OCEAN UNIVERSITY INITIATIVE & i3 Centre de Recherche en Gestion

POLICY BRIEF

Issue #3, August 2020

Publisher: Denis Bailly *ISSN:* 2592-6462

FR EN

Underwater noise

What can we learn from the port of Le Havre case study?

OVERVIEW

There are increasing concerns about the impact of underwater noise on marine life spurred by the steady rise in the number and variety of human activities at sea. In particular, chronic noise levels from commercial shipping have increased significantly in the past 60 years and they are set to continue to rise in the coming years. In response to this concern, the United Nations has signed a voluntary commitment to reduce underwater noise (#OceanAction18553), which recognizes the negative impact that shipping noise can have on marine life. In this policy brief, we examine the role of ports in reducing this type of noise and illustrate our findings through a case study of the port of Le Havre.

FIGURE 1. Male harbor seals in the Seine estuary defend their territories against other males and attract females using underwater vocalizations (listen to harbor seal sounds) (© P. Gourdan)

Laura Recuero Virto
Research coordinator
Ocean University Initiative
University of Brest (UBO)
i3-CRG, Ecole Polytechnique

Hervé Dumez
Director
The Interdisciplinary Institute for Innovation
i3-CRG, Ecole Polytechnique

Pascal Galichon
Director in charge of sustainable development and pilotage
Grand Port Maritime du Havre (Le Havre port authority)

Florent Le Courtois
Underwater noise pollution expert
SHOM (French Naval Hydrographic and Oceanographic Department)

Manuel Muntoni
Program manager - Ecological Restoration Frame of Reference for the Seine Estuary
Groupement d'Intérêt Publique Seine-Aval (GIP Seine-Aval)

This issue was written in collaboration with the Interdisciplinary Institute for Innovation - Management Research Center of the Institut Polytechnique de Paris as part of the project "Anthropogenic underwater noise pollution due to maritime transport".

ACKNOWLEDGEMENTS:
C. Aulert, French Agency for Biodiversity, *C. Boutry,* Boluda Le Havre, *A. Delcher,* APPLH - Le Havre Association of Recreational Fishermen, *P. Dieulafait,* Ecologie pour Le Havre, *C. Fonti,* CMA-CGM, *P. Galichon,* Grand Port Maritime du Havre, *A. Gimard,* French Agency for Biodiversity, *P. Gobbe,* APPLH, *G. Gautier,* Le Havre Plaisance, *V. Guyet,* Cellule de suivi du littoral normand, *A. Leroy,* Ecologie pour Le Havre, *A. Maheut,* Coopérative Maritime Havraise, *C. Roux,* CMA-CGM, *E. Trebaul,* Regional Committee for Maritime Fisheries and Marine Fish Farming *et C. Vogel,* Ifremer.

Underwater noise

Is the ocean a silent world?

The ocean is filled with sounds. These sounds may come from natural sources, such as breaking waves, rain, earthquakes, ice and marine life. They may also come from a variety of man-made sources related to valuable uses such as communications, navigation, defense, research, exploration and fishing. Among these man-made sounds, some are the byproduct of industrial activities such as shipping, oil exploration and drilling, marine dredging or pile driving for inshore and offshore infrastructure, for instance for the construction of wind farms.

What is underwater noise and why should we care?

Sound is referred to as 'noise' only when it has the potential to cause negative impacts on marine life. Sound in the ocean plays a key role for marine life. Marine organisms rely on sounds to navigate, find food, avoid predators, reproduce, locate mates, communicate and create group cohesion (Buscaino et al., 2016; figure 1). Many marine species produce sounds as well as perceive the sounds around them. In particular, sound is used by marine animals to gather information about their surrounding environment. Sounds cover vast distances in the ocean, since transmission losses are low compared to those in the air. For instance, low-frequency sounds (15-30 Hz) of blue and fin whales have been recorded over ranges of 400 to 1,600 kilometers, showing their ability to communicate across the sea (Sirovic et al., 2007) (listen to blue whale sounds).

Noise from man-made sources can have a series of adverse effects on marine biodiversity and ecosystems, including masking effects whereby the noise interferes with biologically important signals, as well as causing behavioral disturbance (figure 2). For instance, harbor porpoises, which can be found in the English Channel, show strong behavioral responses to high frequency vessel noise at ranges of more than 1,000 meters from ships in shallow waters (Dyndo et al., 2015) (listen to harbor porpoises).

Figure 2. The bottlenose dolphin, which can be found in the English Channel, has its whistle patterns altered when ships are audible and the cohesion of groups with calves is reduced (listen to bottlenose dolphin sounds) (© P. Carzoo)

Moreover, noise from man-made sources can also cause temporary or permanent hearing loss, tissue damage or even death in marine fauna due to the intensity of noise emissions (Van der Graaf et al., 2012). For example, the impacts of noise from offshore wind farm construction include tissue damage and even death for fish (WWF, 2014). Naval sonar and seismic survey activities have been correlated with mortality events of marine mammals. In particular, since the 1950s, there have been 39 mass strandings of Cuvier's beaked whales associated with on-going naval operations, half of which in the Mediterranean Sea (Azzellino et al., 2011).

Why should we care about underwater noise from shipping?

Shipping is the most widespread and persistent source of underwater noise. In some areas of the ocean, noise levels have significantly increased over the past 60 years, primarily due to commercial shipping activity. The global commercial shipping fleet has tripled in the past 50 years and shipping noise is set to continue rising in the coming years, particularly close to shipping lanes and in the Northern hemisphere. Compared to the acute sudden noise produced, for instance, by military sonars, seismic airguns or pile driving, shipping is a source of frequent, chronic and aggregated noise. This type of noise can lead to chronic stress which can affect the health of the populations through changes in fertility, mortality and growth rates (Wright et al., 2009; IMO, 2018). There is mainly evidence of masking and behavioral effects of underwater noise from shipping on marine mammals (IMO, 2018). In particular, underwater noise

Table 1. Options to reduce underwater noise from shipping (Authors' elaboration)

OPTIONS WITH GLOBAL EFFECTS
Design: Hull, propeller, engine Can increase energy efficiency and reduce underwater noise and the emission of air contaminants.
Design: Type of fuel (LNG, methanol, fuel cells, battery hybrid) To reduce underwater noise and the emission of air contaminants.
Design: Larger vessels To reduce underwater noise and the emission of air contaminants.
Operational: Ship maintenance (hull, propeller) To increase energy efficiency and reduce the emission of underwater noise and air contaminants.
Operational: Ships operate at design load conditions To increase energy efficiency and reduce the emission of underwater noise and air contaminants.
OPTIONS WITH LOCAL EFFECT
Operational: Ships reduce speed, change route, travel in convoy Can reduce underwater noise and can increase shipping costs.
Operational: Ships use onshore power supply facilities at ports To reduce the emission of underwater noise and air contaminants.

from commercial shipping can mask communications of baleen whales, belugas, bottlenose dolphins, short-finned pilot whales, killer whales and Cuvier's beaked whales (Aguilar Soto, 2006; CBD, 2012).

How can underwater noise from shipping be reduced?

A number of design and operational options can be implemented to reduce underwater noise from shipping (table 1). Most of these options combine a reduction in underwater noise with increases in energy efficiency and/or decreases in emissions of air contaminants. All the design options and some of the operational options listed below reduce underwater noise at the global level. Certain operational options related to shipping traffic and onshore power supply facilities reduce underwater noise locally. Changes in the design of hulls and propellers can have a strong impact on reducing underwater noise, although some of these options need to be integrated at the building stage. Operational options can be implemented in the short-term.

Table 2. Actions by ports to favor the reduction of underwater noise from shipping (Authors' elaboration)

OPTIONS WITH GLOBAL EFFECTS
Port fees charged according to underwater noise performance Rebates for ships with better performance or differentiated fees according to performance.
OPTIONS WITH LOCAL EFFECT
Underwater noise mitigation equipment to protect local fauna Devices to displace marine fauna such as acoustic deterrents or to act as a barrier against noise such as air bubble curtains.
Underwater noise criteria in selecting port service providers Terminal operators, towage operators, dredgers.
Proper port and barrier design, onshore energy facilities Relocation of noisiest activities, physical barriers against noise propagation, onshore energy power, electric charging systems, bunkering facilities for alternative fuels, etc.
Reduction in ship waiting time at ports through collaboration along the whole logistic maritime chain Mooring, berthing, anchoring, cargo handling; possibly leading to mutual benefits, for instance, through the reduction in waiting time compensation paid by ports.

What actions can ports take to reduce underwater noise from shipping?

Even if there is no one universal best solution as every port has its own characteristics and local fauna, there is a set of actions that ports can implement to reduce underwater noise from shipping (table 2). Most of these actions reduce the noise levels generated close to a port. Some actions are related to the ships' noise performance and reduce underwater noise at the global level.

Le port of Le Havre

What is the role of Le Havre as a commercial hub?

The port of Le Havre is the largest French port for container traffic and the 5th largest in Northern Europe. It has well-developed infrastructure and offers easy nautical access. Situated on the right bank of the Seine estuary, Le Havre is one of the ports on the Seine Axis with Rouen, and Paris. These ports operate in a very competitive environment and their strategic positioning has improved since the 2011 French port reform and with the port extension at Le Havre, Port 2000. The French port development strategy aims to further increase port performance by better integrating seaports, inland ports, multimodal platforms and logistic centers, thus further embedding the port cluster of Le Havre/Rouen in the Seine valley economy.

What environmental challenges is Le Havre facing?

Northern European ports share similar environmental concerns. At the port of Le Havre, the main concerns are water quality and port development. Air quality is also an issue due to the fact that ships generate air emissions (see the box on the next page).

Another environmental challenge is noise. In Le Havre, vessels generate airborne noise in a location that is very close to residential areas. An important source of noise in the port used to come from the bucket dredges that disappeared after World War II. Underwater noise would be a source of concern if port works and extensions were undertaken. But these would be subject to environmental requirements, since the port is located within a wetland which is covered by a strong regulatory framework.

Why focus on Le Havre to study the actions that ports can take to reduce underwater noise from shipping?

Le Havre is a major port located on several shipping routes leading to the Atlantic Ocean, the North and Baltic Seas and even as far as the Arctic Ocean. Shipping density in the area is one of the highest in the world.

Best practice: The Environmental Ship Index

Five North West European ports (Hamburg, Bremen, Antwerp, Rotterdam and Le Havre) have developed a simple indicator for classifying the environmental impact of ships. The Environmental Ship Index was established in 2011 as part of an international program developed through the International Association of Ports and Harbors.

Since 2019, 57 ports have been using the indicator which evaluates air emissions (NO_x, SO_x and CO_2). Based on this indicator, each port can decide how it rewards ship owners. Some ports propose reductions in port fees for ships that have higher scores in the indicator. Other ports, like the port of Le Havre, provide incentives for ship owners to increase their noise reduction performance by reducing the level of fees.

The indicator is regularly updated in order to include other environmental concerns such as water quality. While the inclusion of underwater noise is not currently under discussion, air noise could be introduced as a new component of the indicator. In fact, the port of Le Havre has participated with 17 other ports in the NEPTUNES project which aims to support the mitigation of noise from seagoing ships and has developed guidelines for a noise labeling method, based on the vessels' noise reduction performance.

What do we know about underwater noise from maritime transport near to Le Havre?

Shipping in the Channel is mostly composed of large commercial ships that can radiate high noise levels. In this area, shipping activity is one of the densest in the world and almost continuous. The soundscape is dominated by low frequency noise produced by ships. However, because of the geomorphology of the area surrounding the harbor, mainly characterized by shallow waters, noise is rapidly attenuated. This results in high noise levels in the one-third octave band centered on 125 Hz, one of the Marine Strategy Framework Directive (MSFD) frequency bands, but they do not spread far.

Figure 3 shows averaged noise levels for the winter of 2016, computed using noise modeling tools and validated using *in situ* measurements. Red to purple cells (125 to 110 dB re 1 µPa) indicate an area subject to high pressure. Thus, it is an area that can present a risk of hearing loss for baleen whales (Mysticeti), although they are unlikely to be present in this area. Blue cells cover those areas further away from shipping lanes, where noise levels from boats decrease quickly (110 to 90 dB re 1 µPa, in blue areas). In the green cells, near the coasts, noise levels are almost negligible because of the strong absorption (below 90 dB re 1 µPa.

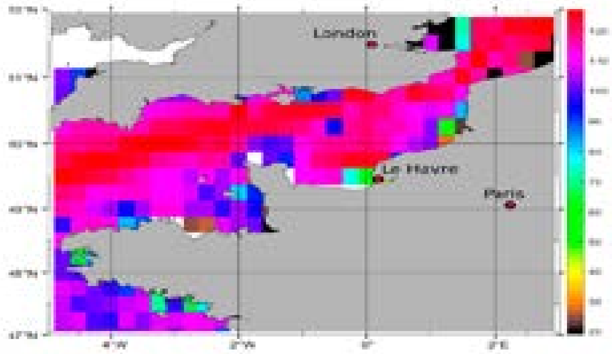

Figure 3. Contribution of shipping to ambient noise (dB re 1 µPa) for the winter of 2016 in the one-third octave band centered on 125 Hz (© Shom)

Comparisons of noise level simulations between 2016 and 2012 indicate that the contribution of shipping to low frequency ambient noise may have decreased in the Channel. This could be due to the fact that commercial shipping has decreased in terms of the number of boats since 2008, even though ships are of a larger size. The Le Havre area is the habitat for several marine mammals. Harbor and grey seal populations live in the area (Figure 4). As their vocalization is low frequency (mainly below 1000 Hz), noise from ships may mask their communication. This area also hosts harbor porpoise populations, mainly in winter.

Figure 4. Seal in Port 2000 basin, August 2019 (© GMPH)

The European Union Directive

The Marine Strategy Framework Directive (MSFD) is one the first international regulations to recognize underwater noise as pollution. Anthropogenic pressures of impulsive noise and continuous noise are assessed respectively under criteria 1 and 2 of descriptor 11. This descriptor was assessed in 2012 as part of the initial assessment process and again in 2017 for the second assessment cycle to monitor progress made. The MSFD requires that pressures do not exceed levels that affect populations of marine fauna. These levels remain to be identified through collaboration between the Member States, but important methodological progress has been made in assessing the pressures.

What are the other local sources of underwater noise?

The role played by the Channel during World War II and its hydro-morphological dynamics explain that underwater mines are constantly discovered in this area. Unexploded underwater mines are major threats to the safety of human activities and to marine life. Once found, underwater mines are detonated under controlled conditions. About 40 detonations were carried out in 2016 on the French coast, between Cherbourg and Dunkirk. Impulsive emission data are reported in the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) noise registry.

surface area of the intertidal mudflats located at the estuary mouth, close to Le Havre, has shrunk five-fold (Delsinne, 2005), with significant consequences on the nursery function of this sector for the marine populations of the English Channel (Rochette et al., 2010).

Among the changes induced by the anthropization of the Seine valley, the deterioration in water quality is one of the main pressures on the ecological functioning of the estuary. In fact, the development of industrial centers, the predominance of the agricultural sector and the presence of approximately 17 million people in the watershed explain that in the early 1980s, the Seine was considered to be one of the most polluted rivers in the world.

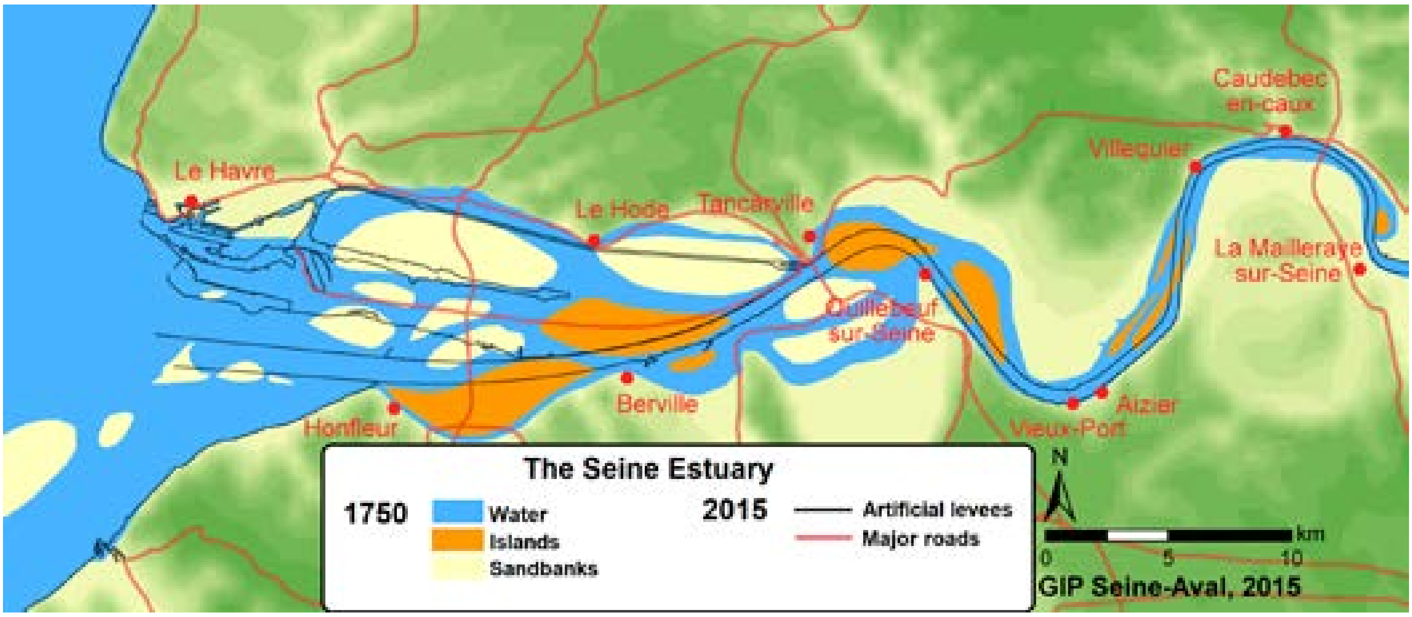

Figure 5. Changes to the Seine estuary between 1750 and 2015. Since the beginning of the 19th century, intense industrial and urban development has led to a high degree of human intervention on the estuary. The construction of infrastructure such as harbors, dykes or banks has resulted in a deep hydro-morphological modification of the river profile (© GIP Seine-Aval, 2015)

What other types of environmental pressures are to be found in the Le Havre area?

Estuaries are transitional zones between marine and freshwater ecosystems and are subject to tidal marine dynamics. Because of their position at the interface between the land and the sea, estuaries provide safe access for navigation and usually support a large number of human activities. Accordingly, they are exposed to high levels of anthropogenic pressure (McLusky and Elliott, 2004).

The development of infrastructure such as harbors, dykes and banks along the Seine estuary began in the first half of the 19th century, mainly motivated by the urban, agricultural and industrial development of its valley (Figure 5) (Fisson et al., 2014)[1].
These changes have had some important consequences on the morphological structure of the estuary and the quality of its habitats. For example, since 1875, the

[1] For a more recent review of environmental indicators in the Estuary of the Seine, see GIP Seine-Aval (2017).

In particular, the artificial levees built along the edges of the river channel, have drastically decreased the lateral connectivity between the principal channel and the flood bed, on which several species are dependent for particular stages of their lifecycle (reproduction, nursery, shelter). Moreover, the reduction in the depurative capacity of the estuary is assumed to be the result of these artificial levees, as they decrease the residence time of the water within the estuary.

In the early 1980s, increased awareness of these environmental issues led to the establishment of a strict regulatory framework. Measures to improve water quality have also been implemented. As a result, industrial discharges have been reduced four-fold. However, a large variety of micro-pollutants including polycyclic aromatic hydrocarbons (PAH) organochlorines, polychlorinated biphenyls (PCB) and metals are still present in the estuary, particularly in its sediments. Several negative effects on the health of organisms have been observed (Fisson, 2017).

FIGURE 6. The Seine estuary and its industrial, harbor and urban activities (right bank of the estuary mouth looking onto Port 2000 and the city of Le Havre behind) (© GMPH)

Water quality, nonetheless, has improved remarkably, as shown by the significant increase in the dissolved oxygen concentration recorded since the first decade of the 21st century. Hypoxia events, driven by an important nutrient load combined with high temperatures and low flow rates, have disappeared since the establishment of the regulatory framework for wastewater discharge and the installation of wastewater treatment plants.

Another issue concerning water quality is the large load of nutrients, especially nitrogen, discharged into the coastal zone by the River Seine. This phenomenon affects the growth of planktonic organisms and can exacerbate the occurrence of harmful algal blooms, thus resulting in an important economic loss for local fisheries.

Can causal relationships be drawn between anthropogenic pressures and the environmental status of the Le Havre area?

Within an estuary, human-induced pressures and natural estuarine processes are inextricably linked, making the evaluation of clear cause-effect hierarchies a very difficult task (Figure 6). In fact, estuaries are both naturally (because of the high degree of variability in their physicochemical characteristics) and anthropogenically stressed areas. In response to this stress, estuarine communities have adapted to this high spatial and temporal variability.

Several authors have observed similarities between communities belonging to naturally highly stressed areas and communities living in anthropogenically stressed areas, making anthropogenic stress particularly difficult to detect in naturally "stressed" areas, like estuaries. This difficulty in identifying human-driven stress in estuaries is referred to as the Estuarine Quality Paradox (Elliott and Quintino, 2007), a most relevant concept given the increased demand for studying the effects of anthropogenic impacts on estuarine ecosystems, especially in the light of the Water Framework Directive.

Some promising attempts have been made to gain a better understanding of the effect of the morphological changes induced by new infrastructure on the functioning of the Seine estuary ecosystem through ecological network analyses (Tecchio et al., 2016). Network indices have partially captured the combination of changes on the functioning of the estuary but they cannot yet be considered to be a fully operational tool. Much work remains to be done to integrate the temporal variations of physical factors (e.g. hydrodynamics) in order to better discriminate between the different factors which play a role in the estuary over the same period of time.

Policy issues

A long-term solution to the impact of underwater noise emissions from commercial vessels on marine fauna would be for the Member States of the specialized agency of the United Nations for commercial shipping, the International Maritime Organization, to adopt a legally binding international commitment. In the short-term, given the uncertainties regarding the biological impacts of underwater noise emissions from shipping at both individual and population levels, a precautionary approach should be adopted.

In the port of Le Havre, in terms of reducing underwater noise from shipping, solutions with local effects (Tables 1 and 2) do not seem to be the most appropriate since no concerns regarding the impact of noise on marine fauna have been documented. This does not mean that there are no impacts on local marine fauna, but that there is no evidence for the time being. Data gathering is a necessary step to understand the influence of noise linked to port activities at the local level. In particular, data gathering is needed to understand the interaction between noise and fauna for monitoring and evaluation purposes.

Concerning solutions with global effects to reduce underwater noise from shipping, such as port fees or priority in allocating berth slots, they will probably not be implemented in the short term in Le Havre either, since underwater noise is not perceived as a major problem by local stakeholders.

Given this context, it would be useful to push for an agenda that clearly identifies the synergies between energy efficiency, air quality (including air noise) and underwater noise reduction. Indeed, the Environmental Ship Index already used at the port of Le Havre includes emissions of air pollutants. Air pollutants are a primary concern at the local level for populations located close to major ports. As such, major ports are pro-active in setting up actions to reduce this local pollution and these efforts could also be used to decrease underwater noise (Table 2).

The case of the port of Le Havre is very interesting in that, like most ports, it suffers from various types of local pollution where it is difficult to uncover causal effects. There is little or no data on the impacts of underwater noise on marine fauna locally, there are often no critically endangered marine mammals nearby and the local population (and hence the port authority) is primarily concerned with air and water quality. Besides, the local population often depends economically on the port's activities and hence has an interest in preserving them. Properly understanding the effects on underwater noise of the different options available for improving energy efficiency, air quality and water quality would help ports choose those solutions that also contribute to reducing underwater noise. These solutions could then be scaled up to a large number of ports, through the development of environmental indexes and classification societies' notations.

Topics for future research

Explicitly identifying the synergies between energy efficiency, air quality (including air noise) and underwater noise reduction

While actions to improve energy efficiency and air quality are already being taken, underwater noise is generally not yet perceived as a major environmental issue by ports or ship owners. However, some concerns have been raised concerning critically endangered species for which information exists about the potential impact of underwater noise. Improved understanding of the synergies between energy efficiency, air quality and underwater noise could provide useful information to policy-makers. In particular, actions on energy efficiency and air quality that also have an impact on underwater noise could be made a priority. Examples of these synergies are shown in Table 1.

Mapping underwater noise vulnerability per port

These maps would be useful both for ports and for ship owners. Different frequencies, and hence, vessel components impact different marine fauna. Individual ports' decisions will often depend on the local presence of fauna.

The experience of aviation noise control could provide some guidance

There are differences but also significant similarities between aviation noise and shipping noise emissions. Local demands regarding air noise quality close to airports have boosted global pressure on the aviation industry to adopt existing quieting technology. The experience gained from aviation noise control could provide some guidance in terms of the lessons learned, the process, incentive building, monitoring tools and criteria, among other factors.

Sources and further reading

- Aguilar Soto, N., Johnson, N., Madsen, P. T., Tyack, P. L., Bocconcelli, A., Borsani, J. F., 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (Ziphius cavirostris)? Marine Mammal Science 22: 690–699.
- Azzellino, A. et al., 2011. Risk mapping for sensitive species to underwater anthropogenic sound emissions: Model development and validation in two Mediterranean areas. Marine Pollution Bulletin 63, 56–70.
- Berkowitz, H. and Dumez, H. (eds), 2017. Racket in the oceans: why underwater noise matters, how to measure and how to manage it. Paris: Observatory for Responsible Innovation / Palaiseau (France): i3-CRG (CNRS – École polytechnique).
- Buscaino et al., 2016. Temporal patterns in the soundscape of the shallow waters of a Mediterranean marine protected area. Scientific Reports 6: 34230.
- CBD, 2012. Scientific synthesis on the impacts of underwater noise on marine and coastal biodiversity and habitats. Subsidiary Body on Scientific, Technical and Technological Advice (SBSSTA), 16th meeting, UNEP/CBD/SBSTTA/16/INF/12. Montreal: Convention on Biological Diversity.
- Delsinne, N., 2005. Évolution pluri-millénaire à pluri-annuelle du prisme sédimentaire d'embouchure de la Seine. Facteurs de contrôle naturels et d'origine anthropique. (phd thesis). University of Caen.
- Dyndo, M., Wiśniewska, D. M., Rojano-Doñate, L., Madsen, P. T., 2015. Harbour porpoises react to low levels of high frequency vessel noise. Scientific reports, 5, 11083. doi:10.1038/srep11083.
- Elliott, M., Quintino, V., 2007. The Estuarine Quality Paradox, Environmental Homeostasis and the difficulty of detecting anthropogenic stress in naturally stressed areas. Mar. Pollut. Bull. 54, 640–645. https://doi.org/10.1016/j.marpolbul.2007.02.003.
- Fisson, C., 2017. Industrialisation de l'estuaire de la Seine : Quel héritage pour la qualité des eaux ? Fascicule 3.6 (Fascicule Seine-Aval No. 3.6). GIP Seine-Aval.
- Fisson, C., Leboulenger, F., Lecarpentier, T., Moussard, S., Ranvier, G., 2014. L'estuaire de la Seine : état de santé et évolution. Fascicule Seine-Aval 3.1. 55p.
- GIP Seine-Aval, 2017. Indicateurs environnementaux pour le suivi de la DTA de l'estuaire de la Seine. Rapport du GIP Seine-Aval pour la DREAL de Normandie, 20p.
- IMO, 2014. Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life. London: IMO subcommittee on Ship Design and Equipment.
- IMO, 2018a. Further information related to impacts of underwater noise on marine life. Submitted by International Whaling Commission. Marine Environment Protection Committee, 72nd session, agenda item 16, MEPC 72/INF.9, 19 January 2018. International Maritime Organization, London, UK.
- Kinda, G. B., Le Courtois, F., Stéphan, Y., 2017. Ambient noise dynamics in a heavy shipping area. Marine pollution bulletin, 124(1), 535-546.
- Le Courtois, F., Kinda, G. B., Stéphan, Y., 2018. Evaluation du bon état écologique au titre du descripteur 11. Shom.
- McLusky, D.S., Elliott, M., 2004. The Estuarine Ecosystem. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198525080.001.0001.
- Merchant, N., et al., 2019. Impulsive noise pollution in the Northeast Atlantic: Reported activity during 2015-2017. Marine pollution bulletin, in press.
- Merk, O., et al., 2011. "The Competitiveness of Global Port-Cities: the Case of the Seine Axis (Le Havre, Rouen, Paris, Caen) - France", OECD Regional Development Working Papers, 2011/07, OECD Publishing. http://dx.doi.org/10.1787/5kg58xppgc0n-en.
- NEPTUNES, 2019. Best practice guide version 1.0. Mitigation of noise from ships at berth.
- Rochette, S., Rivot, E., Morin, J., Mackinson, S., Riou, P., Le Pape, O., 2010. Effect of nursery habitat degradation on flatfish population: Application to Solea solea in the Eastern Channel (Western Europe). J. Sea Res., Proceedings of the Seventh International Symposium on Flatfish Ecology, Part I 64, 34–44. https://doi.org/10.1016/j.seares.2009.08.003.
- Sirovic, A., Hildebrand, J.A., Wiggins, S.M., 2007. Blue and fin whale call source levels and propagation range in the Southern Ocean. The Journal of the Acoustical Society of America, 122(2) 1208-15.
- Tecchio, S., Chaalali, A., Raoux, A., Tous Rius, A., Lequesne, J., Girardin, V., Lassalle, G., Cachera, M., Riou, P., Lobry, J., Dauvin, J.-C., Niquil, N., 2016. Evaluating ecosystem-level anthropogenic impacts in a stressed transitional environment: The case of the Seine estuary. Ecol. Indic. 61, 833–845. https://doi.org/10.1016/j.ecolind.2015.10.036.
- Van der Graaf, A.J., Ainslie, M.A., André, M., Brensing, K., Dalen, J., Dekelin, R.P.A., Robinson, S., Tasker, M.L., Thomsen, F. and Werner, S. 2012. European Marine Strategy Framework Directive-Good environmental status (MSFD GES): Report of the technical subgroup on underwater noise and other forms of energy. Brussels: European Commission.
- Wright, A.J. (ed.), 2009. Report of the workshop on assessing the cumulative impacts of underwater noise with other anthropogenic stressors on marine mammals: From ideas to action. Monterey, California, USA, 26th-29th August, 2009. Okeanos - Foundation for the Sea, Auf der Marienhöhe 15, D-64297 Darmstadt.
- WWF, 2014. Environmental Impacts of Offshore Wind Power Production in the North Sea, WWF, Norway.

OCEAN UNIVERSITY INITIATIVE

The Ocean University Initiative was initiated by the local authorities in Brittany. It is implemented by the University of Brest (UBO) with the aim of creating the conditions for establishing in France of an institute of the United Nations University dedicated to the ocean and the coasts, and with the means to carry out pioneering work in three areas: research, training and communication.

OCEAN University Initiative
UBO - IUEM
Rue Dumont d'Urville
29280 PLOUZANÉ

Coordinator: *Denis Bailly*
contact@ocean-univ.org
ocean-univ.org

AN INITIATIVE SUPPORTED BY

Campus Mondial de la Mer · UBO Université de Bretagne Occidentale · OFB Office français de la biodiversité · Brest Métropole · Région Bretagne · République Française