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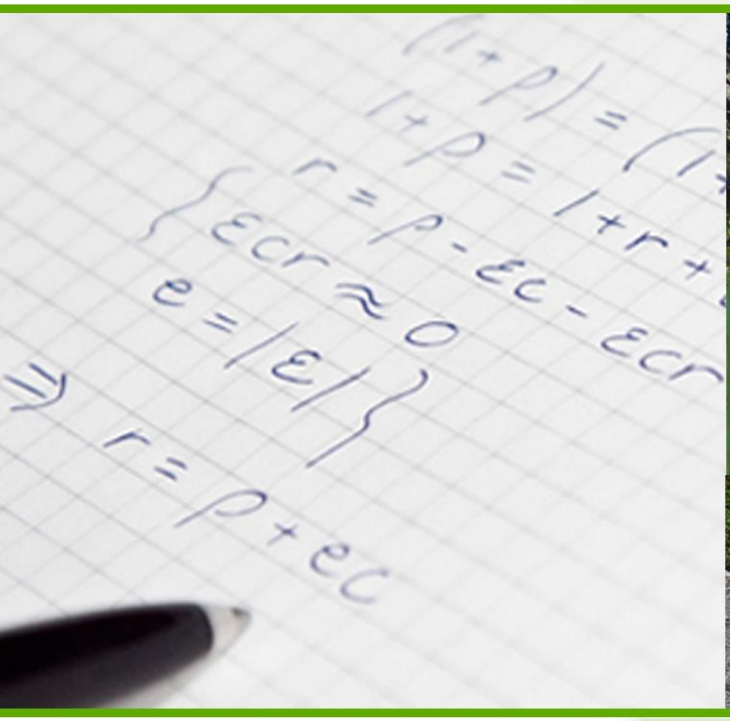
Economic impact of underwater noise



Economic impact of underwater noise

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29 April 2014

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SUMMARY

This report is a socio-economic assessment linked to the project Baltic Sea Information on the Acoustic Soundscape (BIAS). Based on a literature review and a questionnaire to participants in BIAS, the report reviews the potential economic impact of underwater noise, and increased knowledge about such noise, for different actors in society. The assessment also touches upon the demand for studies on the extent and effects of underwater noise.

The potential economic impact of underwater noise is analyzed as the benefits and costs of reducing underwater noise. One aspect of the *benefits* of reducing underwater noise is that this could reduce the impact on marine life, which in turn can imply benefits to society via an increased provision of marine ecosystem services. The particular marine ecosystem services that are potentially mainly influenced by underwater noise was identified as the supporting ecosystem services of food web dynamics, diversity, habitat and resilience, and the provisioning ecosystem services of the provisioning ecosystem services of food, inedible goods and genetic resources, and the cultural ecosystem services of enjoyment of recreational activities, scenery, science and education, cultural heritage, inspiration, and the legacy of the sea.

Another aspect of the *benefits* of reducing underwater noise is the positive effect noise reduction measures can entail for different actors. This is not only about how at least some of them can benefit from an increased provision of ecosystem services, but also about such things as a decrease in fuel consumption (and associated emissions) for shipping and recreational boating, and the improved comfort on-board a more silent boat/ship.

Measures for reducing underwater noise also involve *costs*. At present, the presence of regulations and/or general concern for underwater noise implies restrictions for actors causing impulsive noise, and thus they incur costs associated with these restrictions. The general approaches for requiring actors to reduce noise are source selection (e.g., alternative foundation techniques instead of pile driving), temporal and/or spatial closures, modification of operational parameters (e.g., use of vibratory pile driving instead of impact pile driving), using mitigation equipment (e.g., bubble screens) and using mitigation procedures (e.g., safety zones). In the Baltic Sea, this means that noise reduction costs are primarily an issue for actors involved in marine constructions such as wind power plants and harbour constructions. If restrictions against ambient noise would be introduced, also actors in shipping, fisheries and recreational boating would be affected.

The presence of regulations such as the EU Marine Strategy Framework Directive (2008/56/EC) and the increasing attention paid to underwater noise imply an increasing demand for studies investigating and monitoring the extent of underwater noise. The BIAS project can be expected to further contribute to this increasing demand. The BIAS project can also be expected to contribute substantially to knowledge about underwater noise in the Baltic Sea, in particular with respect to the existence of noise, the contribution of noise sources and the spatial and temporal characteristics of underwater noise.

There are substantial gaps of knowledge regarding the benefits and costs of reducing underwater noise. Therefore the report also suggests a number of extensions of the present study:

- On the whole, knowledge of the impact of underwater noise on marine life is too limited for allowing conclusions about to what degree underwater noise affects the provision of ecosystem services. This implies a need for further studies on how impulsive as well as ambient underwater noise affects marine life. Such studies are also needed as a basis for

further work on the benefits of reduced underwater noise that are associated with an increased provision of ecosystem services.

- It is interesting to note that there are also another aspect of benefits that can be studied quite independently of the impact on ecosystem services, i.e. decreased fuel consumption and other technological advantages of measures against underwater noise. Those types of benefits are likely to be of great importance for attitudes among actors towards noise reduction measures, and should therefore also be subject to further study.
- More detailed information on costs for measures that are, or could be, carried out for reducing underwater noise. Such information could make it possible to identify cost-effective measures, i.e. identifying those measures that fulfil restrictions against underwater noise to the lowest costs.

1 INTRODUCTION

This report is a socio-economic assessment linked to the project Baltic Sea Information on the Acoustic Soundscape (BIAS). The main objective of the assessment is to review the potential economic impact of underwater noise, and increased knowledge about such noise, for different actors in society. The assessment will also take into account what impact the presence of underwater noise might have on the demand for studies on the extent and effects of underwater noise.

The assessment is based on a literature review on the benefits and costs of reducing underwater noise (Section 2) and results of a questionnaire to participants in BIAS (Section 3). Conclusions are found in Section 4.

2 LITERATURE REVIEW ON BENEFITS AND COSTS

Figure 1 shows conceptually what the economic impact of underwater noise is about for society. The presence of underwater noise might potentially cause economic damage to society by its influence on marine life, and this is illustrated by a marginal damage cost curve which is increasing in the extent of underwater noise. The marginal damage costs are the increase in total damage costs when the extent of underwater noise increases with one unit. This suggests that the benefits of reducing underwater noise are equal to the damage costs that can be avoided thanks to a reduction in underwater noise.

On the other hand, it might require resources for reducing underwater noise. This is illustrated by the other curve in Figure 1, which illustrate the marginal reduction costs. These costs are the increase in total reduction costs when the extent of underwater noise is reduced by one unit. Typically, measures for reducing underwater noise are likely to be more and more expensive the more noise is to be reduced, which explains that the marginal reduction cost curve is increasing for movements from the left to the right along the x axis, i.e. when the extent of underwater noise is reduced. However, the measures could also introduce benefits in terms of technological improvements enabling, for example, reduced fuel consumption in shipping. One way of introducing such types of benefits in Figure 1 is to subtract them from the marginal reduction costs, i.e. moving the marginal reduction cost curve downwards.

Figure 1 also suggests that given that the present extent of underwater noise is N^o, it is profitable to society to reduce the extent underwater noise with one unit, because for this change the benefits, i.e. the reduction in damage costs, is greater than the increase in reduction costs. The same is true for all reduction until the underwater noise extent for which the marginal damage costs is equal to the marginal reduction costs, i.e. at N*.

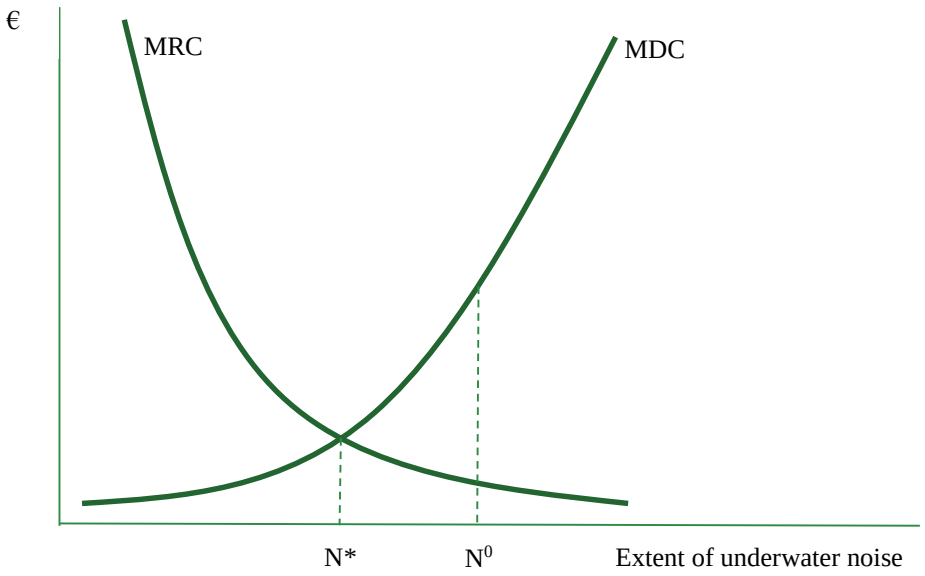

Figure 1. Marginal damage costs (MDC) of underwater noise and the marginal costs of reducing (MRC) underwater noise.

The rest of this section is about indications about the benefits and costs of reducing underwater noise collected through a brief literature review.

2.1 The benefits of reducing underwater noise

One important type of benefits of reducing underwater noise is about reducing the potential damage for society that is caused by the impact of such noise on marine life. This means that it is necessary to have a method by which the impact on marine life can be translated into consequences on society. This can be accomplished by expressing the impact of underwater noise in terms of the impact on the provision of marine ecosystem services. This type of benefits is the focus of this section. In Section 3, another types of potential benefits touched upon above is brought up: The technological advantages of reducing underwater noise in terms of possibilities to, for example, reduce ships' fuel consumption.

There are various typologies of marine ecosystem services available; Table 1 lists services that have been used by the Swedish Agency for Marine and Water Management (SwAM). This typology draws on the categories introduced by the Millennium Ecosystem Assessment (MA, 2005). If underwater noise introduces an impact on any of these ecosystem services, this could have an economic impact, particularly since effects can be expected to be inter-linked and cumulative. For example, if underwater noise would make habitats (S5) less suitable for fish, this could potentially influence the stock of fish that directly or indirectly through food web dynamics (S3) are of interest for commercial and/or recreational fisheries. This could imply a reduced provision of fish for food (P1), fish for fish meal (P2) or recreational opportunities (C1). This reduced provision would constitute a cost for society. It should also be observed that the potential presence of cascading (top-down) effects in ecological communities can have an impact on ecosystem services depending on marine resources outside those directly impacted by noise.

Van der Graaf et al. (2012) reviews the impact of impulsive noise of low and mid frequency, and the impact of ambient noise. Sources of impulsive noise are, for example, pile driving, seismic surveys and explosions. Laboratory and field studies reviewed by Van der Graaf et al. (2012) have shown that impulsive noise can result in substantial physiological and behavioural impact on fish and mammals. Van der Graaf et al. (2012) refer to Norwegian studies that indicate that catch rate in fisheries might be influenced by impulsive underwater noise. Hawkins et al. (2012) also review the evidence of impact of noise on fish catch and conclude that such an impact could exist. For example, they report that commercial trawl and longline catches of Atlantic cod and haddock have been shown to fall substantially during seismic surveys in the Barents Sea. However, they also emphasize that there is still a general lack of knowledge of the nature of this impact. Normandeau Associates (2012) concludes that one of the largest knowledge gaps related to underwater noise is the lack of data on the acute and cumulative responses of fishes and invertebrates to underwater noise. The reason for why this knowledge gap is crucial is the need for such knowledge for being able to quantify any impacts of sound-generating marine activities.

Ambient underwater noise refers to background noise, which can have very different sources, e.g. shipping and the continuous sound from energy installations such as wind farms in operation. Van der Graaf et al. (2012) concludes that ambient noise might disturb communication between marine mammals and fish and result in physiological and behavioural stress. For example, Bårnstedt et al. (2009) found that spawning cod and haddock use acoustic

signals that are in the same frequency area as the underwater sound caused by wind power plants. On the other hand, several studies also indicate that the potential effect of underwater sound from wind power plants in operation on fish species is very local, see the overview in SEPA (2010).

In an ecosystem service perspective, the fact that effects of underwater noise (particularly impulsive noise) on marine organisms such as fish and mammals have been shown to exist suggests that there is also a potential impact on the provision of ecosystem services. For example, habitat (S5) disturbance can lead to increased competition, increased predation or decreased foraging. Such changes in community interaction can have a direct impact on several supporting ecosystem services. This is indicated in the fourth column of Table 1 by the potential negative effect on food web dynamics (S3), diversity (S4) and resilience (C6). This could in turn imply a reduced provision of fish for food (P1) and for other purposes than food (P2), and genetic resources (P3). Recreational fisheries could potentially also be negatively affected (C1). Further, negative impact on marine life, not least marine mammals and large fish, could also influence people's well-being through other cultural ecosystem services, e.g. loss in aesthetic, educational, cultural, inspirational services, and because people care about the existence of a healthy marine environment (C2-C6). However, the present knowledge of large-scale effects is too small for allowing conclusions about the extent of these impacts. Even more uncertainty is associated with potential indirect effects on regulating services because of changes in supporting services, and therefore Table 1 does not indicate any main impact of underwater noise on regulating services.

Table 1. List of marine ecosystem services (S=supporting, R=regulating, P=provisioning, C=cultural). Source: SwAM (2012).

	Ecosystem service	**Brief definition** (after Garpe, 2008)	**Main potential impact of underwater noise**
S1	Biogeochemical cycling	Maintenance of the cyclical movement of energy and materials within ecosystems.	0
S2	Primary production	The conversion of dead material (inorganic) to living material (organic) by means of phytosynthesis.	0
S3	Food web dynamics	Maintenance of who-eats-who (trophic) relationships among organisms.	Potential negative impact
S4	Diversity	Maintenance of the variety in genes, species, ecosystems and ecosystem functions.	Potential negative impact
S5	Habitat	Maintenance of the environments in which organisms live.	Potential negative impact
S6	Resilience	Maintenance of the extent to which ecosystems can absorb perturbations and continue to regenerate without degrading.	Potential negative impact
R1	Climate and atmospheric regulation	Maintenance of the chemical composition of the atmosphere and ocean.	0
R2	Sediment retention	Ecosystems' stabilization and retention of sediments, thus mitigating coastal erosion.	0
R3	Eutrophication mitigation	Ecosystems' removal of excess nitrogen and phosphorus.	0
R4	Biological regulation	Organisms' regulation of the abundance of other organisms, e.g. pests and pathogens.	0

R5	Regulation of hazardous substances	Breaking down, storing and burying of toxic substances and societal waste.	0
P1	Food	Provision of fish and other food fit for human consumption.	Potential negative impact
P2	Inedible goods	Provision of marine products not used as food for humans, e.g. fish meal and sand extraction.	Potential negative impact
P3	Genetic resources	Provision of marine genetic resources of actual or potential value.	Potential negative impact
P4	Chemical resources	Provision of marine resources for pharmaceutical, chemical and biochemical use.	0
P5	Ornamental resources	Provision of marine products for the purpose of decoration or handicraft, e.g. amber.	0
P6	Energy	Acquisition of energy directly from the marine environment.	0
P7	Space and waterways	Provision of the sea surface as a medium for e.g. transports, site for energy provisions and other constructions.	0
C1	Enjoyment of recreational activities	Provision of opportunities to have different types of recreation and tourism.	Potential negative impact
C2	Scenery	Provision of opportunities to enjoy aesthetic values including the appreciation of beauty and silence.	Potential negative impact
C3	Science and education	Provision of opportunities to have educational activities and research.	Potential negative impact
C4	Cultural heritage	Provision of opportunities to use the marine and coastal environment for spiritual, sanatory or historical purposes.	Potential negative impact
C5	Inspiration	Provision of opportunities to inspire art and advertisement.	Potential negative impact
C6	The legacy of the sea	The appreciation of the marine and coastal environment nature for ethical (non-use) reasons.	Potential negative impact

2.2 The costs of reducing underwater noise

The probable effect of underwater noise on marine life has motivated regulations for limiting the extent of such noise. These regulations are likely to have an economic effect in the sense that they affect the conditions for actors causing underwater noise, which might result in reduction costs. For example, such costs could arise because an actor has to undertake measures that reduce noise when carrying out noisy activities, and/or that such activities are banned in certain areas, either completely or during time periods when fish or other organisms can be expected to be particularly sensitive to noise, such as during spawning periods.

One influential regulation is underwater noise as a part of the descriptors of Good Environmental Status (GES) in the EU Marine Strategy Framework Directive (2008/56/EC). In the directive, the qualitative descriptor #11 for determining GES is formulated as:

> *"Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment."*

Descriptor #11 was further developed in COM (2010) in the following way, including the definition of two criteria (11.1 and 11.2) and one indicator per criteria (11.1.1 and 11.2.1).

> *"Descriptor 11: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.*
>
> *Together with underwater noise, which is highlighted throughout Directive 2008/56/EC, other forms of energy input have the potential to impact on components of marine ecosystems, such as thermal energy, electromagnetic fields and light. Additional scientific and technical progress is still required to support the further development of criteria related to this descriptor (22), including in relation to impacts of introduction of energy on marine life, relevant noise and frequency levels (which may need to be adapted, where appropriate, subject to the requirement of regional cooperation). At the current stage, the main orientations for the measurement of underwater noise have been identified as a first priority in relation to assessment and monitoring (23), subject to further development, including in relation to mapping. Anthropogenic sounds may be of short duration (e.g. impulsive such as from seismic surveys and piling for wind farms and platforms, as well as explosions) or be long lasting (e.g. continuous such as dredging, shipping and energy installations) affecting organisms in different ways. Most commercial activities entailing high level noise levels affecting relatively broad areas are executed under regulated conditions subject to a license. This creates the opportunity for coordinating coherent requirements for measuring such loud impulsive sounds.*
>
> *11.1. Distribution in time and place of loud, low and mid frequency impulsive sounds*
>
> *— Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1µPa 2 .s) or as peak sound pressure level (in dB re 1µPa peak) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1)*
>
> *11.2. Continuous low frequency sound*
>
> *— Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1µPa RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate (11.2.1)."*

SwAM (2012) refers to the Precautionary Principle for concluding that the considerable lack of knowledge of the effects of underwater noise on the marine life motivates restrictions against underwater noise in the marine environment. However, SwAM (2012) could not suggest Swedish indicators for GES descriptor #11 and identified the need to establish threshold limit values for underwater sound and increased knowledge of how such sound affect marine life. Germany has introduced such threshold limit values: An exclusion zone of 750 m from pile driving is required for marine mammals and measures must be employed by operators to keep the received level at 750 m below a particular sound exposure value and a peak-to-peak sound pressure value (Erbe, 2013).

In a review of international regulation of underwater noise, Erbe (2013) concludes that countries that have introduced such regulations are using similar general approaches for requiring actors to reduce noise. These general approaches include:

1. The source
    - Source selection, e.g. alternative foundation techniques instead of pile driving.
2. Location and timing
    - Time/area closures, e.g. applied to seismic surveys.
3. Operational parameters
    - Soft-start/ramp-up, e.g. applied to seismic surveys or pile driving.
    - Use of vibratory pile driving instead of impact pile driving.
4. Mitigation equipment
    - Bubble screens to absorb and scatter some of the energy from pile driving.
5. Mitigation procedures
    - Safety zones, e.g. shut-down zones, low-power zones and observation zones.
    - Marine mammal observers for monitoring safety zones for animal presence.
    - Pre-shoot survey for detection of marine animal presence.
    - Low-power and shut-down in case of animals entering zones.
    - Passive acoustic monitoring for operations in poor visibility.

Regulations and/or general concern for the consequences of underwater noise thus influence activities causing underwater noise. For example, it is evident from applications about constructions of wind power plants that measures that reduce noise from pile driving are expected. For example, the Environmental Impact Assessment for a suggested wind farm off the Swedish county of Halland in the Kattegat specify that primarily because of the risk of impact on spawning cod, pile driving will not take place in the period of 1 January-30 June, and a “ramp-up” method will be applied when pile driving is carried out. This means that the piling pressure will gradually increase in order to discourage seals, porpoises and fish from the area. (Favonius, 2012)

As a conclusion, the presence of regulations and/or general concern for underwater noise implies restrictions for actors causing such noise. This means that actors might incur costs when they have to take these restrictions into account. At present, the restrictions are primarily about impulsive sounds such as noise from pile driving, which for the case of the Baltic Sea implies that noise reduction costs are primarily an issue for actors involved in marine constructions such as wind power plants and harbour construction. If restrictions against ambient noise would be introduced, also actors in shipping, fisheries and recreational boating would be affected.

The presence of regulations and the increasing attention paid to underwater noise also implies an increasing demand for studies investigating and monitoring the extent of underwater noise. The need to specify quantitative underwater noise indicators and establish threshold limit values

related to GES descriptor #11 also implies that there is a need for more studies about the impact of underwater noise.

As an extension of the present study, it would be of interest to survey the effects and actual costs for measures that are, or could be, carried out for reducing underwater noise. This could make it possible to identify cost-effective measures, i.e. identifying those measures that fulfil restrictions against underwater noise to the lowest costs.

3 RESULTS FROM A QUESTIONNAIRE TO BIAS PARTICIPANTS

Six selected participants in BIAS were invited to answer a questionnaire in order to obtain their best professional judgments concerning the economic impact of underwater noise. These judgments are likely to further indicate what impacts might be more or less probable. Table 2 lists the questions posed to the BIAS participants and reports the answers provided by four participants. Those participants represents a mix of researchers and agency officials based in four different Baltic Sea countries: Denmark, Finland, Lithuania and Sweden. Two participants did unfortunately not answer the questionnaire. The next few paragraphs summarize the participants' answers. The reader is referred to Table 2 for the complete answers.

The participants' answers to the questions on the main effects of underwater noise on ecosystem services, and the source of this noise, are largely consistent with the findings in Section 2. It is evident that the sources of the noise that might have large effects should be subject to further investigation; there are particularly large gaps of knowledge for effects and sources of ambient noise.

According to the participants, it is very likely that the BIAS project will increase the demand for investigations in the Baltic Sea of the extent of underwater noise and effects of underwater noise. This demand is also stimulated by an increasing general concern of government agencies on underwater noise issues. The participants also expect the BIAS project to contribute to knowledge about underwater noise in the Baltic Sea, in particular with respect to the existence of noise, the contribution of noise sources and the spatial and temporal characteristics of underwater noise.

As to costs and benefits for different group of actors in the Baltic Sea because of measures against underwater noise, the participants indicated in general that there are large uncertainties associated to what extent such costs and benefits will be realized in the next 10 years, and to what extent the BIAS project will have impact on costs and benefits. However, it should be emphasized that participants indicated the possibility that each group of actor can both incur costs and enjoy benefits:

- *Fisheries* might incur costs due to construction of silent vessels and fishing gear, but on the other hand reduced noise levels could benefit fisheries because of less impact on fish.
- *Shipping* might be negatively impacted through increased costs of ship construction because of noise reduction measures and increased costs of traffic because of introductions of speed limits and changes in shipping routes. On the other hand, more silent shipping is likely to entail benefits in terms of a decrease in fuel consumption (and associated emissions) and improved comfort for passengers and crew. In addition, noise reduction measures implying less vibration and cavitation could be beneficial for ship hull and equipment.
- *Marine constructions such as wind power plants* incur costs for measures delimiting noise during construction, and there might also be costs for reducing ambient noise from

constructions in operation. On the other hand, noise reduction measures might also be beneficial for constructions because of less vibrations and a reduced loss of energy.

- *Tourism and recreation including boating and recreational fisheries* could have to install less noisy engines and propulsion systems, which would imply costs. On the other hand, more silent boating can increase comfort and reduce fuel consumption (and associated emissions). In addition, recreational fisheries is positively impacted if reduced noise levels have a positive impact on fish.

This list indicates that each group of actors might have something to gain from measures reducing underwater noise. While this does not say anything about whether the benefits would be greater than the costs for each group (and for individual actors within each group), the potential presence of benefits can still be of great importance for attitudes among actors towards noise reduction measures. This suggests that an interesting extension of the present study would be not only to survey the costs for measures reducing underwater noise (see Section 2), but also to make an in-depth study of potential noise reduction benefits.

Table 2. Questions to BIAS participants and their answers.

Question	Answer #1	Answer #2	Answer #3	Answer #4
1. What effects on marine life of underwater noise in the Baltic Sea do you judge as the most important when it comes to impact on society, i.e. impact on ecosystem services?	Our knowledge on how economically important fish stocks, such as cod and herring, are affected by noise are very sketchy. If such fish turn out to have problems reproducing, navigating or foraging due to increased noise levels, this would certainly be a problem of high importance.	P1, C1: negative impacts on fish species which are exploited by commercial or recreational fisheries R3: changes in fish stocks could influence the lower trophic levels, with potentially unwanted consequences in the ecosystem function R4: decreased production of prey fish could decrease populations of predatory species (fish, birds, marine mammals) P3: genetic resources may be damaged as a new environmental stressor (noise) can selectively influence the fitness of species and individuals	Species like harbour porpoises, seals, fish and birds can be negatively impacted by ambient noise and affect tourism, fishing maybe and non-specific ecosystem food webs.	Lithuanian Baltic Sea area has sensitive areas where spawning grounds of commercial species including Baltic herring (Clupea harengus) prevails mainly in coastal areas and cod (Gadus morhua) spawning grounds prevails in the exclusive economic zone of Lithuanian Baltic Sea area where ecosystems of a such can be impacted in the way of acoustical masking and behavioral reactions (see: Fay and Popper 2008 “Fish bioacoustics”). The further mentioned effects can lead to stock deterioration when noise is coupled with other factors such as chemicals and eutrophication also bad season etc

		C1, C6: marine mammals, and their aesthetic and legacy values etc. could decrease		(see: alostatic pressure). The impulsive noise sources however have an instant physical effect on fish and mammals.
2. What are the main sound sources of the effects you listed in question 1?	Probably shipping and oil/gas exploration noise.	Currently not well known, but potentially vessels, pipelines, wind power, construction.	Seismic survey noise and intermittent noise i.e. construction work, while it remains to be shown if ship traffic and wind power generated ambient noise as well can cause negative impacts.	Lithuanian case (not including future activities): 1. Shipping including fisheries; 2. Military activities (explosives, sonar); 3. Sand extraction (TSHD "trailing suction chopper dredger"); 4. Oil activities (Moored tanker loading SPM); 5. Cable laying 2014-2015 Litgrid, Lithuania-Sweden (TSHD "trailing suction chopper dredger")
3. Are there any differences in different parts of the Baltic Sea in terms of effects of underwater noise (question 1) and sources of underwater noise (question 2)?	Different areas have different importance, e.g. for cod. The areas of most concern are the ones used for reproduction of fish.	The noise levels are likely to be linked to the spatial variations in the intensity of human actions.	Heavy ship traffic across the Baltic from southwest towards northeast, especially the areas within the triangle Öland – Gotland – Bornholm, Arcona sea and Öresund as well as areas in the Kattegat.	Yes
4a. Do you expect regulations for underwater noise to become homogenous across Baltic Sea countries?	Yes		No	No
4b. If no to question 4a, what regulatory differences across Baltic Sea countries do you expect?		In EU countries, coherent regulations could be applied, but obviously not in near future. Economic development can be an issue to influence the acceptance of regulations.	No, regulations have to be linked to sensitive areas and sensitive time of the year depending on the species involved. Integrated ship noise if harmful should be regulated at high traffic lanes.	Regulations however expected to be different due to different anthropogenic pressures (?)
5. What impact do you judge underwater noise issues and regulation **in general** will have in the next 10 years concerning: 5a. Demand for investigations in the Baltic Sea of the extent of underwater noise and	High impact	Smallish investigations	If scientifically sound effects can	Rising concern of governmental

effects of underwater noise?		may take place	be regulated we can foresee less impact and a healthier ecosystem.	organizations on noise issues.
5b. **Costs** that different actors in the Baltic Sea will incur because of measures against underwater noise? 5ba. Fisheries	Small	Some expenses in construction of silent vessels and active fishing gear	Not enough baseline information to judge from!	As stated in the draft Programme of Measures, there is no GES set for D11, as well as there are no indicators suggested for the descriptor D11, therefore there are no measures proposed for improvement of the GES. Thus costs estimated so far for this descriptor equal 0. However, it is stated in the PoM that such measures as modernisation of ship fleet (in the PoM described as a basic measure) is necessary, but not sufficient measure to improve the sea water quality according to this descriptor. We assume that the following measures and their costs from those described in the PoM could to some extent reflect costs related also to the reduction of underwater noise: 1. The requirement laid down in Annex VI of the IMO MARPOL Convention to use 2nd generation engines (Tier II) entered into force on 1 January 2011. It applies to all ships built since 2011 and to ships with engines over 5000 kW. Because of this requirement (devoted basically

				to the reduction of nitrogen oxides emissions) some Lithuanian ships (it could be five ships), during the next docking (approximately in 2014) would need modernization of engines. It could be assumed that more modern engine would mean not only reduction of NOx emissions, but also reduction of noise. It was estimated that upgrade (modernization) of one engine costs approx. EUR 100 thou. Consequently, the total investments will amount to approximately EUR 500 thou. 2. Pursuant to the same Annex VI of the IMO MARPOL Convention, as from 1 January 2013, all operating ships should have a Ship Energy Efficiency Management Plan (SEEMP). Also, the Energy Efficiency Design Index (EEDI) was made mandatory for new ships. The cost of such measure per ship will amount to approximately EUR 1200. As noted, these are necessary, but not sufficient measures. However, no any other additional measures were analysed and proposed for the D11 by Lithuanian experts.*
5bb. Shipping	Small	Noise issues may become actual in building of new vessels, cost for	Probably, but may be very difficult to decide on due to	[See above for fisheries.]

		construction of especially passenger ships. Noise may become a factor in setting speed limits and in construction of new shipping routes – increased costs in traffic.	different national views.	
5bc. Marine constructions such as wind power plants	Small	Delimiting noise during construction, and developing wind power plant which eliminate vibration may be demanded in some countries or areas.	Yes definitely if scientifically sound evidence are available!	There are now wind power plants in Lithuanian waters so far.
5bd. Tourism and recreation including boating and recreational fisheries	Small	Some more silent engines and propulsion systems may become installed, with some extra costs.	Yes definitely if scientifically sound evidence are available!	
5be. Other actors, if any				
5c. **Benefits** (including increased employment opportunities) that different actors in the Baltic Sea will gain because of measures against underwater noise? 5ca. Fisheries	None	Delimiting noise levels could support viable fish stocks and ecosystems. Silent vessels and fishing gear could increase catch levels.	Difficult to say, there are so many different options here to conclude on the impact of just ambient noise. Nevertheless, benefits should be positive.	Stock protection
5cb. Shipping	None	Silent ships are likely to be silent also inside, more comfort for passengers and crew. Delimiting of vibration and cavitation could be beneficial for the ship hull and equipment. Smooth underwater surfaces reduce noise, but also decrease fuel consumption.	Noise is energy so minimizing ship noise from propellers and other parts of the ship will save energy as well as emissions.	Great advances in ship building engineering

		Silent shipping could benefit the marketing of services.		
5cc. Marine constructions such as wind power plants	None	Delimiting vibration may be good for the structures of the power plants? Marine wind power could gain popularity and market values through delimiting the noise levels.	Same as above from an energy perspective.	Accomplishment of green EU schemes in construction (?)
5cd. Tourism and recreation including boating and recreational fisheries	None	Silent boating can be more comfortable- an issue which could benefit marketing of boats and services. Environment-friendly boating benefits marketing.	All noise reducing factors most likely is positive for the ecosystem, thereby supporting Good Environmental Status.	Protection of stock and ecologically sensitive areas
5ce. Other actors, if any				
6. What impact do you judge **the BIAS project** will have concerning: 6a. Demand for investigations in the Baltic Sea of the extent of underwater noise and effects of underwater noise?	High impact	BIAS is very important in this issue, in highlighting the key issues and the magnitude of the underwater noise pollution.	Yes!	Positive
6b. **Costs** that different actors in the Baltic Sea will incur because of measures against underwater noise? 6ba. Fisheries	High	Probably few	Not sure but if yes fine for us.	
6bb. Shipping	High	Probably few	I hope the noise Baltic wide baseline can be gathered by the project.	
6bc. Marine constructions such as wind power plants	High	Perhaps some impacts for the construction	I hope the noise Baltic wide baseline can be gathered by the project.	
6bd. Tourism and recreation including boating and recreational fisheries	High	Probably few impacts	No, I do not expect this to happen in the project.	
6be. Other actors, if any				
6c. **Benefits** (including increased employment opportunities) that different actors in the Baltic Sea will gain because of				

measures against underwater noise? 6ca. Fisheries	None	Probably few	Difficult to say!	Stock protection
6cb. Shipping	None	Probably few	Noise is energy so minimizing ship noise from propellers and other parts of the ship will save energy as well as emissions.	Great advances in ship building engineering (if implemented regionally)
6cc. Marine constructions such as wind power plants	None	Probably few	Same as above from an energy perspective.	Accomplishment of green EU schemes in construction (?)
6cd. Tourism and recreation including boating and recreational fisheries	None	Probably few	All noise reducing factors most likely is positive for the ecosystem, thereby supporting Good Environmental Status.	Protection of stock and ecologically sensitive areas
6ce. Other actors, if any		Probably few		
6d. Increased knowledge in society of the effects of underwater noise?	High	BIAS project may not tell much about the effects but could importantly contribute to the knowledge of existence of underwater noise, highlight the contribution of noise sources and the spatial and temporal characteristics of underwater noise.	Here I sincerely hope the BIAS project can have an important impact!	Likely to be
*) This answer was given by a BIAS non-participant on the suggestion of the BIAS participant who answered the other questions.				

4 CONCLUSIONS

The list below is used for presenting the main conclusions from the report:

- Reducing underwater noise entails both costs and benefits.
- One aspect of the benefits of reducing underwater noise is that this could reduce the impact on marine life, which in turn can imply benefits to society via an increased provision of marine ecosystem services. The particular marine ecosystem services that are potentially mainly influenced by underwater noise was identified as the following ones:
    - The supporting ecosystem services of
        - Food web dynamics
        - Diversity
        - Habitat
        - Resilience
    - The provisioning ecosystem services of
        - Food
        - Inedible goods
        - Genetic resources
    - The cultural ecosystem services of
        - Enjoyment of recreational activities
        - Scenery
        - Science and education
        - Cultural heritage
        - Inspiration
        - The legacy of the sea
- Another aspect of the benefits of reducing underwater noise is the positive effect noise reduction measures can entail for different actors. This is not only about how at least some of them can benefit from an increased provision of ecosystem services, but also about such things as a decrease in fuel consumption (and associated emissions) for shipping and recreational boating, and the improved comfort on-board a more silent boat/ship.
- Measures for reducing underwater noise also involve costs. At present, the presence of regulations and/or general concern for underwater noise implies restrictions for actors causing impulsive noise, and thus they incur costs associated with these restrictions. In the Baltic Sea, this means that noise reduction costs are primarily an issue for actors involved in marine constructions such as wind power plants and harbour constructions. If restrictions against ambient noise would be introduced, also actors in shipping, fisheries and recreational boating would be affected.

- As an extension of the present study, more detailed information on costs for measures that are, or could be, carried out for reducing underwater noise would make it possible to identify cost-effective measures, i.e. identifying those measures that fulfil restrictions against underwater noise to the lowest costs.
- The presence of regulations and the increasing attention paid to underwater noise imply an increasing demand for studies investigating and monitoring the extent of underwater noise. The BIAS project can be expected to further contribute to this increasing demand.
- The BIAS project can also be expected to contribute substantially to knowledge about underwater noise in the Baltic Sea, in particular with respect to the existence of noise, the contribution of noise sources and the spatial and temporal characteristics of underwater noise.
- On the whole, knowledge of the impact of underwater noise on marine life is too limited for allowing conclusions about *to what degree* underwater noise affects the provision of ecosystem services. This implies a need for further studies on how impulsive as well as ambient underwater noise affects marine life. Such studies are also needed as a basis for further work on the benefits of reduced underwater noise that are associated with an increased provision of ecosystem services. However, it is interesting to note that there are also another aspect of benefits that can be studied quite independently of the impact on ecosystem services, i.e. decreased fuel consumption and other more technological advantages of measures against underwater noise. Those types of benefits are likely to be of great importance for attitudes among actors towards noise reduction measures, and should therefore also be subject to further study.

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