



SPE 168412-MS

Review of Sound and Marine Life Guidelines for Marine Seismic Operations

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This paper was prepared for presentation at the 2014 SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production held in Long Beach, California, 17-19 March 2014.

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Abstract

Potential impacts from anthropogenic sound on marine life, including from geophysical operations, have received ever-increasing attention in recent years from regulators, environmental non-governmental organizations, fishing organizations and the public. As a result, many national government agencies and international agencies have developed a range of guidelines and regulations aimed at mitigating these potential impacts.

Regulations vary between countries and regional authorities, and in several locations there are no official guidelines in place. Regulations are frequently amended, often in reaction to public demand and overly conservative estimates of potential impacts. Operating globally, the geophysical industry faces many challenges as it seeks to understand and properly implement the disparate and changing regulatory requirements.

The geophysical industry is committed to conducting offshore activities in an environmentally responsible manner, including compliance with mitigation and monitoring guidelines and regulations. More than four decades of worldwide seismic surveying and various scientific research indicate that the risk of direct physical injury to marine mammals is extremely low. In addition, there is no scientific evidence that demonstrates biologically significant negative impacts on marine life populations. Nevertheless, the members of the International Association of Geophysical Contractors (IAGC) support measures that are proportionate to the potential risk and based on the best available science to minimize any potential impact of their operations.

IAGC proactively engages with government agencies in their development of regulations and IAGC also supplies guidance to its members where none exist, including its guidance documents *Recommended Mitigation Measures for Cetaceans during Geophysical Operations* (1) and *Guidance for Marine Life Visual Observers* (2), both published in 2011, and *Guidance on the Use of Towed Passive Acoustic Monitoring during Geophysical Operations* (3), published in January 2014.

This paper will review the current status of guidelines globally and serve as an update to the 2008 SPE paper on this topic (4). In addition, this paper discusses how guidelines have evolved since 2008, how they have impacted the geophysical industry, and the actions IAGC has undertaken to address the issue.

Introduction

From breaking waves and the communication of whales and dolphins, to transportation and military research, the ocean is full of sound. Sound even comes from overlooked sources, such as lightning strikes and undersea earthquakes. Industry-wide mitigation measures such as visual and acoustic marine mammal monitoring, “soft-start” source procedures, and implementation of exclusion or “safety” zones, minimize the impact of seismic surveying’s addition to this soundscape. Because of these mitigation measures, cautiously tailored to the geographic region, risk assessment and previous research, the consensus among researchers, academia and regulators has been that there is no evidence that short-term exposure to seismic surveying’s acoustic sources cause any biologically significant adverse impact to any species.

In fact, a recent environmental impact assessment from the United States Geological Survey stated, “it is unlikely that the project would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects...As a result of the monitoring and mitigation measures, no marine mammals are expected to be exposed to sounds...at levels causing behavioral disturbance” (5). The geophysical industry is committed to conducting

offshore activities in an environmentally responsible manner, including complying with mitigation and monitoring regulations and guidelines to reduce potential impacts to marine life. However, the geophysical industry believes that mitigation measures should be based on risk assessment and the best available science instead of the commonly applied precautionary principle.

Many countries have implemented regulations or guidelines which specify mitigation measures for the protection of marine life when conducting seismic operations in their territorial waters. These mitigation measures vary from country to country, while in many jurisdictions, there are no guidelines in place. Operating globally, the geophysical industry faces many challenges as it seeks to understand and properly implement the disparate and changing regulatory requirements.

Brief Review of Current Guidelines

The following is a summary by region of current guidelines and recent efforts to update guidelines. Table 1 provides a summary and comparison of the mitigation measures required by Australia, Brazil, Canada, Ireland, New Zealand, the United Kingdom, and the United States.

Australia

In 2012, the National Offshore Petroleum Safety Environment Authority (NOPSEMA) was created to regulate offshore safety and environment relative to oil and gas activities in Australia. Currently, the seismic industry is subject to approvals of both an Environment Plan from NOPSEMA under the *Offshore Petroleum and Greenhouse Gas Storage Act* (OPGGGS Act) and an optional referral from the Department of Environment and Water Resources (DEWR) pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The DEWR originally enacted the *EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales* in 2001, providing mitigation measures for vessels conducting seismic surveys in Australian waters. The most recent version of the guidelines was released in September 2008 (6).

In addition to encouraging the use of Passive Acoustic Monitoring (PAM), the *Policy Statement* delineates three exclusion zones: the observation zone, the low power zone, and the shut-down zone. For proposed seismic surveys, the observation zone is a 3 km horizontal radius from the acoustic source, the low power zone is a 2 km horizontal radius, and the shut-down zone is a 500m horizontal radius. However, for seismic surveys “that can demonstrate through sound modelling or empirical measurements that the received acoustic signal at 1 km will not likely exceed 160dB re $1\mu\text{Pa}^2\cdot\text{s}$ for 95% of the time,” the low power zone is 1 km and the other zones remain unchanged (6). If a whale is sighted within the 3km observation zone, an additional MMO or trained crew member must monitor the whale’s activity. If a whale is sighted within or entering the low power zone, the acoustic source is powered down to the lowest possible setting, and if a whale is sighted in the shut-down zone, the acoustic source must shut-down completely. A report on the conduct of the survey, including any whale sightings, must be submitted to the department within two months of survey completion. NOPSEMA has provided ‘Cetacean Sightings Application Software’ for the recording of sightings and survey information. While the *Policy Statement* is particular to whales, NOPSEMA is also increasingly requiring shut-downs for turtles in survey-specific permits.

NOPSEMA and the Department of Industry released draft amendments to the Offshore Petroleum and Greenhouse Gas Storage (Environmental) Regulations (OPGGGS(E)R) on December 6, 2013 with the aim to streamline environmental approvals (7). It remains to be seen what the final regulations will entail; the final regulations are expected in first quarter 2014.

Brazil

In Brazil, seismic operations are conducted in accordance with the *Guide for Monitoring Marine Biota during Seismic Data Acquisition Activities* (April 2005) (8). A draft revision of this guide was published in 2007, but the *Guide* has not yet been updated (9). The Brazilian guidelines require three qualified marine mammal observers on each vessel, visual clearance of a 1000m warning zone, and a 500m shut-down zone. The draft revisions include specific educational and prior observational experience requirements for on board visual observers and a requirement that all boats associated with the seismic survey keep a minimum distance of 300m from any marine mammals, except bow-riding dolphins. In practice, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) implements these draft guidelines, and additional requirements to employ aerial monitoring and PAM, during conditions of both good and poor visibility, as conditions to permits.

Canada

In 2003, the Canadian Department of Fisheries and Oceans (DFO) began a science advisory process of developing guidelines which included a review by government, academic, industry and environmental non-governmental organization

experts of (i) available information on potential impacts of seismic sound on a variety of marine life, (ii) current mitigation measures and effectiveness of mitigation measures, and (iii) post mitigation residual impacts. This scientific review process cumulated in the peer-reviewed report, *Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals* (10), which is reviewed annually. The National Energy Board, the Canada-Nova Scotia Offshore Petroleum Board, and the Canada-Newfoundland and Labrador Offshore Petroleum Board regulate seismic surveys conducted for the purpose of oil and gas exploration through administration of the *Statement of Canadian Practice with respect to Mitigation of Seismic Sound in the Marine Environment* (11). The *Statement* requires that all seismic surveys be planned to avoid spawning fish areas and to prevent the diversion of fish or groups of marine mammals from known migration routes or corridors. Similar to the JNCC guidelines, the *Statement* requires a 500m exclusion zone, a thirty-minute pre-survey visual observation period, and the use of soft-start procedures. The Canadian guidelines stipulate the shut-down of the seismic source if a marine mammal or sea turtle listed as endangered, threatened, or species of concern enters the 500m safety zone at any time when the seismic sources are operational (11). PAM or other cetacean detection technology must be used during ramp-up for same period of time as visual monitoring in low visibility conditions or operating in areas identified as critical habitat or areas identified in environmental assessment for vocalizing cetaceans.

Ireland

In 2007, Ireland's Department of the Environment, Heritage, and Local Government (DEHLG) implemented the *Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters* (12). The Irish guidelines require a 1000m "monitored zone", a 60-minute pre-survey visual observation period in water depths greater than 200m, and a 30-minute pre-survey visual observation period in water depths less than 200m, and mandate that all soft-starts begin during daylight hours to allow visual observation of the safety zone (12). In addition, a marine mammal observer must monitor and report on activities likely to cause disturbance or possible impacts to cetaceans. In March 2012, DEHLG provided draft *Guidance to Manage the Risk to Marine Mammals from Manmade Sound Sources in Irish Waters* (13). The draft guidance includes the mitigation requirements from the *Code of Practice*, but also provides that a survey may continue uninterrupted once a marine mammal enters the 1000m safety zone after start-up. Once issued, DEHLG intends to include the *Guidance* as part of license conditions for any exploration and production operation, including seismic surveys. As of this writing, the draft guidance is awaiting final publication.

New Zealand

The New Zealand Department of Conservation updated its 2006 guidelines and published a revised *Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* in 2013 (14). The 2013 Code is the regulatory requirement in New Zealand's Exclusive Economic Zone (EEZ). Among other mitigation measures, the Code requires the use of PAM "at all times while the acoustic source is in the water," including monitoring by a PAM operator for at least 30 minutes prior to activation (14). The survey cannot commence until marine mammals are absent from the mitigation zone for at least 30 minutes and fur seals have not been observed for at least 10 minutes. The *Code* stipulates a mitigation zone of a 1500m radius from the vessel for a "species of concern" and a 200m radius for any other marine mammal. Preceding initiation of operations in a new location during night or poor visibility conditions, an MMO must conduct pre-survey visual observation for 2 hours of "good sighting conditions during the daylight hours preceding proposed operations" (14).

United Kingdom

The United Kingdom (UK) guidelines concerning seismic surveys and marine mammals, originally implemented in 1995, made the UK the first country to regulate seismic survey operations with regard to potential impacts on marine mammals. The UK Department of Energy and Climate Change (DECC, formerly the Department of Trade and Industry) regulates offshore oil and gas activities and receives scientific guidance from the Joint Nature Conservation Committee (JNCC). For each individual seismic survey, DECC consults the JNCC on whether consent should be granted. If consent is granted, the survey must follow the *JNCC Guidelines for Minimising the Risk of Injury and Disturbance to Marine Mammals from Seismic Surveys* (15). The *Guidelines*, most recently updated in August 2010, advise on the use of marine mammal observers to conduct watches for marine mammals during the pre-survey search and advise the crew on the implementation on the guidelines. The *Guidelines* recommend the use of a redesigned Marine Mammal Recording Form developed under a project funded by the E&P Sound and Marine Life Joint Industry Programme (16). IAGC also endorses the Marine Mammal Recording Form as the official IAGC recommended reporting form and urges that, in the absence of government required forms, this reporting form be utilized globally by the geophysical industry (17).

The 2010 version of the JNCC seismic guidelines reflect amendments to the definition of deliberate disturbance of "European Protected Species" (EPS), which now excludes trivial disturbance and includes deliberate injury to cetaceans and turtles (15). JNCC considers that compliance with the guidelines reduces the risk of injury to protected species to negligible

levels. The JNCC guidelines still require visually monitoring a 500m exclusion zone for 30 minutes prior to the commencement of the soft-start procedure, but recommend in deep water (>200m) the pre-survey visual observation should extend to 60 minutes. According to JNCC, a longer monitoring time in deep water “is likely to lead to a greater detection and tracking of deep diving marine mammals” (15). However, in order to facilitate more effective timing of proposed operations in deep water, the visual search for marine mammals can commence before the end of the survey line and while the seismic source is active, accommodating surveys which have relatively fast line turn times. If a marine mammal is sighted within the 500m exclusion zone, the soft-start procedure for any subsequent survey lines must be delayed for at least 20 minutes to allow the marine mammal adequate time to vacate the area. If a marine mammal is detected after the seismic survey has begun, either during the soft-start procedure or at full power, there is no requirement to stop the survey. This shut-down exception represents a significant difference between the JNCC guidelines and guidelines implemented in many other countries requiring shut-down of seismic sources if certain species are detected in the exclusion zone.

United States Gulf of Mexico

The US Department of the Interior regulates offshore oil and gas activities in the United States through the Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE). In 2012, BOEM and BSEE issued a Joint Notice to Lessees and Operators (NTL) No. 2012-G02 replacing previous NTL No. 2007-G02 (18). The 2012 NTL requires seismic operators in the Gulf of Mexico’s deep waters (>200m) to ensure that the 500m exclusion zone is clear of “all marine mammals and sea turtles” for startup, but only requires shut-down for whales observed in the exclusion zone. BOEM defined “whales” in the NTL as all marine mammals *except* dolphins and manatees (18). In the June 2013 settlement to litigation challenging BOEM’s permitting of seismic activity in the Gulf of Mexico without proper environmental assessment, the U.S. District Court for the Eastern District of Louisiana extended the shut-down requirements to manatees (19). As a result of the settlement, BOEM can require seismic surveys to cease operations in water depths less than 20 meters from March 1 until April 30, the first time-and-area restriction imposed in the Gulf of Mexico. Preparations for deep penetration seismic surveys are, however, still permissible. In addition to heightened reporting requirements, seismic survey operations in the Gulf of Mexico must also employ passive acoustic monitoring during periods of low visibility in water depths greater than 100m and minimum separation distances of 30 to 40 kilometers between any active seismic energy sources operating under separate permits. Pursuant to the Settlement, the agencies will prepare a programmatic environmental impact statement for geophysical activities in the Gulf of Mexico and the National Marine Fisheries Service will develop regulations addressing authorization for the incidental take, or harassment, of marine mammals by 2015.

In addition to the seven countries reviewed above, many other jurisdictions have or are in the process of developing guidelines to mitigate potential impacts of seismic survey operations on marine life, including multi-national organization efforts like ACCOBAMS *Guidelines to address the impact of anthropogenic noise on cetaceans in the ACCOBAMS area* (20), ASCOBANS *Final Report of the Working Group on the Assessment of Acoustic Disturbance* (21), and OSPAR *Assessment of the Environmental Impact of Underwater Noise* (22). In 2010, Greenland also published *Guidelines to Environmental Impact Assessment of Seismic Activities in Greenland Waters* (23), which includes recommendations of best practices for interactions with marine mammals. In other geographic regions, such as Sakhalin Island in Russia and the Beaufort and Chukchi Seas of the United States, there exists a long history of mitigation measures developed from project-specific environmental impact assessments, rulemakings, and permit applications. It is the responsibility of Industry to engage with regulatory authorities worldwide, to be knowledgeable about the variety of mitigation measures, and be informed when new guidelines or revisions to guidelines occur.

Recommended Approaches to Mitigation Measures

Organizations such as IAGC participate in working groups with academia, researchers and government regulators to assess the possible effects of exploration and production activities—including seismic surveys—on the marine environment, and to develop effective mitigation measures. They have repeatedly confirmed that four decades of world-wide seismic surveying activity and scientific research on marine mammals have shown no evidence that sound from seismic activities has resulted in injury to any marine mammal species. As the U.S. National Marine Fisheries Service recently stated, “To date, there is no evidence that serious injury, death, or stranding by marine mammals can occur from exposure to air-gun pulses, even in the case of large air-gun arrays” (24). Nevertheless, the geophysical industry supports a process of developing mitigation measures based on risk assessment and the best available science instead of the commonly applied precautionary principle.

IAGC supports the update of regional and species-specific mitigation measures and guidelines that reflect new research and data as it becomes available. This approach allows for the scope of mitigation measures to be commensurate to the known risks and specific to the local populations of marine mammals, environmental conditions and proposed operations. As noted

in the 2005 National Research Council report *Marine Mammal Populations and Ocean Noise*, “It does not make sense to regulate minor changes in behavior having no adverse impact; rather, regulations must focus on significant disruption of behaviors critical to survival and reproduction” (25).

In the absence of country-required regulations and unless otherwise suggested by risk assessment, IAGC members implement basic minimum mitigation measures such as using a soft-start or ramp-up procedure according to its published guidance documents. IAGC published *Recommended Mitigation Measures for Cetaceans during Geophysical Operations* (1) and *Guidance for Marine Life Visual Observers* (2) in 2011, and *Guidance on the Use of Towed Passive Acoustic Monitoring during Geophysical Operations* (3) was published in January 2014. While PAM is increasingly considered by regulators as a qualified tool for conducting marine mammal monitoring at sea during night time or poor visibility conditions, the performance of commercially available PAM systems can be variable. Still, IAGC recommends the geophysical industry consider the use of alternative monitoring technologies such as PAM in periods of poor visibility and darkness (1). Soft-start or ramp-up procedures and the source itself remain key mitigation measures as the gradual increase of sound ensures that the marine mammals can avoid the source in good and poor sighting conditions alike. The key objective of any seismic operation is to ensure that marine mammals are not present in the exclusion zone when the seismic source is initiated.

The geophysical industry is committed to conducting offshore activities in an environmentally responsible manner, including complying with mitigation and monitoring regulations and guidelines for the protection of marine life. To date, many countries, including the seven reviewed above, have developed guidelines requiring mitigation measures during seismic survey operations and several multi-national organizations have suggested recommended guidelines. Primarily due to gaps in scientific knowledge, current guidelines are generally based on the precautionary principle. The current number and complexity of mitigation measures and guidelines, or lack thereof, presents challenges to the industry. Through IAGC, the geophysical industry is dedicated to meet these challenges by (i) understanding and implementing the mitigation guidelines required by each country, (ii) implementing appropriate mitigation measures in jurisdictions without guidance, (iii) funding scientific research to address knowledge gaps, and (iv) engaging in dialogue with governments, regulatory agencies, and international agencies.

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	Australia (6)	Brazil (8), (9)	Canada (11)	Ireland (12), (13)	New Zealand (14)	United Kingdom (15)	United States – GOM (18), (19)
Title and version cited	EPBC Act Policy Statement 2.1- Interaction between offshore seismic exploration and whales (Sept. 2008)	Guide for monitoring marine biota during seismic data acquisition activities (April 2005); Draft Guide for monitoring marine biota during seismic data acquisition activities (2007)	Mitigation of Seismic Noise in the Marine Environment- Statement of Canadian Practice (2007)	Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters (August 2007); Draft Guidance to Manage the Risk to Marine Mammals from Man-Made Sources in Irish Waters (March 2012)	Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations (2013)	Guidelines for Minimising the Risk of Injury and Disturbance to Marine Mammals from Seismic Surveys (August 2010)	Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program (2012)
Type of surveys covered by guidelines	Seismic	Seismic	Any survey using an airgun or airgun arrays	All seismic; Multibeam and side-scan sonar within 1500m of enclosed bays (*remainder of Table only discusses seismic)	Seismic	All seismic	Seismic
Species covered by guidelines	“Whales” including baleen whales and larger-toothed whales but excluding smaller dolphins and porpoises	Marine mammals and sea turtles	Marine mammals (all cetaceans and pinnipeds) and sea turtles	All cetaceans	All marine mammal species, including fur seals, whales, dolphins	All cetaceans and turtles	All GOM marine mammals and sea turtles
Shut-down zone	500m	500m	500m	1,000m	200m to 1.5 km	500m	500m
Observer qualifications and requirements	<ul style="list-style-type: none"> • Must be “trained in whale identification and behaviour, distance estimation and reporting” • Trained crew member permitted where likelihood of encountering whales is low 	<ul style="list-style-type: none"> • Must have experience in marine mammal surveys or completion of a training course • Observers report directly to IBAMA • Each seismic vessel must have 3 observers 	Requires “qualified marine mammal observer” however qualifications are not specified in guidelines	Observers must attend JNCC marine mammal observer training course or equivalent and have a minimum of 6 weeks marine mammal survey experience	<ul style="list-style-type: none"> • Two qualified observers, w/ 12 weeks experience, and 2 PAM observers are required • Completion of DOC approved MMO or PAM course mandatory 	<ul style="list-style-type: none"> • Observers must attend a JNCC recognized MMO short course • Two observers are required when daylight hours exceed ~ 12 hours 	Observers must meet qualifications specified in guidelines; observers may be trained crew members
Pre-survey observation period	30 minutes	30 minutes	30 minutes	30 minutes in depths < 200m; 60 minutes in depths > 200m	30 minutes	30 minutes in depths < 200m; 60 minutes in depths > 200m	30 minutes

	Australia (6)	Brazil (8), (9)	Canada (11)	Ireland (12), (13)	New Zealand (14)	United Kingdom (15)	United States – GOM (18), (19)
Pre-survey visual observation requirements	<ul style="list-style-type: none"> • During daylight hours, observers must visually monitor the 3 km radius around the vessel in every direction for 30 minutes • Low-power zone (1km for sources <160dB, 2km for sources >160dB) and shut-down zone must be clear of whales before initiating soft-start procedure 	<ul style="list-style-type: none"> • During daylight hours, 2 observers must visually monitor the 1000m radius around the vessel for 30 minutes • 1000m warning zone must be clear of marine mammals and sea turtles before initiating soft-start procedure 	<ul style="list-style-type: none"> • During daylight hours, observer must visually monitor the 500m safety zone for 30 minutes • 500m safety zone must be clear of whales (other than dolphins and porpoises) and sea turtles before initiating soft-start procedure 	<ul style="list-style-type: none"> • Observer must visually monitor the 1000m safety zone for 30 minutes in depths <200m and 60 minutes in depths >200m • 1000m zone must be clear of marine mammals before initiating soft-start procedures 	<ul style="list-style-type: none"> • During daylight hours, two observers must visually monitor 1.5 km radius around source vessel for 30 min • Activation of seismic source cannot begin if a “species of concern” with a calf is sighted w/in 1.5km, if “species of concern” or fur seal sighted w/in 1km radius or if any other marine mammal is sighted within 200m radius 	<ul style="list-style-type: none"> • Before activation of any seismic source, observer must visually monitor the 500m safety zone around the source vessel for 30 minutes in depths <200m and 60 minutes in depths >200m • 500m safety zone must be clear of marine mammals for 20 minutes before initiating soft-start procedure 	<ul style="list-style-type: none"> • Before activation of any seismic source, 2 observers must visually monitor the 500m safety zone and adjacent waters for 30 minutes • 500m exclusion zone must be clear of marine mammals and sea turtles before initiating ramp-up procedures
Soft-start or ramp-up procedure	<ul style="list-style-type: none"> • Initiate soft-start with lowest energy-output / volume airgun • Gradually add airguns over a 30 minute period • Visual observations are required continuously 	<ul style="list-style-type: none"> • Initiate soft-start with lowest energy-output / volume airgun • Gradually add airguns over a 20-40 minute period 	<ul style="list-style-type: none"> • Initiate soft-start with lowest energy-output / volume airgun • Gradually add airguns over a 20 minute period 	<ul style="list-style-type: none"> • Initiate soft-start with smallest airgun • Gradually add airguns over a 20-40 minute period • Visual observations are required continuously 	<ul style="list-style-type: none"> • Initiate soft-start with single airgun • Gradually add airguns over a 20-40 minute period • Visual observations are required continuously 	<ul style="list-style-type: none"> • Initiate soft-start with smallest airgun • Gradually add airguns over a 20-40 minute period 	<ul style="list-style-type: none"> • Initiate ramp-up with smallest airgun in terms of energy output and volume • Gradually add airguns over a 20-40 minute period • Visual observations are required continuously
Visual observation procedure during operations	Visual observations are required during seismic survey operations	Visual observations are required during the entire survey duration	When safety zone is visible, visual observations are required	Continue monitoring during sound-producing activity and for 30 minutes following in depths <200m and 60 minutes in depths >200m	During daylight hours, continuous visual observations of a 1.5 km radius surrounding the vessel are required	Visual observations encouraged during all daylight hours, but only required during pre-survey period (before soft-start procedure)	During daylight hours, continuous visual observations required by 2 observers

	Australia (6)	Brazil (8), (9)	Canada (11)	Ireland (12), (13)	New Zealand (14)	United Kingdom (15)	United States – GOM (18), (19)
Shut-down procedure	<ul style="list-style-type: none"> Shut-down of seismic sources required if whale enters 500m safety zone at any time Required power-down to single airgun if whale enters low-power zone (1km or 2km) at any time After the whale has been observed leaving the low-power zone or 30 minutes has elapsed, the seismic source may be reactivated using soft-start procedures 	<ul style="list-style-type: none"> Shut-down of seismic sources required if marine mammal or sea turtle enters the 500m safety zone at any time After the whale has been observed leaving the 1000m warning zone or 30 minutes has elapsed, the seismic source may be reactivated using soft-start procedures 	<ul style="list-style-type: none"> Shut-down of seismic sources required if a whale or sea turtle listed as endangered, threatened, or species of concern enters 500m safety zone at any time After the whale has been observed leaving 500m safety zone or 30 minutes has elapsed, the seismic source may be reactivated using soft-start procedures 	<ul style="list-style-type: none"> No shut-down of seismic sources required; If cetacean detected w/in 1000m safety zone during soft-start the seismic energy output should not be increased Once soft-start procedures performed effectively activity may continue even if marine mammals enter safety zone 	<ul style="list-style-type: none"> Shut-down of seismic sourced required if at least one “species of concern” with a calf enters 1.5 km zone Shut-down of seismic sources required if “species of concern” enters 1 km zone Operations cannot recommence until animals have left respective zones (see above) or 30 minutes has elapsed since last detection 	No requirement to shut-down seismic source once the soft-start has commenced.	<ul style="list-style-type: none"> Shut-down of seismic sources required if a whale or manatee enters 500m exclusion zone at any time After a 30 minute visual survey has determined the absence of marine mammals and sea turtles, the seismic source may be reactivated using ramp-up procedures
Nighttime or low-visibility requirements	Operations may proceed at night or during low visibility provided there where no more than 3 whale-instigated power-down or shut-downs in the preceding 24 hours	Activation of seismic sources cannot begin during the night or low-visibility conditions	In areas where an endangered or threatened whale is “reasonably expected to be encountered,” soft-start procedures cannot commence at night or during low-visibility <i>unless</i> PAM is utilized	Soft-start procedures must begin during daylight hours to allow for visual observation of the safety zone; Once soft-start performed, activity may continue even if weather conditions deteriorate	Seismic sources cannot be activated unless PAM carried out for at least 30 min w/ no detection of vocalized cetacean in safety zone; If new area, pre-survey visual observations for 2hrs in daylight preceding operations	Encourages soft-starts to begin during daylight hours	Ramp-up procedures cannot be initiated at night or during times of low-visibility when the exclusion zone cannot be visually monitored
Passive Acoustic Monitoring	Not required, experimental use permitted	Not required, but encouraged	Encouraged when safety zone is not visible and seismic survey is in areas w/ endangered or threatened cetaceans	Not stated	Required at all times while seismic source is in water	<ul style="list-style-type: none"> Likely to be required in areas with sensitive species Best practice at night or in low visibility 	Not required, but encouraged

Table 1. Summary and comparison of mitigation measures currently required by guidelines in seven countries.