We are pleased to report that funding for this work has been successful. Fieldwork in 2022 was financed by SATURN while the 2021 field season was financed by complementary funds from other projects, such as the Office of Naval Research (ONR) from the U.S. and the LIFE Programme of the European Climate Infrastructure and Environment Executive Agency.

Drone operated by Dr. Patricia Arranz during the development of the CETTUS project. In the Canaries, the UAVs were operated under a UAV Operator license (Register # 2020064914) and an Advanced Certificate of aircraft piloted by remote control (RPA20605OT and RPA20605OP) under the Spanish Aviation Safety and Security Agency (AESA). Images © Universidad de La Laguna.

During the field seasons in 2021 and 2022, we tagged 17 pilot whales and collected over 100 hours of recordings. This data has allowed us to better understand the impact of ship noise on these populations and how it affects their behavior. The sampling tasks were performed south of the Teno-Rasca maritime strip, an area known for its steep bathymetry, which makes it ideal for observing pilot whales directly from a land-based observation station. This station, located on the mountain of Chayofita in Los Cristianos, enabled our research team to track groups of animals and make predictions about their movements. Furthermore, we used an Automatic Identification System (AIS) receptor to record maritime traffic in the area during tagging operations and for the duration of the time that a DTAG was affixed to a pilot whale. A visual survey of the boats was also carried out every

Above: Tagging maneuver on a pilot whale. The DTAG is attached to a tagging pole. **Below:** Land station observers in front of Los Cristianos fast ferry and marina. Images used with permission from the Ministry of Ecological Transition and the Demographic Challenge (MITECO)

15 minutes to obtain a more complete understanding of the maritime traffic in the area and its potential impact on the pilot whale populations we are studying.

Our preliminary analysis of the data collected from the tags has revealed some interesting findings about the feeding cycles of these animals. The recordings include both diurnal and nocturnal feeding cycles. The mean time that the DTAGs remained on the pilot whales was 6.6 hours, with the tag remaining on one animal for as little as 1.2 hours and as long as 20.3 hours. These findings are aiding us in better understanding the behaviors and habits of these pilot whale populations and how they may be affected by anthropogenic stressors.

In order to expand our understanding of anthropogenic disturbances, we are collaborating with Dr. Patricia Arranz to investigate the impact of these disturbances on the nutritional health of individual animals. To achieve this goal, we are utilizing a variety of techniques such as measuring the morphometrics, allometrics, and body condition of cetaceans in their natural habitats.

Recently, we have been utilizing unmanned aerial vehicles (UAVs) to study the body shape, allometric relationships, and body condition of free-ranging short-finned pilot whales. We have taken photographs of the dorsal and lateral sides of the whales, measuring their body length, width, and height. We have also classified the whales into three age classes based on their total body length (BL). We have collected data from 77 whales (mean ± SD), including 9 calves (2.37 m ± 0.118), 31 juveniles (2.90 m ± 0.183), and 37 adults (3.72 m ± 0.440).

Our findings are providing us with a deeper understanding of the health status of these populations and the ways in which they may be vulnerable to anthropogenic stressors. This information is critical for the long-term monitoring and conservation of these species. Our study is providing insights into the morphometrics, allometrics and body condition of free-ranging short-finned pilot whales and how they can be used to assess and monitor the health of cetacean populations. This will help us to better understand the vulnerability of these species to potential anthropogenic stressors and contribute to the management and conservation of these species.

As we continue to gather data and analyze our findings, we are excited to share more of our progress and discoveries with you in the coming months. This research project is being conducted in collaboration with Dr. Patricia Arranz, Dr. Frederik Christiansen and Dr. Kate Sprogis. If you have any questions or would like to learn more about our research, please don't hesitate to reach out to us. We look forward to keeping you updated on our progress and contributing to the conservation and management of these animals.

Learning from Vibrations

Pablo Pla Caro
LAB-UPC

Vibrations are perceived in one way or another by every living being on Earth. Under certain conditions, these vibrations can propagate long distances through an elastic medium (such as air or water) and generate pressure waves, tightly related to the motion of the tiny particles that constitute the medium.

Acoustic pressure has been used as a unique metric to study the possible negative impacts of anthropogenic underwater noise on aquatic organisms. It is only fairly recently that a new question has arisen which could assist naval, offshore and shipping industries towards quieter oceans:

Are underwater organisms more sensitive to these pressure fluctuations or to the motion of the particles?

Committed to addressing this challenge, researchers at the Laboratory of Applied Bioacoustics (LAB), from the Universitat Politècnica de Catalunya, BarcelonaTech (UPC), have concentrated their efforts in the past two years to design and build a unique experimental laboratory setup: the ***AquaVib***.

Supported by a firm structure anchored to a thick reinforced concrete platform, a pair of heavy electrodynamic shakers cap both ends of the three interchangeable acoustic chambers equipped with different sensors to measure acoustic pressure, particle motion, temperature and dissolved oxygen in a regulable seawater flow. Within the central chamber, aquatic organisms can be exposed to controlled vibroacoustic cues with characteristics similar to those radiated by ships navigating our oceans, from regular fishing boats to the largest cargo ships with 400 meter long hulls and over 200 gigatons in weight.

The design of the *AquaVib* is conceived in a way that the rate between the acoustic pressure and the motion of the water particles can be set at two different configurations, allowing to assess their contributions separately. The combination of control over these two sound variables, an automated regulation of the water temperature and dissolved oxygen contents, and the possibility for visual inspection through the transparent chamber, provides the LAB-UPC team with a multimodal approach to investigate possible physiological, pathological and ultrastructural effects of the exposed organisms to each of these two sound components.

Preliminary experiments with mussels

Above: Researchers Marta Solé (right) and Pablo Pla (left) using the AquaVib setup.

(*Mytilus edulis.*) and Norway lobsters (*Nephrops norvegicus*) have served to fine-tune the system and to define, in collaboration with SATURN partner TNO, adequate test protocols as a rigid basis for this cutting-edge approach.

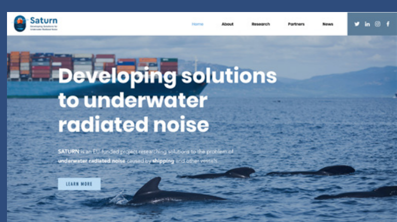
In the upcoming year, the LAB-UPC group will study four different species of marine invertebrates that are considered of interest due to their major role in aquatic ecosystems and for their commercial importance. Our ultimate goal is to identify and quantify possible risks, and acute and long-term impacts on marine invertebrates directly related to the exposure to underwater radiated noise from shipping, assessing particle motion and acoustic pressure effects separately. This work will contribute to defining the most effective mitigation measures and marine spatial planning developed by the SATURN consortium, which aims to improve current maritime policies.

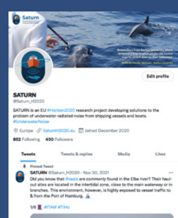
Right Top: the AquaVib with the large steel acoustic chamber mounted.

Right: Mussels exposed to controlled vibroacoustic cues in the transparent acoustic chamber.

Stay Up-to-Date

The communications team at MaREI, UCC regularly posts about SATURN research and activities, along with related news and research on underwater radiated noise from vessels, on our website and social media accounts. Follow us and head to our website news page to learn more about the project and download resources, including publications, infographics and more. This year, the team will be producing more infographics along with policy briefs related to SATURN research.





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TNO in SATURN

Measuring and modelling particle motion

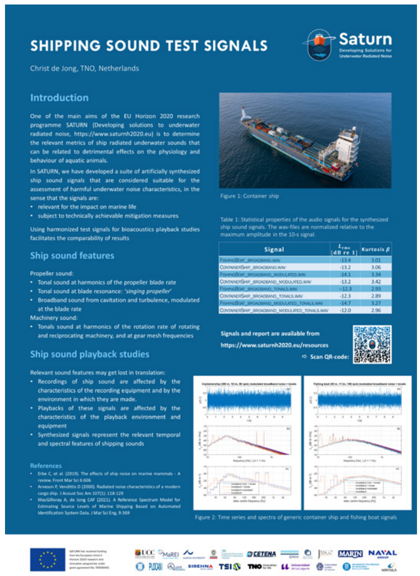
Christ de Jong, TNO

The Netherlands organisation for applied scientific research, TNO, is involved in a variety of tasks in the SATURN project, including the provision of acoustic support to biologists and maritime researchers.

The first highlight of our activities in 2022 was the completion of the development of [a suite of artificially synthesized ship sound signals for use in future laboratory studies.](https://www.saturnh2020.eu/resources-1/harmonised-test-signals) These signals are considered suitable for the assessment of harmful underwater noise characteristics in the sense that they are relevant for the impact on marine life as well as subject to technically achievable mitigation measures. Using harmonized test signals for the different bioacoustics playback studies facilitates the comparability of results. These signals are offered as a standard reference for external stakeholders and future projects. They were presented at the Aquatic Noise 2022 conference in Berlin and are available from https://www.saturnh2020.eu/resources-1/harmonised-test-signals.

Another highlight was the completion of the Committee Draft (CD) for a new ISO standard procedure for measurements of ships in shallow water (ISO 17208-3). This was developed by an international group of experts, led by Christ de Jong (TNO) with support from SATURN. The CD passed the ISO balloting process, and the working group is now working on the comments towards the next stage, aiming at submission of a Draft International Standard for ballot in 2023. The proposed measurement procedure was tested by TSI in the November 2022 sea trials carried out by TSI (SATURN Task 2.2).

In SATURN Task 2.3, TNO and JASCO are jointly developing the capability to create maps that represent the particle motion component of underwater sound from ships. This is relevant for evaluating



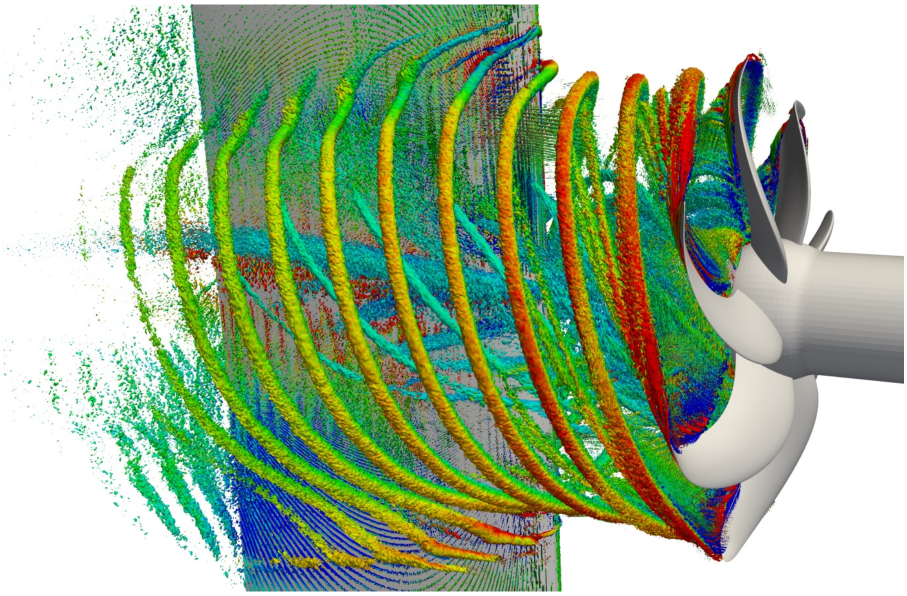
Above: Poster by TNO for Aquatic Noise 2022.

Below: Deployment of the sound particle motion measurement rig from the RHIB.

the impact of shipping sound on fish and invertebrate species, that are sensitive to particle motion. Different models for sound particle motion have been applied and verified through a process of benchmarking. The results were presented by Victor Oppeneer (TNO) at the International Conference on Underwater Acoustics (ICUA 2022) in Southampton.

To be able to validate these models against field data, for a realistic offshore location in shallow water, TNO deployed its particle motion measurement rig at a location in the North Sea, in the The Hague offshore test area. The rig was deployed from a rigid-hull inflatable boat (RHIB), on the seabed at about 15 depth. It collected data from the sound produced by a small controlled airgun source during various runs with the RHIB at different distances from the rig. In addition to these measurements for model validation, the rig continuously recorded sound pressure and sound particle acceleration over the three deployment days. These data will provide typical signals from passing ships that can be compared with models, as well as provide insight on background noise levels, including flow-noise and noise from surface wave breaking and rain.

Together with SATURN partner Aarhus University, TNO supported the development of a proper and efficient implementation of ship acoustic modelling in the DEPONS model for assessing population effects of disturbances on marine populations. Various discussions were held concerning the analysis of D-tag and satellite tag data and acoustic modelling of ship sound emission and propagation for the scenarios studied to derive dose-response relationships for relevant vessel noise metrics.



Above: Visualization of the vortices shed by a marine propeller on a downstream hydrofoil, mimicking a rudder.

Tackling the hydro-acoustics of marine propellers by means of high-fidelity simulations

Mario Felli and Antonio Posa

CNR-INM

Recent literature on naval hydrodynamics has demonstrated the need of high-fidelity numerical simulations to properly capture the complex fluid dynamics giving rise to acoustic phenomena. Meanwhile, the growing computing power of supercomputers gives the opportunity of exploiting High Performance Computing to carry out eddy-resolving simulations, able to resolve a wide range of scales of the flow. In the framework of the SATURN project, this large computing power was leveraged by scientists at CNR-INM to carry out numerical simulations of the flow downstream of marine propellers on computational grids consisting of billions of points, which are at least a couple of orders of magnitude beyond the most advanced studies in both industry and academia today. State-of-the-art, eddy-resolving simulations were performed to resolve all energy-carrying structures of the flow, which are acoustics sources, both on the surface of propellers and in their wake. Parallel computing was adopted, to split these large problems across thousands of computing cores, to tackle flow problems of unaffordable size for typical workstations. Capturing the complex physics of the turbulent flow around marine propellers and downstream of them, in their wake, enabled reconstructing their hydro-acoustics in several scenarios, including open-water configurations, propellers operating in the wake of upstream rudders, typical of the propulsion of underwater vehicles, and propellers operating upstream of rudders, typical of the propulsion of surface ships. This significant effort resulted in several recent publications in the framework of the SATURN project, where more details on both the fluid dynamics and the hydro-acoustics of marine propulsion can be found.

Papers published in 2022 from CNR-INM

Posa, A., Broglia, R., Felli, M., Cianferra, M. and Armenio, V., 2022. Hydroacoustic analysis of a marine propeller using large-eddy simulation and acoustic analogy. *Journal of Fluid Mechanics*, 947, p.A46.

Posa, A., Felli, M. and Broglia, R., 2022. Influence of an upstream hydrofoil on the acoustic signature of a propeller. *Physics of Fluids*, 34(4), p.045112.

Posa, A., Broglia, R. and Felli, M., 2022. Acoustic signature of a propeller operating upstream of a hydrofoil. *Physics of Fluids*, 34(6), p.065132.

Posa, A., Felli, M. and Broglia, R., 2022. The signature of a propeller–rudder system: Acoustic analogy based on LES data. *Ocean Engineering*, 259, p.112059.

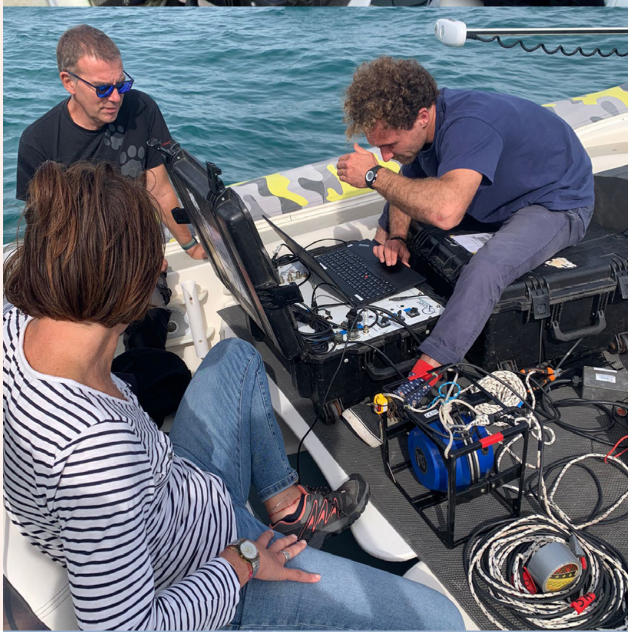
See more publications of SATURN's research at www.saturnh2020.eu/results.

Testing New Propeller Technologies

Sylvie Armenio
Naval Group & Sirehna

A key element of SATURN's research is examining technological solutions to reduce underwater radiated noise. Throughout 2022, NAVAL GROUP and its subsidiary SIREHNA have been studying optimal propulsive technologies. Within SATURN, the two organisations have been focusing on the test of a non-conventional propeller with vertical blades (trochoidal concept) provided by ADV-PROPULSE, mounted on a scaled model of a ferry manufactured by FORMES&VOLUMES. The acoustical performance of this propeller will be measured via a scaled model on a lake in March 2023. Numerical predictions are also planned in 2023 for this model in order to improve the capability of propulsive providers to predict accurate hydroacoustic signatures before their industrialisation.

Direct observations of trawling URN in the Northern Adriatic Sea



CNR-ISMAR

Fishing activity is an extremely important economic sector in the Northern Adriatic Sea. As a consequence, bottom trawling and rapid are relatively common fishing techniques. The sound introduced into the marine environment by these activities is a matter of concern in the Adriatic Sea. To address this issue and collect the first direct observations , CNR-ISMAR and Quiet-Oceans, together with Fondazione Cetacea, ran a dedicated experimental session with the aim to characterize the underwater noise produced by a trawler while it was actively fishing in shallow water (less 20 meters). The experiment was conducted in Rimini, Italy at the beginning of October 2022. Measured underwater radiated noise (URN) will be used as input for mapping the cumulative underwater sound generated by fishing activity in the study area.

OCEANOISE2023

Michel André, Peter Sigray & Tom Akamatsu
OCEANOISE2023 co-chairs

The call for abstracts is now open for OCEANOISE2023, a conference in to Vilanova i la Geltrú from May 22-26. The conference brings together international leading experts in noise measurement, modeling and mapping, physiological and behavioural effects as well as regulation and mitigation procedures.

The format of the conference includes keynote communications and plenary sessions with invited speakers whose objective is to challenge current knowledge on ocean noise. This call for abstracts, which will be open from 15 January to 15 March 2023 concerns the 5mn-talks that will be scheduled every day in the late afternoon. The call will address the same themes as during the chaired sessions and the authors will be asked to pick up one of them when submitting their abstract. Unlike the chaired sessions, the 5 minute talks will not be chaired nor a round table will be organised afterwards. Instead, a general discussion (with a glass of wine) will follow around the posters of the day (associated with the 5 minute talks), where all participants will be invited to informally give their input or discuss with the speakers.

For information, abstract submission, and registration, visit the OCEANOISE 2023 website at https://2023.oceanoise.com.

Mitigating ship noise using bubble injection

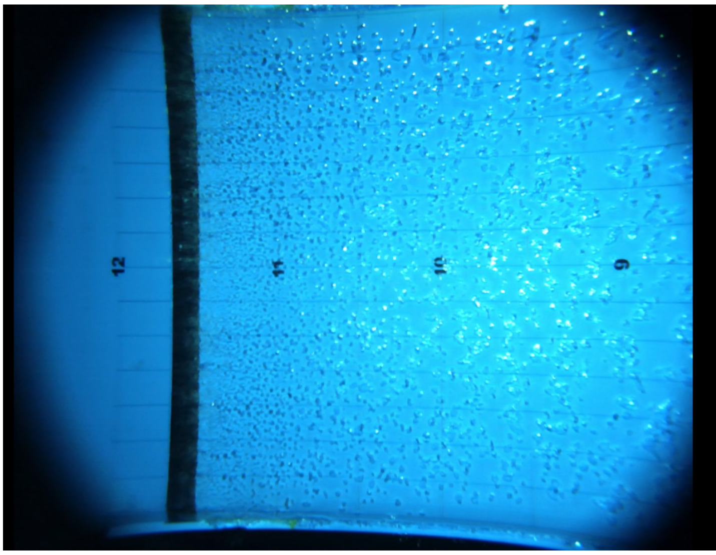
MARIN

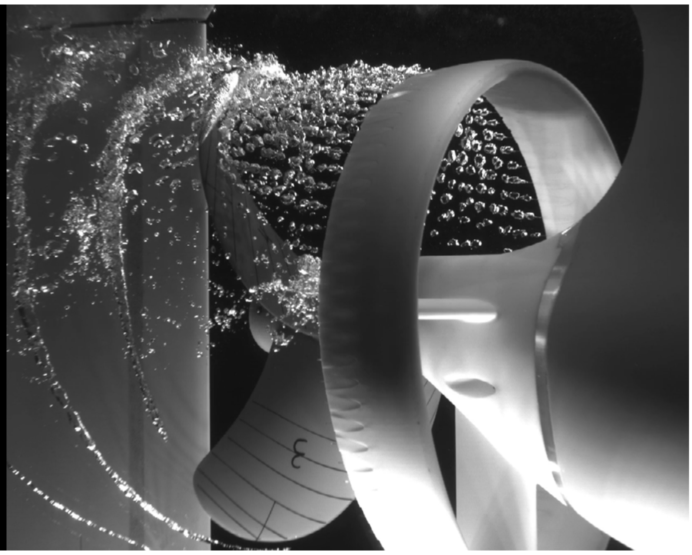
In WP4 MARIN is performing model tests to evaluate the effectiveness of two air injection systems for reducing ship underwater radiated noise. The 'Masker' system aims to mitigate machinery room noise by injecting a bubble curtain over the keel and sides of the hull, thereby isolating the ship hull from the surrounding water. The 'Prairie' system aims to mitigate the noise of propeller cavitation by injecting air into the flow directly upstream of the propeller. Introducing air into the cavity adds compressibility to the water vapour, which weakens the cavity collapse. Both systems have already been applied on naval ships for a long time, but there is a lack of quantitative information concerning their effectiveness in open literature . The systems can be applied to newbuild vessels or retrofitted to existing ships. The ship hull used by MARIN for the model tests is a 94 m coastal tanker, known as the Streamline tanker.

Exploratory model tests concerning the effect of bubble curtains were discussed in the previous newsletter. Those tests focused on whether air injected using porous hoses formed an air layer beneath the hull. The outcome of those tests was positive and, therefore, that system has now been evaluated in terms of its effectiveness in reducing the underwater radiated noise from machinery inside the ship.

Above: View of the 7.8 metre long ship model hull with steel midsection. See image on the next page for a snapshot of air bubble layer under the ship model hull, injected through porous hoses.

To represent a real ship structure a ship model with a metal mid section was used. A shaker introduced broadband vibrations in the structure, which lead to underwater radiated sound, thus mimicking the effect of a ship's engine room. The sound was measured at various ship speeds and air flow rates, including a baseline case with the injection system switched off. The 'insertion loss' (reduction of noise) due to the bubble layer is determined by taking the difference between the measured sound spectra of the tests with





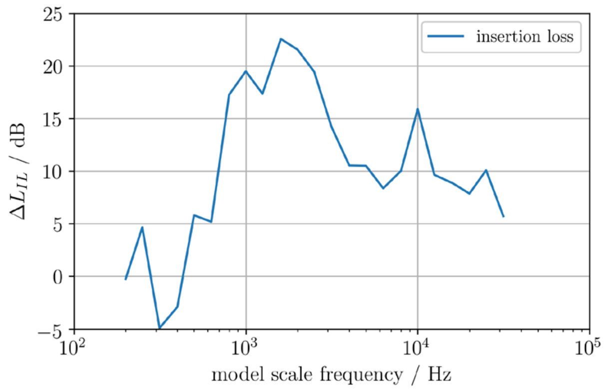
Above Left: A snapshot of air bubble layer under the ship model hull, injected through porous hoses (black vertical strip on left hand side). The model is sailing from right to left in the left photograph. **Above Right***:* Snapshot of air injection into the propeller disc using Prairie system.

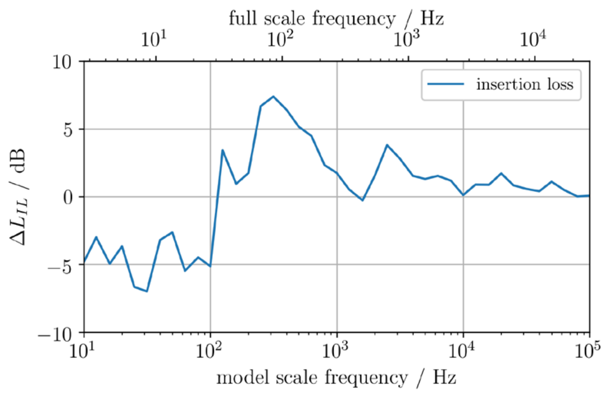
air and those without air. An initial analysis of the results revealed that an insertion loss of up to about 22 dB was measured! However, the insertion loss was found to be negative at certain low frequencies i.e., the air injection system leads to an increase in noise levels. This could be due to bubble resonance.

The insertion loss depends on the void fraction (i.e. amount and size of bubbles) which is a function of both air flow rate and ship speed, and was measured at various positions over the hull midsection. These results are currently being analysed so that the relation between insertion loss and void fraction (as well as flow rate and ship speed) can be established.

For tests of the Prairie system another model of the Streamline tanker was manufactured. A duct was added just upstream of the propeller, fitted with needles that injected small bubbles into the flow. The noise generated by the cavitating propeller was measured both without air injection and with air injection at various air flow rates. A preliminary analysis of the performance of the system showed an insertion loss of up to 7 dB, located in a frequency range typically containing high cavitation noise levels (about 80 Hz on full scale). We note that the increase in noise levels (negative insertion loss) at lower frequencies (up to about 30 Hz on full scale) has also been reported in the literature. The cavitation dynamics and interaction with the air was also observed with high-speed video cameras, and a special optical technique has been used to determine the size distribution of the injected bubbles.

It is concluded that good and complete datasets have been acquired to evaluate the use of air bubbles to mitigate machinery noise and propeller cavitation noise. Preliminary results are promising. The data is presently being analysed in more detail, while activities to model the mitigation mechanisms will start soon. This gives the shipping industry more options to reduce the impact of shipping noise on sea life.





Top: Preliminary results for Masker system: insertion loss in decidecade bands determined for one air flow rate and model speed. The frequency axis relates to model scale, but it is expected that the frequencies do not change significantly for full scale.

Above: Preliminary results for Prairie system: insertion loss in decidecade bands computed for one air flow rate and propeller operating condition for Prairie system. Both model and full scale frequencies are shown in the figure.

BOOM CRASH WROOM

A Didactic Lab on Underwater Radiated Noise

Francesco Falcieri
CNR-ISMAR

During the UNESCO "Ocean and Climate Village" held in Venice (March 28th – April 3rd 2022) CNR-ISMAR held a didactic lab called "BOOM CRASH WROOM" with the aim of raising awareness among the new generations on Underwater Radiated Noise and its consequences on marine organisms and ecosystems.
The lab was divided into a short introductory lecture during which participants learned about the physics of sound, its uses in the oceans, and its potential impacts. Participants were then asked to represent what they have learned with a drawing made on-site. Overall, 74 primary school students and 23 middle school students participated in the event.

We hope to hold another workshop in 2023 at the Venice Biennale to teach the next generation about how animals use sound underwater and the impacts that underwater noise can have on the marine environment.

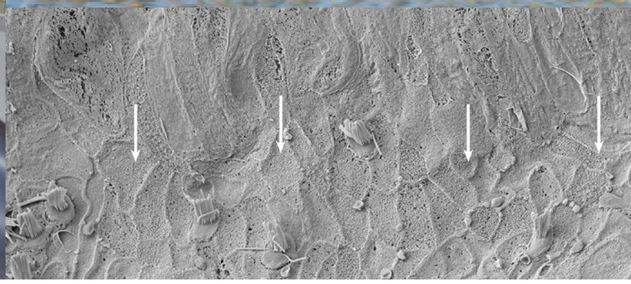
Above

Children participate in the BOOM CRASH WROOM Workshop during the UNESCO Ocean and Climate Village.

Progress on the SATURN Virtual Research Environment

José Antonio Diaz
PLOCAN

SATURN is producing an online collaborative platform for housing technical and analytical tools for processing, analysis, and visualisation of underwater radiated noise from ships and boats. A consultation meeting on this forthcoming 'Virtual Research Environment' (VRE) was held online in May to discuss different input data and expectations and suggestions. A library of underwater sounds is the first set of data uploaded to the platform, and a Python notebook was developed for processing and visualisation of the data. Plans are currently being made to host the SATURN 2023 General Assembly in Gran Canaria in the city of Las Palmas in May.



Above: TiHO researchers examining a stranded (deceased) harbour porpoise. **Top Right**: A harbour seal in the Elbe River with a DTAG, which captures important information such as noise exposure, behaviour, and key metadata. **Right:** Image of an inner ear from a harbour seal with evidence of hearing impairment. The arrows highlight the regions with missing sensory cells.

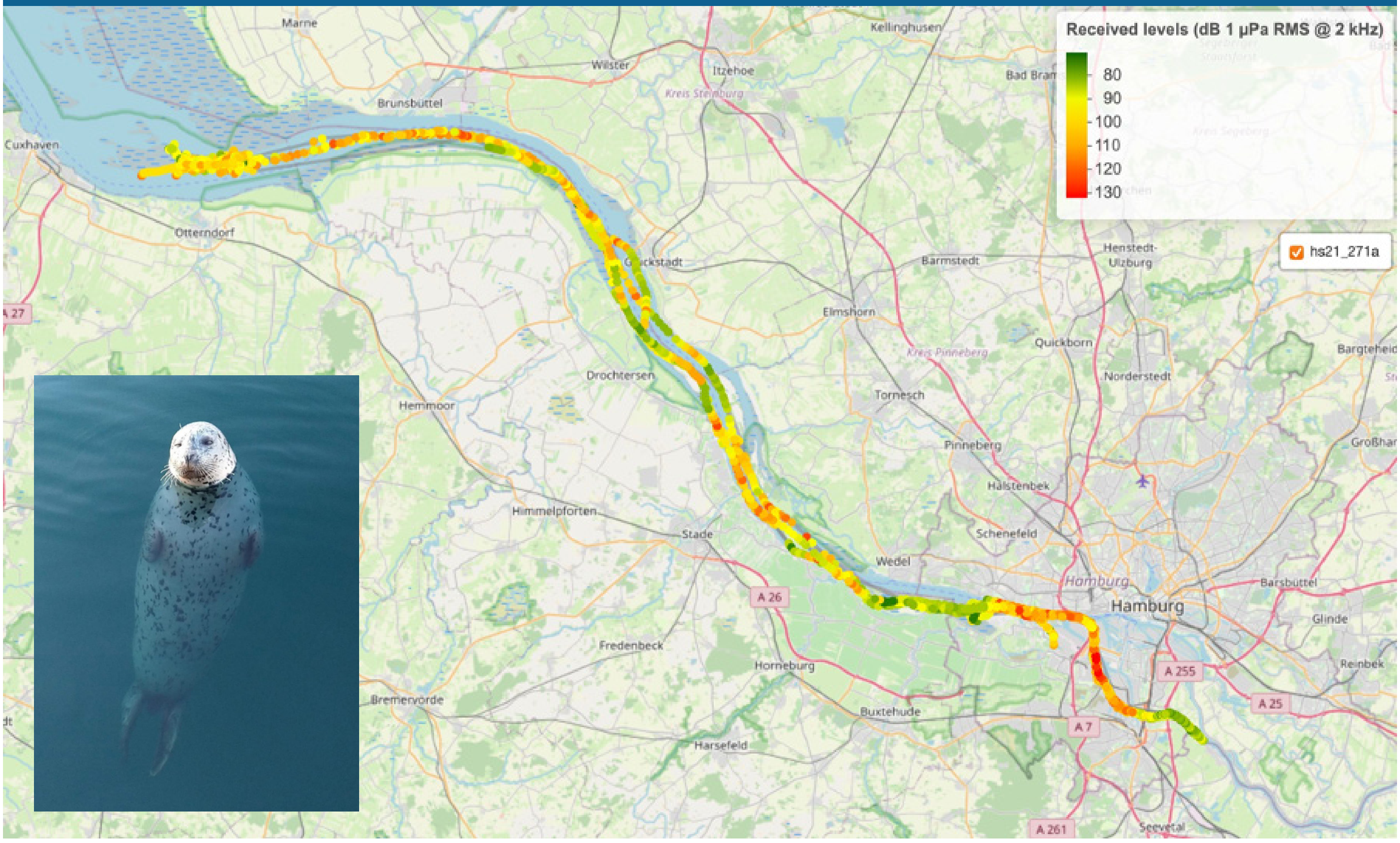
TIHO in SATURN

Researchers at the Institute for Terrestrial and Aquatic Wildlife Research at the University of Veterinary Medicine Hannover (TiHo) have conducted extensive long-term studies combining post-mortem data from by-caught or stranded harbour porpoises from the North Sea over the last three decades. We emphasized the analysis on lung pathology as an impaired lung function might limit diving ability and restrict the changes in diving behaviour associated with responses to noise. A total of 475 harbour porpoises in a very fresh to good state of preservation stranded on the North Sea coast of Schleswig-Holstein (Germany) between 1990 and 2020. More than 50% of animals had pathological findings in the lung, and a slight increase in the severity of the pathological findings in the lungs was detected throughout the three decades.

We also analysed the inner ears of stranded harbour porpoises and harbour seals from the North and Baltic Seas and Elbe River to detect potential cases of permanent hearing loss. Two individuals (one adult harbour porpoise from the Baltic Sea and one juvenile harbour seal found in the Elbe River) out of 30 showed evidence of hearing impairment. Both individuals had focal loss of sensory cells in the apex of the cochlea, which is the region within the inner ear where the low frequencies are encoded. These lesions are compatible with noise-induced hearing loss, including but not limited to shipping.

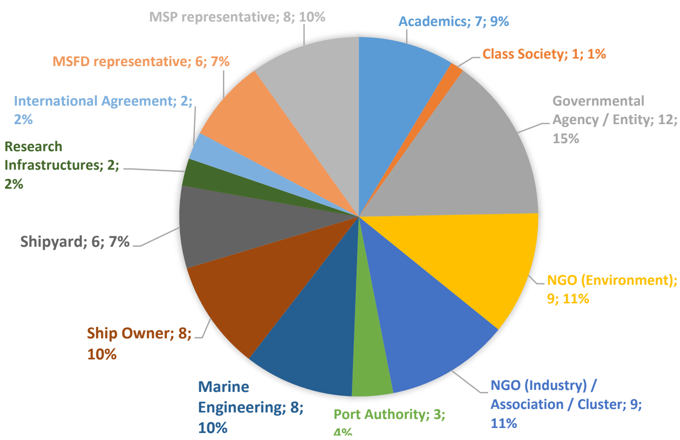
Moreover, we have deployed 8 DTAGs on harbour seals in the Elbe River. As an example, you can see here a representative dataset of dosimeter recordings of a seal from the Elbe River (see figure on page 20 (next page)). This particular seal remained within the Elbe river for all 22 days and visited Hamburg Port multiple times. The DTAGs simultaneously capture noise exposure, behaviour and contextual metadata. The colour of the dots illustrate the sound levels in the 2kHz decidecade band, a measure of noise exposure, and we see a wide range of exposure levels that shows high potential for SATURN to find different responses to these noise exposures. We have already developed an automated tool to detect intervals of elevated noise in the sound recordings. This was applied to quantify vessel noise exposures from previous deployments of DTAGs on nine harbour seals from the Wadden Sea. The results clearly show that seals in industrialised waters are exposed repeatedly to vessel noise and that exposures cannot be predicted reliably from AIS data.

Above: A tagged harbour seal and its track through the Elbe river.



Building SATURN's Stakeholder Network

Eric Baudin
Bureau Veritas



Above: Makeup of the SATURN Stakeholder Group to date.

A total of eighty two organisations have now signed up to be members of the SATURN Stakeholder Group (SSG). This level of success has been achieved with the skilled guidance of work package leaders Bureau Veritas who have coordinated this effort in conjunction with project partners who have all reached out through their own networks to widen the network. SSG members are drawn from a mix of academic and R&D structures, marine engineering companies, shipyards, shipowners and class societies who have joined together with policy makers (governmental agencies, MSP and MSFD representatives) and NGOs. This breakdown illustrates that we have a balanced and diverse sectoral view, but the broad geographical spread also highlights the extent to which URN is now recognised as a global concern. We are planning a series of engagements with the full membership during 2023. There will also be a number of dedicated sessions with subgroups to address specifics such as the SATURN Virtual Research Environment (VRE) architecture by academics and researchers, and validation of action plan for upgrading the SATURN MSP tool with MSP representatives.