

Rapid Communication

Comparing seismic survey mitigation regulations: lessons for South Africa from international frameworks

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Underwater seismic surveys generate high-intensity, low-frequency noise that can negatively affect a range of marine fauna. As a result, countries have implemented mitigation regulations to reduce the potential impacts of this activity. This study examines seismic survey mitigation regulations from Australia, the United States, Brazil, New Zealand, Canada and the United Kingdom, and compares them with the current regulations in South Africa. We focused on setting the radii of exclusion zones, ‘soft-start’ procedures, passive acoustic monitoring, marine mammal observer qualifications and standards, and regulatory oversight. Of the six countries reviewed, Australia and New Zealand have implemented the most robust mitigation measures. Furthermore, Australia stands out for its independent regulatory authority overseeing offshore environmental compliance. We recommend the establishment of an independent regulatory board in South Africa to oversee the development of environmental impact assessment guidelines and mitigation protocols. By adopting these measures and aligning with international best practice, South Africa could become a regional, if not global, leader in science-based environmental regulation and the protection of marine fauna from seismic surveys.

Keywords: environmental compliance, environmental impact assessment, international best practice, marine fauna, marine mammal observers, passive acoustic monitoring

Introduction

Marine seismic surveys are a mapping technique used to locate oil and gas reserves beneath the seafloor by deploying airgun arrays that emit low-frequency, high-intensity impulsive sounds (Richardson et al. 1995; Hildebrand 2009). Underwater sound pressure levels (SPL) of ≥ 230 dB re 1 μ Pa @ 1 m root-mean-square (SPL_{rms}) are considered extremely high, and this is significant in conducting marine seismic surveys and underwater environmental impact assessments (Southall et al. 2007). Airguns used in seismic surveys produce broadband signals with source levels exceeding 230 dB re 1 μ Pa @ 1 m SPL_{rms}, even for relatively small arrays (~3 000 in³) (Caldwell and Dragoset 2000). Given their intensity, frequency range and propagation characteristics, these signals can alter the acoustic environment of marine ecosystems and potentially affect a wide range of marine fauna (Southall et al. 2023).

Seismic surveys have been found to impact many species, including zooplankton, crustaceans, fish, diving seabirds and marine mammals (McCauley et al. 2003,

2017; Popper and Hastings 2009; Day et al. 2017; Pichegru et al. 2017; Kavanagh et al. 2019; Purdon et al. 2025). While seismic surveys are not routinely associated with acute mortality or mass strandings, particularly in marine mammals, sublethal impacts, including behavioural disturbance, are more frequently reported (Southall et al. 2023). These may include displacement from critical habitats, changes in dive patterns or vocalisation, disruption of foraging or migration patterns, and potential long-term fitness consequences when experienced cumulatively in an already noisy environment (Southall et al. 2023).

To reduce these negative impacts, particularly on marine mammals which are dependent on sound, several countries, including the United Kingdom (UK), Australia, Brazil, New Zealand and the United States (USA), have implemented mitigation measures for marine seismic surveys (Weir et al. 2007; Compton et al. 2008). The UK was the first country to introduce formal guidelines through the Joint Nature Conservation Committee (JNCC), which include measures such as exclusion zones (EZ),

'soft-start' procedures, and visual and acoustic monitoring (Table 1) (Weir et al. 2007). Since then, other countries have adopted and altered these regulations to suit their unique marine faunal and governance requirements (Weir et al. 2007; Reyes Reyes et al. 2016). Best-practice approaches go beyond the JNCC standards and include integrating acoustic monitoring, baseline data collection, independent oversight and post-survey impact reporting. Mitigation can occur at two distinct stages: (1) during the environmental impact assessment (EIA) and project-planning phase, when a survey's timing, area and source parameters are set and baseline data and acoustic models are developed; and (2) during operational measures implemented on board the seismic survey vessel during data acquisition, such as monitoring performed by a marine mammal observer (MMO) or passive acoustic monitor (PAM), the use of so-called 'soft-starts, or real-time acoustic detection. These roles, along with other key mitigation terms, are defined in Table 1.

South Africa lacks formal, nationally legislated seismic mitigation regulations (Purdon 2018) and instead typically relies on the JNCC recommendations, adapted by specialists during the development of the environmental management plan (EMP). As a signatory to several international environmental agreements, including the International Maritime Organisation (IMO), the Convention on Biological Diversity (CBD), and the Convention on the Conservation of Migratory Species (CMS), all of which recognise underwater noise as a form of marine pollution, South Africa has a responsibility to implement effective mitigation policies. The need for a specific regulatory framework tailored to South Africa's unique marine faunal environment and cultural heritage was highlighted in 2021, when a seismic survey planned along the Transkei coast of the Eastern Cape Province was halted by a court interdict because of an outdated EMP (le Roux et al. 2022).

Methods

Comparison of seismic survey mitigation policies among countries

This article presents a desk-based, qualitative comparison of seismic survey mitigation policies from six countries, based on guidelines of the JNCC: Australia, the USA, Brazil, New Zealand, Canada and the UK. These countries were selected for their robust regulatory frameworks and relevance to international best practice. The analysis focused on key mitigation components and examined both the EIA (planning) and operational stages, emphasising the need for more-detailed, policy-based regulations in South Africa to address both stages clearly.

Our comparative analysis focused on the following key mitigation components for seismic surveys:

- Regulatory oversight — including the licensing authority, its independence, enforcement capacity and conflict of interest (at the EIA stage).
- EIA process — including baseline data requirements, acoustic modelling, public consultation and cumulative impact assessments. EIAs consider all impacts, meaning environmental (e.g. oil spills, chemical pollution, noise pollution, animal entanglement, ship strikes,

Table 1: Terminology relevant to marine seismic survey mitigation

Term	Definition	Stage
Marine mammal observer (MMO) or protected species observer (PSO)	A trained individual responsible for visually detecting and reporting marine mammals and other marine fauna during offshore operations to ensure mitigation procedures are followed.	Set during EIA; enforced operationally
Passive acoustic monitoring (PAM) operator	A trained operator responsible for the use of underwater hydrophones to detect vocalising marine mammals.	Set during EIA; enforced operationally
Exclusion zone (EZ)	A designated area around a sound source where no sensitive species may be present before and/or during operations; depending on the EMP, the EZ is defined using acoustic modelling or static fixed radii.	Set during EIA; enforced operationally
Soft-start/ramp-up	A gradual increase in sound intensity at the beginning of operations to allow animals to leave the area before airguns reach full power.	Set during EIA; enforced operationally
Environmental management plan (EMP)	A legally required document in South Africa detailing mitigation, monitoring and environmental compliance measures for a project.	EIA planning
Environmental impact assessment (EIA)	A formal process used to predict and evaluate potential environmental and social impacts of a proposed project, including stakeholder engagement and mitigation planning.	EIA planning

habitat degradation), social and cultural (e.g. tourism, recreational use, traditional and cultural practices, coastal communities), and economic (e.g. fisheries, shipping, energy development). Here, we focused specifically on the acoustic impacts (i.e. noise pollution) on marine mammals, while drawing on examples of other impacts to illustrate best practices (at the EIA stage).

- Delineation of an exclusion zone (EZ) — including the method of survey delineation (fixed versus modelled), the survey size, species-specificity, and criteria for airgun shutdowns (requirements set at the EIA stage, operationally enforced).
- ‘Soft-start’ and pre-watch procedures — including minimum duration of the airgun array and modifications for depth or species sensitivity (requirements set at the EIA stage, operationally enforced).
- Night-time operations — this entails the requirements for monitoring technologies during poor visibility or at night (requirements set at the EIA stage, operationally enforced).
- MMO and PAM protocols — including deployment standards, personnel qualifications and operational limitations (requirements set at the EIA stage, operationally enforced).
- Post-survey reporting and transparency — this involves report submission procedures and required contents, and follow-up mechanisms (EIA follow up using operational data).

Each mitigation element was then compared with current South African practices, as implemented through the EMP process. Definitions of key mitigation terminology, such as MMO, PAM, EMP, EIA, ‘soft-start’ and EZ, are summarised in Table 1.

The goal of the comparison among countries was not to evaluate mitigation effectiveness of seismic surveying in the field, which would require species-level impact data, but to assess the design, scope and regulatory rigour of the existing mitigation frameworks in response to acoustic pollution produced by seismic surveys. Lastly, based on our review, we also provide recommendations to improve seismic survey governance in South Africa, focusing primarily on the protection of marine mammals in line with international guidelines. Where relevant, gaps in protection for other sensitive species (e.g. turtles, penguins, whale sharks) are also noted.

Comparative analysis of regulations and guidelines

Regulatory approaches and oversight

Regulatory approaches vary globally between and within countries (Table 2). In South Africa, the Petroleum Agency SA (PASA) manages applications and makes recommendations for offshore oil and gas exploration rights under the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA). PASA promotes petroleum exploration and assesses technical and commercial aspects of applications, but it does not issue environmental authorisation. This is decided by the Minister of Mineral Resources and Energy, as the competent authority under the National Environmental Management Act 107 of 1998 (NEMA), based on EIAs. The Department of Forestry, Fisheries and the Environment (DFFE) serves as the appeal authority for environmental authorisation decisions.

Although this division of responsibility is intended to balance economic development and environmental protection, concerns remain about potential conflicts of interest, as PASA has both a promotional and advisory role in the licensing process.

This contrasts with Australia’s governance model, where the National Offshore Petroleum Titles Administrator (NOPTA) oversees exploration and production licensing (NOPTA 2025), whereas the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) serves as the independent regulator for offshore petroleum activities and is widely regarded as a global benchmark. NOPSEMA enforces science-based, risk-oriented environmental plans that are supported by acoustic modelling, cumulative impact assessment and adaptive management (NOPSEMA 2025). Other countries like the USA, New Zealand, Brazil, Canada and the UK rely on multi-agency systems (Table 2), which, like in South Africa, can lead to conflicts of interests. Therefore, South Africa would benefit from establishing an independent regulator to enhance transparency and regulatory vigour.

EIA requirements and planning phase

Though all the countries assessed require EIAs, the criteria and consistency differ (Table 2) (Nowacek et al. 2013; Wright et al. 2013). Australia, New Zealand, Canada and the USA have the most rigorous frameworks for acoustic modelling and public consultation (Table 2). A concern is the lack of standardised EIA requirements, leading to inconsistent approvals and mitigation plans (Prideaux and Prideaux 2015). Australia’s NOPSEMA addresses this through scientific review of EIAs, but inconsistencies persist, prompting recommendations for clearer modelling guidelines and cumulative impact assessments (Prideaux and Prideaux 2015).

EIAs should drive species-specific and habitat-specific mitigation efforts, including the timing of surveys to avoid sensitive periods (e.g. whale migration or breeding seasons), limiting airgun use and power, and restricting operations to daylight in high-risk areas. These actions focus specifically on reducing acoustic impacts on vulnerable fauna, complementing broader EIA considerations. Detailed national standards for South African EIAs would improve consistency, quality and ecological protection across projects.

Exclusion zones

The EZ is set during the EIA and the enforced operationally. EZs in the USA, Australia, New Zealand and Canada are defined via acoustic modelling (Table 2), while South Africa, the UK and Brazil use fixed radii, which do not account for environmental variables like bathymetry and temperature (Bröker 2019). Species respond differently to noise, and fixed zones can be inadequate. For example, modelled sound exposure levels from a case study in South Africa revealed that baleen whales were exposed to potential temporary and permanent threshold shifts up to 3 000 m from the seismic signal source (Purdon et al. 2025). Shutdown zones should reflect species sensitivity and cumulative sound exposure (Prideaux and Prideaux 2015).

Table 2: Comparative summary of seismic survey mitigation regulations across seven countries

Mitigation measure	Australia ^{1,2}	USA ^{3,4,5,6,7}	Brazil ^{7,8,9}	New Zealand ^{10,11}	UK ^{12,13}	Canada ^{14,15,16,17,18,19}	South Africa ^{20,21,22}
Environmental regulatory authority	National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) – independent	The Bureau of Ocean Energy Management (BOEM) issues leases and reviews EIA's; the Bureau of Safety and Environmental Enforcement (BSEE) ensures operational and environmental compliance; NOAA's National Marine Fisheries Service (NMFS) issues authorisations for protected species	Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA)	Regulated by the Department of Conservation (DOC) and the Environmental Protection Act (EPA)	The Joint Nature Conservation Committee (JNCC) is an official agency that guides regulators	Impact Assessment Agency of Canada (IAAC) – environmental assessment, compliance determined by the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), the Canada-Nova Scotia Offshore Petroleum Board (C-NSOPB), or the Canada Energy Regulator (CER); input from Fisheries and Oceans Canada (DFO) and Environment and Climate Change Canada (ECCC)	Department of Mineral Resources and Energy (DMRE) – competent authority under the National Environmental Management Act (NEMA); Department of Forestry, Fisheries and the Environment (DFFE) – appeal authority; Petroleum Agency South Africa (PASA) – advisory role under the Mineral and Petroleum Resources Development Act (MPRDA)
Licensing authority	National Offshore Petroleum Titles Administrator (NOPTA)	Bureau of Ocean Energy Management (BOEM)	National Agency of Petroleum, Natural Gas and Biofuels (ANP)	New Zealand Petroleum and Minerals	North Sea Transition Authority	Atlantic offshore licences issued by C-NLOPB/C-NSOPB; federal offshore elsewhere by CER	Petroleum Agency South Africa (PASA) – manages and recommends rights under the MPRDA; final approval by the Minister of Mineral Resources and Energy, subject to Environmental Authorisation from the DFFE
Pre-survey environmental impact assessment (EIA)	Required; includes acoustic modelling	Required; includes acoustic modelling	Required in shallow or sensitive areas	Marine mammal impact assessment	Strategic environmental assessment	Mandatory under Impact Assessment Act	EMP required; often lacks modelling
Public consultation	Required	Required	Only in sensitive areas	Required	Required	Required	Required
Qualifications for marine mammal observers (MMO)/ protected species observer (PSO)	Independent trained observers	NMFS-approved; degree and experience	Academic degree plus 100-sea-days experience	12 weeks + 3 years' experience	JNCC-approved; 20 weeks of experience	"Qualified", but undefined	JNCC-trained, with curriculum vitae submitted to client
MMO requirement	≥2 per shift	2 PSO, 2 h max.	≥3 MMOs	≥2 MMOs, with 1 on duty	"Sufficient" MMOs	MMO always on duty	2 MMOs + 1 PAM operator (typical)
Passive acoustic monitoring (PAM)	Mandatory, case-by-case	Mandatory; 4 h on/2 h off	Used throughout; 3 or 4 operators	≥2 PAM operators, with 1 always active	"Sufficient" PAM operators	For night-time or during low visibility	EMP-based; typically required
Exclusion zone (EZ)	1 km for whales and dolphins; 500 m shut-down zone. EZ can be determined by acoustic modelling	1 500 m for beaked whales and sperm whales Physeter macrocephalus; 500 m for other species	1 km for soft-starts, and 500 m for full power	1 km for species of concern; 1.5 km for species of concern with other marine mammal. Acoustic modelling used to define the EZ for high-risk surveys	500 m	Minimum of 500-m EZ, delineated by acoustic modelling in sensitive areas, to ensure that the source level does not exceed 160 dB re 1 µPa's	500 m for all cetaceans and turtles
Pre-watch monitoring	30 min	30-min visual and acoustic monitoring	30 min	30 min for PAM operators and MMOs	30 min for PAM operators and MMOs in waters <200 m; 60 min in waters >200 m	30 min	30–60 min per EMP
Soft-start procedures	30 min	20–30 min	20–40 min	20–40 min	20–40 min; delay required if fauna present	20 min	20–40 min

Table 2: Comparative summary of seismic survey mitigation regulations across seven countries

Mitigation measure	Australia 1,2	USA 3,4,5,6,7	Brazil 7,8,9	New Zealand 10,11	UK 12,13	Canada 14,15,16,17,18,19	South Africa 20,21,22
Airgun shutdown	Modelled sound levels of ≤ 160 dB re $\mu\text{Pa}^2\text{s}^{-2}$ – observation zone: 3+ km; low-power zone: 1 km; shutdown zone: 500 m. Surveys without modelling – observation zone: 3+ km; low-power zone: 2 km; shutdown zone: 500 m	For beaked whales Kogia spp., sperm whales and baleen whales, the EZ is 1 500 m; for any other protected species the EZ is 500 m	Yes, for all species, and EZ must be clear for 30 min	For species of concern within their respective EZ	No shutdown required once soft-start and full power has been reached	For any threatened or endangered marine mammal or turtle as well as any other marine mammal or turtle identified in the IAA act	Based on the EMP recommendations which generally require shutdowns for all cetaceans and turtles within 500 m of the source
Night-time operations	Permitted with restrictions	Permitted with PAM	Permitted with PAM	Permitted with PAM	Permitted with PAM	Permitted with PAM; new technologies are also encouraged	Permitted with PAM, based on EMP
Post-survey monitoring and reporting	Reports required by Department of the Environment	Mandatory reporting to BOEM and NMFS within 90 days	Required by IBAMA	Required for government evaluation	Required and sent to the regulator for the specific survey as well as JNCC	Final report submitted to Fisheries and Oceans Canada	Report mandatory and required by PASA
Seasonal and area restrictions	Closed areas for breeding and sensitive species	Time/area restrictions for some species	Seasonal closures for breeding hump-back whales and southern right whales Eubalaena australis; permanent closed areas for manatees and the Franciscana dolphins Pontoporia blainvillei	Avoid sensitive areas and these restrictions are highlighted by the marine mammal impact assessment	Some seasonal limitations depending on area and species	Restrictions are regulated through the IAA act and regional rules	Seasonal closures for breeding whales

1. Home | NOPSEMA
2. National Offshore Petroleum Titles Administrator
3. Home | Bureau of Ocean Energy Management (BOEM)
4. Home | Bureau of Safety and Environmental Enforcement
5. Home | Bureau of Ocean Energy Management (BOEM)
6. Welcome to NOAA | NOAA Fisheries
7. Vilaro and Barbosa (2018)
8. Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)
9. Home | National Agency of Petroleum, Natural Gas and Biofuels
10. Seismic Surveys Code of Conduct: Our work
11. Home | New Zealand Petroleum and Minerals
12. JNCC – Adviser to Government on Nature Conservation
13. About us | The North Sea Transition Authority
14. 14. Impact Assessment Agency of Canada | Canada.ca
15. Fisheries and Oceans Canada
16. Environment and Climate Change Canada | Canada.ca
17. Home | C-NLOER
18. CNSOER
19. Canada Energy Regulator
20. Le Roux et al. (2022)
21. Mineral and Petroleum Resources Development Act 28 of 2002 | South African Government
22. Petroleum Agency SA – Explore South Africa
23. National Environmental Management Act 107 of 1998 | South African Government

Pre-watch and soft-start protocols

These are likewise set during the EIA and then enforced operationally. Globally, recommended times for acoustic soft-starts vary from 20–40 min, and the pre-watch period is typically 30 min (Table 2). However, deep-diving species like beaked whales may be missed, prompting the JNCC to recommend a 1-h pre-watch in waters deeper than 200 m. Similar measures have been adopted in New Zealand's Code of Conduct (DOC 2017) and are advised informally in Australia (NOPSEMA 2023) and the USA (BOEM 2021) for high-risk species or environments. Continuous visual and acoustic monitoring during operations is considered best practice, but clearer pre-watch and soft-start guidelines should be set in any EMPs or regulations for South Africa.

Standards for MMOs and PAM operators

The regulatory guidelines for observers are set during the EIA and enforced operationally. Australia, the USA, New Zealand and Canada specify minimum qualifications for a MMO or PAM operator and allow for additional personnel as needed (Table 2). However, the required qualifications and observer numbers vary. The USA and Brazil require relevant degrees and field experience for an MMO or PAM operator (Table 2). In South Africa, however, clients select personnel based on JNCC training, and there are no legislated standards, which may lead to regulatory gaps and conflicts of interest. Standardised, independently regulated qualifications would improve consistency and accountability among observers.

Night-time operations

The extent of permissible night-time seismic surveying is also set during the EIA and enforced operationally. In Brazil, the USA, Australia and Canada, PAM is mandatory during low visibility (Table 2) yet the technique has several notable limitations, such as it requires expertise, cannot estimate distances well, and only detects vocalising animals like odontocetes. Other marine fauna, like turtles, pinnipeds, diving seabirds and low-frequency vocalising baleen whales, are either undetectable by PAM or masked by vessel noise (Clark et al. 2009). Although South Africa mandates that EMPs stipulate mitigation for all marine fauna, including diving seabirds, turtles, pinnipeds and cetaceans, PAM is limited in its ability to detect many of these taxa. Despite these constraints, PAM still remains the best practice, even though the given EMP might lack clarity on whether PAM should be continuous, limited to only poor-visibility conditions, or restricted to pre-watches and soft-starts. Best practice would ideally entail continuous PAM coverage over a 24-h period. Given the limitations of PAM in detecting low-frequency or non-vocalising cetaceans and other marine fauna, emerging technologies—such as infrared imaging (Smith et al. 2020) or detection through the use of artificial intelligence (AI) (Marzetti et al. 2021)—should be encouraged, tested to prove their efficiency, and formally incorporated into EIAs or MMO/PAM guidelines.

Post-survey reporting

Countries such as the USA, Australia and New Zealand require post-survey reporting to relevant authorities

(Table 2). These reports often inform adaptive management and policy refinements. In South Africa, post-survey reporting is required by PASA but does not stipulate standardised content or a need for follow-up. Therefore, clear expectations and transparent reporting mechanisms should be formalised within a regulatory framework.

Towards best practice in South Africa

Best practice in seismic survey mitigation for South Africa should include: independent regulatory oversight without conflicts of interest; science-based environmental assessments incorporating acoustic modelling and cumulative impact analysis; species-specific EZs; defined pre-watch and soft-start procedures; accredited MMOs and PAMOs; mandatory PAM or alternative detection tools during night-time operations, such as thermal imaging; and transparent post-survey reporting.

Importantly, mitigation must also account for non-vocalising animals like turtles, diving seabirds and whale sharks, which cannot always be detected using PAM or thermal imaging. As part of the EIA, surveys should be planned to minimise disturbance, for example by avoiding sensitive periods (e.g. migration by humpback whales *Megaptera novaeangliae* or the *Sardinops sagax* sardine run), using the lowest possible volume for airguns, minimising source sound pressure levels, and applying higher standards in sensitive areas. Operational strategies such as daylight-only operations in sensitive areas, enhanced visual monitoring, thermal imaging at night, and MMO/PAM comprise last-resort mitigation measures, as impact reduction should be largely achieved through the initial EIA planning phase. Regulatory frameworks should include species-specific measures and habitat-based planning to ensure protection when standard detection is impossible.

Key seismic survey mitigation measures recommended for South Africa

To align with international best practice and address the regulatory gaps identified in this review, we recommend five key mitigation measures for South Africa.

1) Establish an independent regulatory board to oversee seismic survey approvals, EIAs and mitigation implementation. This board should include industry experts, marine bioacoustic experts, species-specific and taxon-specific biologists, legal experts and environmental practitioners (Purdon et al. 2025). It must function independently of any government departments responsible for promoting oil and gas exploration, to eliminate conflicts of interest.

2) Establish comprehensive EIA guidelines at the planning stage. In this regard, South Africa's EIA regulations must:

- Mandate baseline ecological assessments to identify the species present and most at risk, with a clear focus on both vocalising (e.g. odontocetes) and non-vocalising species or species that are masked by other sound sources (e.g. turtles, seabirds, whale sharks, fish and baleen whales). Although EIAs consider broad environmental, economic and societal impacts (fisheries, coral reef health, chemical spills, vessel traffic, entanglement, etc.), the recommendations should also specifically target the mitigation of acoustic impacts on

sensitive marine mammals.

- Include acoustic modelling protocols to define flexible, species-specific EZs that account for propagation conditions of the sound source and cumulative sound exposure.
 - Require transparent public participation processes, proper advertisement to affected parties, and adequate time for review and comment.
 - Incorporate cumulative impact assessments across concurrent surveys or industrial activities in the same region.
 - Plan in terms of spatial and temporal mitigation by identifying and avoiding key migratory corridors, nesting beaches or seasonal foraging hotspots, and scheduling surveys for periods of lowest biological sensitivity where feasible (e.g. avoid whale migration and breeding seasons).
 - Define operational limits before permitting by setting conditions such as daylight-only operations in sensitive areas and limiting airgun power and usage to reduce sound exposure.
- 3) Set up a national mitigation protocol concerning operational/shipboard mitigation. A South African-specific mitigation protocol drawing on lessons from New Zealand's 'Code of Conduct' (DOC 2013) could be set up through the independent regulatory board. This document should consist of a stand-alone document that complements the EIA guidelines and defines national minimum standards for seismic surveys. This should include clear guidance on:
- The qualifications, team size, duty rotations and responsibilities of MMOs and PAM operators. Hence, guidelines should define what constitutes qualified observers, requiring minimum education levels (e.g. a relevant degree in marine science or ecology), field experience (e.g. >100 days at sea) and performance-based assessment. Certification should include knowledge of species identification, acoustic data interpretation and behavioural response analysis, as well as field experience verification. Observers should subsequently undergo competency evaluation and continuing professional development.
 - Use of soft-starts and pre-watch should be mandatory with minimum specifications, but could be altered through a given EIA based on environmental sensitivity and species.
 - Requirements for standardised acoustic- and visual-detection protocols and shutdown.
 - Mitigation requirements for marine and non-marine mammal species, especially those not detectable by PAM (e.g. low-frequency baleen whales, turtles, diving seabirds and whale sharks). These could include continuous visual monitoring during daylight, continuous acoustic monitoring, thermal imaging at night and AI-assisted detection.
- 4) Ensure genuine independence of marine animal observers. The fact that MMOs and PAM operators are hired through consultancy agencies paid directly by seismic operators, possibly creates conflicts of interest and communication barriers with the regulators. Therefore, South Africa should establish a system whereby mitigation personnel report directly to the independent regulator, and all data (including marine mammal sightings and operational compliance) must be submitted unfiltered.
- 5) Standardise post-survey reporting and compliance

reviews. Final survey reports must include PAM data, mitigation actions, and visual and enumerated logs of species encounters. These should be submitted to the regulator within a set period (e.g. 30–90 days) and made publicly accessible. Post-survey reviews should be used to adapt and improve future mitigation protocols.

Conclusions

To better align with international best practice and to position itself as a leading authority in marine environmental governance, South Africa needs to reconstruct its seismic survey framework to ensure robust, science-based and enforceable protection for marine fauna. Key improvements will be the establishment of an independent regulatory board, clear definitions of the qualifications of MMOs and PAMs, mandatory species-specific exclusion zones informed by acoustic modelling, enhanced mitigation strategies for non-vocalising species, and consistent post-survey reporting and compliance reviews. By integrating adaptive management, transparent oversight and modern detection technologies, South Africa could achieve a regulatory framework that is both regionally relevant and globally respected.

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