The future challenge of decreasing underwater acoustic pollution

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1. Noise between use and abuse

Mankind is noisy by nature. The impact of noise on human societies is well known. The World Health Organization declared that environmental noise is an important public health issue, featuring among the top environmental risks to health (WHO Europe, 2018). The burden of disease from environmental noise embraces cardiovascular disease, cognitive impairment in children, sleep disturbance, tinnitus and annoyance. A specific European Union Directive relating to the assessment and management of environmental noise was issued in 2002 (European Noise Directive 2002/49/EC). In this time of pandemics, the words of Robert Kock of the Institute for Infectious Diseases, Berlin, Germany, Nobel Prize in Physiology and Medicine in 1905 for his investigations and discoveries on tuberculosis, sound as a precursor of events: "*one day mankind will have to fight noise with similar strength as the fight against cholera and plague pandemics*".

Ocean acoustics is not a new science (e.g. Dosso and Dettmer, 2013). The speed of sound in water was measured with excellent accuracy as long ago as 1862 with the famous experiment on Lake Geneva (Fig. 1). A significant frequently cited milestone was the development in the same year as the sinking of the Titanic (1912) of the first underwater acoustic transducer able to detect the presence of floating icebergs from a ship. Huge developments followed, mainly for military applications, that allowed the fast development of modern oceanography after the Second World War. Since then, anthropic activities in the oceans, shipping, fishing, naval, oil and gas, scientific research, construction, not forgetting leisure, have increasingly disturbed the natural soundscape of oceans, rivers, and lakes on Earth.

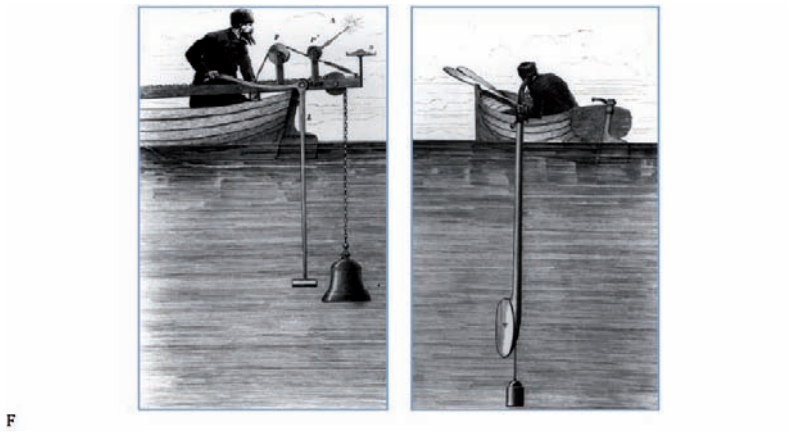

Fig. 1 - Colladon and Sturm's 1862 experiment to measure the speed of sound in Lake Geneva (J. D. Colladon: Souvenirs et M moires, Impr. Albert-Schuchardt, Geneva, 1893).

What is new is the growing awareness at different levels of our society - scientific research, non-governmental organizations, policy makers, and citizens - that anthropogenic noise, always superimposed on natural sound, is a threat for life in subaquatic environments and should be treated as an emerging pollutant. This is very well stated in the Proposed Mission Starfish 2030: Restore our Ocean and Waters, where the reduction and regulation of underwater noise is identified as one of the four targets to achieve the ambitious objective of "Zero Pollution".

Similar trends in the collective awareness of environmental emergencies in oceanic environments occurred with respect to ocean acidification and marine litter. The former is a problem that does not appear to the naked eye of the common citizen. Researchers had to demonstrate that the positive role of the oceans as buffers of increasing concentrations of anthropogenic CO_2 in the atmosphere does not come free. The negative counterpart is that the CO_2 is captured by the oceans at the expense of a decreasing oceanic water pH and, consequently, adversely affects marine life, especially in the lowermost positions in the trophic webs, with huge aftereffects on the survival of biological species and the geographical distribution of fish stock. An easier but equally important message to spread across all levels of our society has been the presence not only of plastics floating on river and ocean waters of the entire planet, but also microplastics permeating the tissues of edible species.

In spite of the efforts of researchers to identify, describe, understand and communicate timely dramatic changes occurring to the environment, resilient measures are often implemented once the impact on economy and society is demonstrated. It is a common opinion among scientists that anthropogenic underwater noise will be the next of such trends in collective awareness.

2. Noisy blue economy

Acoustic pollution has been recognized for its impact on human health, necessarily onshore.

Its impact on marine living organisms has been long ignored, or underestimated, by most.

There are five main types of anthropogenic sources of underwater noise today: Marine traffic (including leisure boats), military sonars, explosions, pile driving (mainly for wind turbines offshore), and seismic exploration (for hydrocarbon prospecting and scientific research). The noise generated by these activities is superimposed on the natural ambient sounds present in the oceans forming the pristine soundscape, composed of biological sounds emitted by living organisms for different purposes, physical (ocean turbulence), atmospheric (meteorological), and geophysical sounds (Fig. 2). The sum of noise and sound has characterized the Anthropocene ocean since the industrial revolution, with impacts on the health of marine animal populations that are still far from being fully understood (e.g., Duarte et al., 2021).

The five types of anthropogenic noise described above are generated by industrial, economic and recreational activities that form the core of the blue economy that will sustain the blue growth (Commission Staff Working Document, 2017; European Commission, 2020). It is important to remember that established and emerging noise-generating industries (Table I) will expand their activities with the implementation of the blue economy with value-added expected to double by 2030 (Fig. 3, OECD, 2020).

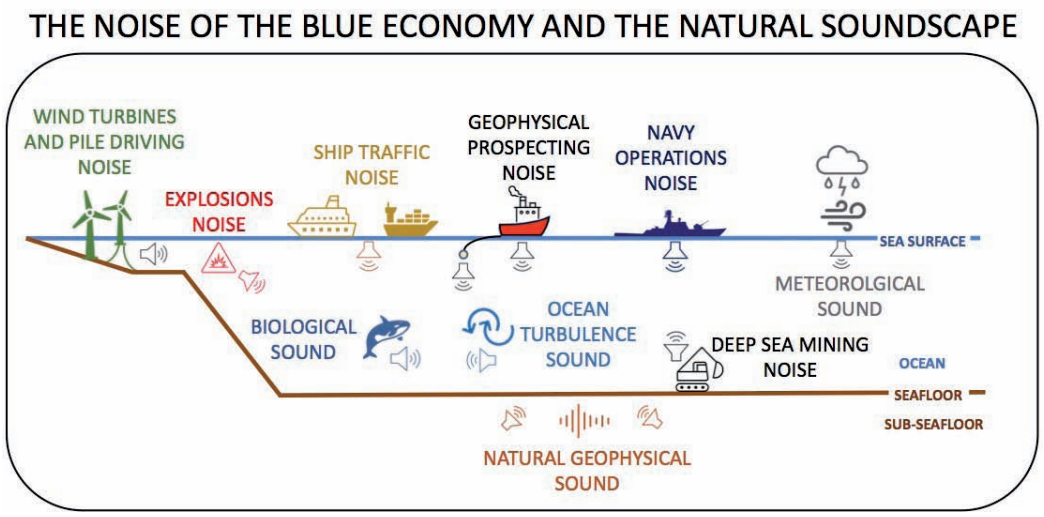

Fig. 2 - Anthropogenic noise vs natural sounds in the marine environment.

The sustainability of the blue growth process should therefore consider the noise levels produced by industrial sectors that are traditionally associated, at least in the general public opinion, with 'green' and 'sustainable' economy, like energy from renewable sources - offshore wind, wave, tides. In general, the renewable energy industry implies, for its success, the implementation of a worldwide network of energy storage, for which the issue of sustainability and ethics of provision raw material is of fundamental importance. The onset of the deep-sea mining industry, driven primarily by the need of energy storage for the renewable energy industry, is therefore expected to increase further the acoustic pollution in the oceans in the framework of the blue economy.

We should not forget to add scientific research to these industry-based activities when considering acoustic pollution. Oceanographic vessels produce noise like any other vessel (with the exception of rare silent research vessels built for hydrographic purposes) and routinely use acoustic devices for data acquisition that affect marine ecosystems in various ways. Research fleets should be the first to adapt to the requirement of silent vessels. A special case in scientific research is the use of impulsive pneumatic acoustic sources for the geophysical prospection of the sub-seabed. These are the devices unfortunately and improperly called 'airguns'. Airguns are not only the tools that enable geophysical service companies to provide energy industry the data necessary to locate offshore oil and gas reservoirs. These tools are employed routinely in scientific research to explore the Earth's interior with the objective of understanding the basic composition of the planet, paleo-climate evolution and submarine geohazards. Marine geophysical research uses noise to provide a service of knowledge and safety to our society. This activity, a pillar in the blue growth, will have to adapt to the concept of sustainability and participate in the decrease of acoustic pollution in the oceans.

Table 1 – Established and emerging ocean-based industries after OECD (2016). In bold the industries that contribute significantly to anthropogenic noise.

Established ocean-based industries	Emerging ocean-based industries
Industrial capture fisheries	**Industrial marine aquaculture**
Industrial seafood processing	**Deep- and ultra-deep water oil and gas**
Shipping	**Offshore wind energy**
Port activities	**Ocean renewable energy**
Shipbuilding	**Marine and seabed mining**
Offshore oil and gas (shallow water)	Maritime safety and surveillance
Marine manufacturing and construction	Marine biotechnology
Maritime and coastal tourism	High-tech marine products and services
Marine business services	
Marine R&D and education	
Dredging	

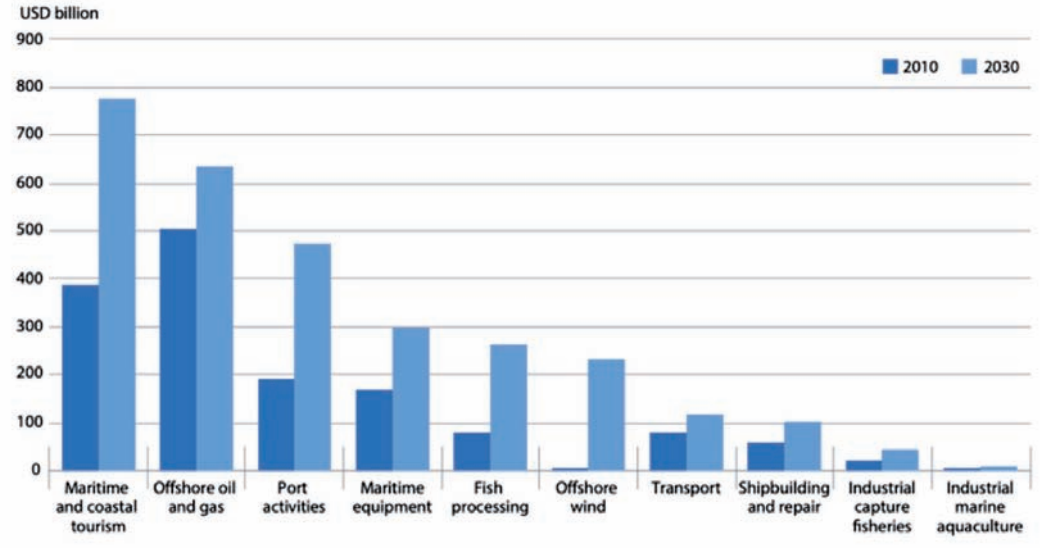

Fig. 3 - Ocean-based industries' value-added was expected to double by 2030 (EOCD, 2020)

3. The future challenge of decreasing underwater acoustic pollution

The objective of decreasing acoustic pollution can be achieved only with large-scale application of innovative technologies that will limit noise levels while ensuring the efficiency of the industrial processes needed to sustain the blue economy.

This process requires the setting of ambitious targets that will stimulate joint academic and industrial scientific and technological research with the support of European and national policies. An example of the challenge can be found in the mitigation measures considered for the limitation of ship-generated noise. One often considered mitigation measure is the enforcement of vessel speed thresholds in vulnerable environments. This attenuates the propeller noise and limits impulses from cavitation. Alternatively, and preferably, technological solutions for building innovative ships that will not emit harmful levels of noise during lifetime operations will more effectively contribute to counteract the trend of increasing noise levels while at the same time stimulating the blue economy.

The challenge of reducing noise emissions while maintaining the efficiency of operations should be governed by a rigorous science-based approach. The identification of acoustic thresholds for a scale of impacts and the implementation of registries of impulsive noise emissions are the present targets of the EU Technical Group on (underwater) Noise. Accordingly, new research should shift towards the understanding of impacts in an ecological framework considering the effects on the whole trophic networks that connect zooplankton to top predators and on fishery activities, targeting the ecosystem rather than individual animals or species and cumulative impacts of activities rather than individual projects or programmes. The improved opportunities for acoustic monitoring of oceanic regions will enable the implementation of widespread experimental activities to define thresholds of impact and to validate numerical models of noise propagation and generate noise level prediction tools for operators in order to transform present-day timely and costly procedures of environmental impact assessment into an affordable and sustainable improved procedure.

Such a shift requires an upgrade of the strategies supporting research that will have to consider the sharing of all available marine infrastructures to participate in experimental activities and monitoring. Mobile and moored marine observatories are now maintained in most world oceans, and in all European marine regions. Acoustic sensors, however, are very rarely planned in the implementation of such observing systems. In addition, a huge potential is coming from the possibility to use fiber-optic cables laid on the seafloor for digital communications as acoustic sensors. With an effort of coordination and cooperation between industry and scientific research, we may find that a global network already exists to accelerate the process of understanding the impact of anthropogenic noise on marine ecosystems.

Scientists, policy makers, private stakeholders and non-governmental organizations should work together to make silent blue economy and oceanographic research become a reality. Cross-disciplinary scientific cooperation embracing from shipbuilding to tourism, technological innovation, big-thinking, and basin-wide approaches will contribute to the achievements of ambitious goals. All European science-polices are pointing at underwater noise as one of the major challenges in the next decade: The Joint Programming Initiative on Healthy and Productive Seas and Oceans (JPI Oceans), The European Marine Board, the proposed European Partnerships on Zero-emission Waterborne Transport and for a

Climate Neutral, Sustainable and Productive Blue Economy are in line with the Proposed Mission Starfish 2030: Restore our Ocean and Waters. The change to a quieter ocean is about to begin.

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