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VIA EMAIL ONLY
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October 13, 2020

James Kendall
Bureau of Ocean Energy Management
Alaska Region
3801 Centerpoint Drive, Suite 500
Anchorage, AK 99503,

RE: SCOPING COMMENTS ON COOK INLET LEASE SALE 258

Dear Dr. Kendall:

In the press releasing announcing this lease sale and comment period, you state:

"We look forward to receiving thoughtful, substantial input. We especially need to hear from residents of the communities along Cook Inlet as to how the proposed leasing area is currently being used and what specific areas need extra attention. This kind of substantive input helps us ensure that we do the required environmental analysis in a careful, rigorous way."

Yet Inletkeeper has previously asked BOEM and its predecessor to conduct research on toxic industry dumping, pipeline spills and leaks, endangered beluga whales and seismic blasting impacts in Cook Inlet, to no avail. In fact, the federal government has failed to conduct any semblance of comprehensive reviews in Cook Inlet and the Gulf of Alaska since the Outer Continental Shelf Environmental Assessment Program (OCSEAP) in the 1980's.

Since that time, the socioeconomic and environmental conditions in our region have changed dramatically. For example, Lower Cook Inlet has experienced considerable regime change as our air and waters have warmed since the 1980's, shifting from considerable shellfish biomass to a larger finfish presence. Additionally, for the first time ever, federal fisheries managers closed the Pacific cod fishery in the Gulf of Alaska last year due to warming waters and climate change. Yet BOEM continues to whistle past the graveyard in its single-minded pursuit to produce more fossil fuels.

Furthermore, similar to the last lease sale in Cook Inlet – when BOEM gave Homer residents three-hour notice for a public hearing - BOEM has again flubbed the public comment process. In this instance, BOEM required concerned Alaskans to search-out and use the obtuse commenting process found at www.regulations.gov because BOEM directed the public to a broken internet link for its more-accessible public comment site - and refused to extend the public comment period when alerted to the defect.

BOEM's refusal to provide additional time for Alaskans and others to comment, and its refusal to conduct even the basic research needed to understand the complex ecology of Lower Cook Inlet and the threats posed to it from oil and gas exploration and development, indicate BOEM is simply "checking the boxes" for this sale, and does not truly seek to obtain information from anyone affected by its decisions.

Attached find a preliminary report on acoustic monitoring conducted in conjunction with Hilcorp's seismic blasting work in Lower Cook Inlet in Fall 2019. Aside from the substantive results of the research – which BOEM must consider - an important conclusion focuses on the fact BOEM has done nothing to understand or address the acoustic footprint from oil and gas exploration in this region. Most notably, BOEM has failed to compile even rudimentary information on baseline conditions for fish, cetaceans and shellfish impacted or potentially impacted by high intensity seismic air gun deployment. This oversight is but one example of BOEM's head-in-the-sand approach to leasing our federal lands and waters.

But the fact remains, continued fossil fuel development – in the face of everything we now know about global warming – is a fool's errand. Congress passed the Outer Continental Shelf Lands Act (OCSLA) in 1953, the year our nation executed Julius and Ethel Rosenberg. While the physics around climate change had been recognized since the early 1800's, Congress had relatively little information on which to act when it first passed laws governing the outer continental shelf. The law has been amended several times since then, most recently in 2005, when the adverse effects of climate change became distressingly clear, and when Congress laid the groundwork for BOEM to pursue renewable energy leasing and development in federal waters.

Yet despite the mountains of peer-reviewed science showing the devastating consequences of climate change on our marine systems and to all life on earth, BOEM and its employees have stood flat-footed, refusing to conduct basic research on oil and gas impacts to our biosphere and ignoring its obligations to pursue cleaner energy alternatives. Instead, BOEM simply puts its head down and pushes ahead under a statutory construct that is inherently amoral and which hastens the demise of the very systems that support life on earth.

As you and other BOEM employees work through yet another fossil fuel lease sale in Lower Cook Inlet, I hope you carry with you the prescient and courageous words of Dr. Martin Luther King:

"One has not only a legal, but a moral responsibility to obey just laws. Conversely, one has a moral responsibility to disobey unjust laws."

Yours for Cook Inlet,

Bob Shavelson
Inletkeeper

Enc. Passive Acoustic Monitoring of Cetaceans & Noise During Hilcorp 3D Seismic Survey in Lower Cook Inlet, Alaska. Preliminary Final Report, October 2020.

PASSIVE ACOUSTIC MONITORING OF CETACEANS & NOISE DURING HILCORP 3D SEISMIC SURVEY IN LOWER COOK INLET, AK

Final report – October 2020

Manuel Castellote[1], Michael Stocker[2] and Arial Brewer[1]

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Abstract

A 3D seismic survey was acoustically monitored in September and October 2019 in lower Cook Inlet, AK. The area is a highly productive, biologically rich, but little monitored marine mammal habitat. Last dedicated surveys were completed in the 1980's. This seismic survey was an opportunity to monitor cetacean presence with passive acoustic methods, beyond the areas monitored by vessel-based protected species observers, and complementing the aerial survey effort related to the survey. This study aimed to document cetacean species diversity, disturbance of the acoustic environment generated by the seismic survey, and potential for spatial displacement of detected cetacean species. Sampling effort lasted 69 days and covered 4 locations, Chinitna Bay, Iniskin Bay, Port Graham, and the survey area in the central part of the lower Inlet. Each seismic acquisition line period elevated the 1-minute average SPL (20 Hz – 12 kHz) up to 30 dB above background, and affected frequencies up to 1200 Hz. Median SPL yielded 84.4 dB for the post-survey period, the lowest background noise levels reported for all Cook Inlet. Six cetacean species were identified. Porpoises dominated the acoustic detections, followed by fin whales, killer whales, humpback whales, white-sided Pacific dolphins, and beluga whales. A wide-scale spatial displacement was documented for porpoises and humpback whales, with detections reduced or absent during the seismic survey period, and highly significant increases in presence after the survey ended. Fin whales significantly increased their vocal activity during the survey, likely to reduce masking effects. Killer whales increased their presence in embayments during the survey, as a possible protection from elevated levels of seismic noise. Beluga whales were detected briefly at Port Graham, the southernmost detection for their range on the west side of lower Cook Inlet. Pacific white-sided dolphins were briefly detected at Iniskin Bay and near the survey zone. This study provides several important conclusions related to this research framework. There is an urgent need for proper coordination between industry and research. This will help mitigate the total lack of baseline data on seasonal occurrence of cetaceans in an area of high interest for industry. The need for an expanded framework when considering disturbance effects is reflected in these results. A more robust means of assessing and mitigating acoustic impacts related to spatial displacement or auditory masking should be considered a conservation management priority.

INDEX

Citation: Castellote M, Stocker M, Brewer A. 2020. Passive acoustic monitoring of cetaceans & noise during Hilcorp 3D seismic survey in Lower Cook Inlet, AK. Final report – October 2020. Submitted to Hilcorp, BOEM, and NMFS. 23 p.

1. Background

In June 2017, Hilcorp acquired 14 Outer Continental Shelf (OCS) blocks from BOEM Lease Sale 244. A 3D seismic survey was planned in September and October 2019 for an area comprising 42 OCS blocks, including eight of Hilcorp's 14 leased blocks, covering approx. 969 km^2 (Fig. 1).

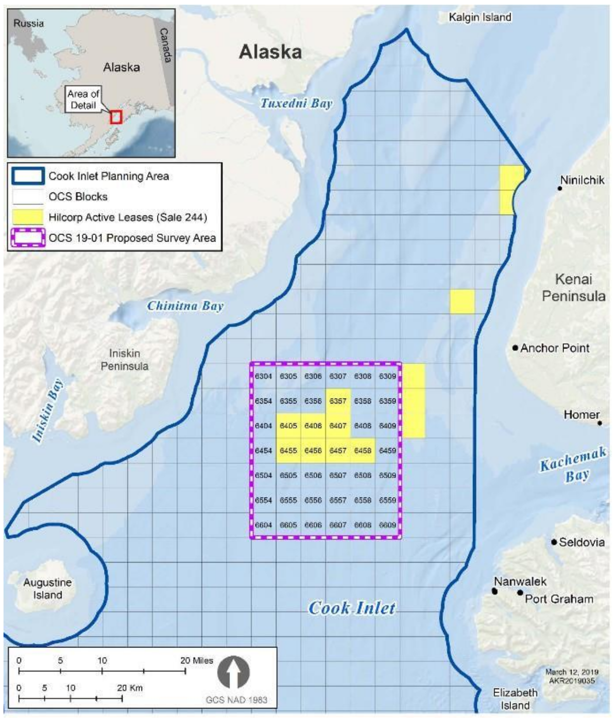

Figure 1: Hilcorp's survey area (pink) and BOEM lease 244 (blue) in lower Cook Inlet.

This offshore area of Cook Inlet has not been monitored for marine mammal presence for the last ~40 years, as most current effort is focused on coastal zones for the endangered Cook Inlet beluga (Shelden *et al*. 2015). Only old surveys have covered this area, during the mid- to late 1970's (Harrison and Hall, 1978) and early 1980's (Leatherwood *et al*. 1983). This seismic survey was an opportunity to monitor cetacean presence with passive acoustic methods, beyond the areas monitored by vessel-based PSOs, and complementing the aerial survey effort related to the survey. Knowing this region is an important cetacean habitat (Ferguson *et al*. 2015, Muto *et al*. 2018), and very little work has been done to document cetacean seasonal occurrence, this study aimed to document species diversity, disturbance of the acoustic environment generated by the 3D seismic survey, and potential for spatial displacement by the acoustic disturbance.

2. Methods

2.1 Data sampling

Four passive acoustic moorings developed for Cook Inlet research (Lammers *et al*. 2013, Castellote *et al*. 2016) were deployed on September 13th 2019 around the survey area (Fig. 2) for a duration of 69 days. One mooring was placed at the southwest corner of the survey area, as a reference for near-distance disturbed area. The selection of this location was based on water current speeds, depth, previous knowledge on marine mammal presence, and safety for the seismic survey operation. Two moorings were deployed on the west side of Cook Inlet, one at the mouth of Chinitna Bay and one at the mouth of Iniskin Bay, and the fourth mooring was deployed at the entrance of Port Graham, south of Kachemak Bay. These locations are known to be important habitat for several cetacean species and represent far-range areas of disturbance (37.4 km from nearest border of survey area for Iniskin, 8.5 km for Chinitna, and 20.5 km for Port Graham).

The acoustic moorings contain a calibrated sound recorder (DSG-ST, Loggerhead Instruments) sampling at 24 kHz on a continuous mode, an echolocation logger (C-POD, Chelonia Limited) sampling the frequency range 20-160 kHz on a continuous mode, a temperature and pressure sensor (Hobo, Onset Corp.) sampling every 5 minutes, and an acoustical release (PORT-LF Edgetech) connecting the submerged mooring package to its anchor line. Instruments stay 5 feet from the seafloor, and were deployed at 99 feet depth (in reference to MLLW level) for southwest corner, 61 feet at Chinitna Bay, 61 feet at Iniskin Bay, and 100 feet for Port Graham. Moorings were recovered on November 19th and 20th 2019.

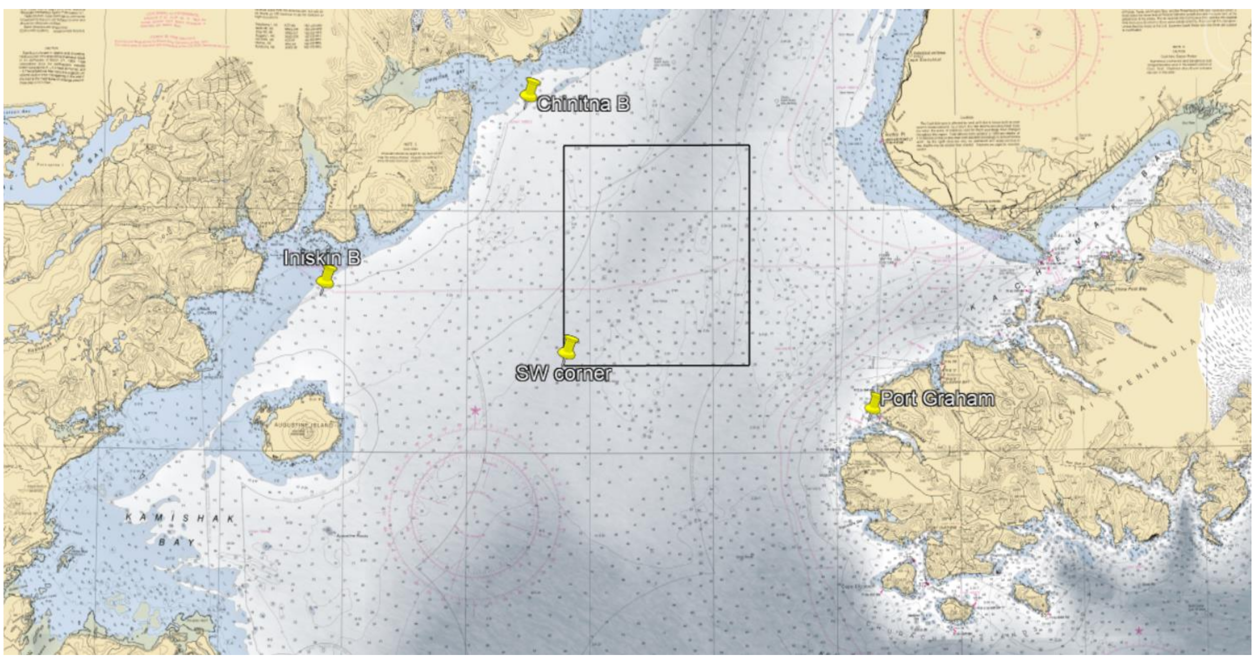

Figure 1: NOAA chart #16640 showing the seismic survey area limits in black, and the mooring locations in yellow pins.

2.2 Analysis of cetacean signals

Sound recordings were processed with PAMguard v2.01.03 using a whistle and moan detector, a spectrogram correlation detector, and an energy sum detector to find odontocete whistles and calls, as well as mysticete low frequency moans and downsweeps. The whistle and moan detector has been successfully used in Cook Inlet data for detecting signals from killer whales (*Orcinus orca*), Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), beluga (*Delphinapterus leucas*), and humpback whales (*Megaptera novaeangliae*). The spectrogram correlation detector was set up to look for fin whale (*Balaenoptera physalus*) 20 Hz notes, and the energy sum detector for minke whale (*Balaenoptera acutorostrata*) boings tuned for signals recorded in Chukchi Sea. The whistle and moan detector was run in all four datasets, but the spectrogram correlation detector, and an energy sum detector, aimed to identify fin whale and minke whale signals, were run only in the SW-Corner dataset, as it is not expected to find these species in the shallower near shore locations of the other three deployments. C-POD data from all moorings was processed with C-POD.exe version 2.044 for echolocation signals from any odontocete.

All detectors were run on data preprocessed by a seismic veto module to avoid airgun signals interfering with the detectors.

Presence and absence results were summarized as detection positive minutes (DPM), that is any minute with at least an acoustic detection. A t-student test was used to assess differences in results for the conditions of seismic survey and post-survey for DPM per day for each species. Datasets were tested for normal distribution and homogeneity of variance.

2.3 Analysis of seismic survey noise

Data from the SW Corner location was processed with Acoustic Ecology Toolbox (Dugan *et al*. 2011) in Matlab. Calibrated data was processed on a 1 Hz and 1 minute resolution for the frequency range 20 Hz to 12 kHz. Analysis was applied to two periods, the seismic survey, starting on 9/14/2019 at 9am when *Polarcus Alima* (the contract survey vessel) started to collect the 1st acquisition line, and ending on 10/17/2019 at 3 am when last airgun shot was detected (34 days, 816 hours), and the post-survey period starting on 10/17/2019 at 4am and ending on 11/20/2019 at 5pm (35 days, 840 hours), 1 hour before our vessel approached the mooring site for its recovery. Both periods were processed to obtain SPL values (in RMS dB re 1µPa) per minute, median SPL values over the entire survey and post-survey periods, and survey excess levels over the post-survey period. Results are presented graphically.

3. Results

Sound recordings and echolocation scanning results were obtained from the 4 sites from September 13th until November 21st 2019, covering the entire seismic acquisition period that ended on October 17th 2019, and the 34 following days after the acquisition period. Sampling the period prior to the seismic acquisition (including September 10th and 11th when a sound source verification was completed) was not possible due to the short period of time available to organize this study.

Detections were obtained for unidentified porpoises, likely harbor and Dall's porpoise (*Phocoena phocoena* and *Phocoenoides dalli*), Pacific white-sided dolphin, killer whale, beluga, fin whale, and humpback whale (table I). The minke whale detector did not yield any detection.

Table I: Total number of detection positive minutes (DPM) for all species and locations monitored.

	Detection positive minutes						
Location	**Porpoise**	**Pacific white-sided dolphin**	**Beluga**	**Killer whale**	**Humpback whale**	**Fin whale**	**Minke whale**
Iniskin	1111	6	0	120	553	-	-
Chinitna	3212	0	0	161	661	-	-
SW Corner	2616	51	0	680	144	8383	0
Port Graham	2616	0	5	997	100	-	-

3.1 Porpoise results

Overall, the larger number of acoustic detections was for porpoise echolocation (Fig. 2). Discrimination between Dall's and harbor porpoise echolocation has not been attempted yet, but PSO observations during the seismic survey suggest most of the detections in this study might be for Dall's porpoises. Classification of Dall's and harbor porpoise echolocation will be completed at a later stage, using click frequency peak energy as criterion following Kyhn *et al*. (2013).

Temporal distribution of acoustic detections for each species and location is presented as detection positive minutes (DPM) per day in Fig. 3. Results show significant differences in occurrence between the 'during survey' and 'post survey' periods. Porpoises are detected at all 4 locations, Chinitna yielded the highest amount of time with detections (3212 DPMs), followed by an unexpected tie between SW Corner and Port Graham (both with 2616 DPMs), and Iniskin (1111 DPMs). Porpoise occurrence in Chinitna, SW Corner, and Port Graham showed a very similar trend, with very low detections or absence of detections during the seismic survey period and a highly significant increase in detections 3 or 4 days after the seismic survey is over, however, Iniskin Bay did not show significant differences in detections during and after the seismic survey (Fig 4).

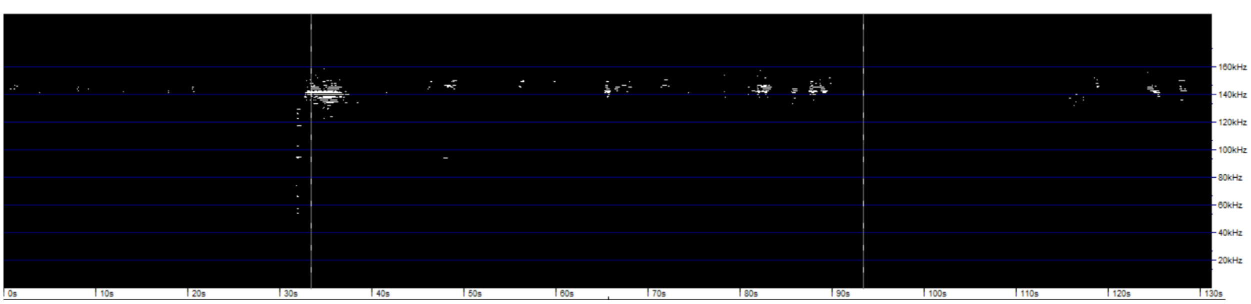

Figure 2: A sequence of 130 seconds of C-POD data with 532 porpoise echolocation clicks (white dots) from Iniskin on 9/16/19 at 3:52 am AK local. Y axis in panel corresponds to peak frequency, note all white dots are centered around 140 kHz.

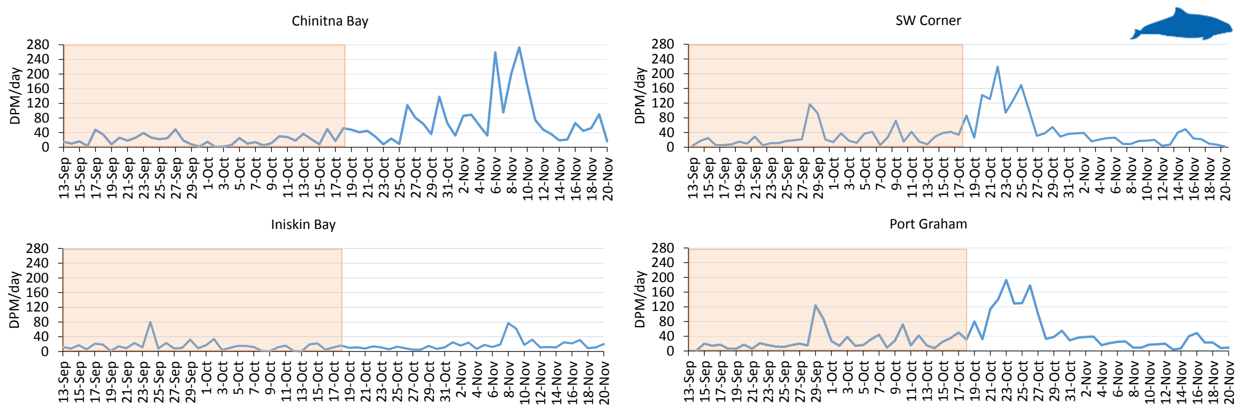

Figure 3: Temporal distribution of porpoise acoustic detections in DPM per day for each location. Orange block denotes the seismic survey period.

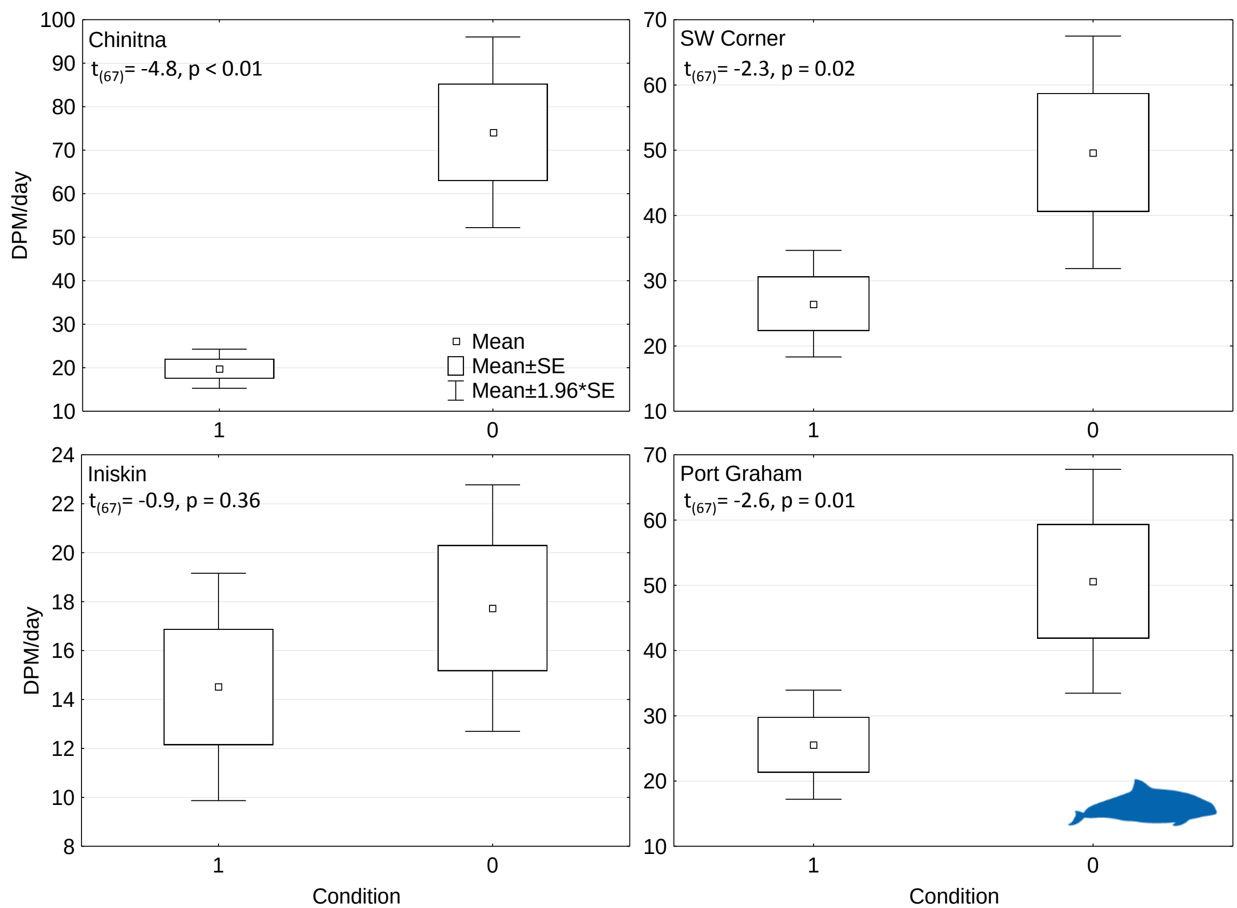

Figure 4: Box-whisker plots showing the distribution of porpoise DPM per day as mean and standard error, for the two conditions, during the seismic survey (1 in panels), and post survey (0 in panels). Statistical results are included in each panel.

3.2 Humpback whale results

Humpback whale acoustic detections were almost exclusively composed of downweep moans (Fig. 5). Similar to the porpoise results, humpback whale detection results show significant differences in occurrence between the 'during survey' and 'post survey' periods, with an increase in detections soon after the seismic survey ended for two of the 4 locations sampled: Chinitna Bay and Iniskin Bay (Fig. 6 and 7). These two locations yielded the highest amount of detection time with 661 DPMs for Chinitna, and 553 DPMs for Iniskin. Humpback whales were detected a small amount of time in both the SW Corner (144 DPMs) and Port Graham (100 DPMs) locations.

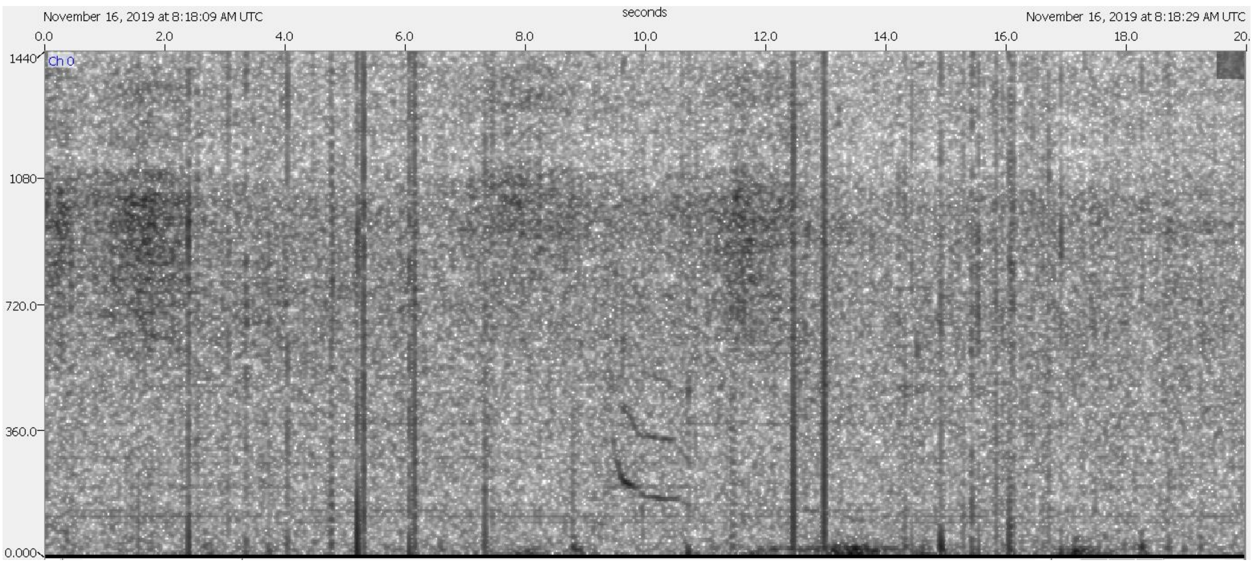

Figure 5: Spectrogram showing 20 seconds of data and 0-1440 Hz from 11/17/19 at 2:09 am AK local time with a humpback whale moan at second 10 between 170 and 500 Hz.

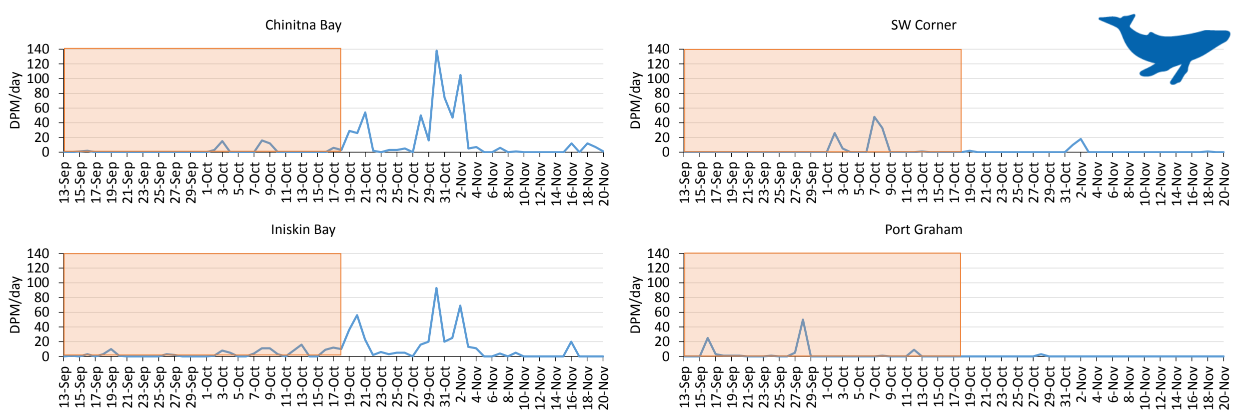

Figure 6: Temporal distribution of humpback whale acoustic detections in DPM per day for each location. Orange block denotes the seismic survey period.

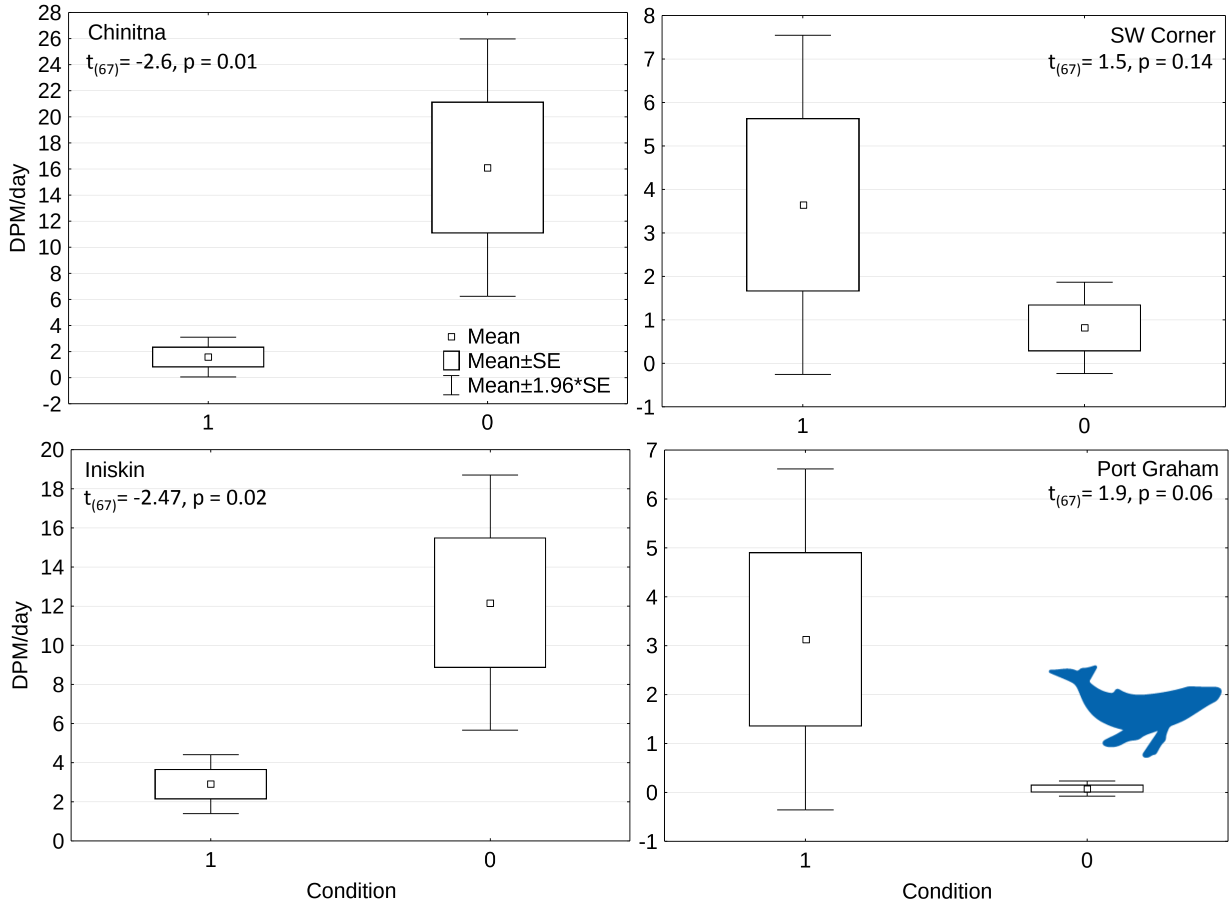

Figure 7: Box-whisker plots showing the distribution of humpback whale DPM per day as mean and standard error, for the two conditions, during the seismic survey (1 in panels), and post survey (0 in panels). Statistical results are included in each panel.

3.3 Killer whale results

Killer whale acoustic detections included echolocation, calls, and whistles (Fig. 8). Contrary to the previous results for porpoises and humpback whales, killer whale detections show an opposite pattern of occurrence between the 'during survey' and 'post survey' periods for two locations: a significant increase in detections during the survey period for Chinitna and a very significant increase for Port Graham, but no significant differences are found for SW Corner or Iniskin (Fig. 9 and 10). Killer whale acoustic detection time was highest at Port Graham (997 DPMs), followed by SW Corner (680 DPMs), Chinitna (161 DPMs), and Iniskin (120 DPMs).

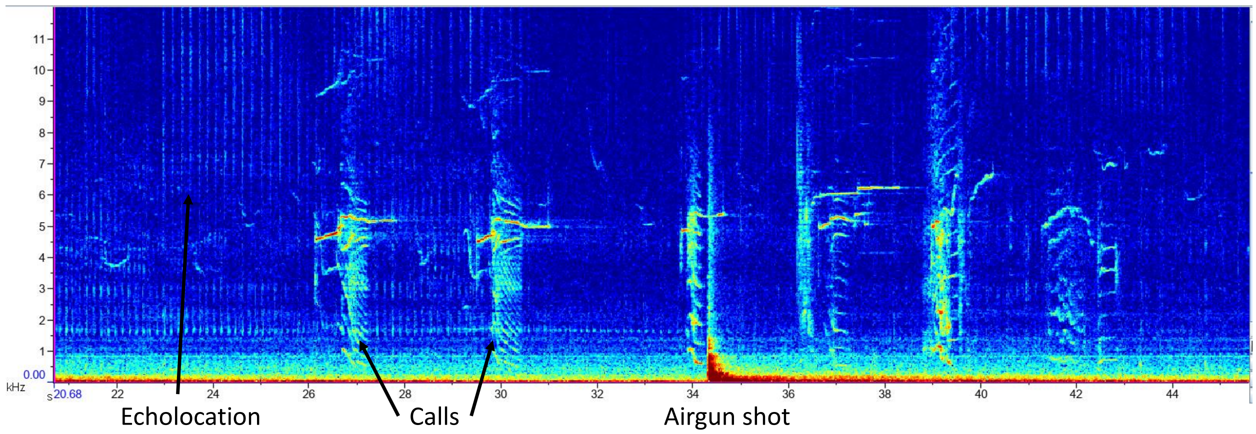

Figure 8: Spectrogram showing 25 seconds of data ~~and~~ at 0-12 kHz from 9/30/19 at 8:55 AK local with killer whale calls and echolocation.

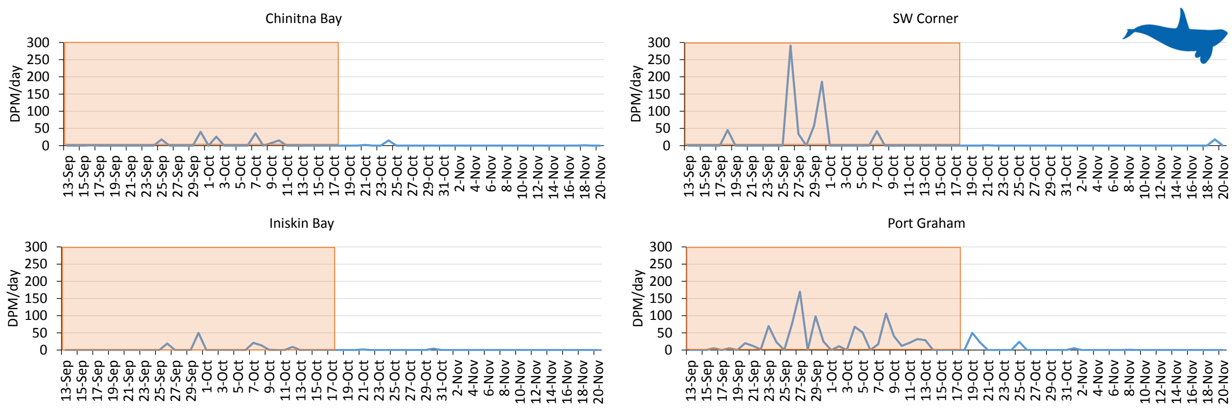

Figure 9: Temporal distribution of killer whale acoustic detections in DPM per day for each location. Orange block denotes the seismic survey period.

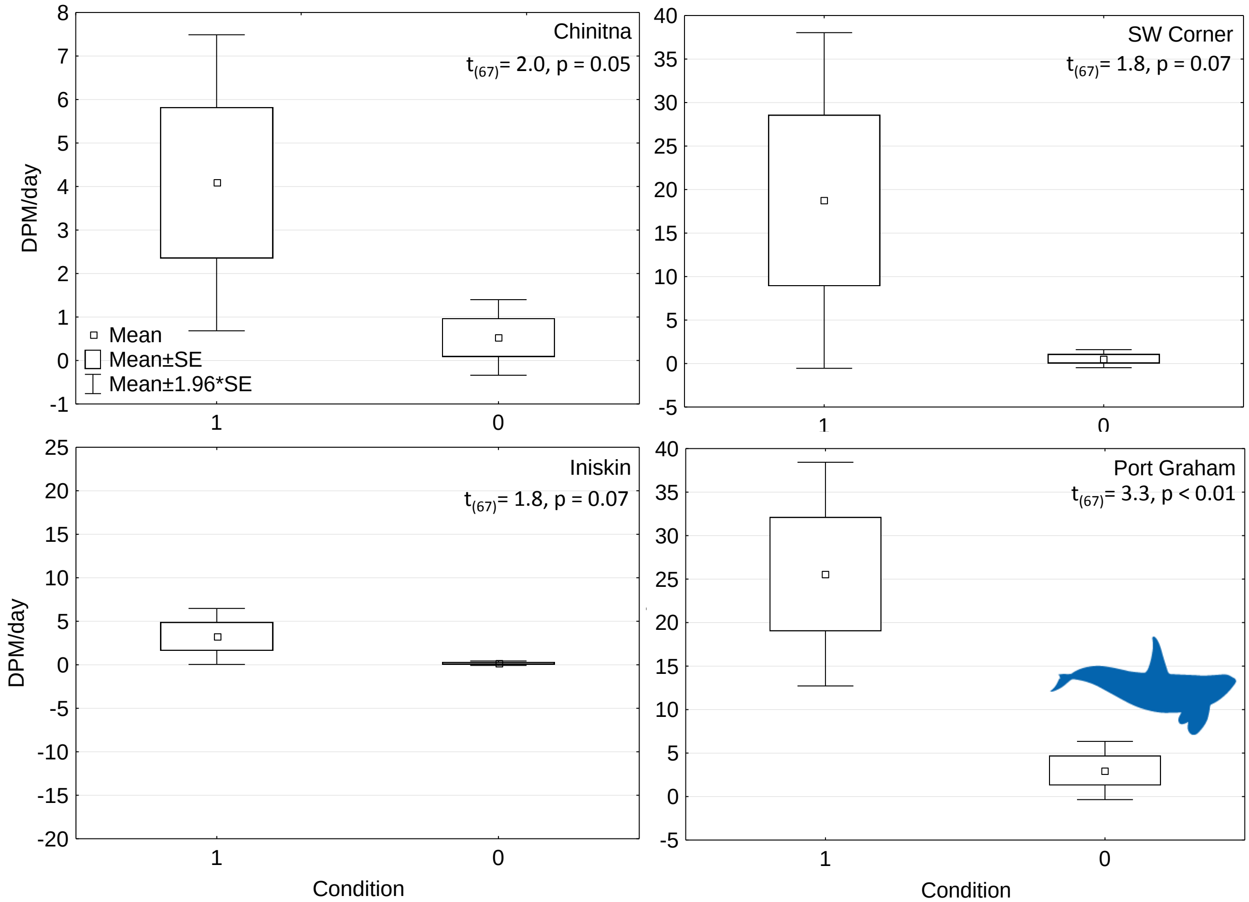

Figure 10: Box-whisker plots showing the distribution of killer whale DPM per day as mean and standard error, for the two conditions, during the seismic survey (1 in panels), and post survey (0 in panels). Statistical results are included in each panel.

3.4 Fin whale results

Fin whale acoustic detections were composed of both backbeat and classic 20 Hz notes (Fig. 11). Similar to killer whales, fin whale detection results at the SW Corner location show an opposite pattern of occurrence between the 'during survey' and 'post survey' periods: there is a highly significant decrease in detections during the post survey period (Fig. 12 and 13).

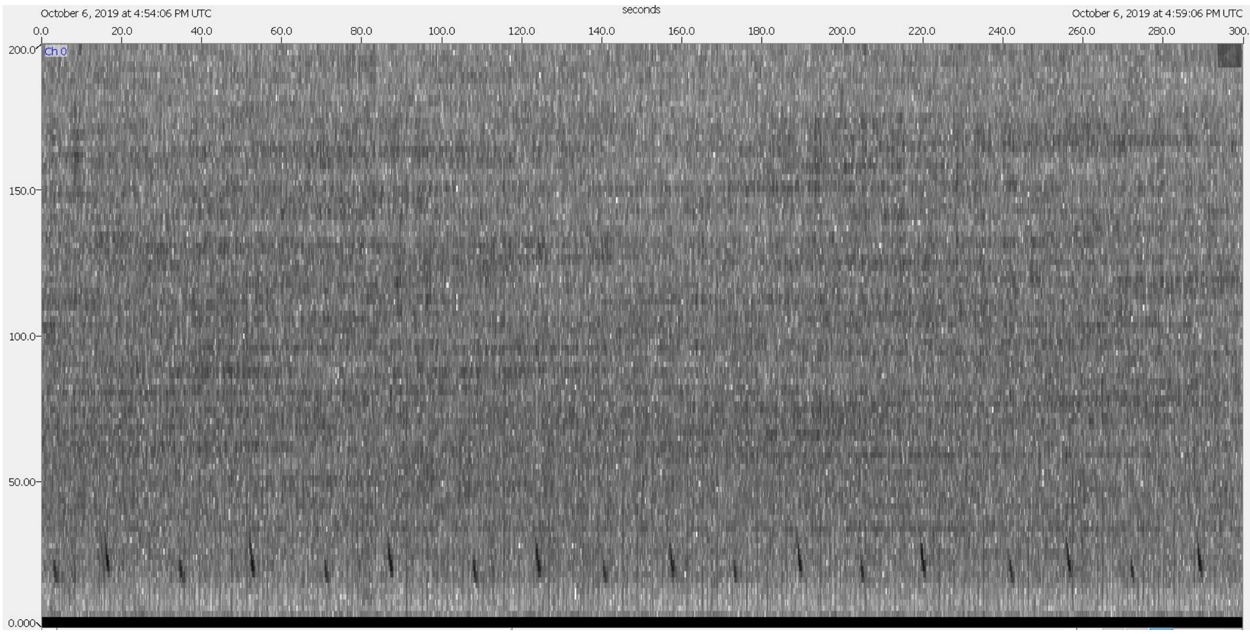

Figure 11: Spectrogram showing 300 seconds of data and 0-200 Hz from 09/6/19 at 12:54 pm AK local with a fin whale song sequence including two notes types, backbeats (lower bandwidth notes) and classic 20 Hz notes.

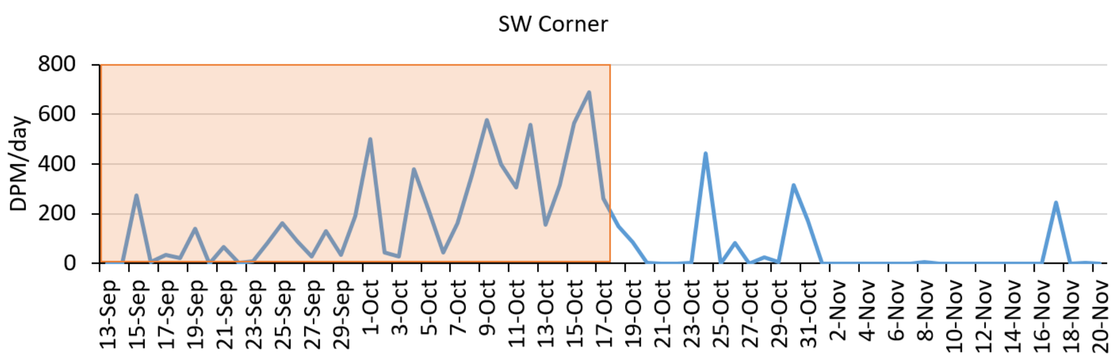

Figure 12: Temporal distribution of fin whale acoustic detections in DPM per day at the SW Corner location. Orange block denotes the seismic survey period.

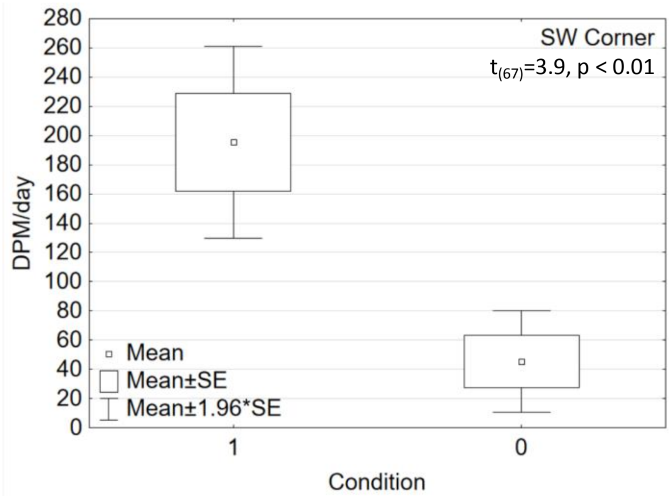

Figure 13: Box-whisker plot showing the distribution of fin whale DPM per day as mean and standard error, for the two conditions, during the seismic survey (1 in panels), and post survey (0 in panels) for the SW Corner location. Statistical results are included inside the panel.

3.5 Pacific white-sided dolphin results

Whistles from this species were detected sporadically in short encounters at Iniskin and SW Corner (Fig. 14). Detections at Iniskin occurred on 10/19/19 for a total of 6 minutes between 16:11 and 18:20 AK local time. Detections at SW Corner occurred on 2 days, 09/16/19 and 09/30/19 for a total of 26 and 25 minutes respectively. On 9/16/30 there were three encounters, the first one from 5:03 to 6:09 am AK local time, the second from 10:13 to 11:43 am, and the third one from 17:49 to 17:54. On 09/30/19 there was one encounter from 9:56 to 10:39 am AK local time.

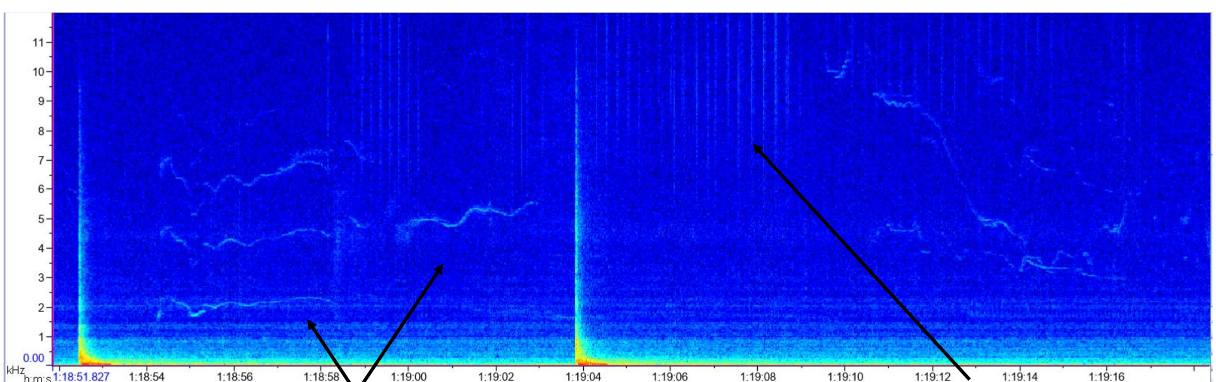

Figure 14: Spectrogram showing 21 seconds of data and 0-12 kHz from 09/30/19 at 10:10am AK local with multiple whistles and echolocation from Pacific white-sided dolphins.

3.6 Beluga whale results

Beluga whale echolocation signals (Fig. 15) were detected at Port Graham on 10/1/2019 for a total of 5 minutes between 12:07 to 12:15pm AK local. No calls or whistles were detected in this encounter.

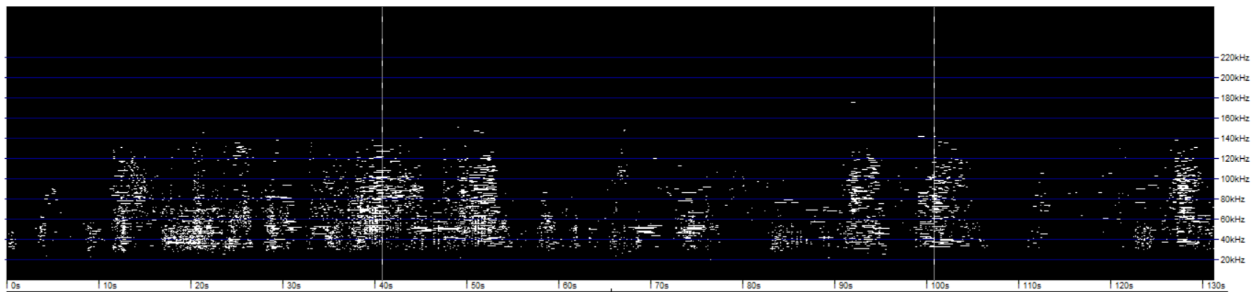

Figure 15: A sequence of 130 seconds of C-POD data with 5176 beluga echolocation clicks (white dots) from Port Graham on 10/1/2019 at 12:06pm AK local. Y axis in panel corresponds to peak frequency, note white dots have a frequency distribution of 30 to 140 kHz.

3.7 Noise analysis results

The seismic survey period yielded a 1-minute median SPL value of 105.3 dB, with a maximum of 127.2 dB. The post survey yielded a 1-minute median SPL value of 84.4 dB, with a maximum of 95.8 dB (excluding outliers). Difference between medians was 20.9 dB (Fig. 16).

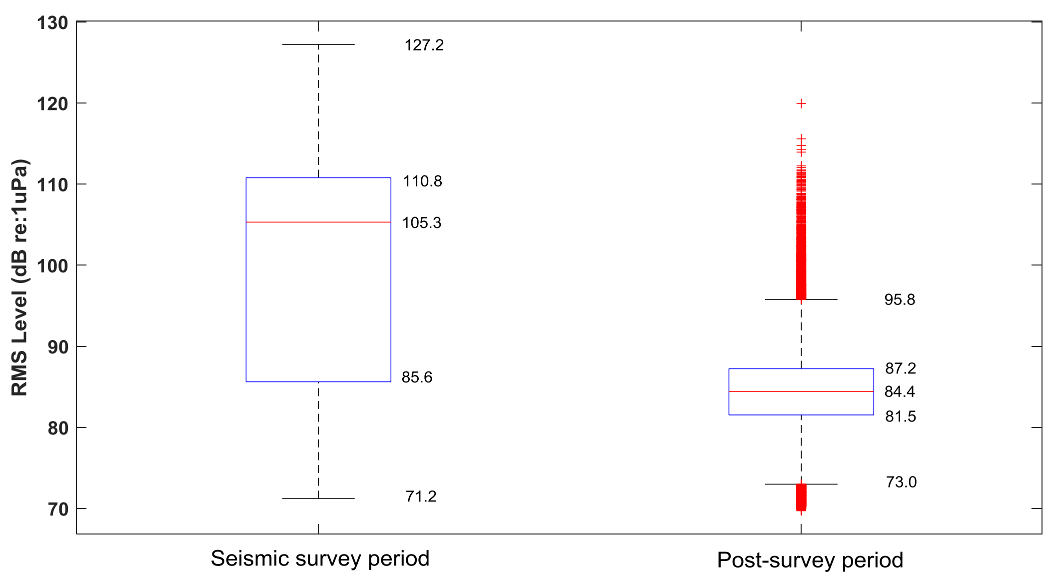

Figure 16: Box-whisker plot (line: median, box: 25th and 75th percentiles, whiskers: maximum and minimum) with SPL results for 1 Hz/ 1 minute resolution for the frequency range 20 Hz to 12 kHz for the seismic survey and post-survey periods.

The SPL temporal distribution show a clear survey footprint, where each acquisition line period elevates the SPL up to 30 dB above background levels ranging 85 to 111 dB. These noise-elevated periods clearly occur in sequences equivalent to each seismic acquisition line ran by *Polarcus Alima.* Short gaps where noise levels return to baseline, in the range 81 to 87 dB, correspond to the vessel turning periods in between acquisition lines when airguns were not active (Fig. 17).

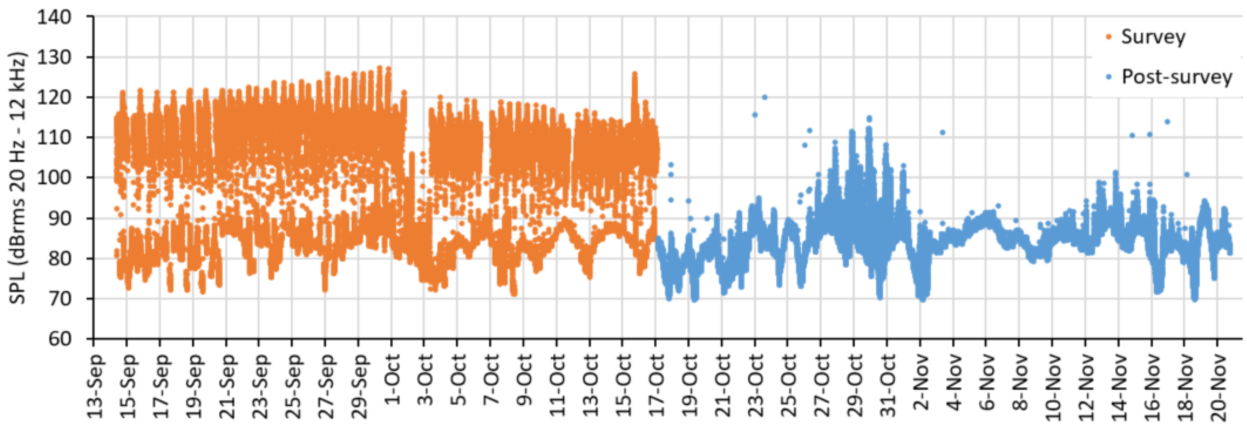

Figure 17: SPL per minute for the frequency range 20 Hz – 12 kHz for the two periods, seismic survey and post-survey.

When the temporal distribution in SPL is organized in 24 hour slots (diel distribution) for the survey and post-survey periods, patterns in noise variation are revealed (Fig. 18). The elevated periods from the acquisition lines and the silence periods for vessel turns follow the same daily schedule form 9/14/19 to 9/20/19 with no seismic activity at night (~2am to ~9am). Starting on 9/21 seismic acquisition occurs more regularly without a night break, running ~4 lines every 24 h cycle. On 10/2/19 and part of 10/3/19 there was no seismic airgun activity. The post-survey period shows several instances of elevated noise levels for the period October 26th until 31st, these correspond to the leap tides for the month of October 2019 with highest tidal swing for the month, and results reflect the increased noise levels caused by peak currents. Other elevated noise periods of lower amplitude and longer duration (e.g., Nov 5th and 6th) correspond to stormy weather, and results reflect rain and wave action noise.

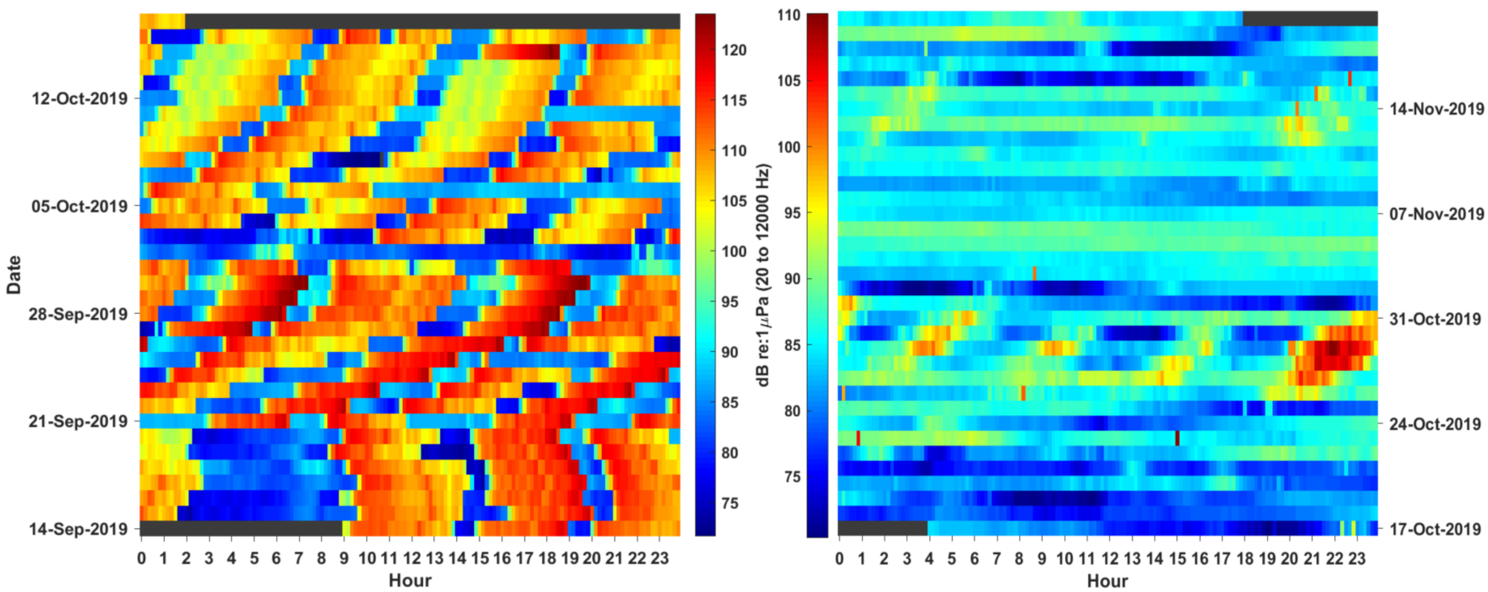

Figure 18: Diel plot for SPL per minute for the range 20 Hz-12 kHz for the two periods, seismic survey period (left panel) and post-survey period (right panel). Each horizontal line corresponds to the 24 hours of the day, days are stacked vertically. Note the color scale differs between panels.

Comparison of power spectral density for the range 20 Hz – 12 kHz, between the seismic survey and the post-survey periods indicate airgun noise exceeds background noise by up to 30 dB in the band 35 to 60 Hz, by 20 dB in the band 100 to 200 Hz, by 10 dB in the band 350 to 400 Hz, and airgun noise disturbance is no longer observed at frequencies beyond 1200 Hz (Fig. 19).

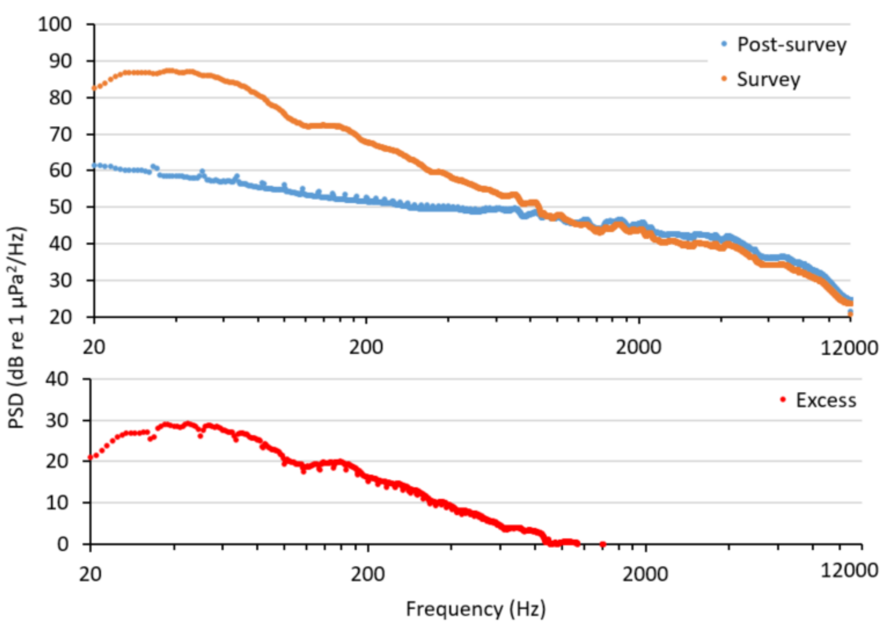

Figure 19: Power spectral density (PSD, dB re 1 μPa^2/Hz) calculated for 1 minute segments for the range 20 Hz – 12 kHz for the seismic survey and post-survey periods (upper panel), as well as the seismic survey excess levels over the post-survey levels (lower panel).

4. Discussion

4.1 Cetacean presence

All expected species in this area of Cook Inlet were acoustically detected except minke whales. It is known that minke whales typically present low calling rates, and their boing signal production is seasonal (Rankin & Barlow 2005, Delarue & Martin 2013). The visual effort by aerial and vessel based PSOs from the seismic survey operation reported 11 sightings of solitary minke whales (Fairweather Science 2020), suggesting that this species is easily missed acoustically.

Porpoise echolocation dominated the detection results. These were detected almost on a daily basis in all 4 locations monitored, reflecting the importance of this porpoise habitat, as well as the importance of acoustics for this species, as it is known porpoises echolocate almost continuously in search of prey due to their high metabolic requirements (Wisniewska *et al*. 2016). Results from this study show how porpoise presence remained at a minimum during the seismic survey period in three of the four monitored locations. Porpoise presence increased significantly 3 or 4 days after the seismic survey ended suggesting a spatial displacement of wide scale. Elevated noise conditions by the seismic survey could not mask porpoise signals as these occur at much higher frequencies than the acoustic signature of airgun shots, thus the low detection rate during the survey period is unequivocally attributed to this species lower presence. Visual effort results show how porpoise sightings (13 sightings in total), remained low compared to the amount of acoustic detections obtained in this study during the post-survey period (detected on average 1.1 hours each day for all 4 locations). There are precedent studies showing a wide scale displacement for harbor porpoises by seismic surveys as well as reduction in foraging activity (e.g., Pirotta *et al*. 2014, Sarnocinska *et al.* 2020). A few short disturbance events are likely insignificant to the energetic status of a porpoise, but disturbances may have fitness consequences when repeated frequently or lasting long periods (Wisniewska et al., 2018). The scale of the spatial and temporal displacement reported here could convey fitness consequences if the disturbed habitat is critical for this population. Unfortunately, we have no information on feeding habitat preferences for harbor and Dall's porpoises in this region, and information on energy expenditure and intake on porpoises is lacking. These details would be needed to estimate impact on fitness levels, thus the effect of the observed displacement cannot be quantified.

Humpback whale detection results show interesting differences between the west side monitoring locations (Iniskin Bay and Chinitna Bay) and the SW Corner and Port Graham. The two west locations reflect strong differences in humpback whale presence during and after the seismic survey, suggesting a strong change in acoustic behavior or spatial displacement. Detections in SW Corner and Port Graham were low and differences were not statistically significant, thus an effect could not be identified in these 2 locations. However, the lack of effect here is likely due to the low level of detections (144 DPMs in SW Corner and 100 DPMs in Port Graham). Baseline data on humpback whale presence in these areas in September and October from previous years, or even better, having sampled the weeks prior to the seismic survey, would have been very useful to evaluate whether humpback whales reacted to the acoustic disturbance in these two locations. No sighting database could be found among the Homer based whale watching industry, and dedicated marine mammal surveys by state or federal agencies are lacking. In any way, the displacement observed at Iniskin Bay and Chinitna Bay suggests humpback whales are sensitive to seismic survey noise, as these locations were 37.4 km and 8.5 km respectively from nearest border of survey area, and in very shallow waters where low frequency sound propagation is highly attenuated. There is at least one precedent where humpback whales have shown strong reaction to seismic survey noise. Cerchio *et al*. (2014) described how singing behavior by humpback whales was disrupted by a seismic survey. The seismic survey's visual effort obtained 46 sightings through the survey period (Fairweather Science 2020), suggestive of a change in acoustic behavior rather than spatial displacement, but without baseline data on typical presence in this area a spatial displacement cannot be ruled out. Alternatively, airgun signals could have the potential to mask humpback whale downsweeps yielding low detection rates during the survey period, as these overlap in frequency. However, the data from Iniskin in particular shows moans with typically higher received levels than the airgun shot signatures, as this location is far from the survey zone, thus a masking effect is unlikely.

Results for killer whales show an opposite effect. Killer whale calls are detected more often during the seismic survey than during the post-survey period, and these differences are statistically significant at Port Graham and Chinitna Bay. It could be possible that killer whales prefer to spend more time in these embayments during the seismic survey period, because here noise disturbance is reduced by poor propagation characteristics, however this idea does not fit with results from the SW Corner location, where noise disturbance was highest (more detections occurred during the survey period, although differences between periods were not statistically significant). Baseline data on killer whale seasonal occurrence in these areas would allow a proper interpretation of these results, however, none was found.

Fin whale detection results are intriguing. This is a low frequency specialist and its communication channel is by far the most impacted by the seismic survey from all species detected in this study. However, the amount of time with fin whales present in our data peaked during the seismic survey period, and plummeted the same day the survey ended, with only a few days of high levels of presence during the post-survey period. This highly significant differences in vocal activity can be explained by the whales leaving the area by the end of the seismic survey, or by a drastic reduction of their vocal activity once the disturbance ceased. Unfortunately, we do not have information on fin whale seasonal occurrence in the lower Cook Inlet. However, a well-documented anti-masking mechanism in cetaceans is the increase in vocal activity by both increasing the amplitude and the duration of the signals, or by increasing the repetition rate of emissions (Erbe *et al*. 2016). Other studies on fin and blue whales elsewhere have shown an initial increase in detections and calling rates in the presence of seismic survey noise (Castellote *et al*. 2012, Di Iorio & Clark 2009), thus this seems a plausible explanation for the results presented here. One consideration to note, however, is that the post-survey period included several weeks of stormy weather, in particular the month of November, where the least amount of fin whale detections occurred. This is evident in Figure 18, where noise levels are elevated for several days or weeks within this month due to wave action and rain. It is possible that the fin whale detector performance decreased by the masking effect of this natural source of noise which overlaps in frequency with fin whale signals.

Two other species were detected in this study, Pacific white-sided dolphins and beluga whales. For both, detections were very brief and thus it is not possible to assess any effect by the acoustic disturbance caused by the seismic survey. Both species are not commonly occurring in this area of Cook Inlet, and visual observers did not report sightings for Pacific white-sided dolphins, and reported 2 sightings of drifting dead belugas (Fairweather Science 2020), although it is part of their recognized distribution range. Cook Inlet beluga historical (pre-decline) distribution suggests these were more abundant in this area of lower Cook inlet, mainly in coastal habitat during winter months (Shelden *et al*. 2015). The beluga detection at Port Graham is the southernmost detection on the east side of Cook inlet for its recent range. This detection is extending the south limit defined by ADF&G and NMFS sightings in Kachemak Bay and Iniskin Bay in the 1990's and early 2000's, and is only surpassed in latitude by the Kamishak Bay sightings on the west side of the Inlet in the 1980's and 1990's by ADF&G herring aerial surveys. Port Graham is not included in the Cook Inlet Critical habitat, its Area 2 (winter habitat) ends west of Kasitsna Bay (NMFS 2011). This detection was composed exclusively of echolocation clicks, but their frequency characteristics are unequivocal (see Castellote *et al*. 2016). Acoustic data alone cannot assign these as Cook Inlet belugas, although it is the most likely attribution.

4.2 Seismic survey noise disturbance

The acoustic disturbance caused by the seismic survey was monitored only at the SW Corner location. Airguns were present in data from all four locations, and further analysis is ongoing to characterize the acoustic footprint, but highest noise levels were obtained at the SW Corner as this was the nearest mooring to the survey area, and is used as a reference. This mooring was deployed on 9/13/19 at 15:14 AK local time, and recordings started at 16:00, thus we missed the airgun array activity for the sound source verification completed on 9/10/19 and 9/11/19. First airgun shots were detected on 9/13/19 at 21:27 for about 2h 42min, and 1st continuous seismic acquisition started on 9/14/19 by 9am, thus the seismic survey period was considered to start on 9/14/19. The acoustic disturbance generated by the 1945 in^3 airgun array of the *Polarcus Alima* was drastic at this location, with median broadband levels in excess of 20.9 dB re: 1 µPa from baseline background noise levels, and reaching an excess of 30 dB for 1 minute SPL averages. These levels predominated the entire 34-day period with short breaks except one day and a half in October (Fig 17 and 18). It is important to underscore here that levels reported here are for 1-minute averages, meaning that the total acoustic energy is calculated including the silence gaps in between airgun shots (lasting 10-15 seconds). If this analysis were to focus just on the airgun shots excluding the silence gaps in the sequence, the levels reported would be several orders of magnitude higher. However, the interest here is to report the change in the acoustic environment (or soundscape) as a whole, and not the instantaneous acoustic pressure within the airgun shots.

Background noise levels during the post-survey period indicate this area is relatively quiet for that time of the year. The reported median SPL of 84.4 dB has a narrow variance, with the 15th and 75th percentiles just 3 dB above or below this value (Fig 16). These results are in stark contrast with background noise measurements in the upper and mid Cook Inlet, where levels exceeded 100 dB on average (Castellote *et al*. 2018). Despite being obtained during a stormy period, these background noise levels reflect a pristine condition of the acoustic environment in this area of Cook Inlet. This context worsens the seismic survey acoustic disturbance, because not only the disturbance was of large magnitude both in acoustic pressure and time, but it disturbed an otherwise largely undisturbed environment. Median noise values during the survey period exceed peak periods during the post-survey period generated by waves, rain or currents, thus the acoustic disturbance far exceeded any natural variation in background noise in this area, and the most typical SPLs during the survey period rarely occurred during the post-survey period. This is reflected in Figure 16, where the range for the 25th to 75th percentile (the box) for the survey period barely overlaps the box for the post-survey period, and the median level for the survey period exceeds the 75th percentile for the post-survey period. Figure 18 is also helpful to visually compare SPLs across these two periods. The amount of time with noise levels in the blue-light blue color (90-95 dB) is scarce in the survey period, and is typical in the post-survey period, in contrast the amount of time with noise levels in the orange-red color (100-110 dB) is typical in the survey period and scarce in the post-survey period, and darkest red periods do not reach the SPL levels observed in the survey period.

Another important consideration of the noise disturbance generated by the seismic survey is in the spectral domain. Figure 19 clearly denotes how the bulk of the increase in noise levels is caused by low frequencies. In fact, no differences are observed between the survey and post-survey periods above 1200 Hz. Thus, it is important to recognize that the acoustic disturbance is rather limited in frequency range. Again, these results are based on 1-minute averages, thus the frequencies affected would extend far beyond the 1200 Hz if only the airgun shots were analyzed. Figures 8 and 14 provide a simple example of this averaging effect, the airgun shots in these non-averaged spectrograms exceed background noise levels up to frequencies beyond 10 kHz. Because the acoustic environment was predominantly disturbed in the 0-1200 Hz, those species whose communication channels fall within this frequency range would be most compromised. Reduction of cetacean's acoustic space has been highlighted as a serious conservation concern (Hatch *et al*. 2012, Forney *et al*. 2017). In contrast to physical harm from intense anthropogenic sources (i.e. level A takes), which can have acute impacts on individuals, masking from chronic noise sources has been difficult to quantify at individual or population levels, and resulting effects have been even more difficult to assess (Clark *et al*. 2009). However, there is growing recognition that sub-lethal effects are likely to be relatively widespread and may have a greater impact than direct physical injury (Rolland et. al 2012) . Such effects may include animals leaving biologically important habitat (citation?), or auditory masking of sounds associated with communication, predator detection, or navigation (Erbe et. al 2016). The results presented in this report, although far from ideal (i.e., no baseline, no pre-survey), document a wide-scale displacement of porpoises and humpback whales, and likely behavioral responses by killer whales and fin whales from a seismic survey in an area of poor ecological knowledge, acoustically pristine, and with very limited cetacean baseline information.

5. Conclusions

Little work has been focused on long-range lower amplitude noise effects on cetaceans. In part this is because there is a legal obligation to control and mitigate only close-range acute impact, but also because acoustic disturbances at this scale can only be incorporated in research studies in coordination with industry. This study provides several important conclusions related to this research framework. There is an urgent need for proper coordination between industry and research, in particular in areas of important biodiversity, where ecological knowledge is limited, or where endangered species have the potential to be impacted. The Hilcorp 3D seismic survey in Lower Cook Inlet completed in fall 2019 featured these three particularities, but little coordination was encouraged. Our analysis power, results, and interpretations are impacted by the lack of a pre-survey sampling period. This could have been easily avoided if the opportunity to acoustically monitor this seismic survey would have been proposed earlier in time. The importance of baseline marine mammal distribution and seasonal occurrence data needs to be underscored in lower Cook Inlet, and especially in sectors such as oil and gas, or whale watching, as these are already interacting with this region of Cook Inlet and could easily compile opportunistic sightings. Similarly, several academic or research groups operate in this region for other scientific purposes that could contribute to this visual collection and archival effort. This is all of paramount importance in view of the interest by BOEM for opening more OCS blocks in lower Cook Inlet, the near future increase in shipping related to the expansion of the Port of Alaska, as well as the potential for Pebble Mine to develop mining-transport activities on the west side of the lower Inlet. The documented response by several cetacean species to long-range acoustic disturbance from a seismic survey highlights the need for an expanded framework when considering disturbance effects. Acknowledging scientific uncertainty, and providing managers and stakeholders a more robust means of assessing and mitigating takes related to acute noise exposure but also spatial displacement or auditory masking should be considered a conservation management need.

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7. References

Castellote M, Thayre B, Mahoney M, Mondragon J, Lammers MO, Small RJ. 2018. Anthropogenic noise and the endangered Cook Inlet beluga whale, *Delphinapterus leucas*: Acoustic Considerations for Management. Marine Fisheries Review 80(3): 63-88.

Castellote M, Small RJ, Lammer, MO, Jenniges JJ, Mondragon J, Atkinso, S. 2016. Dual instrument passive acoustic monitoring of belugas in Cook Inlet, Alaska. Journal of the Acoustical Society of America 139: 2697–2707.

Castellote M, Clark CW, Lammers MO. 2012. Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. Biological Conservation 147: 115–122.

Cerchio S, Strindberg S, Collins T, Bennett C, Rosenbaum H. 2014. Seismic Surveys Negatively Affect Humpback Whale Singing Activity off Northern Angola. PLoS ONE 9(3): e86464.

Clark CW, Ellison WT, Southall BL, Hatch L, Van Parijs SM, Frankel A, Ponirakis D. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. Marine Ecology Progress Series 395: 201−222.

Delarue J, Martin B. 2013. Minke whale boing sound detections in the northeastern Chukchi Sea. Marine Mammal Science 29(3): E333–E341.

Di Iorio, L., Clark, C.W., 2009. Exposure to seismic survey alters blue whale acoustic communication. Biology Letters 6: 51–54.

Dugan PJ, Ponirakis DW, Zollweg JA, Pitzrick MS, Morano JL, Warde AM, Rice AN, Clark CW. 2011. SEDNA - Bioacoustic Analysis Toolbox Matlab Platform to Support High Performance Computing, Noise Analysis, Event Detection and Event Modeling. IEEE Xplore, vol. OCEANS-11, Kona, Hawaii.

Erbe C, Reichmuth C, Cunningham K, Lucke K, Dooling R. 2016. Communication masking in marine mammals: A review and research strategy. Marine Pollution Bulletin 103: 15–38.

Fairweather Science. 2020. 2019 Hilcorp Alaska Lower Cook Inlet Seismic Survey Marine Mammal Monitoring & Mitigation Program Final Report. Submitted to National Marine Fisheries Service and United States Fish and Wildlife Service. Prepared for Hilcorp Alaska. January 2020.

Ferguson MC, Curtice C, Harrison J. 2015. Biologically Important Areas for cetaceans within U.S. waters – Gulf of Alaska coast region. Aquatic Mammals 41(1): 65-78.

Forney KA, Southall BL, Slooten E, Dawson S, Read AJ, Baird RW, Brownell RL Jr. 2017. Nowhere to go: noise impact assessments for marine mammal populations with high site fidelity. Endangered Species Research 32: 391-413.

Harrison, C. S., and J. D. Hall. 1978. Alaskan distribution of the beluga whale, *Delphinapterus leucas*. Canadian Field Naturalist 92(3):235–241.

Hatch LT, Clark CW, Van Parijs SM, Frankel AS, Ponirakis DW. 2012. Quantifying loss of acoustic communication space for right whales in and around a U.S. National Marine Sanctuary. Conservation Biology 26(6): 983-94.

Kyhn LA, Tougaard J, Beedholm K, Jensen FH, Ashe E, *et al*. 2013. Clicking in a Killer Whale Habitat: Narrow-Band, High-Frequency Biosonar Clicks of Harbour Porpoise (*Phocoena phocoena*) and Dall's Porpoise (*Phocoenoides dalli*). PLoS ONE 8(5): e63763.

Lammers M., Castellote M, Small RJ, Atkinson S, Jenniges JJ, Rosinski A, Oswald JN, Garner C. 2013. Passive acoustic monitoring of Cook Inlet beluga whales (*Delphinapterus leucas*). Journal of the Acoustical Society of America 134(3): 2497–2504.

Leatherwood S, Bowles AE, Reeves RR. 1983. Aerial surveys of marine mammals in the southeastern Bering Sea. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 42(1986):147–490.

Muto M, Helker V, Angliss RP, Allen BA, Boveng PL, Breiwick JM, Cameron MF, Clapham P, Dahle SP, Dahlheim ME. 2018. Alaska marine mammal stock assessments, 2017. NOAA Technical Memorandum NMFS-AFSC-378. Alaska Fisheries Science Center, Seattle, WA.

NMFS. 2011. Endangered and threatened species: designation of critical habitat for Cook Inlet beluga whale. 76 Fed. Regist. 20180 (11 April 2011), p. 20,180–20,214.

Pirotta E, Brookes K, Grahamh IM, Thompson PM, 2014. Variation in harbor porpoise activity in response to seismic survey noise. Biology Letters 10: 20131090.

Rankin S, and Barlow J. 2005. Source of the North Pacific "boing" sound attributed to minke whales. Journal of the Acoustical Society of America 118:3346–3351.

Rosalind M. Rolland, Susan E. Parks, Kathleen E. Hunt, Manuel Castellote, Peter J. Corkeron, Douglas P. Nowacek, Samuel K. Wasser and Scott D. Kraus (2012) "Evidence that ship noise increases stress in right whales" Proc. R. Soc. B doi:10.1098/rspb.2011.2429

Sarnocinska J, Teilmann J, Balle JD, van Beest FM, Delefosse M and Tougaard J. 2020. Harbor porpoise (*Phocoena phocoena*) reaction to a 3D seismic airgun survey in the North Sea. Frontiers in Marine Science 6: 824.

Shelden KEW, Goetz KT, Rugh DJ, Calkins DG, Mahoney BA, Hobbs RC. 2015. Spatio-temporal changes in beluga whale, *Delphinapterus leucas*, distribution: results from aerial surveys (1977–2014), opportunistic sightings (1975–2014), and satellite tagging (1999–2003) in Cook Inlet, Alaska. Marine Fisheries Review 77: 1−60.

Wisniewska DM., Johnson M, Teilmann J*, et al*. 2016. Ultra-high foraging rates of harbor porpoises make them vulnerable to anthropogenic disturbance. Current Biology 26: 1441–1446.

Wisniewska DM, Johnson M,Teilmann J, Siebert U, Galatius A, Dietz R,Madsen PT. 2018. High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). Proceedings of the Royal Society B 285: 20172314.