Appendix 1. Details of sound measurements

Description of analyses

Filtering

The Naxys hydrophones had a frequency range from 5 Hz to 300 kHz according to the datasheet. For the hydrophone in the inner part of the bay, the signal to noise ratio for the airgun signals was very poor. This was mainly because of low frequency ambient noise with frequencies below 5 kHz. Even if this was outside the defined frequency range of the hydrophone it was still detected. Since the calibration for the hydrophone is not valid under 5 Hz, and since we get noise in this range a filter was applied. A band pass filter from 5-10000 Hz was used. The upper frequency of the band was set at a rather high value so it would not affect the steep rize time and the peak of the airgun pulses. The higher frequencies was regarded as unwanted since they cannot be heard by cod, and they do not originate from any of our sound treatments.

The filter used was a 6th-order Butterworth band pass filter from 5-10000 Hz.

Metrics

For the airgun pulses, each peak was detected by a function "findpeaks" in matlab. The minimum spacing between the detected peaks was set to 8 seconds since there was 10 seconds between each airgun pulse. Then a range around the detected peaks (3 seconds before, and two seconds after) was sent to analyses. The peaks that did not have this range around the them, if the peak was close to the end of the file, was disregarded. The rest of the peaks with 5 second interval around them was analysed further. For each of the selected 5 second interval, 1 second around the highest peak (0.3 sec before and 0.7 sec after peak) was used for further analysis. The ambient noise for a one second period selected 2 seconds before the peak was also analysed. The following metrics was estimated for the 1 second sequences for peak and for noise:

The same method was applied to the Boat control and the silent control where the findpeaks function found the highest peak in the ambient noise and 1 second around this was analysed. Also here an "ambient noise" test was made by selecting a 1 second long interval 2 seconds before the highest peak.

The metrics used for each of the 1 second long intervals where some included a seismic signal and other had only ambient noise or boat noise.

- Positive peak pressure: maximum peak found in the 1 second long sequence
- Negative peak pressure: minimum peak found in the 1 second long sequence
- The sound exposure which is a measure of the energy in the signal in linear domain. Ex=dt*sum(1sec_data.^2)
- The sound exposure level which is a measure of the energy in the signal in dB: 10log10(Ex/1e-12)
- In addition we also estimated the sound exposure level for the entire treatment by summing over 3 hours instead of one second. This should not be used to represent the total sound,

but can be used as a relative comparison between the treatments since we recorded only 22 of 30 seconds continuously.

For selected pulses frequency analyses was done. For each of the treatments the maximum and minimum peak was selected. In addition 1 second sequences closest to the position of cumulative energy of 25, 50 and 75 % of the total sound exposure level for the treatment was selected.

The 1 second signal sequence was then tapered by a tukey window to set the start and stop values of the signal sequence to zero. Then a fast Fourier transform was used to estimate the frequency spectrum of the signal. The energy spectral density was estimated as

ESD=((abs(P1)).^2)*df) (Energy spectral density, also called "frequency integrated sound exposure spectral density (ISO), where P1 fast Fourier transform of the pressure,

Results:

Here we show a set of figures for each of the hydrophone rigs placed in the inner and outer part of the bay close to the bottom and the vertical array placed in the middle of the bay. The positions of the different hydrophones can be seen in figure 5. For each hydrophone, figures showing the sound pressure (SP), peak pressure (PP) and sound exposure level (SPL) for the two years of exposure (2020 and 2021) are shown.

Inner bay hydrophone

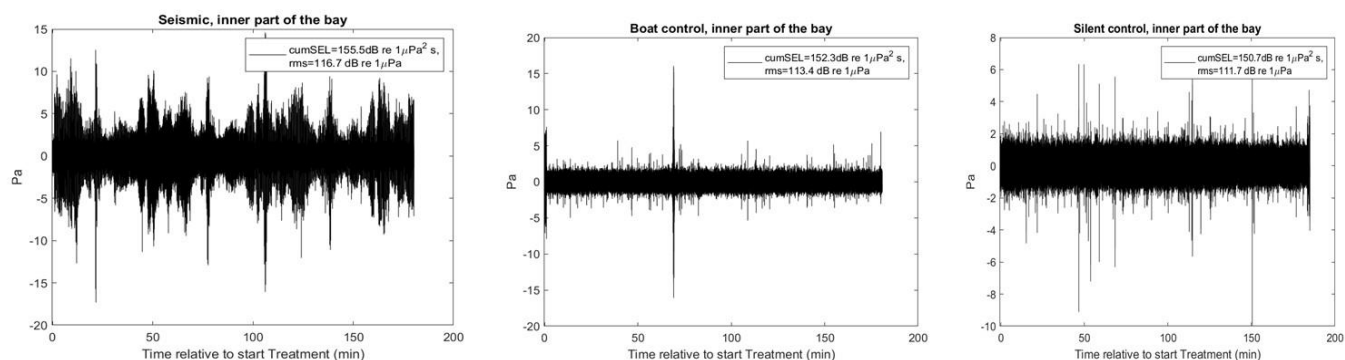Periods used in analyses are shown in table 12.

Figure A1. SP 2020. Sound pressure raw data for seismic, boat control and silent control, respectively for 2020. Notice the differences in y-axes for the three plots. Data are from Block 2.
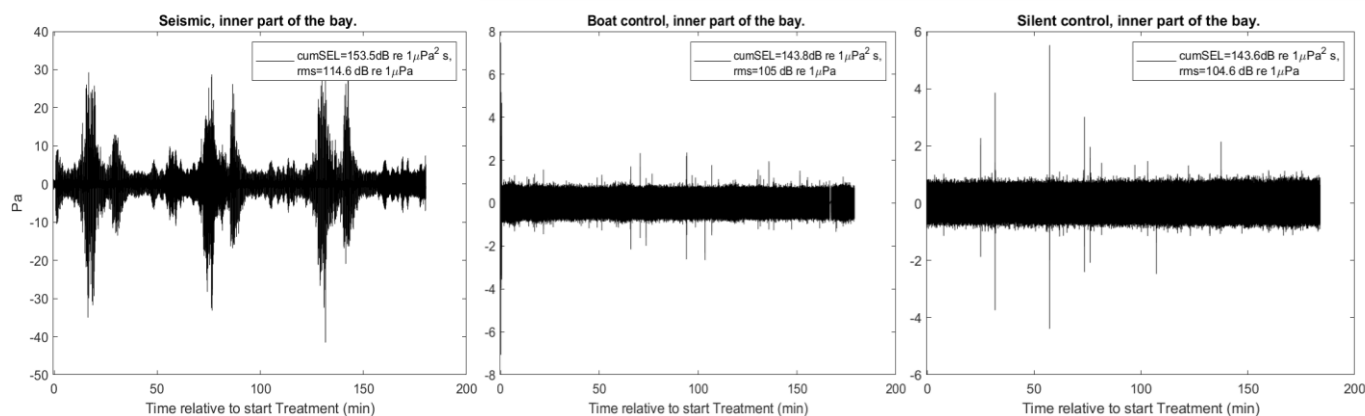

Figure A2. SP 2021. Sound pressure raw data for seismic, boat control and silent control, respectively for 2021. Notice the differences in y-axes for the three plots. Data are from Block 11.
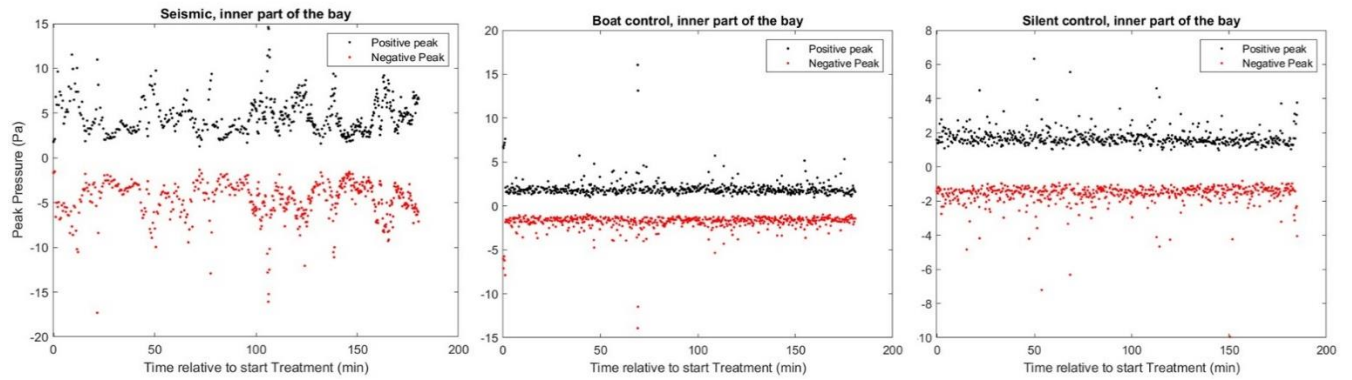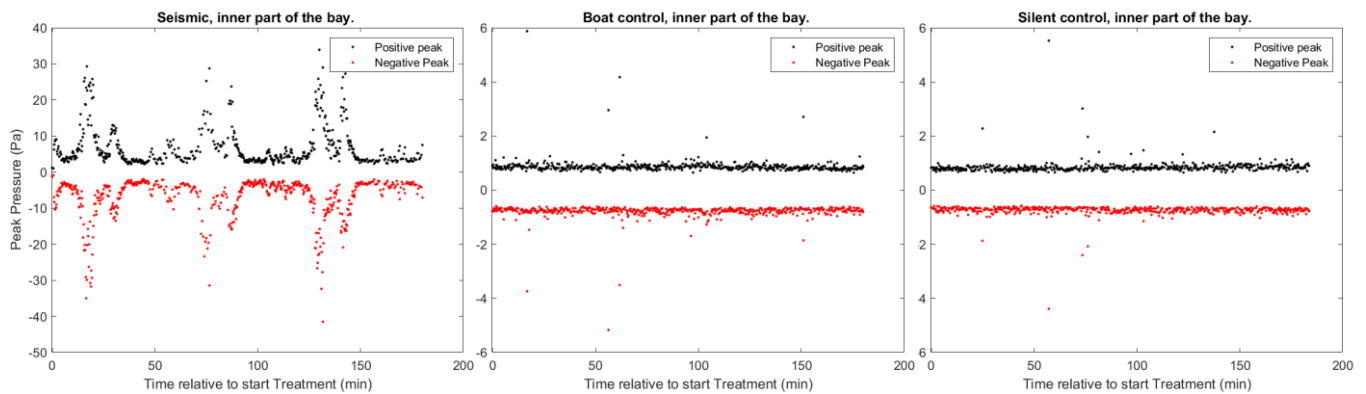
Figure A3. PP 2020. Positive and negative peak pressure for seismic, boat control and silent control, respectively for 2020. Notice the differences in y-axes for the three plots. The data are from block 2.

Figure A4. PP 2021. Positive and negative peak pressure for seismic, boat control and silent control, respectively for 2021. Notice the differences in y-axes for the three plots. The data are from block 11.
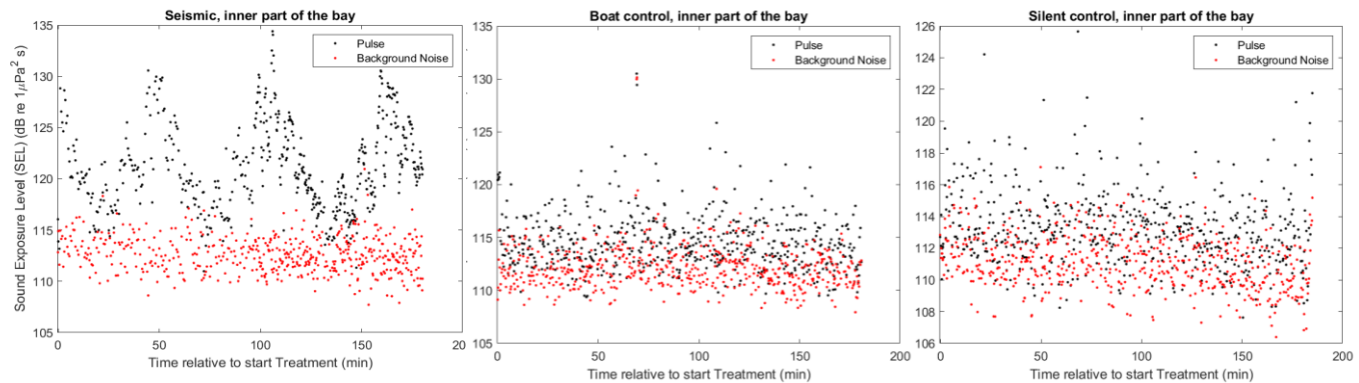

Figure A5. SEL 2020. Sound exposure level of several pulses during treatments seismic, boat control and silent control, respectively, for 2020. All the seismic pulses are not included because only 22 of 30 seconds was recorded. Pulses in the centre of the recording was selected. For the treatments boat and silent controls, both black and red dots represent noise. The black is 1 second around the highest peak every 8th second. The red is around one second taken 2 seconds before the black. Notice the differences in y-axes for the three plots. The data are from block 2.
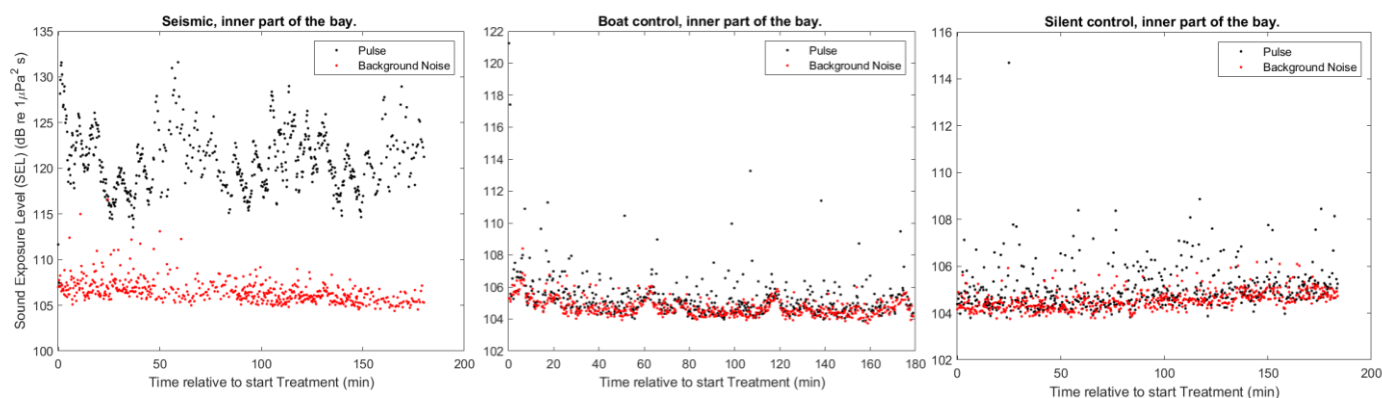
Figure A6. SEL 2021. Sound exposure level of several pulses during treatements seimic, boat control and silent control, respectively, for 2021. All the seismic pulses are not included because only 22 of 30 seconds was recorded. Pulses in the centre of the recording was selected. For the treatments boat and silent controls, both black and red dots represent noise. The black is 1 second around the highest peak every 8th second. The red is around one second taken 2 seconds before the black. Notice the differences in y-axes for the three plots. The data are from block 11.

Outer Bay Hydrophone

Periods used in analyses are shown in table 12. Some examples are shown in the figures below. For 2020, only the treatment "seismic" has been analysed, as the hydrophone failed after a few hours.
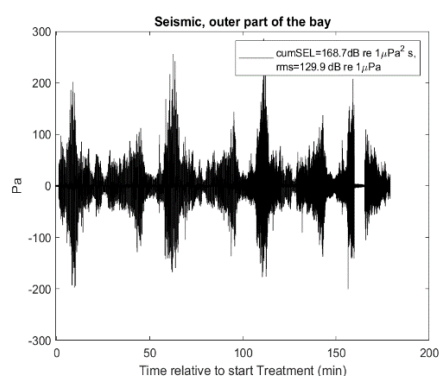

Figure A7. SP 2020. Sound pressure raw data for seismic for 2020. No data are available for boat- and silent control. Notice the differences in y-axes for the three plots. Data are from Block 1.
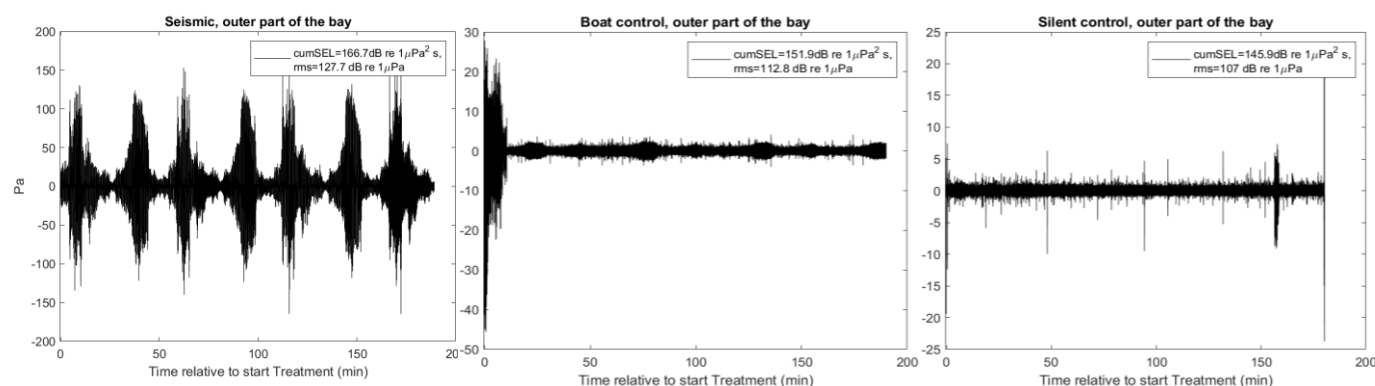

Figure A8. SP 2021. Sound pressure raw data for seismic, boat control and silent control, respectively for 2021. Notice the differences in y-axes for the three plots. Data are from Block 16.
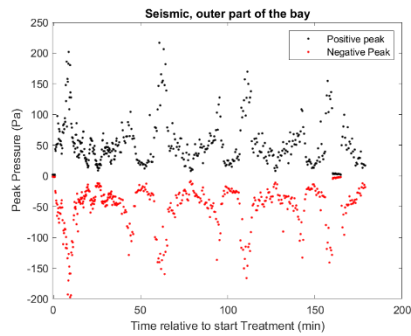
Figure A9. PP 2020. Positive and negative peak pressure for seismic for 2020. No data are available for boat- and silent control. Notice the differences in y-axes for the three plots. The data are from block 1.
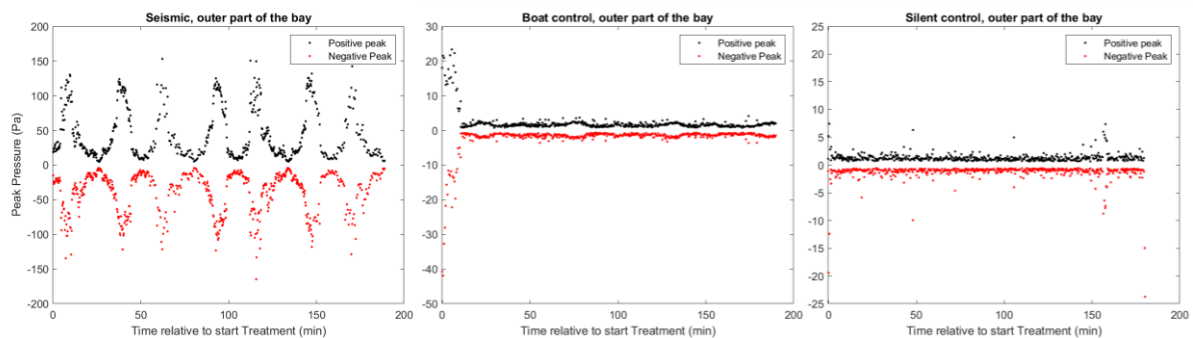

Figure A10. PP 2021. Positive and negative peak pressure for seismic, boat control and silent, respectively, for 2021. Notice the differences in y-axes for the three plots. The data are from block 16.
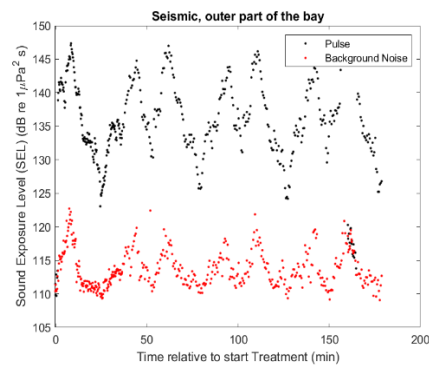

Figure A11. SEL 2020. Sound exposure level of several pulses during treatment seismic for 2020. No data are available for boat- and silent control. All the seismic pulses are not included because only 22 of 30 seconds was recorded. Pulses in the centre of the recording was selected. For the treatments boat and silent controls, both black and red dots represent noise. The black is 1 second around the highest peak every 8th second. The red is around one second taken 2 seconds before the black. Notice the differences in y-axes for the three plots. The data are from block 1.
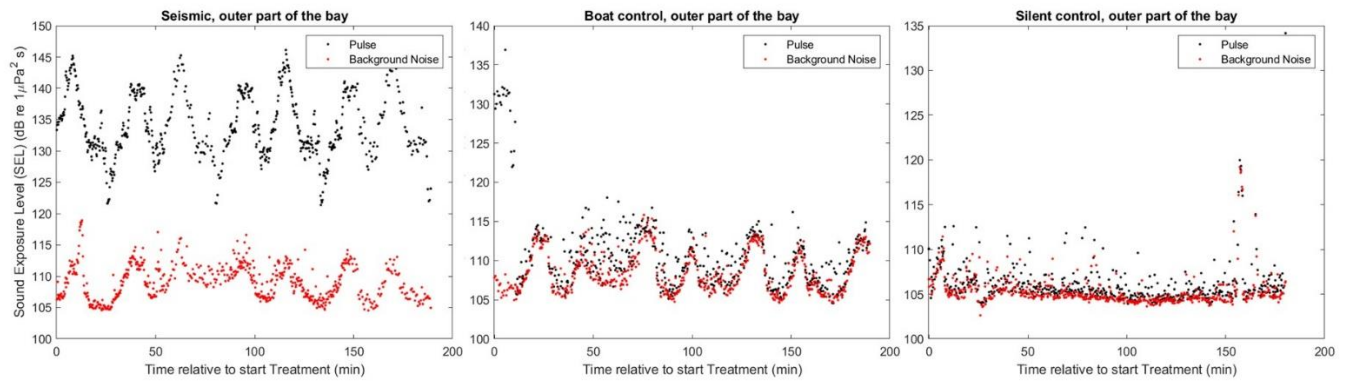
Figure A12. SEL 2021. Sound exposure level of several pulses during treatments seismic, boat- and silent control for 2021. All the seismic pulses are not included because only 22 of 30 seconds was recorded. Pulses in the centre of the recording was selected. For the treatments boat and silent controls, both black and red dots represent noise. The black is 1 second around the highest peak every 8th second. The red is around one second taken 2 seconds before the black. Notice the differences in y-axes for the three plots. The data are from block 16.

Vertical array, centre part of the bay

The vertical array was quite unstable, and the time series hence have gaps of missing data of various length.
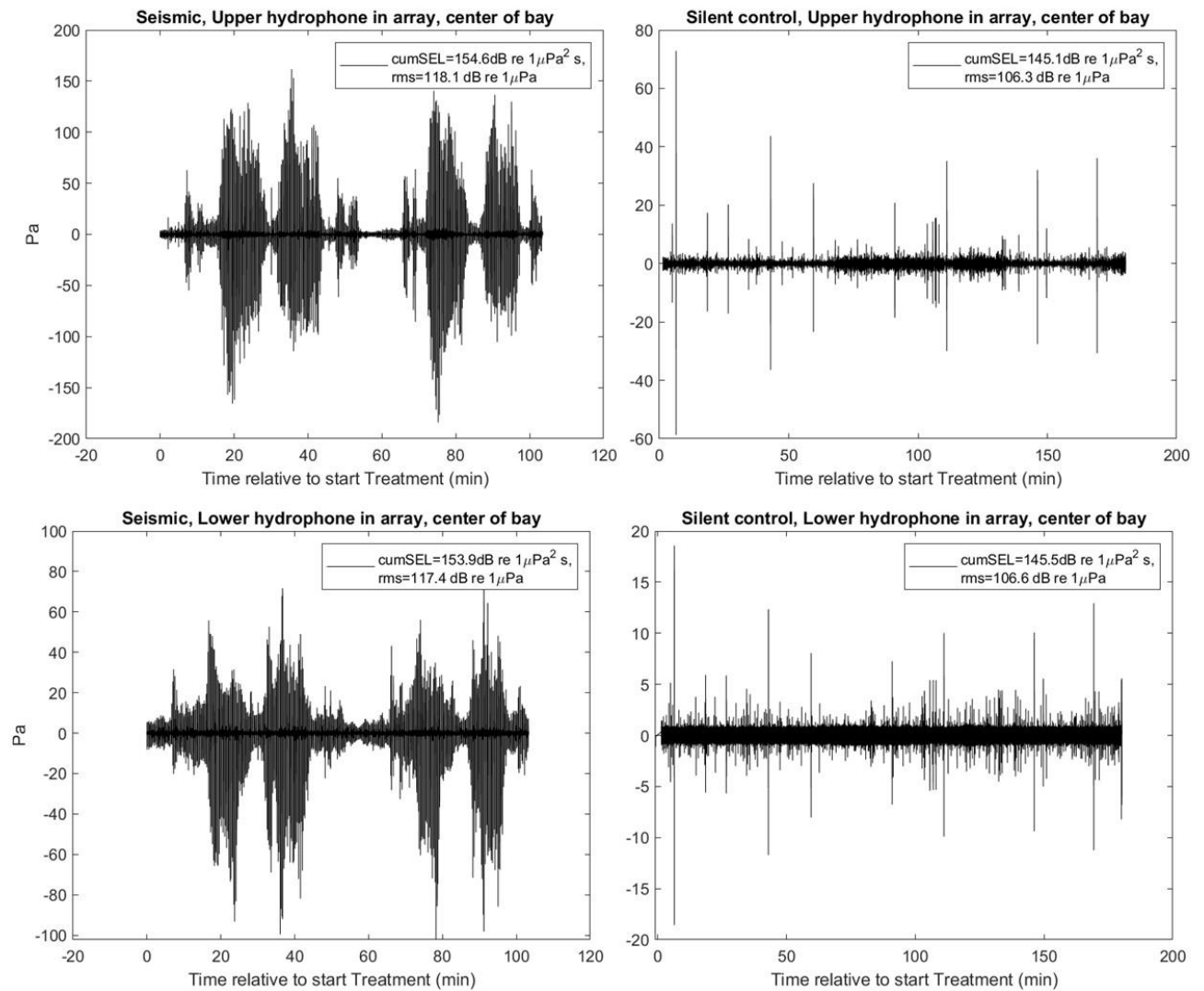
A13. SP 2020. Sound pressure raw data for seismic for 2020 for upper and lower hydrophone for treatments seismic and silent controls. No data are available for boat control. Notice the differences in y-axes for the three plots. Data are from Block 6.
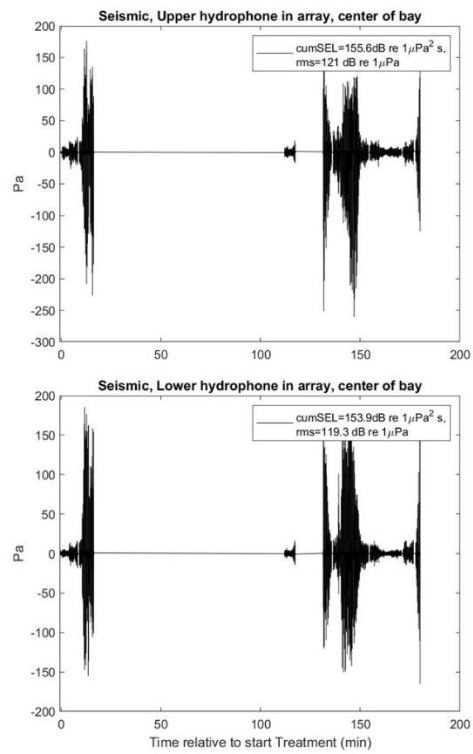
Figure A14. SP 2021. Sound pressure raw data for seismic for 2020 for upper and lower hydrophone for treatment seismic. No data are available for boat- and silent control. Data for the seismic recording are also sometimes missing, as are seen as a straight line in the figure. Notice the differences in y-axes for the three plots. Data are from Block 11.
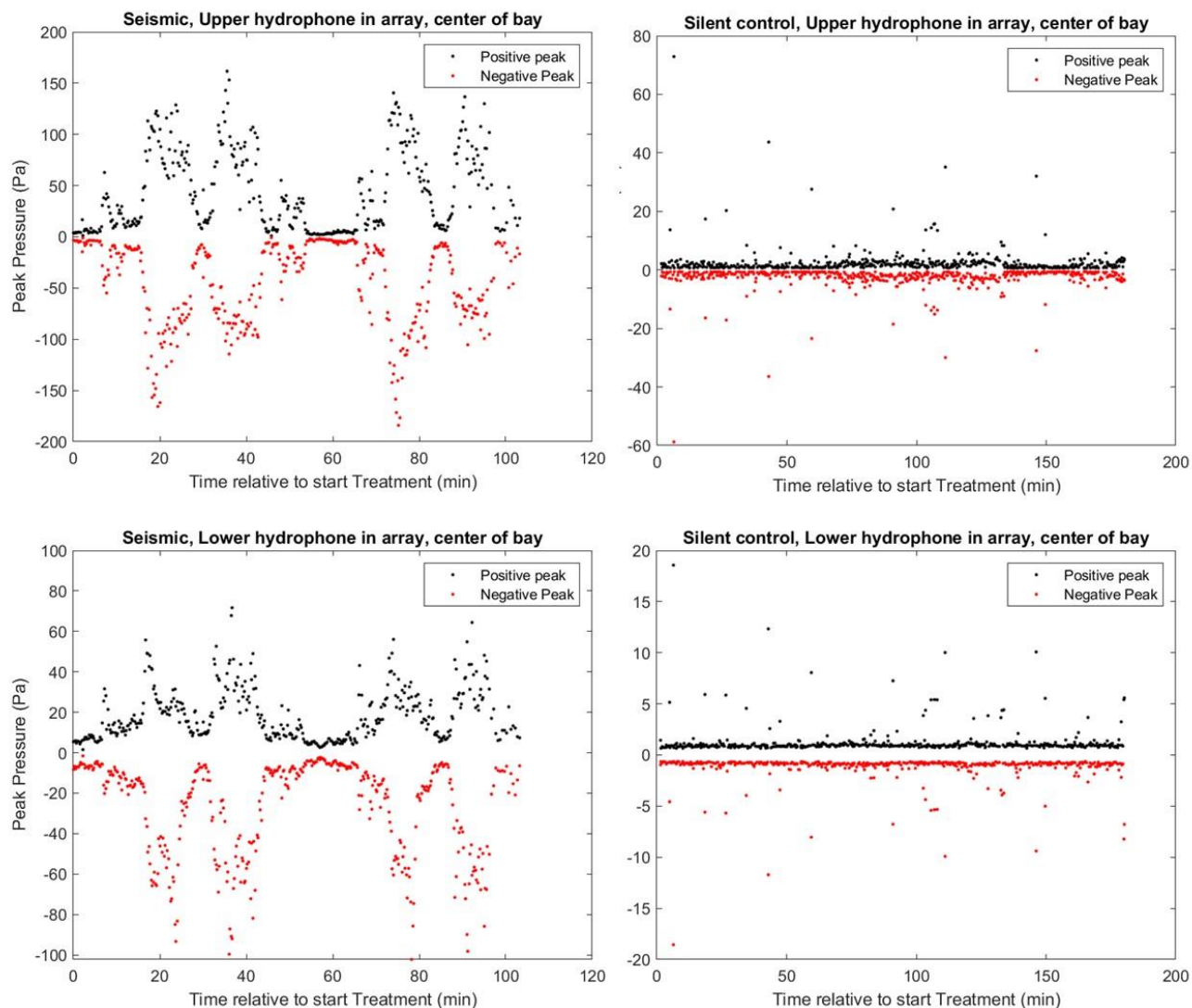
Figure A15. PP 2020. Positive and negative peak pressure for seismic and silent control for 2020. Data for boat control are missing. Notice the differences in y-axes for the three plots. The data are from block 6.
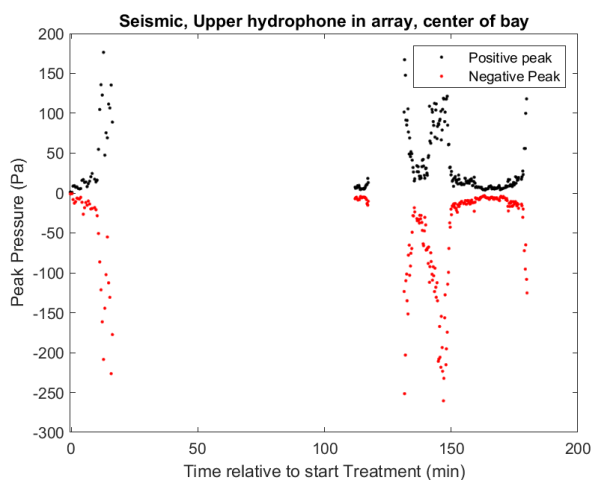

Figure A16. PP 2021. Positive and negative peak pressure for seismic recorded at the upper hydrophone for 2021. Data for boat and silent control, as well as for the seismic at the lower hydrophone are missing. There are also missing data points within the recording of the seismic, as can be seen in the figure. Notice the differences in y-axes for the three plots. The data are from block 11.
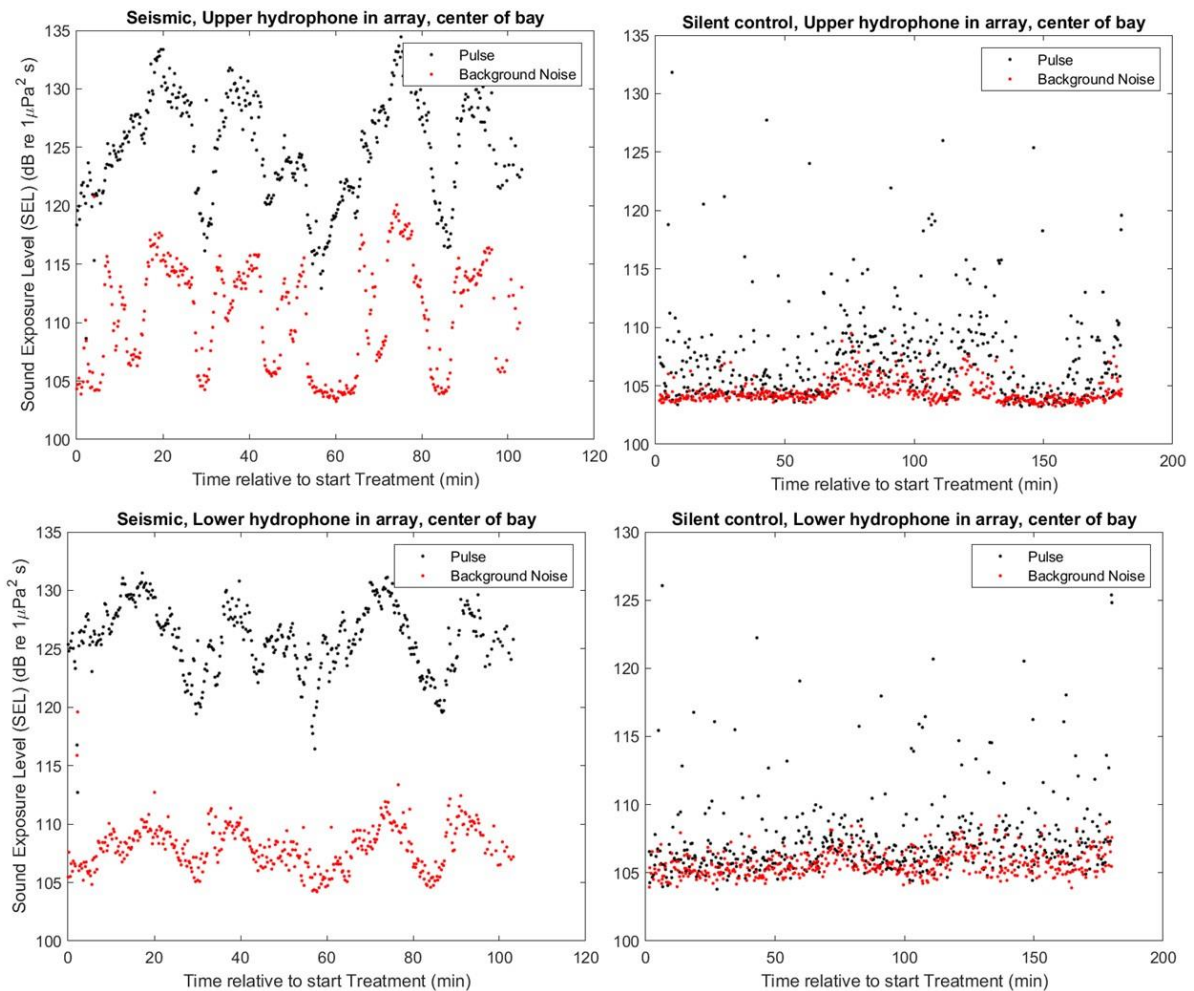
Figure A17. SEL 2020. Sound exposure level of several pulses during treatments seismic and silent control for 2020. Data for boat control are missing. All the seismic pulses are not included because only 22 of 30 seconds was recorded. Pulses in the centre of the recording was selected. For the treatments boat and silent controls, both black and red dots represent noise. The black is 1 second around the highest peak every 8th second. The red is around one second taken 2 seconds before the black. Notice the differences in y-axes for the three plots. The data are from block 6.
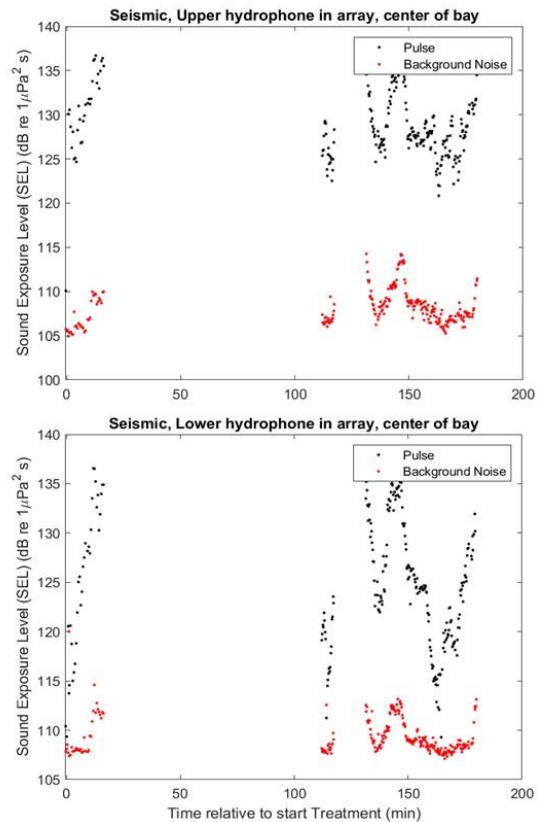
Figure A19. SEL 2021. Sound exposure level of several pulses during treatments seismic for 2021. Data for boat- and silent control are missing. All the seismic pulses are not included because only 22 of 30 seconds was recorded. Pulses in the centre of the recording was selected. For the treatments boat and silent controls, both black and red dots represent noise. The black is 1 second around the highest peak every 8th second. The red is around one second taken 2 seconds before the black. Notice the differences in y-axes for the three plots. The data are from block 11.