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ACOUSTIC IMPACT ASSESSMENT OF SUB-BOTTOM PROFILERS ON MARINE MAMMALS

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DMON : O. Lefort (DMON/D), O. Quédec, J.X. Castrec (DMON), S. Van Iseghem, A. Feld (DMON/PF)

IMN : P. Cotty (IMN/D), M. Nokin (IMN/NSE), X. Lurton, C. Ducatel (IMN/NSE/ASTI)

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ACOUSTIC IMPACT ASSESSMENT OF SUB-BOTTOM PROFILERS ON MARINE MAMMALS

Abstract: Scientific surveys for geoscience use medium-power acoustic sources called *Sub-Bottom Profilers*. Their acoustic signal characteristics are shown not to impact the physiology of marine mammals. Therefore scientific surveys collecting data using Sub-Bottom Profilers do not require specific mitigation plans.

Key words : *Sub-Bottom Profilers, Marine Mammals, Acoustic Impact*

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Summary

1 INTRODUCTION

This document assesses the acoustic impact on marine mammals (MM) when using ***Sub-Bottom Profilers (SBP)***. This type of non-impulsive acoustic source is used to investigate sediment layers (both in nature and in structure) below the seafloor interface. The working principle of this equipment is the transmission of long and wide-band FM signals through the use of low-frequency piezoelectric-arrays. SBPs are mainly used to acquire high-resolution data (vertical resolution about 20 cm) with a maximum depth penetration ranging from 20 (hard sediment) to 120 m (soft sediment).

2 SOURCE CHARACTERISTICS

The characteristics of acoustical sources to consider for risk assessment are SL (*Source Level*) and SEL (*Sound Exposure Level*), determined from recordings of the acoustical signal.

- ***SL*** (in dB ref. 1µPa@1 m) is defined as the maximum amplitude signal at the reference distance R_0 of 1 m and is expressed in dB as follow:

  $$SL(R_0) = 20 \times \log_{10}(p_{\max} / p_{ref})$$

  where $p_{\max} = \max(p(t))$ and p_{ref} = 1 µPa.

- ***SEL*** (in dB ref. 1µPa²×s @1 m) calculated for a single signal at a reference distance R_0 is obtained by integrating intensity over time for the entire duration of the received signal:

  $$SEL_1(R_0) = 10 \times \log_{10}\left(\int p^2(t)dt / p_{ref}^2\right)$$

For a series of N identical shots, the received energy increases proportionally to N; the SEL_N level therefore increases by $10\ \log N$ above the one-shot SEL_1.

Typical level magnitudes of Sub-Bottom Profilers transmitted signals are quite homogeneous between constructors (Ixblue, Kongsberg, Knudsen). The peak levels of acoustic pressure are in the range 213 to 228 dB re 1µPa @1m, according to these constructors. The FM signal features a long modulation typically of few tens of ms with a relatively constant level in the frequency band.

As an example case, an Ixblue Echoes 3500 SBP is considered here. This system equips all Ifremer's deep-sea oceanographic vessels. Fig.1 displays the nominal time signal transmitted, far-field recorded on Ifremer's Research Vessel *L'Atalante*. The typical pulse length is 80 ms, and the usable frequency band is between 1.8 and 5.3 kHz. Fig. 2 displays the measured full-power Source Level (SL) at the reference distance.

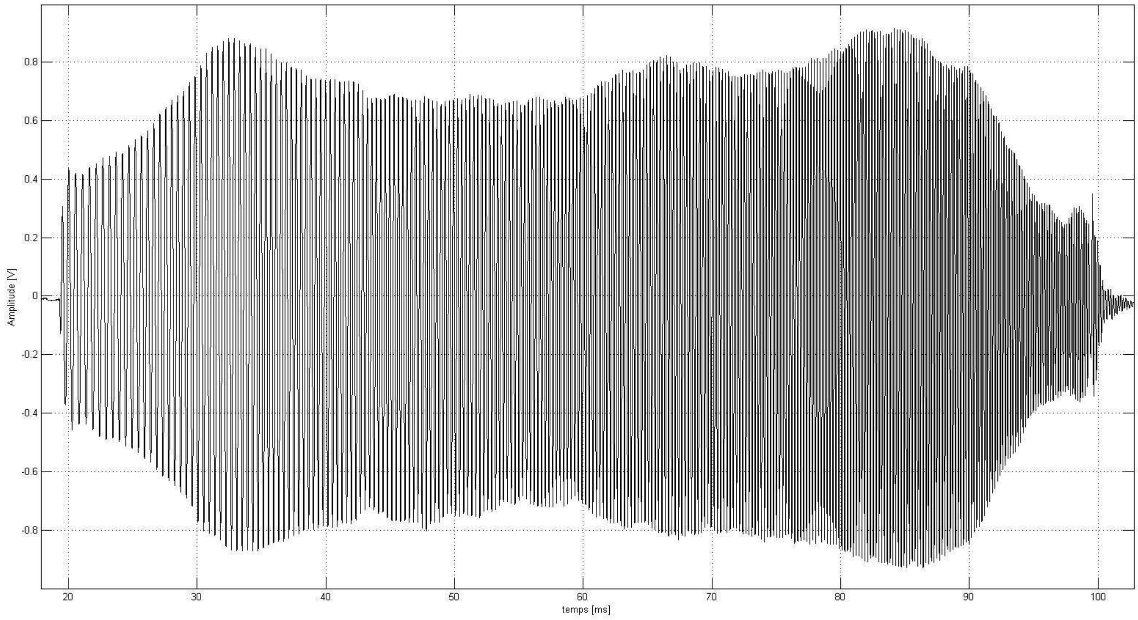

**Figure 1: Echoes 3500 Sub-Bottom Profiler typical time signal – Received voltage (V) vs time (ms)
Ifremer far-field measurement on R/V *L'Atalante***

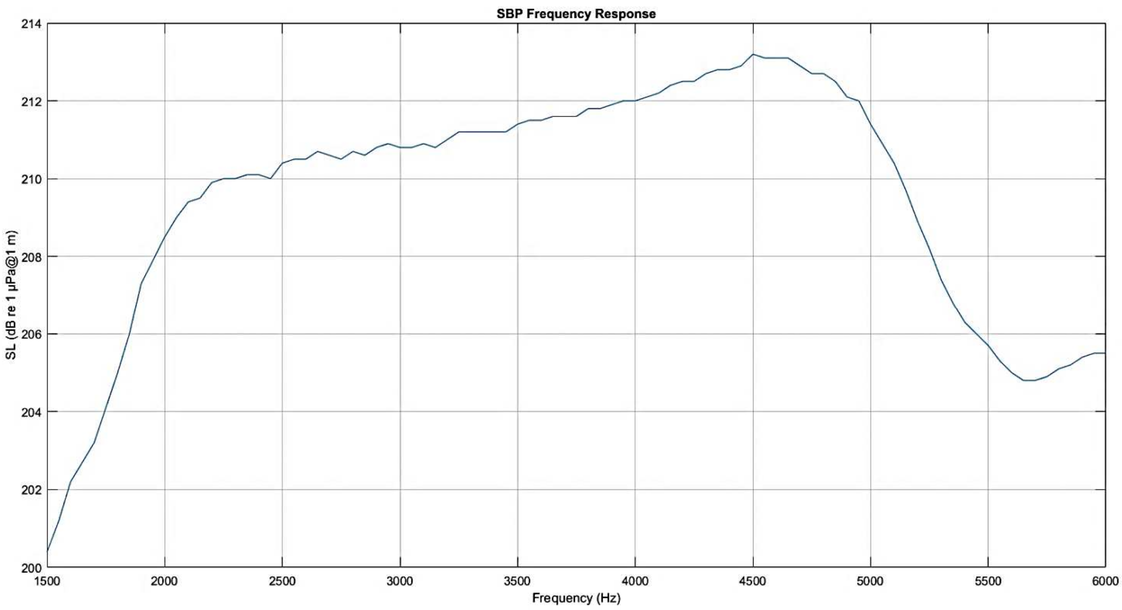

**Figure 2: Echoes 3500 Sub-Bottom Profiler Sound Level at full-power, as a function of frequency
Ifremer far-field measurement**

The maximum Source Level of such a system is then:

$$SL = 213 \text{ dB re1 } \mu\text{Pa @ 1 m}$$

The ***SPL*** (*Sound Pressure Level*) actually received at one point is obtained by correcting SL (at 1 m) by the propagation loss corresponding to the source-receiver range.

The SEL_1 approximately computed from this plot for one shot, for a SL value equal to 213 dB re 1µPa@1m and a pulse length of 80 ms, is given by :

$$SEL_1 = 213 + 10\log(80.10^{-3}) = \mathbf{202\ dB\ re\ 1\ \mu Pa^2.s\ @\ 1m}$$

In order to account for the actual exposure level, one should correct the above elementary SEL_1 (for one shot) by:

- the propagation loss corresponding to the source-animal range, and
- the number of shots N received by the animal.

3 ACOUSTIC IMPACT ASSESSMENT

3.1 Method

Acoustic sources are prone to impact marine mammals when the values of SPL and SEL received by the marine mammals are above specific tolerance thresholds (depending on the signal type and frequency, and on MM species). In 2007 Southall et al. proposed series of such acoustic thresholds [1]. Table 1 presents the physiological harm thresholds for non-impulsive signals (corresponding to those produced by Sub-Bottom Profilers).

	AMPLITUDE THRESHOLD SPL_T	**EXPOSURE LEVEL THRESHOLD** SEL_T
Level A harassment: physiological harm risk thresholds	230 dB re. 1µPa	215 dB re. 1µPa²×s

Table 1: Physiological harm thresholds for non-impulsive signals (from Southall et al. 2007)

Recent research (NOAA [4], Finneran [5]) aims to propose new tolerance thresholds and frequency-weighting functions taking the auditory characteristics of marine mammal species into consideration with greater precision (with a dependence on frequency and MM species). To date, these new findings still have to be fully validated and accepted by regulators. Therefore, Southall [1] still remains for now our reference, pending general approval of a new set of threshold values.

3.2 Calculation of exclusion distances

Levels received in water depend firstly on the level emitted, and secondly on the characteristics of propagation in water [2] (losses due to absorption, divergence and possibly interface reflections). The distances corresponding to physiological risk thresholds are expected to be relatively small, so they can be determined sufficiently accurately by a simple spherical propagation model (the direct source-receiver trajectory delivers the predominant contribution of energy compared to trajectories reflected by interfaces). Discounting the effects of absorption at the low frequencies characteristic of such sources, the transmission loss TL (in dB) compared to a level recorded at the reference distance of 1 m may be expressed as follows [2]:

$$TL = 20\log R$$

where R is the oblique distance in m. In other words, the loss is equal to 20 dB at 10 m, and 80 dB at 10 km.

Conversely, the distance corresponding to a given loss TL may be calculated as:

$$R = 10^{TL/20}$$

Taking into account the transmission losses described above, the maximum received level SPL and the sound exposure level SEL for a given distance R from the source may be obtained by the following equation:

$$SPL(R) = SL(R_0) - TL(R)$$

$$SEL_N(R) = SEL_1(R_0) - TL(R) + 10\log_{10} N$$

where N is the number of shots experienced; this depends on the total duration for which an animal is present in the insonified area. Conventionally, Ifremer assumes in his risk assessment procedures [3] an exposure duration of 10 minutes at full power.

For Sub-bottom Profilers, the highest shooting rate is two shots every second. Consequently, the number of shots to consider for 10 minutes is N = 1200 and the cumulative SEL is computed as:

$$SEL_N(R_0) = SEL_1(R_0) + 10\log N = 202 + 10\log 1200 = 232.8\,\mathrm{dB}\,re\,1\mu\mathrm{Pa}^2.\mathrm{s}\,@1\mathrm{m}$$

These formulas can be used to estimate the distances beyond which the maximum received level and sound exposure levels do not exceed the risk thresholds:

$$SPL(R) \le SPL_T$$

$$SEL(R) \le SEL_T$$

The distances corresponding to the thresholds are then used to define an **exclusion zone** around the acoustic source. If marine mammals are observed within this zone, the acoustic source must be shut-down. According to Ifremer policy [3], mitigation procedures have to be applied systematically in the event of high-power seismic signals for which the received levels determined require exclusion distances in excess of 100 m; this is obviously not a realistic case for Sub-Bottom Profilers.

4 ANALYSIS

4.1 Physiological risks

Considering the maximum level transmitted by the Sub-Bottom Profiler (213 dB re 1 µPa@1m), the risk threshold SPL_T = 230 dB re 1µPa corresponds to a distance smaller than 1 m from the source. So the risk associated with maximal peak amplitude can be discarded.

The SEL predicted for one shot is equal to 202 dB re 1µPa²×s @1 m. Considering this level, the distance corresponding to the threshold SEL_T = 215 dB re 1µPa²×s is again smaller than 1 m. The increase of SEL for an exposure to 1200 shots (corresponding to an exposure time of 10 minutes when shooting twice per second) is equal to 10 log1200 = 31 dB, raising the cumulated SEL to 233 dB re 1µPa²×s at 1 m, hence 18 dB above the SEL_T threshold (215 dB); this 18-dB excess has to be compensated by a decrease of the received level due to propagation loss, corresponding to a safety distance of 8 m.

N.B. The conclusions would be similar for a SBP with a peak level of acoustic pressure of 228 dB re 1µPa @1m (Kongsberg SBP120): the SPL and SEL_1 criteria are unchanged; the SEL_N criterion imposes a safety distance around 45 m.

4.2 Behavioural risks

Researches into behavioural reactions to low-level sounds show that the tolerance limits for Level B harassment (impact on animal behaviour) are in all likelihood much lower [4] than physiological thresholds of Level A. In the absence of scientific research results conclusive enough to be usable today, no precise values can be put forward at this time. Protection of animals against level B disruption cannot therefore be today the subject of regulations based on quantifiable criteria. The Ifremer protocol is thus based on the use of objective thresholds defined only in terms of physiological risks. Note that the estimation of the safety distance, considering an exposure time of 10 minutes at full power inside the main radiation lobe of the acoustic source, is conservative.

5 CONCLUSION

According to the acoustic impact assessment, **the use of Sub-Bottom Profilers** in the above terms and conditions are therefore **not likely to cause direct physiological effects** on marine mammals. Given the marginal nature of this risk level, Ifremer considers that, according to its own code of conduct [3], geoscience surveys **should not require any particular measures of mitigation** related to the emissions by this particular acoustic source.

The responsibility is of course left to the relevant administrative authorities to decide whether the elements presented above (and which can be completed upon request) are consistent with any specific regulatory requirements of the coastal state concerned. Ifremer will obviously comply with all documented and quantitatively justified requirements presented by the coastal state.

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