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Saturn

Developing Solutions for Underwater Radiated Noise

Newsletter No. 1

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Year 1 in Review

Welcome to our first annual newsletter, summarising our research and activities over the first year of our project. SATURN is an EU-funded interdisciplinary research project that brings together 20 institutions to examine and develop solutions to the problem of underwater radiated noise caused by shipping and other vessels. For the next four years, we'll be filling gaps in knowledge around the sources of underwater radiated noise (referred to as URN throughout this newsletter); determining the short-term and cumulative impacts of URN on invertebrates, fish, and marine mammals; and evaluating the most promising solutions to reducing URN.

We hope you enjoy this summary of the activities we've undertaken since kicking off the project in February 2021. Be sure to check our website for more information and for new resources, which will be added soon! Thank you for following our research and engaging with us this year.

- The SATURN Team

Above: A pilot whale in the Canary Islands (photo by Gustavo Perez).

Right: Maria Morell of TiHo, ITAW examines the inner ear of a stranded harbour porpoise. See page four for more details.

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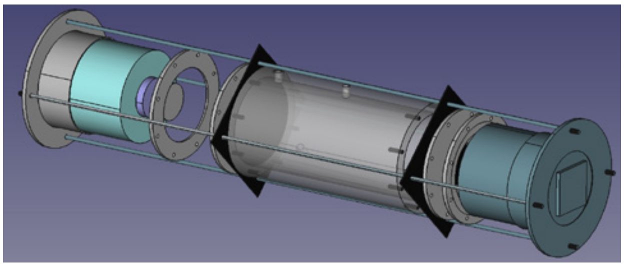
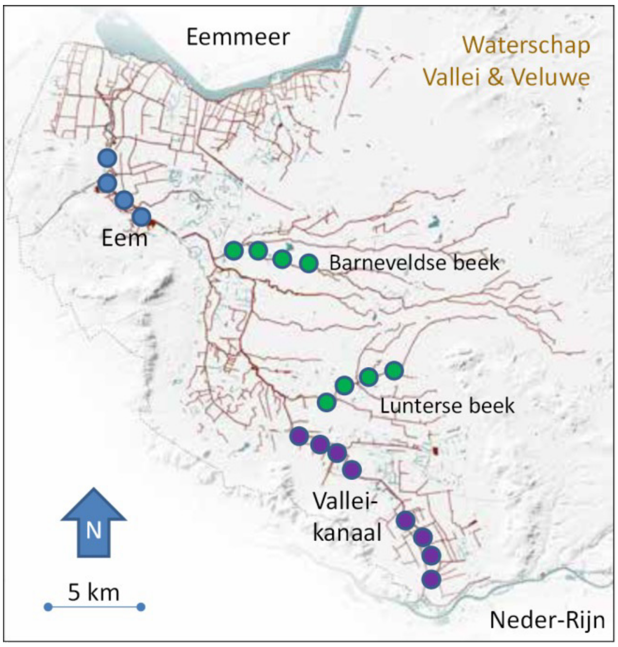
Assessing the Impact of URN on the Behaviour, Health, Energetics, and Populations of Aquatic Organisms



Top: Kees te Velde, a SATURN PhD-student at Leiden University wades in a wetsuit to place Soundtrap recording equipment for underwater soundscape sampling of migratory fish.

Above: Design of the new laboratory facility at UPC for testing sound impact to assess the effects of particle motion and acoustic pressure on invertebrates.

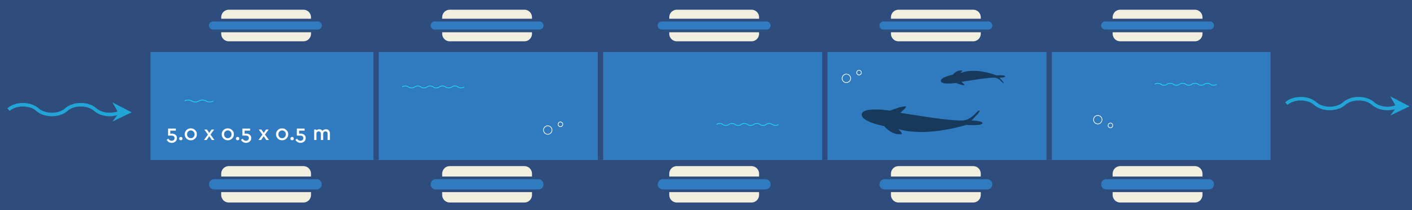
Below: Pilot recording locations in the Rhine.



UPC-Barcelona Tech

In the first year of SATURN, partners at the Laboratory of Applied Bioacoustics at the Universitat Politècnica de Catalunya (UPC-Barcelona Tech) have focused our efforts on the design and construction of a dedicated test device. This will allow us to quantify the physiological, pathological and behavioural responses to controlled ship Underwater Radiated Noise (URN) exposure on different marine invertebrate species, such as cephalopods, crustaceans, cnidarians and bivalves. Thus far, the main development is related to the accurate separation of the two main components presented in the generated sound field: particle motion and sound pressure. Recent literature reveals that each can have a distinct effect, depending upon the species.

It consists in a pair of 1kN-electrodynamic shakers that enclose a rigid tube at both ends, where the animals will be exposed to ship noise recordings at real-field sound pressure/particle motion levels. The control of the relative phase between the pair of shakers, allow us to generate either a sound-pressure- or a particle-motion-dominated exposure field within the tube. In parallel to the acoustic exposure, the oxygen consumption rate and behavioural assessment will be possible thanks to a built-in respirometry system and a see-through tube.



The Migradrome

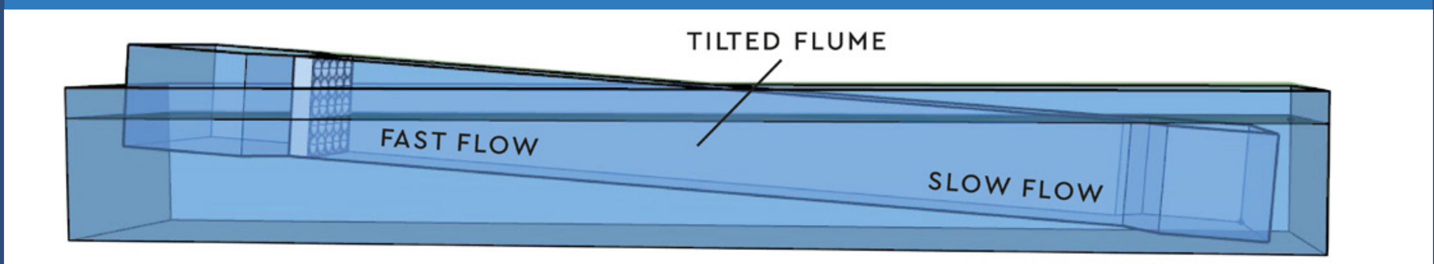
Building a swim tunnel facility to test the impact of sound on the migratory decisions of fishes

All fishes hear, therefore their behaviour can be affected by sound. At University Leiden, we're testing the impact of ambient noise on the movement decisions of a variety of species. To do so, we've designed a novel experimental swim tunnel facility that will test the impact of exposure to underwater sounds on fishes, called the MIGRADROME. The Migradrome consists of a 5 meter long tilted flume swim tunnel, nested within a larger tank measuring 7 meters. On either side, pairs of in-water speakers ensonify the swimway in five locations. Acoustically disconnected pumps can vary the flow, while the tilt can provide a gradient of flow from upstream to downstream.

Over the next year, we'll be conducting small-scale explorative studies with migratory sticklebacks (*Gasterosteus aculeatus*) and ide (*Leuciscus idus*), which will represent different hearing ranges, as well as two larger model species of conservation concern, the sturgeon (*Acipenser sturio/ruthenus*) and the eel (*Aquila aquila*). Fish will be able to choose between fast and slow currents and decide to swim upstream or downstream. Both currents are fully and independently under control, and can be manipulated independently for fixed exposure periods, with acoustic conditions that are typical for aquatic habitats or that reflect anthropogenic activities. We will be testing the basic impact of sound conditions on migratory decisions, but we can also compare and weigh fish decisions in different physical (flow speed, temperature, light) and chemical conditions (presence of food or predator extracts, aversive chemicals), to various levels of sound. Underlying physiological changes in fish will also be assessed by measuring, for example, the rate at which the gill openings beat, or their consumption of oxygen via micro-crystal sensors.

Fish are able to sense pressure and particle motion, which we will control within the cylindrical swim tunnels using the speakers, and partners at TNO have modelled sound pressure and particle motion conditions for various tank sizes, using varied tank wall materials and thicknesses, for fine-tuning exposure conditions. The Migradrome will be ready for pilot testing with sticklebacks this year (2022), and the prototype design and technology will be publicly available for replication and application in laboratories across Europe.

Above: An overhead view of the Migradrome, showing ten speakers that expose the fish to sound to measure the impact of disturbance by vessel noise. **Below**: A side view of the Migradrome, showing the tilted flume.



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University Leiden

Meanwhile, at University Leiden we have gathered pilot recordings in the Rhine, a large river with strong currents that is home to various vessels and other water traffic events. We also collected a large series of cross-section recordings in smaller rivers and streams (at 5 x 4 locations), at various depths and distances from the river bank (in the Grift-Eem water system). These recordings aim at gaining understanding about recording natural soundscapes in a standardized way and getting insight into quiet and moderately busy waterways in use by migratory fish.

Aarhus University

Scientists at the Marine Bioacoustics and Marine Mammal Research Labs at Aarhus University are working to better understand how harbour porpoises are affected by the underwater noise produced by nearby vessels. Harbour porpoises are small marine mammals living in cold water, meaning that they require a constant food supply to stay warm. Man-made disturbances, such as underwater vessel noise, can potentially prevent porpoises from finding enough prey and lead to costly avoidance reactions, and hence impact their short- and long-term fitness. In Danish waters, harbour porpoises occasionally swim into large open pound nets used for catching fish. This situation has provided our groups with a unique opportunity to

Above: SATURN Researchers from Aarhus University measure and tag a harbour porpoise.

Below: In Danish waters, harbour porpoises occasionally swim into large open pound nets used for catching fish.

Bottom: A tagged harbour porpoise is carefully released by a SATURN scientist.

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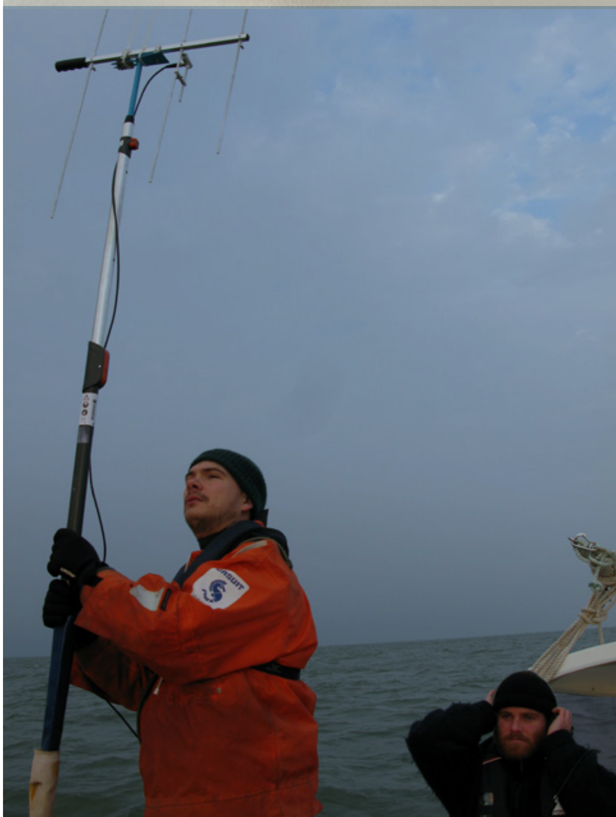
work with local fishermen to tag harbour porpoises (under appropriate permits) with state-of-the-art suction cup tags (DTAGs). DTAGs contain a suite of sensors that record and store acoustic and movement information that allow us to quantify their foraging behaviour and energy expenditure as a function of noise load from the environment. After 1-2 days, the tags detach passively due to a loss of suction and drag and are recovered using a combination of Argos satellite systems and radio tracking. Data on the fine-scale diving and foraging behaviour of animals collected by the tags can then be used to assess impacts from vessel noise on the energy balance of the animals. So far, 22 harbour porpoises have been tagged in inner Danish waters, and under SATURN, we have now successfully tagged four more porpoises, providing a total of over 500 hours of high-resolution data.

Above: The track of a harbour seal along the Elbe river, Germany.

Below: The DTAG, a type of sensor that attaches to an animal via suction cup and records data for analysis. The tags detach on their own and are recovered.

Bottom: A Saturn researcher from TiHo searches for the signal of a DTAG to retrieve it.



Institute for Terrestrial & Aquatic Wildlife Research, TiHo

Researchers at the [Institute for Terrestrial and Aquatic Wildlife Research] at the University of Veterinary Medicine Hannover (TiHo) have also used DTAGs in three harbour seals in the Elbe River. After a preprogrammed period of 22 days, the DTAGs detach from the seals and is then recovered using the Argos satellite system to get an approximate position (within a radius of a few kilometres), followed by UHF tracking, as in porpoises. The large data size necessitates software tools for automatic processing and quality assurance. Our first recovered DTAG has already revealed interesting results, showing that the seal remained within the Elbe river for all 22 days and visited Hamburg Port.

We are now in the process of analysing these DTAG data, both at the University of Aarhus and University of Veterinary Medicine Hannover, to understand 1) how often porpoises and harbor seals are exposed to vessel noise that triggers behavioural changes leading to negative offsets in energy balance, and 2) what the drivers of such responses are in terms of vessel noise levels and characteristics.

To quantify the impact of underwater radiated noise on the health of porpoises and seals, we have analyzed at TiHo the inner ears of stranded (deceased) marine mammals

A nasal swab is taken from a harbour seal to assess the animal's health.

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to detect potential cases of permanent hearing loss. We have optimized a new labeling protocol of the inner ear and have collected individuals from several age classes found in the Baltic, North Sea and Elbe river. The majority of the ears are still being processed. We have recently published [a case of a neonate harbor seal in the journal *Animals*](), where we found lesions in the inner ear, likely congenital. This information will be important to establish a baseline knowledge on "natural" congenital malformation of the inner ear of harbor seals, to further differentiate from potential damage caused by exposure to factors (including noise) that the individuals might encounter during their lifetime. We also describe the protocol to extract and perfuse the ears in harbor seals that will be implemented in SATURN.

In addition, we will provide updated age- and length specific estimates on general animal health, reproductive capacity and hearing capacity, which will influence animal survival and reproduction. We have reviewed TiHo's database on the pathological results of stranded individuals, and blood and swap results of all seal catches of the last 30 years, and already selected interesting cases and targeted organs to be categorized in more depth.

Within TiHo, we will also combine clinical health parameters with behavioural recordings in harbour seals to determine how health influences behaviour, and vice-versa. In previous projects we have established immune-relevant and more recently endocrine-related genes in the blood of seals from the North and Baltic Seas, recently published at the journal *Aquatic Toxicology*, which will be implemented in SATURN. We are currently developing a novel combination of molecular biomarkers in blood to assess noise-related hearing, endocrine and immune responses in harbour seals.

Read the Paper: Selective Inner Hair Cell Loss in a Neonate Harbor Seal (*Phoca vitulina*)

DEPONS

Also at Aarhus University, we are building a simulation tool for assessing impacts of ship noise on harbour porpoise populations. Based on a further development of the existing agent-based population model (DEPONS) we will assess the impacts from underwater noise generated by ships and boats on harbour porpoise populations.

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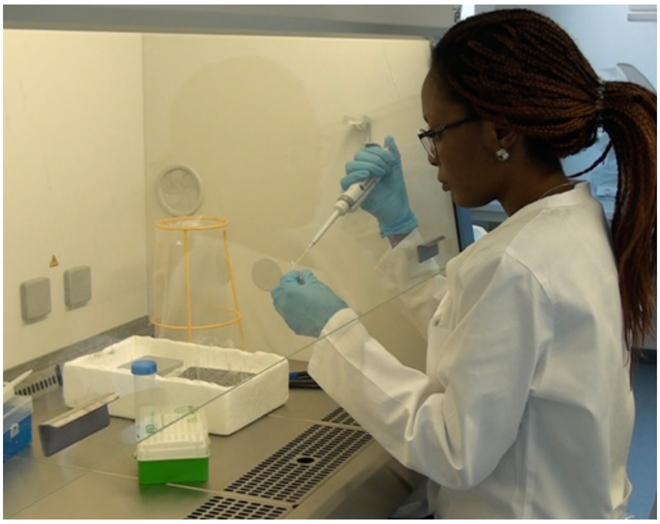
Porpoises from different parts of Kattegat have been tagged with long-lasting GPS-tags to get further data for calibrating animal movements in DEPONS. DEPONS is currently parameterized to simulate effects of pile-driving noise only, further development should create a virtual landscape with simulated ships emitting realistic levels of underwater radiated noise based on ship source levels and sound propagation loss. In support of this work, TNO is working on a proper and efficient implementation of ship acoustic modelling in the DEPONS model for assessing population effects of disturbances on marine populations.



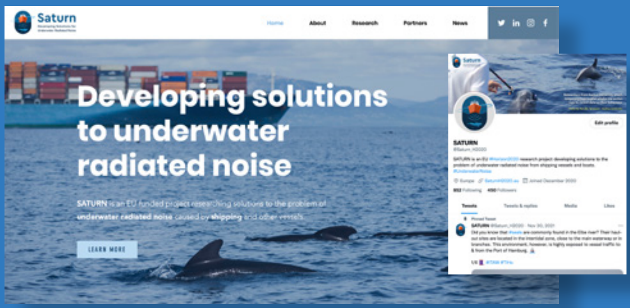
Above: Joy Boyi, a PhD student in TiHo, works on establishing and validating gene expression biomarkers of noise exposure.

Developing an online research dashboard at PLOCAN

Developing online laboratories for research – sometimes called 'virtual research environments' (VREs) – can be useful for sharing data, software, and tools, and for accessing and storing large datasets. For acoustic research in particular, field monitoring campaigns can routinely acquire gigabytes to terabytes of data in weeks, making data storage and sharing a challenge. Researchers at PLOCAN are developing a VRE that will allow online collaborative experimentation, the exchange of methods and data; experimentation and the testing of tools for acoustic measurements; processing data; and metrics relevant to the impact of underwater shipping noise on aquatic life. The ambition in SATURN is to initiate a change towards reproducible research in bioacoustics and URN by providing an online dashboard where new software and data resulting from the project will be processable, accessible, and editable – without the need to install software or download heavy datasets.

Find Us Online!

Our communications team at MaREI, UCC regularly posts about SATURN research and activities, along with related news and research on underwater radiated noise from commercial and recreational vessels. Follow us on our social media accounts and head to our website to learn more about the project and download our resources, where we will be posting publications, infographics, policy briefs, and more.



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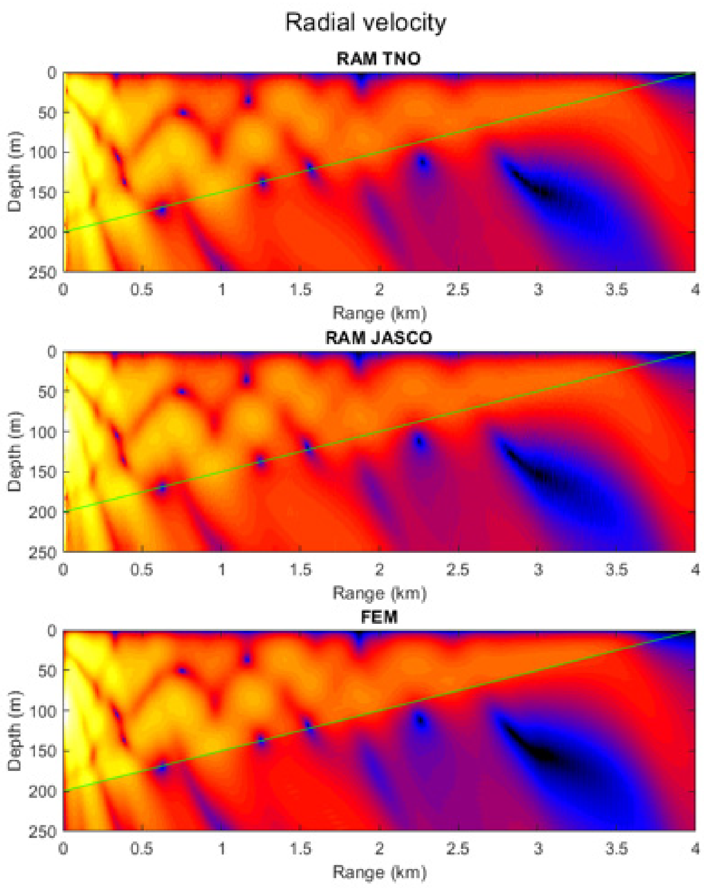
Acoustic Modelling at TNO

The Netherlands organisation for applied scientific research, TNO, is involved in various tasks in the SATURN project. TNO acoustic experts have supported the acoustic design of laboratory facilities for testing the response of fishes and invertebrates when exposed to ship sound, and the studies in which the response of marine mammals to ship sound is determined from tagged animals in the wild. In an initial study, we have identified the main characteristics of ship sound. The relevant spectral and temporal features are represented in well-described synthesized sound signals for use in future laboratory exposure studies. The availability of harmonized sound signals is an important step forward towards standardization of exposure studies. TNO is also actively contributing to the standardization of ship radiated noise measurements. With support from SATURN, TNO has taken a leading role in the ISO working group that will be developing a standard procedure (ISO 17208-3) for measurements of ships in shallow water, over the coming years.



Above: Example of modelling particle motion through benchmarking.

A core expertise of TNO is the development of underwater acoustic models. With such models, maps of underwater sound caused by shipping and wind can be made. The monthly statistical maps of the sound of ships and wind in the North Sea, developed in the JOMOPANS project, give a useful insight in the dominance of shipping sound pressure with respect to ambient noise. The use of modelled sound maps was demonstrated in a seminar of the potential effects of slow steaming on shipping underwater sound and air emissions, after a study for the Belgian government. In SATURN, this modelling capability is being extended to represent the particle motion component of the sound as well. This is relevant for evaluating the impact of shipping sound on fish and invertebrate species, that are sensitive to particle motion. Together with SATURN partner JASCO, models for sound particle motion are now being

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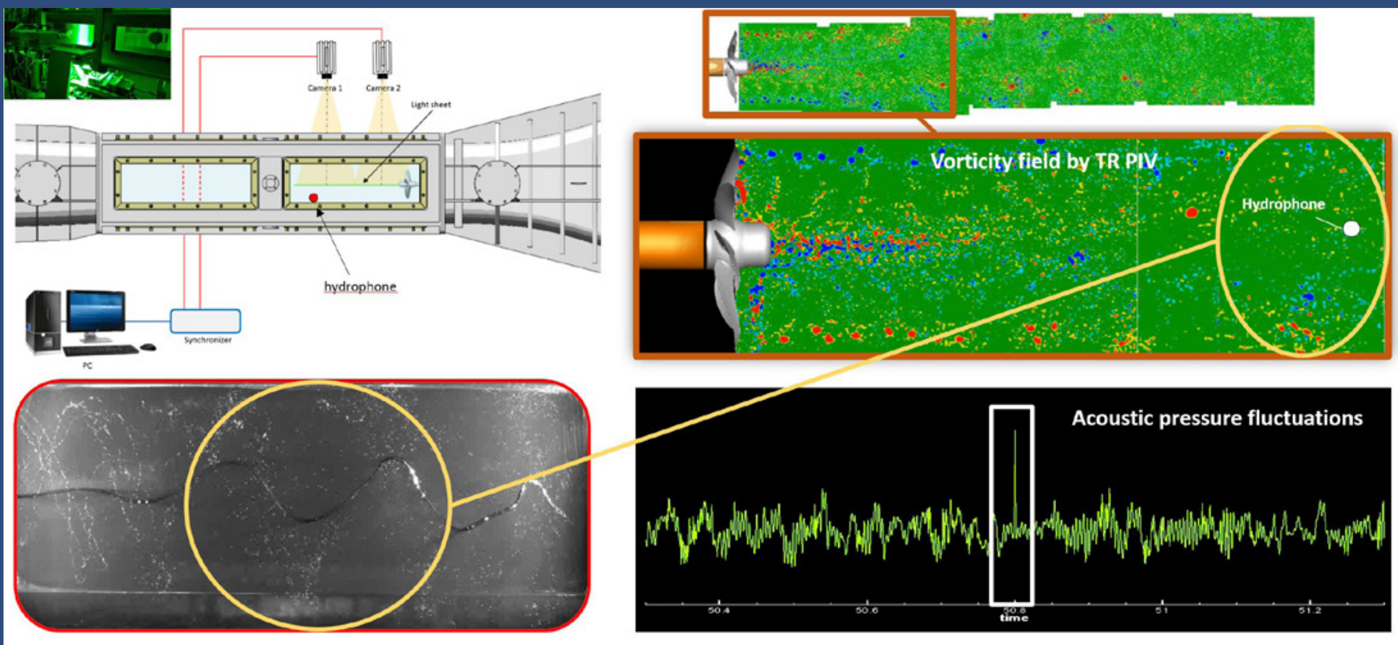
verified through a process of benchmarking, as was done for the models for sound pressure in JOMOPANS. The next step will be to validate these models against field data. We are preparing a measurement campaign of the Dutch coast, near The Hague, in May 2022.

We at TNO are excited about the great opportunity to work with so many esteemed colleagues in this very relevant project, addressing the many knowledge gaps that hamper the management of shipping sound in the oceans.

Photo: TNO's particle motion measurement rig.



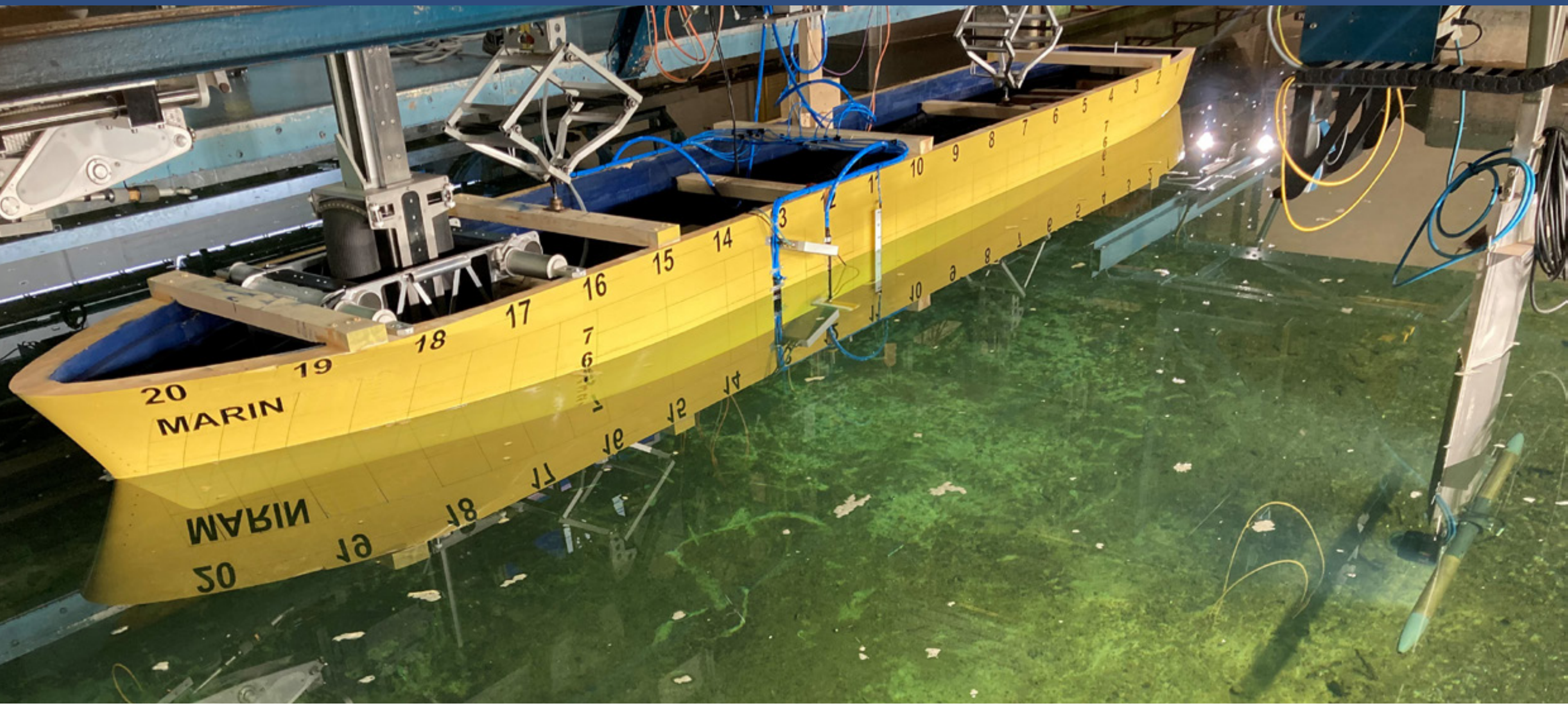
How do vortices generate noise?

Understanding propeller noise at CNR-INM

Above: Figure showing the results of the methodology applied to the study of the mechanisms of sound generation from the interaction between propeller tip and hub vortices.

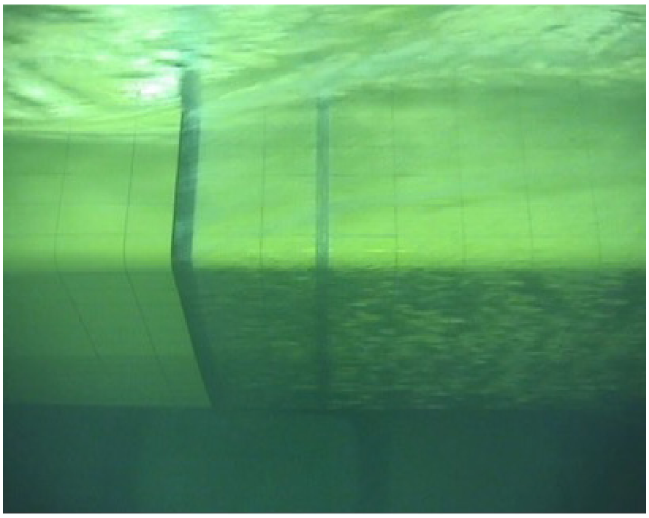
Understanding the fundamental underlying mechanisms of propeller wake vortex sound generation and propagation is very challenging, requiring effective methods able to establish a "cause and effect" relationship between the acoustic perturbation in the far-field and the characteristics of the flow in proximity of the emitting body. To this end, CNR-INM developed and successfully implemented an experimental methodology, based on simultaneous measurements of the acoustic perturbation in the far-field, by hydrophones, and in proximity of the noise sources, by detailed flow and pressure fluctuation measurements and filtering techniques, combined with cross-correlation/conditional techniques. More details on the adopted methodology are documented at:

- Felli et al. (2014). A novel approach for the isolation of the sound and pseudo-sound contributions from near-field pressure fluctuation measurements: analysis of the hydroacoustic and hydrodynamic perturbation in a propeller-rudder system. *Experiments in Fluids.*
- Felli et al. (2015). Experimental approaches for the diagnostics of hydroacoustic problems in naval propulsion. *Ocean Engineering.*



Testing the Effectiveness of ‘Bubble Curtains’ to Reduce Ship Sound at MARIN

Below: Video still of bubbles injected in the flow below a ship hull (shown above) from a porous hose.



MARIN, the Netherlands’ Maritime Research Institute, is currently in the process of evaluating the use of air bubbles to mitigate the source levels of underwater noise radiated by ships. To test the effectiveness of this measure, air bubbles will be injected in the flow below the ship hull to isolate machinery noise, and in the flow upstream of the propeller disc to dampen the cavity collapse, thereby reducing radiated noise. In 2021, several actions were performed to prepare the model tests for this purpose:

- A 94 m coastal tanker, known as the Streamline tanker, was selected as reference ship for which a scale model will be manufactured.
- Different types of porous hoses to inject air bubbles were evaluated using model tests on a similar hull form (see photo at left). A configuration for the tests to be performed in 2022 has been proposed. With the model tests, the effect of air bubbles on propeller performance was also assessed as the bubbles were swept into the propeller plane: these first tests showed a decrease in thrust and torque of a few percent but propulsive efficiency was decreased by 1% only.
- A metal mid-section of the tanker model was designed. This section will be excited using a shaker and the resulting radiated noise in the

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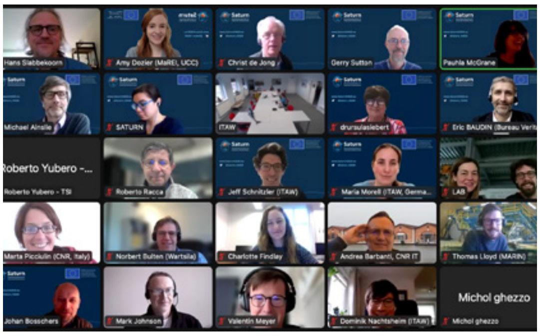
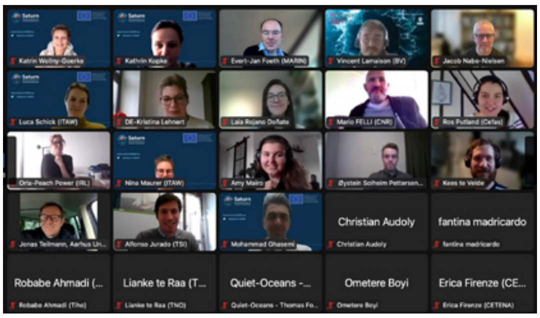
basin will be measured with and without bubbles present thereby providing information on the insertion loss.

- A system to inject bubbles in the propeller disc was designed and manufactured. First tests were successfully completed.

The models tests with the bubble layer below the hull and with the injection into the propeller disc are scheduled to be carried out in Q3 of 2022.





Above: SATURN project partners at the 2nd SATURN General Assembly (not all attendees pictured).

2nd SATURN General Assembly

Update from Project Manager Pauhla McGrane

The 2nd SATURN General Assembly (GA) was held online over 2 days in February (15-16 February 2022), and marked the completion of the first year of the SATURN project. It was attended by over 70 members of the SATURN consortium, which led to some positive and fruitful discussions.

The first day comprised a meeting of the Executive Management Board (EMB) followed by a series of parallel work package sessions, led by WP leaders. This gave everyone an opportunity to input and feed into activities in both their own, and in other work packages. The second day of the GA was held in plenary and featured presentations from all WP leaders outlining their progress to date and future workplans, with a specific focus on the next 12 months of the project.

We were also fortunate to be joined by two of our Canadian colleagues and invited guest speakers, Krista Trounce of the ECHO Program, Vancouver Fraser Port Authority and Michelle Sanders of Transport Canada. Both Krista and Michelle presented on Canadian efforts and collaborative approaches to address underwater radiated noise from vessels, which was very insightful as practical examples of mitigation measures currently in operation.

SATURN Coordinator, Gerry Sutton closed the meeting by providing an overall review of the last year and a roadmap of 2023 activities, highlighting key project deliverables and milestones. We are already looking forward to the 3rd SATURN General Assembly, which we hope will be an in-person event.

Contact: saturn@ucc.ie
Website: www.SaturnH2020.eu
Twitter: twitter.com/Saturn_H2020
LinkedIn: linkedin.com/company/saturnh2020

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