



16<sup>th</sup> December 2019

Committee Secretary  
 Senate Standing Committees on Environment and Communications  
 PO Box 6100  
 Parliament House  
 Canberra ACT 2600

## Fisheries Research and Development Corporation Submission to the Impact of Seismic Testing on Fisheries and the Marine Environment

### Contents

Terms of Reference .....	2
Executive Summary .....	2
Background .....	2
Fisheries Research and Development Corporation .....	3
Responses to the Specific Terms of Reference .....	4
<i>a. the body of science and research into the use of seismic testing</i> .....	4
<i>b. the regulation of seismic testing in both Commonwealth and state waters</i> .....	10
<i>c. the approach taken to seismic testing internationally</i> .....	10
<i>d. any other related matters</i> .....	10
Concluding Comments .....	11



## Terms of Reference

On 16<sup>th</sup> September 2019, the Senate referred to an inquiry into *the Impact of Seismic Testing on Fisheries and the Marine Environment* to the Environment and Communications References Committee for inquiry and report by the last sitting day of May 2020.

The inquiry is to have particular reference to:

- a. the body of science and research into the use of seismic testing;
- b. the regulation of seismic testing in both Commonwealth and state waters;
- c. the approach taken to seismic testing internationally; and
- d. any other related matters

### Inquiry Website:

[https://www.aph.gov.au/Parliamentary\\_Business/Committees/Senate/Environment\\_and\\_Communications/SeismicTesting](https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/SeismicTesting)

## Executive Summary

The Fisheries Research and Development Corporation (FRDC) is a Federal Government Corporation. FRDC's role is to plan and invest in fisheries research, development and extension (RD&E) activities across Australia. This includes, providing leadership and coordination of the monitoring, evaluating and reporting on RD&E activities, facilitating dissemination, extension and commercialisation. The FRDC achieves this through coordinating government and industry investment, to address RD&E priorities of stakeholders. In addition, the FRDC monitors and evaluates the adoption of RD&E to inform future decisions.

The FRDC submission to the Senate's inquiry into the *Impact of Seismic Testing on Fisheries and the Marine Environment* addresses the terms of reference relevant to the FRDC's research (primarily TOR a), development, and extension as it relates to the fishing and aquaculture sectors.

This submission looks at and builds on the FRDC's RD&E investment in Australia's fisheries and aquaculture sectors as well as the Australia's marine resource and their interactions with the Australian petroleum industry (<http://frdc.com.au/research/final-reports/Pages/default.aspx>).

The submission includes references to many activities undertaken over the previous 25-years as well as ongoing research investment. Key partners for FRDC include Australian, State and Territory Governments, the wild harvest, recreational fishing and aquaculture industries and leading research providers in Australia – e.g. universities, CSIRO and ABARES.

## Background

An important part of managing Australia's marine resources is mapping the geology beneath the seafloor using seismic surveys. Marine seismic surveys involve the use of airgun arrays that are towed behind vessels and produce high intensity, low frequency impulsive sounds at regular intervals. These sounds are directed down towards the seabed and are used to generate detailed images of the underlying geological formations. As part of this work, associated environmental impacts must be understood and mitigated.

For over a decade, several Australian fishing and aquaculture sectors, have been concerned about the potential impacts of seismic surveys on their target species. As such, this is considered a priority area for future research.

In response, the Fisheries Research and Development Corporation (FRDC), supported three research projects to investigate these concerns. These projects were supported by industry along with Origin Energy and the CarbonNet Project (Victorian Department of Economic Development, Jobs, Transport and Resources) who were contributors to the projects. Geoscience Australia also developed the Gippsland Marine Environmental Project of which FRDC funded a component (i.e. research into the short-term impacts of seismic sound on Scallops).

### **Fisheries Research and Development Corporation**

The Fisheries Research and Development Corporation (FRDC) is a statutory corporation within the Australian Government's Agriculture portfolio and is accountable to the Parliament of Australia through the Minister for Agriculture and Water Resources. The portfolio aims to enhance the sustainability, profitability and competitiveness of Australia's agriculture, food, fisheries and forestry industries. Formed on 2 July 1991, the FRDC operates under two key pieces of legislation: (i) Primary Industries Research and Development Act 1989 (PIRD Act), and (ii) Public Governance, Performance and Accountability Act 2013.

The role of the FRDC – a cofounded partnership between the Australian Government and the fishing and aquaculture industry – is to plan and invest in research, development and extension (RD&E) activities in Australia. Investment into RD&E is undertaken to assist in the management of Australia's fisheries and aquaculture resource for ongoing sustainability, profitability, and productivity. This means that FRDC's funding is directed at research that has a benefit for the three sectors of the fishing industry: commercial (wild catch and aquaculture), recreational and Indigenous, while also delivering a public good benefit to the Australian community.

Under the Primary Industries Research and Development Act 1989 the FRDC is bound by the following:

- a) make provision for the funding and administration of research and development relating to primary industries with a view to:
  - (i) increasing the economic, environmental and social benefits to members of primary industries and to the community in general by improving the production, processing, storage, transport or marketing of the products of primary industries; and
  - (ii) achieving the sustainable use and sustainable management of natural resources; and
  - (iii) making more effective use of the resources and skills of the community in general and the scientific community in particular; and
  - (iv) supporting the development of scientific and technical capacity; and
  - (v) developing the adoptive capacity of primary producers; and
  - (vi) improving accountability for expenditure on research and development activities in relation to primary industries.

The FRDC translates these into five theme areas (environment, industry, community, people, adoption) for investment of research and each project is categorised by these five areas. The FRDC is required to balance its investment in these areas to avoid only development at the detriment of the environment.

## Responses to the Specific Terms of Reference

Where applicable, under each term of reference we draw upon FRDC funded projects and cite non-FRDC funded research into interactions between the Australian seafood and petroleum industries to address these points. We provide FRDC project numbers and project titles to assist the reader.

Given the remit of the FRDC, this submission to the inquiry will primarily focus on **TOR a** of the Senate enquiry.

### **a. the body of science and research into the use of seismic testing**

Relative to **TOR a**, the FRDC have invested in research (both completed and in progress) related to the effects of seismic surveying and anthropogenic sound (e.g. shipping noise, naval sonar) on the marine ecosystem, inclusive of the inhabiting aquatic organisms (with a focus on commercially targeted species). The FRDC acknowledges that this research topic has traditionally not received a lot of FRDC investment; yet, is being afforded an increasingly higher priority by FRDC's commercial fishing and aquaculture stakeholders given the increased frequency of interactions between the petroleum and seafood industry.

Much of the research funded by FRDC that investigates potential impacts of seismic surveying on the marine ecosystem has been reactive and focuses on individual target species as opposed to ecosystem wide effects of seismic surveying. Focal target species are generally sedentary species that do not display migratory behaviours (e.g. Scallops, Rock Lobster) and so are highly prone to localised anthropogenic impacts.

Relevant completed FRDC funded projects (and their key findings) are outlined below. These studies underwent independent scientific review, at both the proposal and draft final report phase prior to finalisation.

- **2012-008 '[Assessing the impact of marine seismic surveys on southeast Australian scallop and lobster fisheries](#)'**

The final report for this project was independently peer reviewed by the FRDC and project steering committee.

The project investigated the potential impact of seismic surveys on economically important fishery species, specifically Southern Rock Lobster (*Jasus edwardsii*) and Commercial Scallop (*Pecten fumatus*). For Southern Rock Lobster, the research suggests that it is unlikely that seismic surveys cause immediate large scale mortality. Also there was no effect shown in early stage lobster embryos. However, no experiments were conducted on the full suite of embryonic or larval stages so effects on these stages are unknown. Exposure to airgun signals did cause some alteration to adult biology including depression of haemocytes available for immune responses, impairment of reflex behaviours for tail and righting control as well as damage to the sensory hairs on the statocyst (a balance sensory receptor).

With Commercial Scallops, seismic exposure did not cause immediate mass mortality, however, there was a trend between exposure level and mortality with severely compromised physiology over a 4 month time frame after which there was no signs of recovery. There were also significant changes in behaviour and reflexes following exposure. These impacts could cause a reduced tolerance to other stressors but it is still unclear whether the physiological impairment would cause chronic mortality in timeframes beyond those in the project.

- **2013-209 '[Optimising processes and policy to minimise business and operational impacts of seismic surveys on the fishing industry and oil and gas industry](#)'**

The final report has been completed following review by the FRDC.

The project aimed to improve processes of communication and build relationships between the fishing and petroleum industries so that there is a shared understanding of potential impacts (financial, operational and logistical) and how they could be minimised. During the project, the establishment of the [National Offshore Petroleum Safety and Environmental Management Authority](#) (NOPSEMA) improved consultation processes. Case studies recognised areas of negative impact as well as examples of best practice. From these case studies four processes were developed to deal with issues identified:

- Accessible, easy to use central website-based information on the two industry's associated communication processes;
  - Undertaking joint industry roundtable discussion and feedback into overarching policy and process;
  - Holding annual regional stakeholder meetings to discuss future planning and issues; and
  - Undertaking one-on-one industry/individual discussions.
- **2014-041 'Potential impact of low-frequency sound from seismic operations on benthic communities in the Gippsland Basin'**

The final report for this project was independently peer reviewed by the FRDC and project steering committee.

This project was initiated to undertake a before and after assessment to quantify potential impacts from a 2D seismic survey undertaken by Geoscience Australia in the Gippsland Basin off the coast of Victoria. Initially the project was to obtain seafloor images and identify scallops via an Autonomous Underwater Vehicle (AUV). Four acoustic recording units were used with three being used in the vicinity of the seismic survey and one control. A number of dredge samples were also taken in areas outside of the seismic survey area to assess the number of alive and dead Commercial Scallops as well as the meat and gonad condition of Commercial Scallops.

The project did have some issues with technology with the AUV footage prior to the seismic survey not being usable due to poor image quality. Additionally, one unit failed to record during the time that the survey was directly above it. The report has stated that there was no short term impact found and suggested as a recommendation that further studies should focus on longer term impacts.

## Future Research

The FRDC recently (as of December 2019) approved funding for the following projects (the project's 'Need' statements are provided below):

- **2019-051 'Examining the potential impacts of seismic surveys on Octopus and larval stages'**
- CGG Energy Solutions has NOPSEMA approval for a 3D seismic survey in the Gippsland Basin to commence in early 2020. This survey overlaps the Victorian shelter-pot Octopus fishery off Lakes Entrance. This overlap has raised concerns from the fishing industry about the potential impacts to Octopus and the fishers. Tank-based experiments simulating seismic exposure have resulted in high levels of damage in several species of Octopus, however, it is unclear how experiments conducted in tanks translate into the field. Field-based seismic experiments have rarely been conducted on invertebrates, with no such studies conducted on Octopus. However, the benthic and relatively sessile habit of Octopus leaves them potentially vulnerable to impacts, as they have limited capacity to avoid the waterborne and ground-borne energy of seismic signals. CGG has agreed to provide funds to fill the knowledge gap surrounding the potential impact of seismic surveying on Octopus and to do this in conjunction with a commercial scale seismic

survey, with the lack of a full array often a perceived limitation of seismic research. CGG has also agreed to value add to the work around Octopus. This opportunity allows for the potential impact of seismic surveying on larval forms to be examined, with some concerns around localised depletion of larvae of commercially and ecologically important species, such as Southern Rock Lobster and Commercial Scallops. This project will use a field and laboratory experimental approach to provide a thorough assessment of the potential impacts of seismic surveys on *Octopus pallidus* and its catches, along with Rock Lobster larvae and other important larvae. These approaches may assist fisheries and petroleum regulators to make informed decisions on the timing and manner in which future surveys are performed. Importantly, along with that of CGG, it has the support of the Victorian Fisheries Authority, who have also offered in-kind support, the two Octopus fishers in the region, the Lakes Entrance Fishermen's co-op, the Sustainable Shark Fishing Association and Southern Rock Lobster Inc.

- **2019-072 'M-BACI analysis of the effect of a 3D marine seismic survey on Danish Seine catch rates'**

Apart from the general concern regarding impacts of seismic on commercial fishing, there is specific concern from fishers operating in Bass Strait that, as one of the larger 3D surveys in the region, the CGG marine seismic survey (MSS) will:

1. Interrupt their fishing activities as they will not be able to work in active zones while the MSS is taking place; and,
2. Negatively impact on the fishing catch rates both during and after the MSS.

There is a lot of anecdotal information from fishers about the impact of MSS on fishing but little quantitative data to support these claims. With CGG support, a Multiple Before After Control-Impact (M-BACI) survey was designed to address the second issue, particularly the level of impact on Catch per Unit Effort (CPUE) of key species to the Danish Seine fleet in the area, namely Eastern School Whiting (*Silago flindersii*) and Tiger Flathead (*Neoplatycephalus richardsonii*). This project will apply this survey design during the upcoming CGG MSS due to commence in early 2020.

CGG has agreed to fund \$300,000 towards an M-BACI survey of Danish Seine catch rates. This project (with additional FRDC funding) will conduct a survey over at least two periods: Period 1 survey during or immediately after the MSS, and depending on the results from the initial survey, Period 2 survey, 2-4 months following the MSS.

The results will be of value not just in Bass Strait but could have significant ramifications around Australia in areas where oil and gas fields exist around productive fishing grounds.

For further information refer to the '*Seismic & Marine Sound*' page on the FRDC website – <http://frdc.com.au/issues/seismic-and-marine-sound-research> – for a list of FRDC funded projects that relate to interactions between the Australian seafood and petroleum industries.

Of note, the FRDC has funded project 2017-186 '[Oil and Gas: National coordination - seismic and other issues](#)' led by the Western Australian Fishing Industry Council. This project was established to aid the consultative process between the petroleum and seafood industry associated with planned seismic surveying. The FRDC was informed by its stakeholders that this was a key area where FRDC investment might assist in reducing the considerable burden on the seafood industry in dealing with the consultative environmental planning process. The objectives of project 2017-186 are to:

1. Deliver a publicly accessible portal – a "one stop shop" for seismic research bibliographies, case studies and other relevant commercial fishing oil & gas information etc.

2. Deliver ongoing identification and qualification of relevant research papers and reference cases including annotated summaries to ensure relevance for ready and easy access by the commercial fishing sector, oil & gas and the broader community.
3. Deliver a set number of supported research applications relevant to the effects of oil and gas activities on commercial fishing / commercial fishing stocks etc. – i.e. gap analysis and prioritisation.
4. Deliver a "best practice" document for commercial fishing representative bodies to use as a strong base for environment plan submissions.
5. Deliver a "best practice" document for commercial fishing representative bodies to use as a strong base and consistent process for fee-for-service environment plan consultation.

As per Objective One of FRDC project 2017-186, efforts are being made to collate the available and relevant grey and primary literature relevant to build a reference portal (library) of relevant peer-reviewed and grey literature that reports on the effects of seismic sound (and surveying more generally). Given the FRDC project is currently underway, this reference portal has not been finalised. The most up to date version of the (partial) reference list can be found here:

<http://frdc.com.au/-/media/fish-frdc/frdc-seismic-library---list-one.ashx?la=en>

The FRDC notes that there are other similar (inter-) national reference / databases of seismic / petroleum industry references that have been developed (some open and others restricted access). For example:

- Australian Petroleum Production & Exploration Association (APPEA) – reference library: <https://www.appea.com.au/industry-in-depth/technical-information/operations/seismic/reference-links-seismic/>
- The IGEM meta database: <http://www.igem.com.au/landing/about>
- The International Quiet Ocean Experiment – aquatic noise library: <http://iqoe.org/library>

FRDC anticipates that much of this literature will be incorporated in to the reference portal of FRDC project 2017-186 (where relevant).

These reference / databases demonstrate that there is a considerable body of international research undertaken on the effects of seismic and anthropogenic sound (e.g. shipping noise, naval sonar) on the marine environment and aquatic organism. While this research provides an excellent basis for both the Australian seafood and petroleum industries to draw upon the environmental planning phases of proposed seismic testing; FRDC advocates the need to consider how international research findings translates to the Australian context – in terms of species biology, local hydrology/bathymetry etc. These factors and others may influence the interpretation of research findings and the use of international research in an Australian context.

This does not suggest that all research undertaken internationally needs to be replicated in Australia. Though FRDC acknowledges that in some cases, there will be a need for analogous in situ research under local Australian conditions to aid in understanding the commonality of international (and historic and/or laboratory-based) research findings. Rather, the FRDC suggests there is likely a need for an independent, expert driven review of the work that can be contextualised for Australia to provide a reference scenario of risk to the marine ecosystem.

We highlight that this document does not provide a literature review quantifying the effects of seismic surveying and anthropogenic sound on the marine ecosystem. A rapid literature search demonstrates that there is a considerable body of peer-reviewed literature (albeit, largely marine

mammal focused) that assess the potential effects of seismic sound on the marine ecosystem. An example of one such contemporary, peer-reviewed published paper (not funded by the FRDC) is:

- Carroll et al. (2017) A critical review of the potential impacts of marine seismic surveys on fish & invertebrates. *Marine Pollution Bulletin* 114, 9-24. DOI: 10.1016/j.marpolbul.2016.11.038

We have extracted the panel of figures below from Carroll et al. that provides a graphical summary of the published research (both laboratory and field based) that assesses the potential impacts of low-frequency seismic sound on key seafood taxonomic groups – adult and juvenile/larval finfish, sharks and rays (elasmobranches), shellfish (molluscs), crustaceans, and echinoderms.

Of note, this graphical summary highlights that among the studies reviewed there is a lack of consistency of the measured response (impact) that seismic sound has on the species examined. The FRDC recommends the undertaking of a quantitative review of the measured responses (impacts) that seismic sound has on aquatic species using the available literature – for example using a meta-analytical approach (which examines the findings of multiple studies to develop a single conclusion with greater statistical power, while also analysing the effects of study-level factors that potentially drive observed variations) – such as:

- Cox et al. (2018) Sound the alarm: A meta-analysis on the effect of aquatic noise on fish behaviour and physiology. *Global Change Biology* 24, 3105-3116. DOI: 10.1111/gcb.14106

The observed inconsistency among the published research findings poses a challenge for decision makers (e.g. NOPSEMA) in assessing potential environmental impact plans for proposed seismic surveys. FRDC notes that an element of the assessment takes into account contemporary and relevant scientific research to evaluate potential environmental impacts of the proposed seismic survey. This highlights the value placed upon the available scientific research in establishing potential environmental impacts of the proposed seismic survey as well as the proponents planned actions to eliminate or reduce expected impacts to as low as reasonably practicable and to acceptable levels to ensure the environment is protected. Hence, these (at times) conflicting results have the potential to contribute to the further decline of the relationship between the seafood and petroleum industry, as the potential severity of planned seismic survey activities is contested based on different pieces of scientific evidence.

To improve this process, there is a need for some level of agreement between the seafood and petroleum industry on the use of scientific information in estimating the potential risk that seismic surveying has on marine ecosystems (inclusive of the organisms that inhabit it). Collaborative research partnerships between the seafood and petroleum industry, such that being undertaken on the northwest shelf of Western Australia funded by Quadrant Energy using real world seismic vessels and arrays, are important efforts to bridge the gap between the industries (<https://www.aims.gov.au/nw-shoals-to-shore/marine-noise-monitoring-and-impacts>).

The FRDC states that as a minimum environmental plans should be based on robust, independently peer-reviewed scientific data (noting that vast amounts of information in the grey literature, where it is often unclear whether there has been any degree of review).

	Adult/juvenile fish	Fish eggs/larvae	Elasmobranchs
<b>PHYSICAL</b>			
Swim bladder damage	1,2		
Otolith/inner ear damage	3	4	
Temporal Threshold Shift	5	14,34	
Permanent Threshold Shift	3		
Organ/tissue damage	1,2,8		
Mortality	1,2,6-11	11,14	11,13
<b>BEHAVIOURAL</b>			
Startle/alarm response	1,8a	6,7,8a,9,10,17	
Sound avoidance/migration*	8,14,20	7,12,14-18,21-23,24a	18
Other changes in swimming	20		
Predator avoidance			
Foraging			
Reproduction			
Intraspecific communication			
<b>PHYSIOLOGICAL</b>			
Metabolic rates			
Stress bio-indicators	16	6a	10a
Metamorphosis/settlement			
<b>CATCH EFFECTS</b>			
Catch rates / abundance	7,8,21,24	21-23	22,19,21,27,28

1 = Pepper et al. 2003; 2 = Pepper et al. 2016; 3 = Song et al. 2008; 4 = McCauley et al. 2003; 5 = Hastings and Mikris-Ortiz 2012; 6 = Sartzell et al. 1999; 7 = Haahtel et al. 2004; 8 = Breen et al. 2006; 9 = Wardle et al. 2001; 10 = Radford et al. 2016; 11 = McCauley and Kent 2012; 12 = Duen and Kuznetz 1987; 13 = Botsman et al. 1996; 14 = Payne et al. 2009; 15 = Kosturbenko 1973; 16 = McCauley et al. 2000; 17 = Pearson et al. 1992; 18 = Løkkeberg et al. 2012; 19 = Piccott et al. 1984; 20 = Peña et al. 2013; 21 = Skalski et al. 1992; 22 = Sloets et al. 2004; 23 = Engle et al. 1998; 24 = Chapman and Hawkins 1969; 25 = Miller and Cripps 2013; 26 = Thomson et al. 2014; 27 = Løkkeberg and Sodal 1993; 28 = Przaslawski et al. in prep.

1a: Statistically significant hearing loss immediately upon exposure of freshwater adult Northern Pike to 5 pulses at 400 Hz and exposure of Lake Chub to 1 and 20 pulses at 200, 400 and 1600 Hz. Recovery within 18 hrs. A shift was observed only in adults and not in juvenile Pike.

3a: Adult freshwater Northern Pike and Lake Chub exhibited temporary hearing loss, but no damage to the sensory epithelia studied in any of the otolithic end organs, demonstrating that hearing loss in fishes is not necessarily accompanied by morphological effects on the sensory hair cells.

8a: Repeated exposure to air guns resulted in increasingly less obvious startle responses in reflected fish, indicating possible habituation to the disturbance.

10a: Fish exposed to playback of pile-driving or seismic noise for 12 weeks no longer responded with an elevated ventilation rate to the same noise type, and showed no differences in stress, growth or mortality compared to those reared with exposure to ambient noise playback.

24a: Free ranging Whiting school responded to airgun sound by shifting downward, temporary habituation was observed after one hour of continual sound exposure.

\* Includes changes in vertical/horizontal distribution.

- Freshwater brackish species.

	Cephalopod	Gastropod	Bivalve	Larvae	Decapod <sup>a</sup>	Stomatopod	Larvae	Ophiuroid
<b>PHYSICAL</b>								
Air bladder damage					4,5	5		
Otolith/statocyst damage	1-3							
Organ/tissue damage	6		7,8		9			
Mortality/abnormality	6		7,8,10 <sup>b</sup>	5	11	5,9,12	4,13,14	
<b>BEHAVIOURAL</b>								
Startle response	15-19		5,20		4,23			
Sound avoidance	18				22			
Predator avoidance			5		5,12,23			
Foraging					23			
Reproduction					24			
Bioturbation			25		25			25
<b>PHYSIOLOGICAL</b>								
Metabolic rates <sup>b</sup>	26			11	4,12,27,28		13	
Stress bio-indicators	25		25,29	5	1,5,12,23,24,27,30			25
Immune response					5			
Energy stores			10					
Metamorphosis/settlement							31	13
<b>CATCH EFFECTS</b>								
Catch rates / abundance	29	29	7,10,29	8	4,9,27,29,32,33	29		

1 = André et al. 2011; 2 = Solé et al. 2013a; 3 = Solé et al. 2013b; 4 = Christian et al. 2003; 5 = Day et al. 2016a; 6 = Guerra et al. 2004; 7 = Harrington et al. 2010; 8 = Parry et al. 2002; 9 = Courtenay et al. 2009; 10 = current study; 11 = Aguilar de Soto et al. 2013; 12 = Payne et al. 2007; 13 = Pearson et al. 1994; 14 = Day et al. 2016; 15 = Fewtrell and McCauley 2012; 16 = McCauley et al. 2000; 17 = Sanson et al. 2014; 18 = Komak et al. 2005; 19 = Mooney et al. 2016; 20 = Roberts et al. 2015; 21 = Roberts et al. 2016; 22 = Celi et al. 2013; 23 = Wale et al. 2013a; 24 = Lagardere 1982; 25 = Solan et al. 2016; 26 = Käfer et al. 2007; 27 = Christian et al. 2004; 28 = Wale et al. 2013b; 29 = La Bella et al. 10 = Filicetto et al. 2014; 31 = Beacom and Ritschof 1984; 32 = Andriquetto-Filho et al. 2005; 33 = Parry and Gason 2006.

a: IFOC 2004 also examined the effects of various physical and physiological effects of seismic signals on snow crabs but is not included here because no baseline data acquired before seismic survey, and refined experiments in Courtenay et al. 2009 supersede these results.

b: Includes proxies for metabolic rate such as food consumption, growth, respiration, developmental rate.

c: Also includes Chalmer (1986), Koehleeva (1992) and Matishov (1992) as cited in Parry et al. (2002).

**KEY**

- Response at realistic exposure levels
- Response at unrealistic/unknown exposure levels
- No response
- Possible response / conflicting or anecdotal results
- No data, has not been tested
- Not applicable

**Figure caption.** A summary of potential impacts of low-frequency seismic sound on fish. Impacts are classified according to the sound exposure treatments as realistic (i.e. short bursts of low frequency sound at a distance of >1–2 metres) or unknown/unrealistic (i.e. long duration and/or short distance of <2 metres to sound source, nearfield sound exposure in aquaria). There are significant differences between seismic studies regarding sound exposure and the environment in which studies were conducted. Figure taken from Carroll et al. (2016) <http://dx.doi.org/10.1016/j.marpolbul.2016.11.038>

It is also apparent from the panel of figures above that there is a paucity of research into the potential impacts of low-frequency seismic sound on aquatic organisms. For example, there is no research exploring the effects of seismic sound on the biology/physiology and behaviour of sharks and rays (elasmobranchs), a particularly vulnerable taxonomic group given their life history strategy (slow growth and late time to maturity with low reproductive output).

What is unclear are the long-term pervasive effects of seismic surveying on marine ecosystems and the organisms that inhabit them and/or the cumulative effects of multiple seismic survey activities. For example, impacts to the viability of the reproductive potential of species can in turn lead to changes in the recruitment dynamics of populations, which would have ongoing consequences for the long-term population sustainability. While this example is speculative, such a scenario is credible and of concern for the seafood industry that is reliant upon the ongoing replenishment of the fishable resource through population recruitment. In the absence of such information, adhering to the precautionary principle is an appropriate approach to ensure that anticipated impacts are as low as reasonably practicable.

The FRDC recommends that further research assesses the potential (long-term) impacts of low-frequency seismic sound on aquatic key seafood taxonomic groups. Agreement between the seafood and petroleum industry on the prioritisation and planning of future RD&E activities would likely enhance the communal use of research findings as well as consultation throughout the environmental planning process, and aid in restoring the relationship between the industries.

***b. the regulation of seismic testing in both Commonwealth and state waters***

Relative to **TOR b**, the FRDC does not have any comments on the regulation of seismic testing in Australian waters, citing that this is the responsibility of NOPSEMA in assessing environmental impact plans for proposed seismic surveys.

***c. the approach taken to seismic testing internationally***

Relative to **TOR C**, the FRDC does not have any comments on the regulation of seismic testing internationally.

The FRDC does note, that the New Zealand government recently (April 2018) announced a ban to new offshore oil exploration in the New Zealand Exclusive Economic Zone (noting that multiple, existing permits will still remain in effect). This decision was cited as a key step to transition New Zealand towards a carbon-neutral future, but to also provide indirect benefits to reducing / mitigating the effects of seismic and anthropogenic sound on the marine environment and inhabiting organism.

***d. any other related matters***

Consultation between the petroleum and seafood industry associated with planned seismic surveys remains challenging. This is in part due to differences in the scales of the industries. Increasingly, the FRDC is being told of the considerable burden on the seafood industry in dealing with the consultative environmental planning process.

The FRDC has invested in RD&E activities that seek to facilitate and promote meaningful two-way communication between the industries in order to improve environmental planning outcomes while minimising consultation fatigue (e.g. 2013-2019 'Optimising processes and policy to minimise business and operational impacts of seismic surveys on the fishing industry and oil and gas industry'). For

example, as per Objectives 4 & 5 of FRDC project 2017-186 'Oil and Gas: National coordination - seismic and other issues' (outlined above), a series of tools and templates are being developed to:

- Define best practice guidelines for the petroleum industry led consultation process. This includes aiding petroleum in familiarising themselves by developing fishery-specific profiles for each jurisdiction, thus making consultation fit for purpose.
- Establish best practice guidelines for seafood industry representative bodies to use when providing fee-for-service environment plan consultation on behalf of the petroleum industry.

It is anticipated that improvements in the consultative environmental planning process, will aid in restoring relationships between the petroleum and seafood industry.

The FRDC acknowledges the recent co-investment with CCG Energy Solutions in projects that are assessing the potential impacts of a planned seismic survey in southeast Australia (FRDC projects 2019-051 'Examining the potential impacts of seismic surveys on Octopus and larval stages' & 2019-072 'M-BACI analysis of the effect of a 3D marine seismic survey on Danish Seine catch rates'). This co-investment model with the petroleum industry is a relatively new and encouraging approach to funding research to better understand the effects of seismic sound on the marine ecosystem (inclusive of the organisms that inhabit it). However, there is concern that this will create an expectation that the FRDC will increasingly be called upon to (co-)invest in research to demonstrate the potential impacts of seismic sound and the risks associated with seismic surveying. It is worth noting the funds that FRDC uses to invest in RD&E comprises a combination of seafood industry contributions, Commonwealth matching contributions and additional public good (tax-payer) funds. Given the FRDC's funding model, it seems unreasonable for the FRDC to use seafood industry and tax-payers funds to invest in research to demonstrate the impact (or lack) of a sector that does not contribute funds to the FRDC, while derives considerable economic benefits.

The FRDC supports the Quadrant Energy funded research project, being led by Australian Institute of Marine Science (AIMS) to look at potential impacts of seismic sound in the northwest shelf of Western Australia ([https://www.aims.gov.au/docs/media/latest-releases/-/asset\\_publisher/8Kfw/content/world-first-seismic-sound-experiment-conducted-off-nw-australia](https://www.aims.gov.au/docs/media/latest-releases/-/asset_publisher/8Kfw/content/world-first-seismic-sound-experiment-conducted-off-nw-australia)). This model demonstrates the petroleum industry's willingness to investigate issues and commit to a stewardship role in the marine ecosystem. Moreover, this partnership between Quadrant Energy, AIMS and the seafood industry – namely, Pearl Producers Association and the Paspaley Pearl Company – provides an opportunity for mutual agreement / buy in to research outcomes.

## Concluding Comments

The FRDC notes that there currently exists a large body of scientific research into the potential impacts of low-frequency seismic sound on key seafood taxonomic groups. However, there appears to be inconsistency in the research findings as well as information gaps, which in combination makes it challenging for decision makers (i.e. NOPSEMA) to assess the risk and potential impacts of planned seismic survey activities. This in turn creates the potential for a contested space for the seafood and petroleum industry's when defining the risks associated with proposed seismic surveys. In an effort to foster a collaborative approach to the environmental planning process, the FRDC suggests the following actions be made:

- An independent, expert driven review of the available international research that might be contextualised for Australia in order to provide a reference scenario of risk to the marine ecosystem

- A quantitative review of the measured responses (impacts) that seismic sound has on aquatic species using the available literature
- Work towards agreement between the seafood and petroleum industry on the use of scientific information in estimating the potential risk that seismic surveying has on marine ecosystems
- Increased collaborative research partnerships between the seafood and petroleum industry
- Agreement between the seafood and petroleum industry on the prioritisation and planning of future RD&E activities

With respect to future research activities, the FRDC is increasingly being asked to invest in research to demonstrate the impact (or lack) of seismic sound on the marine ecosystem – but is it appropriate for the Commonwealth Government through the FRDC, the seafood industry and the public (tax payers) to fund these activities? The FRDC are encouraged to see instances where individual petroleum companies are establishing (co-)investment partnerships with the seafood industry, institutional research providers and the FRDC. This investment model would better signal the petroleum industry's willingness to investigate issues and commit to a stewardship role in the marine ecosystem. FRDC also anticipates that such leadership from the petroleum industry would considerably enhance their relationship with the seafood industry and the Australian community.

Finally, the FRDC highlights that some of the issues that have prompted this Senate enquiry go beyond marine seismic surveying. The progressive shift to offshore energy resources – including petroleum, wind and wave energies, as part of the development of Australia's blue economy, will likely see similar contests, for example associated with marine spatial access, potential risks and measured impacts, occur. In this manner, there is a need for efforts to progress ecosystem based management that takes into account all users (aquatic and terrestrial) economic and social values and ecological impacts on a shared marine ecosystem.