A seismic source field trial in the Bass Strait: testing the impact of several different source configurations on geophysical quality, received sound and direct impact on scallops and lobsters

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SUMMARY

Beach Energy acquired a seismic source technology field trial in Dec 2021 in the shallow waters (50-80m) of the Bass Strait. The trial consisted of eight source tests acquired along two 2D lines, including: a full-size array (2480 cu.in.) with Sercel G-GUN II in a wide-tow triple source configuration, *eSourceTM* (2098 & 1049 cu. in.), reduced size (300, 700 & 1260 cu.in.), and Distributed Source tests including Shearwaters *Apparition* test (140 & 340 cu.in.). A test of a 70 cu.in. airgun was also recorded during a whale mitigation procedure. The aim of the field trial is to investigate whether any of these source options:

1. Provide the required geophysical data quality
2. Significantly alter the received anthropogenic sound levels (SPL and SEL)
3. Changes the impacts on benthic invertebrates via analysis of scallop and lobster specimens placed on the seafloor

This combined data will then be used to determine if any of the alternative source options are suitable replacements for conventional full-sized arrays and if any provide a meaningful reduction to potential impact on marine organisms.

The study was performed in conjunction with the Institute for Marine & Antarctic Studies, Fisheries Research & Development Corporation, Curtin University, and the Department of Natural Resources & Environment Tasmania.

Scallop and lobster specimens as a model species for crustaceans and molluscs were placed on the seabed below the full array (triple and single source), both eSource arrays and one control location. The specimens were assessed over 6 months for physical damage, chronic effects and survival, pH, refractive index, total and differential haemocyte cell counts, DNA damage and biochemistry. Lobsters were also assessed for righting ability. The results will not be available until Q4 2023. Noise loggers were collocated with the specimens to measure received sound.

The data processing was completed by Shearwater. The results show that all options result in lower S/N raw shot gathers; but also, that modern processing algorithms are able to compensate for most of this through noise attenuation, deblending and designature. eSource (2098 and 1049 cu.in.) and the reduced source size options provide very similar final stack and migrated gather quality to the full array. Both apparition tests (140 & 340 cu.in.) were very similar in 2D stack quality but with slightly lower S/N below 4Hz and above 64Hz. The data quality of the other distributed source tests was better in the shallow but worse in the deep due to poor randomisation achieved. There are differences in gather quality that require further investigation. These results demonstrate that alternative sources and/or smaller volumes have the potential to meet survey objectives whilst reducing impact on marine life.

Key words: field-trial, air-gun, distributed source, apparition, impact, lobsters, scallops, anthropogenic noise.

INTRODUCTION

Acquiring marine seismic data is becoming more onerous due to increased regulatory requirements and a perceived negative impact of seismic sources/surveys on marine life amongst stakeholders and the general public. This is despite most of the published science indicating that in general terms environmental impacts of seismic surveys are short-term, recoverable and localized. A *Before-After Control-Impact* (BACI) study performed by Beach for the Prion 3D survey, immediately preceding this field trial, showed significant growth of scallop biomass and no mortality (Koopman et al, 2022). Studies are now focused on the effect of anthropogenic sound on behavioral response and potential physical injury to auditory tissues or other air-filled organs. Numerous studies have investigated the effect of seismic sources on lobsters or scallops (Day et. Al., 2016), but none have studied both with a full commercial array or with alternative sources. Previous geophysical studies have shown that smaller source sizes could provide equivalent geophysical data quality to standard arrays (Elboth et. Al., 2018), but no studies have jointly investigated the effect of different source sizes on geophysical data quality and marine life

The seismic industry has been investigating alternative marine source options to provide the required seismic data quality whilst reducing the peak sound pressure levels (SPL) and sound exposure levels (SEL). These technologies include improved air-guns (*eSource*), the use of smaller air-guns fired more frequently (*Distributed Source* and *Apparition*) and *Marine Vibroseis*. These technologies are either still under development or recently deployed and subsequently lack comprehensive test data gathered in open oceanic waters.

From a geophysical standpoint, larger seismic arrays have traditionally been preferred as they provide improved low frequency information, offer improved signal-to-noise at greater depth and suppress ambient noise. However, many recent advances in acquisition such as the use of deep-tow solid streamers have significantly reduced recorded noise levels. Advances in data processing, such as Deghosting, shot-by-shot designature, SRME and LS(Q) migration further enable reflection energy to be recovered from a weaker signal, and hence provide another opportunity to reduce the magnitude of the seismic impulse required to adequately image the subsurface.

TEST SUMMARY

The field trial was acquired in the Bass Strait, Australia (Figure 1). The objective was to determine whether the new technology provides the required data quality and determine if such technologies significantly reduce the noise-inducing impact on marine organisms. The two 2D test lines were 40km long and 5km apart in 50-80m water depth. Three sets of Scallop and Lobster specimens were deployed for the triple source x 2480 cu.in., a single x 2480 cu.in., and the *eSource* with 2098 cu.in. and 1049 cu.in. The specimens were collected from acoustically quiet areas in Tasmania and placed on the seafloor approximately two days before each test to enable the specimens to acclimatize.

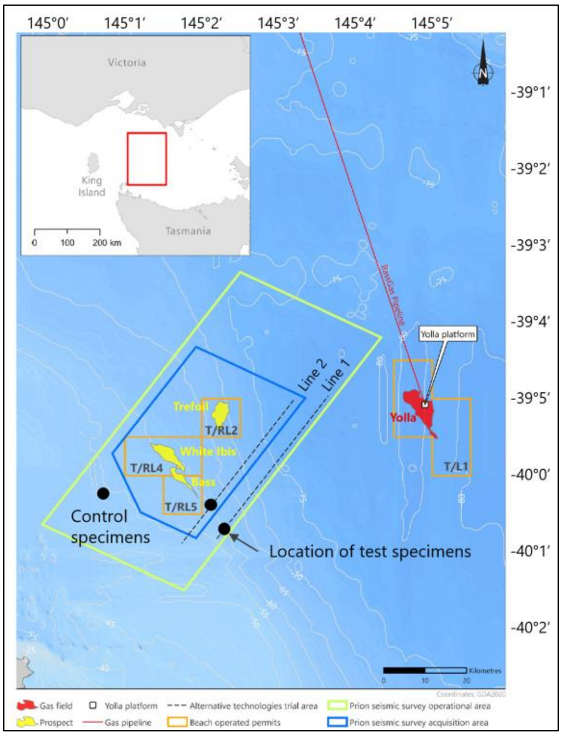

Figure 1. Location map showing the Prion 3D survey (Blue) and the field trial lines (black dashed).

TEST	SHOOTING DIRECTION	LINE NO.	SOURCE SIZES	SP INTERVAL
Single-source baseline	N	2	1 x 2480 cu/in	25 m
Triple-source baseline	S	1	3 x 2480 cu/in	8.33 m (flip/flop/flap)
Dual-string distributed source	N	1	870, 840, 640, 380 cu/in	~2 m (flip/flop/flap)
Single-string distributed source	S	1	620, 450, 290 cu/in	~2 m (flip/flop/flap)
Apparition 340 cu/in	N	1	3 x 340 cu/in apparition	8.33 m
Apparition 140 cu/in	S	1	3 x 140 cu/in apparition	8.33 m
Reduced size sources	N	1	300, 700 and 1260 cu/in	8.33 m (flip/flop/flap)
eSource	S	2	1 x 2098 cu/in	25m

Table 1. Test Summary.

eSource™ is a re-engineered airgun by Teledyne Bolt that reduces the output above 100Hz, while retaining the energy below 100Hz that is critical to seismic exploration. *Apparition* is a distributed source technique offered by Shearwater (Pedersen et al. 2016) that uses near simultaneous activation of two or more smaller arrays combined with deblending.

DATA PROCESSING

The data processing was performed by Shearwater. The processing flow was as consistent as possible, except for the early stages where each source type required a bespoke flow for deblending, deghosting, debubble and designature (Redfearn et. al., 2022). The shot-by-shot directional designature was a critical step as can be seen in Figure 2. This illustrates how weak signal can be rectified and that even a single 70 cu.in. air-gun can provide similar quality reflection data. The significant increase in noise is indicative of the decrease in S/N experienced when source size is reduced.

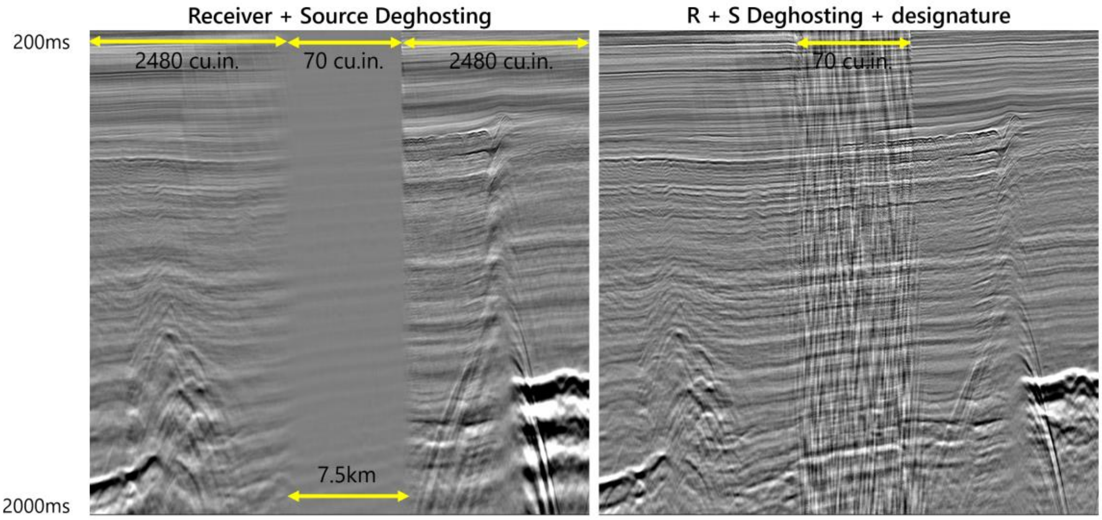

Figure 2. Baseline (2480 cu.in.) with whale mitigation section (70 cu.in.) before and after source designature.

The results show that smaller source sizes and more complex firing patterns result in lower quality raw shot gathers; but also, that modern processing algorithms can compensate for the majority of this through noise attenuation, Deblending, Deghosting, Shot-by shot Designature, Demultiple and Imaging. These advances create final full stack data that are very comparable from all sources tested (in this geological setting). Some differences exist in the distributed source pre-stack data (gathers) that need further investigation.

- *eSource* provides effectively the same stack and final gathers as a standard array (Figure 3)
- 300, 700 & 1260 cu.in. provide similar stack data to the 2480 cu.in. array, with slightly lower S/N at depth.
- The quality of the data from the 70 cu.in. acquired during a whale mitigation event was particularly surprising.
- *Distributed sources* provide better shallow data, due to a smaller SP (2m) and hence higher fold. The deeper data was inconclusive due to issues in acquisition that resulted in no dither for effective deblending.
- *Apparition* data is very similar on the full bandwidth stack but has slightly lower S/N in the 2-4Hz and 64Hz and above as seen in Figure 4. Some deeper events were slightly better, perhaps due to higher fold.

The data analysis at this stage has not included the impact of the different source options on FWI, AVO or Inversion.

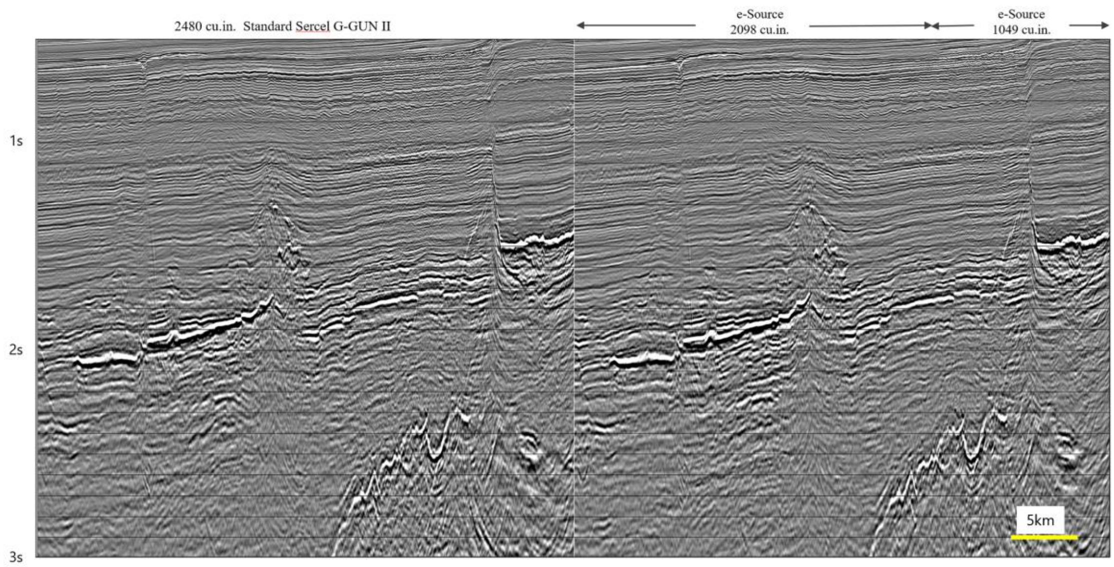

Figure 3. Comparison of final stack data for the 2480 cu.in. G-GUN II, 2098 cu.in. and 1049 cu.in. *eSource*

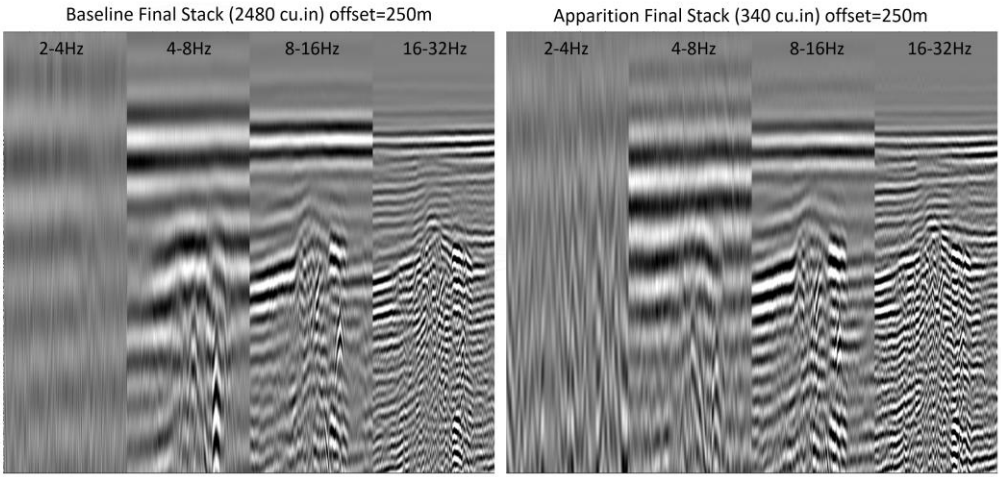

Figure 4. Octave panel comparison of baseline data with the 340 cu.in. apparition.

CONCLUSIONS

Larger seismic sources are almost always better in terms of raw seismic data quality, except in very shallow water. The larger the source, the more low-frequency data it contains, the more energy is likely to be reflected back from the target layers and the more likely the signal is strong enough to be recovered from beneath the noise. Using a smaller source adds technical risk, while generally not offering any upside potential for improving data quality.

The results from this field trial demonstrate that *eSource*, smaller source volumes and distributed source methods (with smaller volumes activated more frequently) can provide similar final data quality to the typical sized source arrays in this geological setting. This is a direct result of improvements in acquisition and processing (such as deep-tow solid streamers, NFH designature, deblending). Although the apparition results have very slightly lower S/N in the low and high frequencies, they still provide the required data quality. Data quality from *Apparition* are expected to improve further when applied in 3D, taking advantage of the improved inline and crossline sampling. These results demonstrate that alternative sources and/or smaller volumes may be sufficient to meet survey objectives whilst reducing SPL. Survey design needs to include a more rigorous approach to determining the optimum source size and technique to provide the data quality required whilst reducing impact on the marine environment. The data analysis to date has not included the impact of the source options on FWI, AVO or Inversion.

The effect of these alternative source options on received sound levels and direct impact on scallops and lobsters will not be available until Q4, 2023.

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