Australian Government
Geoscience Australia

Answers to Questions on Notice and Further Evidence by Geoscience Australia to the Environment and Communications Reference Committee Inquiry on the Impact of seismic testing on fisheries and the marine environment

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Answers to Questions on Notice

***CHAIR:** Yes, and I'm glad to see you're certainly recommending that. But it seems to me that there hasn't been a huge amount of incremental allocation of research effort into understanding some of these things until very recently. They (Greenpeace) claim that data on hearing capabilities exist for only 100 of 27,000 species of fish. Do you know if that's correct? (Page 2 Hansard)*

***CHAIR:** Could you take on notice whether you believe that is the case. They talk about auditory evoked potential, AEP. That's the currently used standard for testing the hearing capability of marine species. Do you accept that that has a number of criticisms, scientifically speaking? (Page 2 Hansard)*

GA Response: It is correct that there is a body of literature on the hearing of approximately 100 fish species (see Ladich and Fay 2013[1]), which indicates that there are potentially substantial differences in auditory capabilities among fish species. However, the greater proportion of these studies used auditory evoked potentials (physiological measures) that do not reflect the sound processing capabilities of the entire auditory system and therefore do not reflect the actual hearing capabilities of fish (see Popper and Hawkins 2019[2]). We refer Senator Whish-Wilson and the committee to the following paragraph from a literature review published by Geoscience Australia in collaboration with Curtin University and CSIRO, that discusses the application of AEPs and the limitations associated with this technique for determining hearing thresholds in fish and invertebrates (a copy of this publication is provided as further evidence).

- *"Hearing thresholds in both marine fish and invertebrates have been studied using behavioural and neurological responses to auditory stimuli called auditory evoked potentials (AEPs) (Ladich and Fay, 2013). Generally, fish species with specialisations for sound pressure detection (e.g. swim bladder) have lower sound pressure AEP thresholds (55–83 dB re 1 μPa) and respond at higher frequencies (200 Hz–3 kHz) than fishes lacking these morphological adaptations, which have thresholds between 78 and 150 dB re 1 μPa and best frequencies of below 100 to 1 kHz (Ladich and Fay, 2013). Fishes examined by measuring AEP particle acceleration threshold levels have thresholds between 30 and 70 dB re: 1 μm s−2 (Ladich and Fay, 2013). For invertebrates, AEPs have revealed responses in cephalopods at 400 Hz (Hu et al., 2009; Mooney et al., 2010), with sensitivity steeply dropping below 10 Hz (Packard et al., 1990). Similarly, a behavioural study on squid (Doryteuthis pealeii) revealed their optimal hearing range of 200– 400 Hz, with the capacity to respond down to at least 80 Hz (Mooney et al., 2016). Prawns showed an AEP response at 500 Hz (Lovell et al., 2006), while the lobster Homarus americanus showed ontogenic variation in AEP response to up to 5000 Hz as adults (Pye and Watson, 2004). **Despite their prevalence in establishing hearing thresholds through neurological responses, AEPs often do not accurately reflect behavioural responses (Hawkins et al., 2015; Sisneros et al., 2016), incorporate natural soundscapes (Ladich and Fay, 2013), or differentiate between pressure and particle motion (Popper et al., 2014), thereby making their application to the prediction of field responses questionable.** Threshold determination using AEPs is also problematic due to tank interference and animal holding which can lead to suspect thresholds such as 1500 Hz for cephalopods (Hu et al., 2009) and 3000 Hz for shrimp (Lovell et al., 2005) (see Section 4). See Supplementary Material 1 for further details on AEPs and hearing thresholds. One of the few studies to investigate thresholds of particle motion on invertebrates found that hermit crabs*

[1] Ladich, F. and Fay, R.R., 2013. Auditory evoked potential audiometry in fish. Reviews in Fish Biology and Fisheries, 23(3), pp.317-364. DOI 10.1007/s11160-012-9297-z

[2] Popper, A.N. and Hawkins, A.D., 2019. An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. Journal of fish biology, 94(5), pp.692-713. https://doi.org/10.1111/jfb.13948

behaviourally respond to 0.09–0.44 m s − 2 (RMS) (Roberts et al., 2016), but unfortunately most threshold studies on invertebrates report sound pressure rather than particle motion"

An alternative approach to understanding hearing in fish has been to distinguish fish on the basis of differences in their anatomy (e.g. fishes lacking swim bladders that are sensitive only to sound particle motion vs fishes that have specialised structures linking the swim bladder to the ear that are sensitive primarily to sound pressure but still detect particle motion – see Popper and Hawkins 2019). It is important to note that future studies on hearing capabilities must include particle motion and be done using behavioural studies undertaken in natural acoustic environments where sounds can be fully calibrated[2].

Senator URQUHART: *In paragraph 6.2 of your submission, you say: This precludes generalisation and extrapolation of results to other regions, seismic surveys, species, or biological responses. It's the bottom part of the second dot point of 6.2, and it talks about the main challenges of generalising seismic impact research. To what extent can a site-specific study of seismic be relevant to all areas? (Page 9 Hansard)*

Dr Carroll: *I can refer you to a publication where we discuss—*

Senator URQUHART: *Is that the same publication that you've been referring to?*

Dr Carroll: *The literature review? Yes. There are a number of—*

Senator URQUHART: *You're going to provide us with a copy of that, aren't you?*

Dr Carroll: *Yes. I'll provide that and the details that talk to that.*

GA Response: We refer Senator Urquhart to section 6 of our submission and to section 5.4 (Interpretation and extrapolation) and the concluding paragraph of our peer-reviewed literature review (Carroll et al. 2017), which specifically addresses the problems associated with extrapolating results from one study and applying them more broadly.

- *"Variation in metrics and methods used to quantify sound exposure makes comparisons among studies challenging, if not impossible**. The lack of standardisation in terminology and measurements related to sound exposure is one of the main limitations in providing a broad-scale assessment of potential impacts of underwater noise.** Until standardisation is improved, research findings on the effects of airguns and other sound sources in the marine environment will only apply to individual studies, and the general applicability of these studies to other marine seismic surveys, regions or taxa will remain questionable"*
- *"One of the main challenges in underwater sound impact studies is the meaningful translation of laboratory results to the field. Underwater sound properties are affected by the sound source and duration, as well as characteristics of the water column, substrate, and biological communities. For example, sound propagation in shallow waters is affected by several factors, which may either increase or decrease an organism's overall exposure to sound. If the range between airgun and animal is greater than the water depth, cylindrical spreading results in an increase in the effective range of sound (Montgomery et al., 2006). However, shallow water also limits the propagation of low-frequency sound, with relatively strong attenuation due the interaction with the sea bottom (Hamilton and Bachman, 1982; Montgomery et al., 2006)."*

- *Variations in sound propagation due to seafloor characteristics, water conditions, and seismic system specifications (McCauley et al., 2003a) therefore mean that it is not ideal to adopt an ad hoc approach and investigate potential impacts by compiling seismic data from multiple historical surveys (Thomson et al., 2014). Instead, potential effects should be examined by focusing on individual surveys in a given location, preferably with sound exposure at the seafloor modelled or measured (e.g. Przeslawski et al., in press). While it is evident that both gear- and species-specific effects may occur (e.g. Løkkeborg et al., 2012), it remains difficult to compare results among studies primarily due to differences in experimental designs (e.g. differences in sound pressure levels, frequency of exposure to airgun emissions and many other factors) (Bolle et al., 2012). Extrapolation of the effects of high-intensity acoustic sources to different species and seismic surveys must therefore be done with caution."*

- *"Our review has identified scientific evidence for high-intensity and low-frequency sound-induced physical trauma and other negative effects on some fish and invertebrates; however, the sound exposure scenarios in some cases are not realistic to those encountered by marine organisms during routine seismic operations. Indeed, there has been no evidence of reduced catch or abundance following seismic activities for invertebrates, and there is conflicting evidence for fish with catch observed to increase, decrease or remain the same."*

- *"While catch or local abundance may be the most relevant responses for fisheries species, they provide no information about the underlying biological cause of catch rate reduction. Rather, studies on physical trauma, behavioural changes, or physiological indicators of stress provide a more mechanistic and valuable understanding of potential impacts. There remains a vast gap in our knowledge about sound thresholds and recovery from impact in most fish and almost all invertebrates. Without this information, generalisations about impacts among taxa, airgun arrays, and regions are not scientifically valid."*

Senator PATRICK: *Sure. Is there any feel for the amount of money that Geoscience has spent on seismic surveys? (Page 10 Hansard)*

Senator PATRICK: *I would appreciate your taking that on notice, and also how much you've spent on science in respect of risk mitigation—in particular, things like effects on marine mammals and effects on sea life. (Page 10 Hansard)*

GA Response: We have provided overleaf a breakdown of costs associated with seismic surveys that Geoscience Australia has undertaken since 2015.

Seismic Survey	Year	Location	Acquisition	Environmental mitigation	Remarks
GA0352	2015	Gippsland	$ 7,378,525.00	$ 1,388,943.00	*Environmental mitigation costs include a separate research project of $1,080,927.72*
GA0349	2015	Houtman	$ 5,934,196.00	$ 352,164.00	
GA0354	2016	Lord Howe Rise	$ 4,495,238.00	$ 249,519.00	*As this was a broad ranging research voyage the cost of acquisition has been calculated based on the number of operational days dedicated to seismic reflection acquisition. For this voyage that is 62% of the total cost. The mitigation costs are attributed to voyages on the basis of the year they were incurred.*
GA0363	2017	Lord Howe Rise	$ 1,054,253.00	$ 107,880.00	As this was a broad ranging research voyage the cost of acquisition has been calculated based on the number of operational days dedicated to seismic reflection acquisition. For this voyage that is 22% of the total cost. The mitigation costs are attributed to voyages on the basis of the year they were incurred.
		Total	$18,862,212.00	$2,098,506.00	

Senator PATRICK: *That helps explain it. I'm really shocked that you've never looked at parametric sonars. I'll just name a couple of products. Atlas Hydrographic have something called Parasound. Kongsberg has a product as well that basically takes two high frequencies—say, 20 kilohertz and 21 kilohertz. It creates a difference frequency of one kilohertz, but it's very directional. I'm just looking at the characteristics for the TOPAS from Kongsberg, which is able to look at depth penetrations of 200 metres in sea water between 20 metres and 11,000 metres. The benefit of this is, because it's a higher frequency, its directional, unlike most seismic surveys using air guns. They're quite omnidirectional; they send sound in all directions. Parametric sonars have very narrow beams of three or four degrees and extremely high resolution because they are narrow band, instead of the broadband nature of typical air guns. Could you take on notice to go back and look through your records? I can give you a couple of vessels in Europe that have these. They're expensive; there's no question. But I'm just surprised they've never been considered. One of these vessels is the Polarstern out of the Alfred Wegener Institute in Germany. Another one is Maria S. Merian from the Leibniz Institute for Baltic Sea Research. All are doing sub-bottom profiling, looking at stratification (Page 12–13, Hansard).*

GA Response: Parametric sonar is used to image the structure of the shallow sub-seabed in high resolution to depths of up to 200-300 m, a technique also known as sub-bottom profiling. Geoscience Australia has used sub-bottom profiling in seabed mapping surveys since 1999. However, it is not used by Geoscience Australia for studies of deeper geological structure because the higher frequency sound of a parametric sonar attenuates very quickly and is ineffective for those deeper studies. Low frequency seismic signals (such as generated by air guns) are required to penetrate to the much greater depths (thousands of metres) to image the geological structures that are targets for hydrocarbon exploration, or for deep crustal imaging. Little is known about the impact of parametric sonar on marine fauna and Geoscience Australia has not undertaken any research on this matter. However, the technology does operate at frequency ranges that are in the hearing range of many marine species.

Senator McKIM: *I know you said you're not here to talk about an NOPSEMA, and that's totally fair enough, but you have referenced NOPSEMA in your submission, at 4.4. This is just following up on a question that Senator Whish-Wilson asked earlier. You've said that NOPSEMA applies the precautionary principle, and you've also said: In instances where there are high levels of scientific uncertainty about risks or potential impacts, seismic surveys are either not allowed to proceed or can only proceed once the survey design has been modified … I'm happy for you to take this on notice, but could you provide some examples to the committee of where NOPSEMA has actually not approved scientific work, on the basis of high levels of scientific uncertainty?*

GA Response: We have sought this information from NOPSEMA who have committed to making the requested information publicly available as supplementary material to their submission by the 11 March 2020.

GA Comment: In response to questions raised by the committee during the hearing regarding Geoscience Australia's published work in the Gippsland Basin (e.g. Page 7 Hansard), please find below abstracts from those peer-reviewed, publically available field and desktop studies. Copies of these publications are provided as further evidence – appended to this document. We have also included an externally reviewed desktop study (Thompson et al. 2014) that was undertaken in response to concerns raised by the fishing industry during stakeholder consultation, preceding a 2015 seismic survey in the Gippsland Basin. This desktop study examined whether a statistical relationship existed between marine seismic signals and fish catch rates in the Bass Strait and Gippsland Basin. We also refer the committee specifically to section 4.2 in Bruce et al. (2018) and section 4.5 in Carroll et al. (2017) for examination/discussion of catch rate analyses relating to seismic surveys.

An integrated approach to assessing marine seismic impacts: Lessons learnt from the Gippsland Marine Environmental Monitoring project

Rachel Przeslawski, Brendan Brooke, Andrew G. Carroll, Melissa Fellows

National Earth and Marine Observation Branch, Geoscience Australia, GPO Box 378, Canberra, ACT, 2601, Australia

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ABSTRACT

Marine seismic surveys are a fundamental tool for geological research, including the exploration of offshore oil and gas resources, but the sound generated during these surveys represents a source of noise pollution in the marine environment. Recent evidence has shown that seismic surveys may negatively affect some cetaceans, fish and invertebrates, although the magnitude of these impacts remains uncertain. This paper applies a case study on marine seismic impacts (the Gippsland Marine Environmental Monitoring (GMEM) project) to the critical assessment of the advantages and challenges of field-based methods in the context of future research and management priorities. We found that an interdisciplinary approach, using both conventional (e.g. dredging) and innovative (e.g. autonomous imagery) experimental components, make for more robust interpretations and also provide a failsafe in case of limited suitable data (e.g. equipment issues related to image acquisition). Field observational studies provide an unparalleled capability to undertake ecologically realistic research, although their practical challenges must be considered during research planning. We also note the need for appropriate environmental baselines and accessible time-series data to account for spatiotemporal variability of environmental and biological parameters that may mask effects, as well as the need for a standardised technique in sound monitoring and equipment calibration to ensure accuracy and comparability among studies.

Quantifying fish behaviour and commercial catch rates in relation to a marine seismic survey

Barry Bruce[a], Russ Bradford[a], Scott Foster[a], Kate Lee[b], Matt Lansdel[a], Scott Cooper[a], Rachel Przeslawski[c]

[a] Commonwealth Scientific and Industrial Research Organisation (CSIRO), GPO Box 1538, Hobart, TAS, 7001, Australia
[b] Sydney Institute of Marine Science, 19 Chowder Bay Rd, Mosman, NSW, 2088, Australia
[c] National Earth and Marine Observations Branch, Geoscience Australia, GPO Box 378, Canberra, ACT, Australia

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ABSTRACT

The impact of seismic surveys on the catchability of marine fish is a contentious issue, with some claims that seismic surveys may negatively affect catch rates. However little empirical evidence exists to quantify the impacts or identify the mechanisms of such impact. In this study, we used a 2-D seismic survey in the Gippsland Basin, Bass Strait, Australia in April 2015 as an opportunity to quantify fish behaviour (field-based) and commercial fisheries catch (desktop study) across the region before and after airgun operations. Three species found in abundance (gummy shark, swell shark, tiger flathead) were acoustically tagged and released within one of two acoustic arrays (experimental and control zone) and monitored before, during and after the seismic survey. In the field study, only 35% of the gummy sharks and 30% of the swell sharks were subsequently detected two days after release, suggesting movement outside the study area. Various tagged individuals returned sporadically over the monitoring period, including during the seismic survey operations. Behaviour consistent with a possible response to the seismic survey operations was observed for flathead which increased their swimming speed during the seismic survey period and changed their diel movement patterns after the survey. We also investigated the potential impacts of the seismic survey on catch rates using Commonwealth fisheries logbook data from Jan 2012–Oct 2015. Fifteen species and two gear types (Danish seine, gillnet) were modelled to examine differences in catch rates before and after the seismic survey. The catch rates in the six months following the seismic survey were significantly different than predicted in nine out of the 15 species examined, with six species (tiger flathead, goatfish, elephantfish, boarfish, broadnose shark and school shark) showing increases in catch following the seismic survey, and three species (gummy shark, red gurnard, and sawshark) showing reductions. With the exception of flathead movement, we found little evidence for consistent behavioural or catch rate changes induced by the seismic survey in the targeted species, although behavioural data were limited because many sharks left the acoustic receiver array prior to the commencement of the seismic survey.

Multiple field-based methods to assess the potential impacts of seismic surveys on scallops

Rachel Przeslawski[a], Zhi Huang[a], Jade Anderson[b], Andrew G. Carroll[a], Matthew Edmunds[c], Lynton Hurt[a], Stefan Williams[d]

[a] National Earth and Marine Observations Branch, Geoscience Australia, GPO Box 378, Canberra, ACT, Australia
[b] Energy Systems Branch, Geoscience Australia, Australia
[c] Marine Ecology Pty Ltd, 82 Parsons St, Kensington, VIC 3031, Australia
[d] Australian Centre for Field Robotics, University of Sydney, Sydney, 2006, NSW, Australia

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ABSTRACT

Marine seismic surveys are an important tool to map geology beneath the seafloor and manage petroleum resources, but they are also a source of underwater noise pollution. A mass mortality of scallops in the Bass Strait, Australia occurred a few months after a marine seismic survey in 2010, and fishing groups were concerned about the potential relationship between the two events. The current study used three field-based methods to investigate the potential impact of marine seismic surveys on scallops in the region: 1) dredging and 2) deployment of Autonomous Underwater Vehicles (AUVs) were undertaken to examine the potential response of two species of scallops (Pecten fumatus, Mimachlamys asperrima) before, two months after, and ten months after a 2015 marine seismic survey; and 3) MODIS satellite data revealed patterns of sea surface temperatures from 2006–2016. Results from the dredging and AUV components show no evidence of scallop mortality attributable to the seismic survey, although sub-lethal effects cannot be excluded. The remote sensing revealed a pronounced thermal spike in the eastern Bass Strait between February and May 2010, overlapping the scallop beds that suffered extensive mortality and coinciding almost exactly with dates of operation for the 2010 seismic survey. The acquisition of in situ data coupled with consideration of commercial seismic arrays meant that results were ecologically realistic, while the paired field-based components (dredging, AUV imagery) provided a failsafe against challenges associated with working wholly in the field. This study expands our knowledge of the potential environmental impacts of marine seismic survey and will inform future applications for marine seismic surveys, as well as the assessment of such applications by regulatory authorities.

Review

A critical review of the potential impacts of marine seismic surveys on fish & invertebrates

A.G. Carroll[a], R. Przeslawski[a], A. Duncan[b], M. Gunning[c], B. Bruce[d]

[a] *National Earth and Marine Observations Branch, Geoscience Australia, GPO Box 378, Canberra, ACT, Australia*
[b] *Centre for Marine Science and Technology, Curtin University, GPO Box U1987, Perth WA 6845, Australia*
[c] *Energy Systems Branch, Geoscience Australia, GPO Box 378, Canberra ACT 2601, Australia*
[d] *Commonwealth Scientific and Industrial Research Organisation, GPO Box 1538, Hobart TAS 7001, Australia*

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ABSTRACT

Marine seismic surveys produce high intensity, low-frequency impulsive sounds at regular intervals, with most sound produced between 10 and 300 Hz. Offshore seismic surveys have long been considered to be disruptive to fisheries, but there are few ecological studies that target commercially important species, particularly invertebrates. This review aims to summarise scientific studies investigating the impacts of low-frequency sound on marine fish and invertebrates, as well as to critically evaluate how such studies may apply to field populations exposed to seismic operations. We focus on marine seismic surveys due to their associated unique sound properties (i.e. acute, low-frequency, mobile source locations), as well as fish and invertebrates due to the commercial value of many species in these groups. The main challenges of seismic impact research are the translation of laboratory results to field populations over a range of sound exposure scenarios and the lack of sound exposure standardisation which hinders the identification of response thresholds. An integrated multidisciplinary approach to manipulative and in situ studies is the most effective way to establish impact thresholds in the context of realistic exposure levels, but if that is not practical the limitations of each approach must be carefully considered.