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CORAL AND SPONGE MITIGATIONS IN RELATION TO EXPLORATORY DRILLING PROGRAMS IN THE NEWFOUNDLAND AND LABRADOR REGION

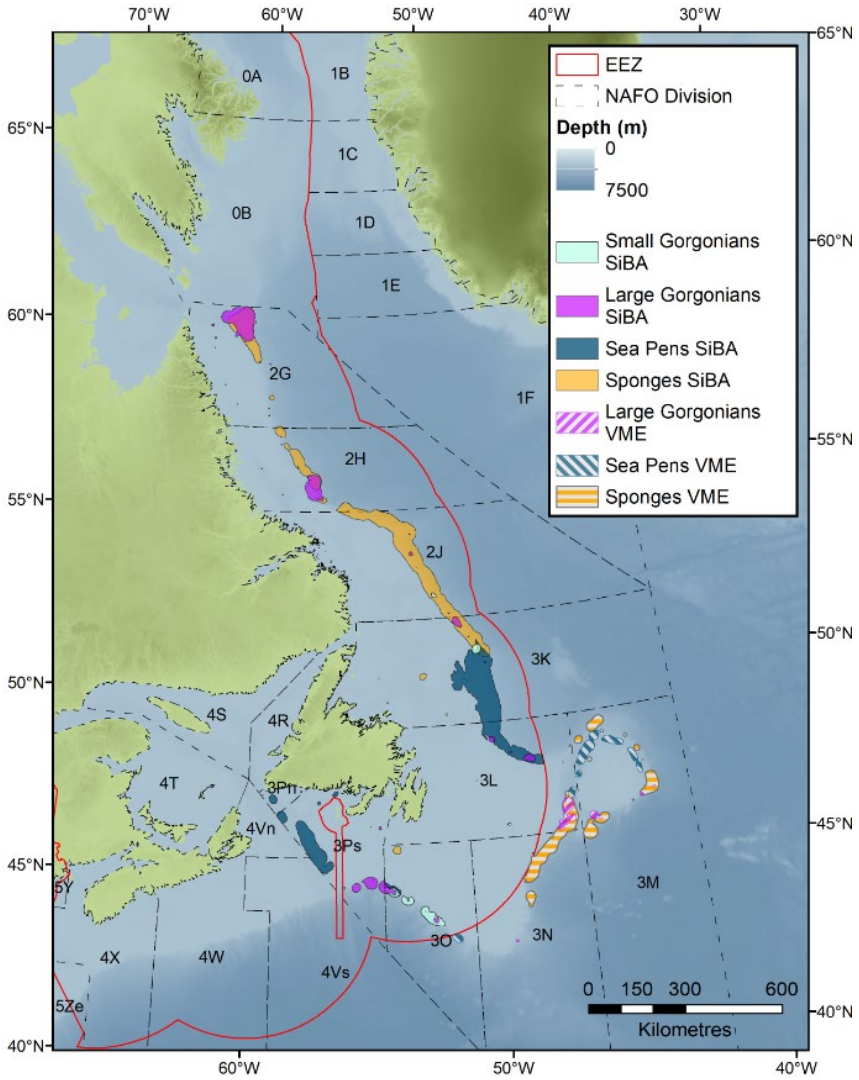

Figure 1. Location of Significant Benthic Areas (SiBAs) and Vulnerable Marine Ecosystem (VME) habitats currently defined in the NL Region.

Context:

The Fish and Fish Habitat Protection Program (FFHPP) of the Department Fisheries and Oceans, Canada (DFO) evaluates proposed works, undertakings, and activities that may affect fish and fish habitat and provides advice to proponents to enable them to avoid and mitigate impacts (DFO 2019a).

FFHPP provides expert advice to the Impact Assessment Agency of Canada (IA Agency) for the Atlantic offshore Canadian Environmental Assessment Act (2012) (sections 13 ,23 and 100 of the Impact Assessment Act (IAA) after provisions related to implementation of the IAA in the Atlantic offshore come into force), as well as the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) under a Memorandum of Understanding between C-NLOPB and DFO during the review of oil and gas activities. Exploratory drilling programs including the drilling, testing, and abandonment of offshore exploratory wells that have the potential to affect corals and sponges through certain activities, including drilling of the well(s) and the release of discharges such as drill cuttings and muds. For such activities, DFO provides advice pertaining to benthic characterization, effects assessment, mitigation measures, and follow-up monitoring requirements.

A Regional Peer Review process was held to provide scientific advice on the avoidance and mitigation of harmful impacts on corals and sponges during exploratory drilling programs in offshore Newfoundland and Labrador. There were several objectives for the meeting, including characterization of potential impacts of exploratory drilling programs, (drilling, testing, and abandonment of wells) on corals and sponges in offshore Newfoundland and Labrador (NL), and techniques/methods to avoid or mitigate potential impacts. The advice generated from this meeting will be used in the development of best management practices for offshore NL to support future reviews. Information gathered will also identify gaps where further research is required.

This Science Advisory Report is from the January 28-30, 2020 Regional Peer Review Process on Coral and Sponge Mitigations in Relation to Exploratory Drilling Programs in the Newfoundland and Labrador Region. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- An avoidance and mitigation framework was developed for exploratory drilling to eliminate or minimize impacts on corals and sponges.
- It is recommended that exploratory drilling activities (including the zone of influence) do not overlap significant benthic areas (SiBAs) and vulnerable marine ecosystem (VME) habitats.
- Outside of SiBAs and VME habitats, the zone of influence from exploratory drilling activities should be at least 2 km away from significant densities of corals and sponges identified during pre-drill surveys. Drilling discharge dispersion models/zone of influence (1.5 mm probable no-effects threshold (PNET) predictions should be used to determine if a larger buffer is necessary.
- Provisional significant density thresholds appropriate for the coral and sponge fauna of the offshore NL Region have been developed. These mitigation thresholds should be reviewed and updated considering new information as it becomes available.
- Best practices are recommended for dispersion models, pre-drill (acoustic and visual) surveys, and follow-up monitoring to assist in avoiding and mitigating the effects of exploratory drilling activities on coral and sponge habitats.
- A precautionary approach was applied to the development of the framework and coral and sponge density thresholds, recognizing that there are knowledge gaps concerning corals and sponges and the impacts of exploratory drilling on them.
- The recommended best practices and mitigation measures for exploratory drilling in relation to coral and sponge areas only consider routine operations and exclude accidental events (e.g., spills) and cumulative effects. With increasing exploratory activity in the region, it will

be important to consider cumulative effects on corals and sponges from anthropogenic activities.

- Data (e.g., raw data and data products, as well as metadata) collected on corals and sponges by industry during seafloor surveys (e.g., bathymetric, visual) relating to exploratory drilling activities in the NL bioregion should be made available to DFO NL Science.

INTRODUCTION

The Fish and Fish Habitat Protection Program (FFHPP) of Fisheries and Oceans Canada (DFO) evaluates and provides advice to proponents on proposed works, undertakings and activities (WUA) that may affect fish and fish habitat (DFO 2019a). Most available research on the impacts of exploratory drilling on corals has focused on impacts specific to reef-forming coral species such as *Lophelia pertusa* (now referred to as *Desmophyllum pertusum)*, and mitigation thresholds outlined by the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) are primarily based on research outside of the northwest Atlantic (DNV 2013). This process aims at building upon existing scientific advice on the mitigation of harmful impacts on corals and sponges during exploratory drilling programs in the Newfoundland and Labrador (NL) Region, by providing regionally specific information to support FFHPP in the development of best management practices to guide review processes moving forward.

In 2019, DFO Science provided national advice on the assessment of the effectiveness of mitigation measures to reduce the potential impacts of oil and gas exploration and production on areas with defined benthic conservation objectives (i.e., Marine Protected Areas [MPAs] and other effective area-based conservation measures [OEABCMs]) (DFO 2019b). As part of this previous advice, it was recommended that oil and gas exploration and production activities within these areas should be managed with higher risk aversion. In a review of the Regional Assessment of Offshore Oil and Gas Exploratory Drilling East of Newfoundland and Labrador (DFO 2020), DFO Science has recommended that mitigations be applied in all areas that are deemed special (e.g., Vulnerable Marine Ecosystem [VME] habitats, Significant Benthic Areas [SiBAs], Ecologically and Biologically Significant Areas [EBSAs]) but are not currently protected by other management measures.

With plans to expand exploratory drilling activities in the NL Region, the potential impact on corals and sponges is growing. The presence of these species is associated with increased biodiversity in the deep sea and impacts to their health and habitats could have cascading effects. To inform future recommendations, FFHPP requested scientific advice on the avoidance and mitigation of harmful impacts on corals and sponges during exploratory drilling programs in offshore NL. The advice aims to provide a summary of the coral and sponge species currently known in offshore NL; to describe exploratory drilling activities that have the potential to impact corals and sponges; to characterize the effects of exploratory drilling on coral and sponge species in the NL Region; to define thresholds for implementing mitigation measures; to provide recommendations on the mitigation tools that are best suited for this region; to identify recommended methods for pre-drill surveys, drilling and monitoring and follow-up for coral and sponges; and to highlight areas where more research is needed. An avoidance and mitigation decision-making framework for exploratory drilling was also developed to aid in the implementation of identified best practices. Ultimately, this work is intended to guide the development of NL best management practices to support the conservation of coral and sponge species during oil and gas exploration activities.

ANALYSIS

Coral and Sponge Species in NL

In order to evaluate impacts on corals and sponge species within the NL Region, a characterization by species, distribution, density, habitat requirements, and sensitivities was carried out as data allowed. A detailed review is presented in the Research Document associated with this process (Gullage et al. in press[1]) along with the data sources and distribution maps.

Species Distribution and Density

There are over 160 species of corals and sponges known to occur in the NL Region. These species have been observed across the continental shelf, in troughs, valleys, and canyons, as well as along the shelf edge. They exist in a variety of shapes and sizes, with some known to occur in high densities, while others are more sparsely distributed. A more complete description of species' biology and ecology, along with relevant references, can be found in Gullage et al. (in press)[1], with a summary provided below.

Corals and sponges play many important roles in deep-sea ecosystems, including providing large- and small-scale habitats and by biogeochemical cycling of organic matter. Throughout their range, these species represent complex, three-dimensional structures, and evidence suggests that they serve as diversity hotspots. Areas of high coral species richness have been positively correlated with areas of high fish species richness. In the NL Region, other marine species are known to use large scale habitats for feeding, resting, predator avoidance, and as nurseries for juveniles. At a smaller scale, the skeleton, tissue, and mucus of some species can be used as habitat for a diverse variety of bacteria. Coral and sponge species may act as hotspots for organic cycling promoting primary productivity in upwelling areas.

In general, comprehensive information relating to life histories, reproduction, distribution, and sensitivities of coral and sponge species in the NL Region is limited. To account for this, species are often categorized into groups according to body size, shape, habitat preferences (i.e., substrate), and/or life history traits. A summary of coral group definitions is provided in Gullage et al. (in press)[1]. In the absence of information at the species level, impacts at the group level are broadly applied to all species within a group. Similarly, because of limitations on the available information on the taxonomic diversity of sponges in the Northwest Atlantic, sponges are generally treated as a single group. For species that are deemed particularly important (e.g., habitat forming species), or are well-represented within the literature, information has been provided at the species level.

Multiple data sources were used to ensure that a comprehensive inventory of coral and sponge species in the NL Region was compiled along with their distribution, and density. The information was primarily drawn from the NL DFO research vessel (RV) multi-species trawl survey database, but also included observations from the Northern Shrimp Research Foundation (NSRF) survey (Northwest Atlantic Fisheries Organization [NAFO] Divisions 0B and 2G), the Central and Arctic DFO RV trawl surveys, and any historic observations that have been

[1] Gullage, L., Wareham-Hayes, V., Neves, B., Wells, N. and F. Cyr. In press. Avoidance and Mitigation of Coral and Sponge Species During Exploratory Drilling Activities Offshore Newfoundland and Labrador. DFO Can. Sci. Advis. Sec. Res. Doc.

documented. In addition, data collected as part of the EU-Spain Bottom Trawl Survey, as well as literature published within the NAFO Regulatory Area (NRA) was also incorporated to capture species observed beyond the Exclusive Economic Zone (EEZ). Independent observations were also included by conducting a comprehensive literature review for the region.

Caution must be exercised when using coral and sponge data collected by trawls because they can be biased to locations where trawling is possible, specimens may be damaged due to trawling and therefore cannot be identified, data from unsuccessful (e.g., damaged net) RV trawl survey sets may not be recorded, and data from some surveys may not be identified beyond the group or class level.

In general, large gorgonians, small gorgonians, sea pens, cup corals, and black corals are widely distributed, in some cases discontinuously, along the edge of the continental shelf, and along the edges of channels and canyons found across the shelf. Compared to large gorgonians, other species tend to occupy a broader range of depths along the shelf edge. Available observations of cup corals and black corals beyond the EEZ suggest these species occupy similar ranges to gorgonian corals along the edge of the Flemish Cap. Contrastingly, soft corals, which can tolerate a large temperature range, exhibit a broader spatial distribution and are found across much of the continental shelf, with a nearly continuous distribution along the shelf edge. Sponges appear to exhibit a similarly broad range; however, it must be noted that sponges have not been identified to lower taxonomic levels, and that the distribution of specific sponge taxa is more restricted than is illustrated at the class level.

Species' abundances and densities have been estimated using trawl survey data augmented by data collected using alternative methods (e.g., Remotely Operated Vehicles [ROVs]), which have provided density information for some species within the NL Region.

While many coral and sponge species can be found in high concentrations, others are often observed sporadically. In some areas dense sponge grounds with up to 50 species have been documented, but typically they are dominated by just a few species (e.g., *Geodia barretti*, G. *phlegraei*, G. *macandrewii*, *Stryphnus fortis*, and *Stelletta normani*). Sea pens can occur in fields >1 km which are typically dominated by a small number of species including *Pennatula aculeata*, *Pennatula grandis*, and *Anthoptilum spp.* The specific density of sea pen fields in the Northwest Atlantic has not been well documented (DFO 2018).

Unique habitats such as bamboo coral (*Acanella arbuscula)* fields have been reported in some areas including the Flemish Pass, along the slope of the southwest Grand Bank, and the Northern Labrador Sea. Somewhat more diverse are thickets of bamboo coral and sponges observed in Baffin Bay, the Flemish Pass, on the northeast Flemish Cap, and in the Haddock and Halibut Channels just east of the Laurentian Channel. These aggregations are known to be predominantly comprised of *Asconema* spp. (glass sponge) and *Keratoisis* sp. (*Keratoisis* cf. *flexibilus)*. In the eastern Canadian Arctic, similar aggregations have been associated with increased infaunal and epifaunal diversity.

Habitat Requirements

Habitat suitability is typically related to depth, temperature, salinity, slope, local topography, surface productivity, current strength, and substrate type. Due to the amount of fishing that has occurred off the coast of NL, the observed depth ranges for corals and sponges may reflect the impact of bottom-contact fisheries. Existing data suggest that coral and sponge species occur at depths of <100 m to over 2,000 m, although most observations have been limited by the minimum and maximum depths of the trawl surveys, with the highest concentrations observed in

the NRA (the Flemish Cap, Flemish Pass, and portions of the Grand Banks) from depths of 600 to 1,470 m. Globally, marine sponges have been observed at depths up to 8,000 m, with species found in waters as shallow as 105 m in the NL Region, and even shallower in coastal areas. In the NRA, catches range between 950 to 1,470 m, but have been observed at depths as shallow as 138 m.

Throughout their geographic extent, different coral and sponge species associate with both soft and hard surfaces. Most sponges show a preference for hard substrates; however, some have developed morphological adaptations that allow them to occupy areas with soft substrates and elevated sedimentation. Heightened levels of productivity associated with surface chlorophyll-a concentrations are also good predictors of habitat suitability for both coral and sponge species. Furthermore, because most cold-water coral and sponge species are sessile, they also rely on the presence of currents which may prevent the buildup of fine sediments, which could smother them, and also expose the hard substrates necessary for settlement and attachment of some species (e.g., large gorgonians and black corals).

Existing Special Areas

Several areas have been identified in the NL Region based on significant concentrations of corals and sponges. A portion of these areas have also been protected using various forms of legislation, including the *Fisheries Act* and the *Oceans Act*. Protection standards have been developed by the Government of Canada for MPAs and other effective area-based conservation measures (OECMs including Marine Refuges [MRs]), in order to better conserve sensitive and ecologically important parts of the ocean. For all federal MPAs, four key industrial activities are prohibited: oil and gas activities; mining; dumping; and bottom trawling. For OECMs, activities proposed within these areas will be assessed on a case-by-case basis. Some activities may be allowed if they are consistent with the conservation objectives of a specific area but before any proposed activity can take place, the Minister of Fisheries, Oceans and the Canadian Coast Guard will need to be satisfied that any risks to the area have been avoided or mitigated effectively. Once oil and gas extraction begins in an OECM, the portion of the oil and gas license or permit that overlaps with the OECM will no longer count towards Canada's marine conservation targets. The term "special areas" is used in the context of this document to refer to special areas for corals and sponges and includes SiBAs, VME habitats and closures, EBSAs, OECMs (including MRs), and MPAs. For a review of these areas, refer to Gullage et al. (in press)[1].

In 2009, the Food and Agriculture Organization (FAO) defined concentrations of coral and/or sponge species as VMEs (FAO 2009), leading to the eventual delineation of 30 VME habitats (nine large gorgonian VMEs, 14 sponge VMEs, and seven sea pen VMEs; Figure 1) in the NRA. SiBAs are similar to VMEs in their definition but are located within domestic waters. Additional work by DFO Science has led to the identification of SiBAs for large gorgonians, small gorgonians, sea pens, and sponges (Figure 1). While the identification and delineation of VMEs and SiBAs does not automatically result in their protection, fisheries closures have been established in the NRA to protect portions of some VME habitats, and OECMs have been established within the EEZ to protect portions of some SiBAs. For more details regarding these areas, refer to Gullage et al. (in press)[1].

DFO (2019b) indicated that the severity of impacts resulting from anthropogenic activities are likely to be elevated because of the heightened concentrations of corals and sponges in these special areas. As a result, exploratory drilling activities occurring within their boundaries should

automatically be subject to avoidance and special mitigation measures, regardless of whether the areas are protected from other human activities or not.

Exploratory Drilling Activities in Newfoundland and Labrador with Potential to Impact Corals and Sponges

As of January 2020, 172 exploration wells had been drilled in offshore NL (Figure 2), and 30 active exploration licenses had been issued within the region.

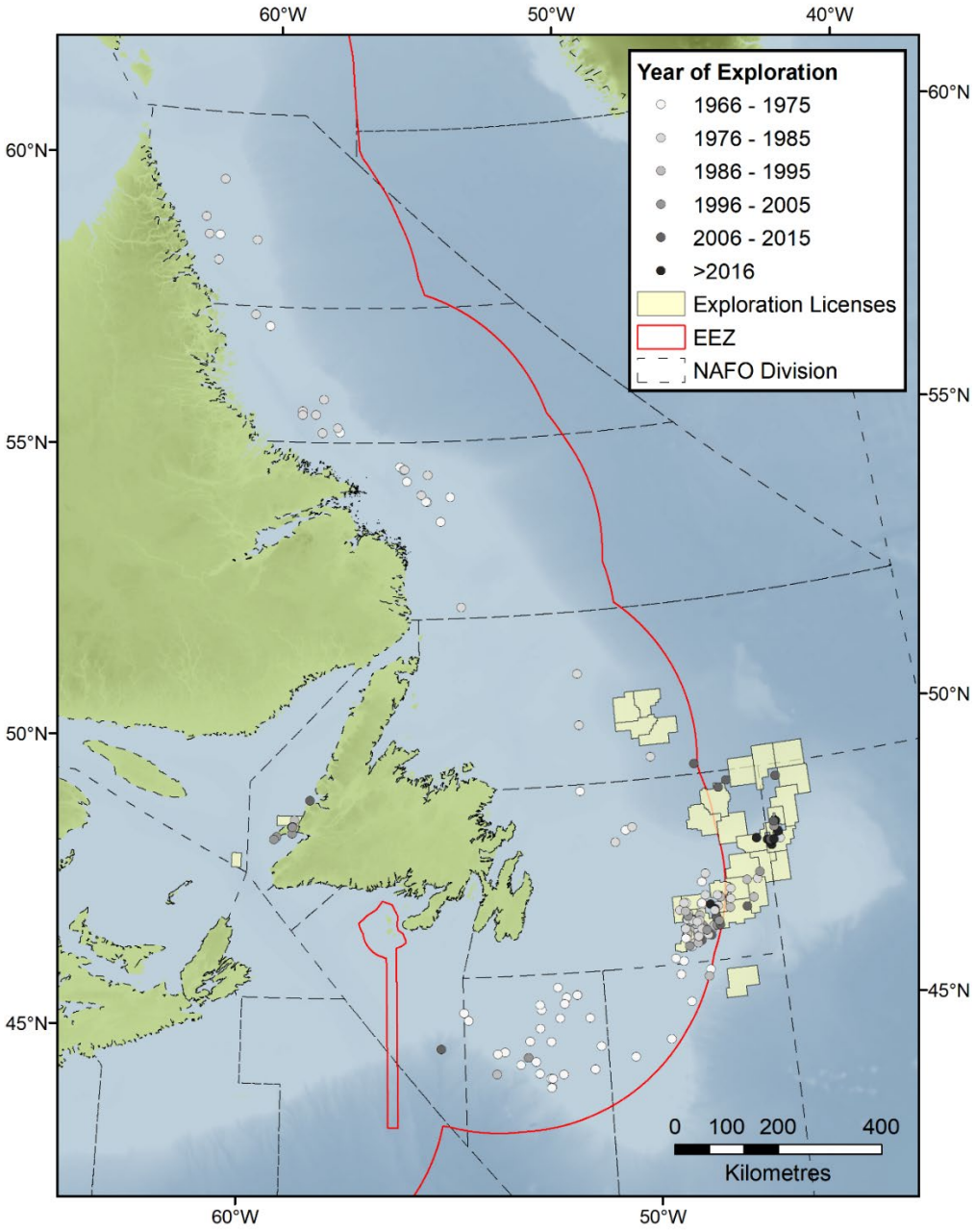

Figure 2. Location of exploration wells and licenses in the NL Region downloaded as shapefiles from the C-NLOPB website in January 2020 (C-NLOPB 2019a).

In areas identified as having a high potential for hydrocarbons, exploratory drilling is required to confirm the presence of commercially viable hydrocarbon reserves. Drilling activity will typically last one to four months. In most cases, offshore exploration wells, particularly those in deep water, are in areas of the marine environment where human impacts have historically been minimal, and little is known about the effects of anthropogenic activities. The existing research indicates that, although some of the impacts are short-lived, effects may last longer for ecosystems containing fragile species such as cold-water corals and sponges.

Routine activities associated with exploratory drilling include positioning, drilling, and abandonment of wells. The types of potential impacts will vary during each phase and depending on the type of equipment that is used. For example, the degree of contact with the seafloor will vary depending on the type of platform and the use of anchoring. Cuttings, drilling fluids, and excess cement may be deposited directly on the seafloor during some points in the drilling process, forming a cuttings pile surrounding the well bore. This may impact corals and sponges through physical contact, exposure to chemicals, and/or sedimentation. Coarser particles settle out relatively quickly near the drill site to form thicker layers of deposition, while finer particles are transported further away by local currents being deposited more thinly over a larger area. During abandonment, cuttings and sediments contaminated during the drilling process will be re-suspended, and there is a further risk of exposing the surrounding benthic community to toxic materials from the cement used to plug the well. Removal of equipment (including anchors) installed on the seafloor may also cause physical damage.

Drilling muds are used to lubricate and cool the drill bit, carry cuttings to the surface, and control pressure in the well. Drilling muds fall into three main classes depending on their make-up, which include: oil-based (OBM), water-based (WBM), and synthetic-based (SBM). In Atlantic Canada, all exploratory drilling is conducted using either WBMs or SBMs as they are less toxic than OBMs; however, documentation indicates that enhanced mineral oil-based muds (EMOBM) or OBMs may be used in place of SBMs in cases where there are sufficient technical justifications. Depending on the type of drilling mud and chemical additives, negative impacts on benthic species have been documented near drill sites (Trannum et al. 2010, Bakhtyar and Gagnon 2012, Edge et al. 2016) with their effects extending from within 100 m (Currie and Isaacs 2005, Trannum et al. 2006) to several kilometers from the well (Continental Shelf Associates 1989).

Depending on the type of drilling mud used, treatment may be required prior to release. If WBMs are being used to bring drill cuttings to the platform, spent and excess mud and cuttings can be released without treatment. However, if SBMs or EMOBMs are being used, the cuttings will be separated from the drilling mud (which is recycled), treated, and may be released directly from the platform, according to the Offshore Waste Treatment Guidelines (OWTG) regulated by C-NLOPB (C-NLOPB 2019b). Although not currently used in the NL Region, if OBMs are used, cuttings are either reinjected or retained and brought to shore for disposal. Depending on the depth of the drill site, the strength of currents in the area, and the type of drilling mud being used, drill cuttings released from the platform can be rapidly dispersed by the water column or may accumulate below the platform. Burial and smothering are the main risks to corals and sponges based on this activity; however, remnants of chemicals on the treated cuttings may also impact these species. Because cuttings piles are resistant to chemical change it is possible that future disturbances may result in a source of contamination even after the site is abandoned (Brakstad and Ramstad 2001, Breuer et al. 2004).

Due to the nature of exploratory drilling activities, there is a possibility that accidental events with the potential to impact coral and sponge species may occur. This is of particular concern

for operations in the NL Region because of harsh weather conditions and the seasonal presence of ice. The causes of accidents occurring during the exploratory drilling phase can be broadly classified as resulting from: extreme weather conditions, ice events, human error, procedural error, and/or equipment failure.

While the most prominent concern of accidental events during exploratory drilling is the release of oil from the well, any incident which results in physical or chemical damage, or exposure to excess sedimentation, could pose risks to coral and sponge species. The recommended best practices and mitigation measures for exploratory drilling in relation to coral and sponge areas included in this report only consider routine operations, and exclude accidental events, as they were not included in the terms of reference for this advisory process.

Impacts of Exploratory Drilling on Corals and Sponges

As exploration for oil and gas expands in offshore NL, the potential for interactions with coral and sponge species grows. The impacts of exploratory drilling on corals and sponges can be classified into three types of disturbances:

- Physical (e.g., platform installation (including anchors, etc.), top hole drilling, equipment placement, well abandonment);
- Sediment (e.g., anchoring activities, top hole drilling); and
- Chemical (e.g., cement, drill cuttings).

In general, these disturbances have been found to impact species behaviour, fitness, and survival; however, specific impacts and responses to these disturbances vary by species. Gullage et al. (in press)[1] provides a detailed review of the possible impacts, effects, and severity of exploratory drilling activities on corals and sponges.

Due to their slow growth, longevity, and sessile nature, coral and sponge species are particularly vulnerable to mechanical disturbances. Activities such as bottom contact fishing, subsea infrastructure installation, dredging, mining, aquaculture, and offshore oil and gas exploration all have the potential to impact corals and sponges. Not only do these activities increase the risk of physical damage, they also expose them to increased sedimentation/turbidity, and in some cases harmful chemicals.

Due to their rigid skeletons and long-lived nature, large gorgonians and black corals are most at risk of damage and mortality from anthropogenic activities. In contrast, smaller, more flexible colonies with faster growth rates and shorter lifespans, such as some species of soft corals, sea pens, and sponges, likely have a lower risk of damage and mortality. However, even the more resilient species can experience long-term declines in survivability and health after physical damage or exposure to increased sedimentation.

Estimates of recovery time to pre-exploration conditions for coral and sponge species within the NL Region are uncertain given the limited available research. The life history characteristics of some coral and sponge species indicate that recovery of individuals and communities could take hundreds of years (Cordes et al. 2016) suggesting that the true temporal impacts of exploratory drilling on these communities could be quite severe.

Most cold-water coral and sponge species obtain nutrients and food directly from the water column and are therefore more sensitive to sedimentation and exposure to waterborne chemicals originating from anthropogenic activities. The effects of excess sedimentation may include smothering, physical damage, reduced feeding and energy availability, reductions in

suitable habitat for larvae settlement, mortality, and general reductions in coral coverage. Larvae may experience more severe impacts including elevated mortality because of sediment decreasing their ability to move. Excess sedimentation may also impact connectivity and disrupt natural larval dispersion, although this has not been thoroughly investigated.

Chemicals released during the stages of exploratory drilling also pose potential risks to corals and sponges, but this may vary by species, chemical type, and concentration. These can include drilling muds as well as Portland cement. Although WBMs are most commonly used because they have been demonstrated to pose little or no risk to the environment, evidence indicates that they do impact some coral species (e.g., by decreasing coral coverage). OBM, which is approved for use only under exceptional circumstances in the NL Region, has more of an impact, with effects typically extending further from the site of exploration. Approximately 30 years ago, SBMs were developed to combine the technical capabilities of OBMs with the low persistence and toxicity of WBMs, but no studies have been published that examine the effects of SBMs on coral species although exposure has been linked to decreases in the abundance of various other benthic species. Portland cement, which is highly alkaline, released on the seafloor during exploration drilling has been linked to reduced rates of recruitment of shallow water coral species when compared to less alkaline concrete mixtures although the presence of hard substrate could potentially expedite recovery after exploratory drilling has ended. It should be noted however that the benefit of providing newly created substrate for larval settlement is unlikely to outweigh the various potential negative impacts that exploratory drilling processes have on coral and sponge species.

The severity of these impacts varies in time and space and are likely to be worse in areas where exploratory wells sites are located near one another or production wells, resulting in the potential for cumulative impacts. There has been very little work completed on cumulative impacts on corals and sponges. Cumulative impacts may include overlap between different exploratory drilling activities and/or with other anthropogenic activities, and these impacts may be exacerbated by environmental drivers, including climate change.

Impacts on Coral and Sponge Species in the NL Region

The specific impacts of exploratory drilling on coral and sponge species known to exist in the NL Region have not been well studied to date. As a result, Gullage et al. (in press)[1] provides a summary of potential impacts, including activities known to cause impacts (e.g., sediment redistribution, burial) similar to those caused by exploratory drilling, activities in locations outside the Northwest Atlantic, and activities that only partially address the potential impacts of exploratory drilling. Proxies for exploratory drilling were selected based on the level of sedimentation, physical damage, and/or chemical exposure associated with them. It is possible that the impacts could vary depending on the specific exploratory drilling activity, as well as the geographic location.

Avoidance and Mitigation Decision-Making Framework

To assist in determining whether avoidance/mitigation should be recommended at proposed drill sites, a decision-making framework was developed (Figure 3). This framework can be applied along with the recommended best practices for limiting the impacts of exploratory drilling on corals and sponges. Provisional significant density thresholds appropriate for the coral and sponge fauna of the offshore NL Region were also developed to determine areas where the density of corals and/or sponges are at a level where avoidance is necessary.

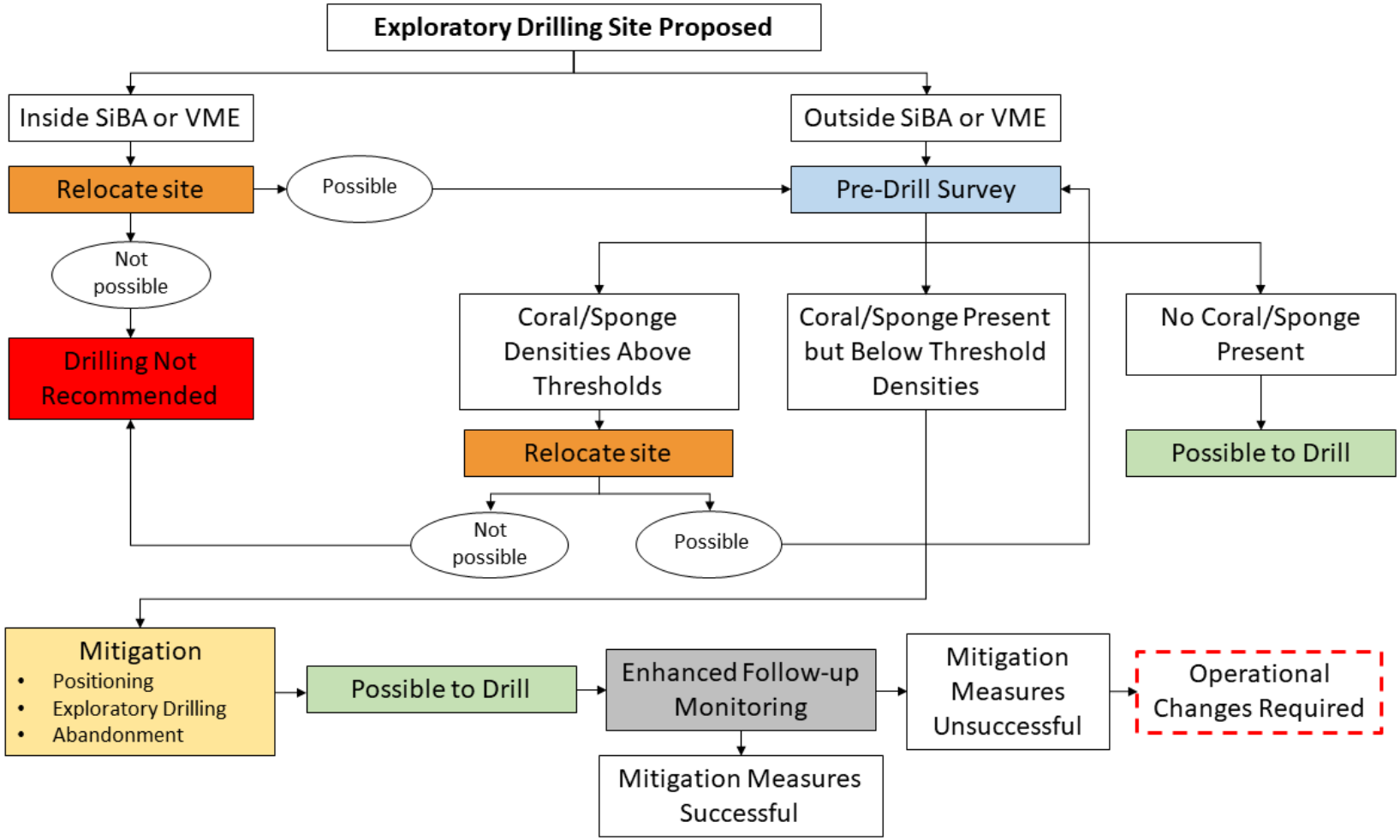

Figure 3. Decision-making framework for avoidance/mitigation of corals and sponges at proposed exploratory drill sites.

Recommendations are also provided for best practices for dispersion models, pre-drill (acoustic and visual) surveys, and follow-up monitoring for coral and sponge habitats. A precautionary approach was applied to the development of the framework and density thresholds, recognizing that there are knowledge gaps concerning corals and sponges and the impacts of exploratory drilling on them.

Mitigation measures are ideally identified and implemented in accordance with the widely accepted “mitigation hierarchy” of: (1) avoid; (2) mitigate; and (3) offset (recognizing that offsetting will not generally be compatible with benthic conservation objectives) (DFO 2019a). Avoidance can have three components: spatial (move location, directional drilling), temporal (activity at a different time), and activity (reinject or skip and ship vs. discharge), although in general, spatial avoidance is considered the best option to avoid impacts to coral and sponge species. Where avoidance is not feasible, other mitigation measures may be effective and would require consideration on a case-by-case basis (DFO 2019b).

DFO Science previously recommended a lower threshold of impact and a higher expectation of mitigation inside areas with defined benthic conservation objectives (DFO 2019b), as these areas are expected or known to have a higher vulnerability to anthropogenic activities. Avoidance of impacts in these areas is the most effective mitigation measure available because it eliminates the potential for interactions between the activity and benthic components, minimizing the likelihood of serious or irreversible harm (DFO 2019b). During a review of the Regional Assessment of Offshore Oil and Gas Exploratory Drilling East of Newfoundland and Labrador (DFO 2020), DFO Science further recommended that special mitigations be applied in areas that are deemed special (e.g., VMEs, SiBAs, EBSAs) but are not currently protected by other management measures. While it was recognized that some of these special areas are already protected fully or partially from some anthropogenic activities (e.g., bottom-contact fishing is prohibited in OECMs and NAFO fisheries closures with benthic conservation objectives), it was recommended that mitigation measures for exploratory drilling be considered at the scale of the actual special areas, not just at the scale of the portions which are protected (DFO 2020). Following from this advice, and specific to areas where high densities of corals and sponges occur, it is recommended that exploratory drilling activities (including the zone of influence) not overlap SiBAs and VME habitats. While EBSAs are important areas that also should be avoided, these areas have been identified and delineated based on their importance to a variety of marine taxa. SiBAs and VME habitats are specific to corals and sponges, and therefore these are the most important areas to avoid. However, pre-drill surveys might also identify significant coral and sponge concentrations inside EBSAs (i.e., densities above threshold), in which case site relocation should be considered.

Outside of special areas, avoidance/mitigation depends on the density of corals and/or sponges identified during the pre-drill survey. It is recommended that outside of SiBAs and VME habitats, where pre-drill surveys have identified coral and sponges at or above significant density thresholds, the zone of influence from exploratory drilling activities should be at least 2 km (Cordes et al. 2016). Drilling discharge dispersion models and/or zone of influence (1.5 mm PNET) predictions should be used to determine if larger buffer areas are necessary. If the proposed drill site falls within an area with corals and/or sponges, enhanced follow-up monitoring programs are recommended.

The various techniques and potential suitability for pre-drill surveys, mitigation measures, and follow-up monitoring in the NL Region are described in Gullage et al. (in press)[1]. Following from this, a series of proposed best practices for these activities were compiled. It should be noted that these best practices are concerning corals and sponges and do not take into consideration

the management, technical engineering or economic aspects. It is further recommended that data (e.g., raw data and data products, as well as metadata) collected on corals and sponges by industry during surveys relating to exploratory drilling activities should be made available to DFO Science to inform areas of uncertainty and knowledge gaps.

Pre-Drill Surveys

Pre-drill surveys are meant to characterize the area surrounding the proposed well-site in order to identify whether aggregations of habitat-forming corals and sponges are present nearby. Results of the survey are used to determine whether avoidance and/or mitigation measures are required throughout the drilling process. As a condition of authorization, drilling activities are prohibited from occurring within 100 m of a coral colony, which is defined as either a *Lophelia pertusa* reef complex, or five or more large corals (>30 cm in height or width), within 100 m^2.

Present methodologies for pre-drill surveys in the NL Region are based on aspects of the Norwegian Oil and Gas Authority (NOROG) guidelines (DNV 2013), which focused primarily on *Lophelia pertusa* reef systems, that have not been observed in the NL Region, and aggregations of gorgonian corals. However, the current guidelines do not consider many smaller species of sea pens (e.g., *Pennatula aculeata*), small gorgonians (e.g., *Acanella arbuscula*), or sponges that are found in the region and can form large scale habitats in soft substrates. Globally, pre-drill surveys typically involve the collection and interpretation of acoustic data and/or visual data; however, requirements often vary by jurisdiction.

Bathymetric Data

While the requirements of pre-drill surveys vary throughout the world, many involve the collection of bathymetric data that are used to aid in the identification of potential coral structures (e.g., reefs) and/or identify areas where bottom types are suitable for coral species. Consideration must be given to the resolution of these images in order to capture the presence of corals and sponges. According to the DNV (2013) recommendations, bathymetric data are collected at a <1 m resolution. Existing project descriptions suggest that 0.5 m resolutions are used in the NL Region (ExxonMobil Canada Ltd. 2017), but higher resolution data have also been collected. Due to their small size, many coral and sponge species and/or communities in the NL Region (e.g., *Acanella arbuscula* fields) would not be observed, nor identifiable, at 0.5 m resolutions (DFO 2018). In fact, because the C-NLOPB definition of coral colonies is based on the presence of large corals (>30cm in height or width), any resolution greater than 0.3 m x 0.3 m risks missing important coral and/or sponge communities warranting visual investigation. On their own, bathymetric surveys are unable to identify the species which are present within the study area. To ensure that taxonomic identification is possible, it is recommended that all proposed drill sites undergo thorough, high-resolution visual surveys as well.

Dispersion Models

Dispersion models are used to assess how suspended sediments generated during the exploratory drilling phase will impact the area surrounding the wellsite. They provide estimates of how far sediments will disperse, as well as how the thickness of sediments changes within the dispersal area. In order to develop reliable dispersion models, sufficient baseline data should be used, as well as appropriate methodologies to predict effects. These models should be developed using the best available current estimates, incorporate a wide range of ocean conditions to fully assess seasonal and inter-annual variations, include regionally representative sediment classes, account for the settlement of the largest possible fraction of suspended material, consider benthic boundary layer processes (e.g., turbulent re-settling/re-suspension

mechanisms), and include a full range of sensitivity analyses for all relevant model parameters. When possible, the performance of the dispersion model should be assessed against previous studies around exploratory drilling sites.

Visual Surveys

Consistent with NOROG guidelines, some pre-drill visual surveys in the NL Region are only conducted at sites that were previously identified by side scan sonar (SSS) and/or multibeam echosounder (MBES) to likely contain coral species (ExxonMobil Canada Ltd. 2017). More thorough visual surveys have also been performed independent of SSS and MBES surveys, through which coral and sponge communities not previously observed were identified. The ability to observe corals and sponges in visual surveys is impacted by the survey design. Alternative visual survey designs are illustrated within Gullage et al. (in press). Different designs can increase the coverage of the survey, particularly near the platform, where the release of drill cuttings and mud have the largest potential effect. Findings from dispersion models should be considered when defining the footprint of the pre-drill survey in order to account for the impact of currents on sediment and cutting distribution, and the pre-drill survey should not be limited to a standard radius (e.g., 500 m) around the well site (Norwegian Standards 2012). A hybrid pre-drill survey approach could also be adopted, whereby the transect video survey design is supplemented by ground truthing any potential coral and sponge sites identified in the SSS and MBES data that are not located along the pre-defined transect lines. This type of survey would be most effective at ensuring that the maximum number of potentially important coral and/or sponge sites within the zone of influence would be identified prior to the initiation of drilling activities.

Based on dispersion modelling, proponents can identify the boundary where sediment thickness will reach the probable no-effects threshold (PNET) of 6.5 mm, which is defined as the threshold above which species exhibit adverse effects as a result of burial. However, this 6.5 mm threshold may not be suitable for corals and sponges as it was based on data for bivalves and crustaceans (Kjeilen-Eilertsen et al. 2004). More recent studies indicate that some corals are susceptible to burial at the 6.5 mm PNET or less (Larsson and Purser 2011). As information on suitable thresholds for coral and sponge species have not been well investigated at this time, a more conservative 1.5 mm threshold is often suggested for the development of pre-drill surveys to account for such discrepancies for more sensitive species. It is recommended that research be conducted to identify a PNET based specifically on the sensitivity of coral and sponge species and implement it for use in dispersion models. This 1.5 mm PNET should be used when developing dispersion models to determine if a larger buffer area is necessary around significant concentrations of corals and/or sponges.

At present, visual data collection can be limited by the speed and resolution of the methods used. There will be a trade-off between the quality of the video and the time required to collect it. It is recommended that all video data be collected at a maximum speed of 0.5 knots, collected along a straight line while maintaining a consistent height of 1-2 m from the seafloor (or as close as practically possible for an AUV). The survey platform (e.g., AUV or ROV) should be equipped with lasers for size estimation and should also have a minimum of one high definition (HD) video camera with adequate lighting, as well as a digital still camera. The analysis of video data should consider abundance and density of coral and sponge taxa, and the survey platform should be capable of collecting reference samples of species that are common, and/or dominant, and/or structure forming for positive identification.

In addition to the proposed drill site, visual surveys should also be performed for the anticipated footprint of the positioning system, taking into consideration any positioning uncertainty. Recent decision statements for exploration projects have indicated that, where anchor and mooring systems will be used for positioning, pre-drill surveys must run at least 50 m from the location of each anchor (CEAA 2019a and 2019b). However, it is also suggested that visual surveys should be run a minimum of 50 m, plus the distance of positioning uncertainty, from the location of each anchor, as well as in the area where the mooring line will be in contact with the seafloor (e.g., 50 m +/- 15 m = 65 m). For projects where dynamic positioning (DP) will be used, visual surveys should also be conducted 50 m, plus the distance of positioning uncertainty, from the location where transponders will be deployed. This ensures that the areas under greatest threat from sedimentation and physical contact with positioning equipment can be relocated if corals and sponges are prevalent.

Current guidelines indicate that, once the visual survey is complete, the data are reviewed to determine whether the presence of aggregations of corals or sponges, or any other sensitive organisms and/or features warrants the implementation of avoidance or mitigation measures. Due to the patchy nature of some coral and sponge species, it is recommended that the entirety of the visual survey data collected during the pre-drill survey be reviewed, reducing the likelihood of missing coral and sponge species near the proposed drill-site.

Provisional Significant Density Thresholds

The existing density thresholds, used to determine whether avoidance/mitigation measures are required for proposed exploratory drilling activities, were developed for large coral species and do not fully consider many of the smaller (<30 cm) species common in the NL Region. It is also problematic for sea pens, a group of corals commonly found in soft sediments in the region, which have part of their bodies (peduncle) buried within the sediment and hidden from view. To ensure that regionally appropriate thresholds for mitigation are used, it is suggested that the life-history characteristics (e.g., longevity, growth rate), rarity, and VME status of the species, be taken into consideration, and that more abundant, shorter-lived corals (e.g., soft corals) warrant different mitigation thresholds than rarer, longer-lived, VME indicator species (e.g., black corals, large gorgonians). Provisional significant density thresholds, based on coral and sponge data collected in the NRA and best available knowledge, have been developed to better reflect the offshore NL Region fauna. The development of these provisional significant density thresholds is briefly described below and in more detail in Gullage et al (in press)[1]. They should be reviewed and updated as new information becomes available.

Significant concentrations of coral and sponges in the NRA and in Canadian waters have previously been identified using kernel density estimations (KDE) applied to RV trawl survey biomass data (Kenchington et al. 2016a, 2016b; 2019). Biomass thresholds defined from KDE have been used to delineate SiBAs and VMEs. Significant density thresholds, based on abundance, have not been previously published for the NL Region. To facilitate the identification of significant concentrations of corals and/or sponges from imagery (e.g., seabed surveys), where direct biomass estimates are not possible, these significant density thresholds were developed. These can be used to identify significant areas of corals and sponges beyond and within the EEZ, when biomass information is not available, but abundance is (e.g., pre-drill visual surveys). Until direct data from underwater imagery are collected, analyzed, and validated, the proposed density thresholds should be used to determine locations where avoidance is required.

The recommended significant density threshold values (number of organisms per 100 m^2) are summarized in Table 1. Thresholds were calculated for VMEs and SiBAs in the NRA and Canadian waters, respectively, at two gear efficiencies (1% and 5%, detailed in Gullage et al. in press)[1]. Published coral and sponge biomass thresholds developed for VMEs and SiBAs (Kenchington et al. 2016a, 2016b and 2019) provided the basis for these calculations, in combination with data on the number of individual corals/sponges per trawl catch and average individual coral/sponge weights (Gullage et al. in press)[1]. Density thresholds were calculated at both 1% and 5% gear efficiencies because these encompass approximate Campelen trawl efficiencies for corals and sponges in the region (Kenchington et al. 2011). Although these density thresholds were calculated based on biomass thresholds developed for VMEs and SiBAS, where exploratory drilling is not recommended, they can be used to assess the results from visual surveys conducted outside of these areas. The 2007 EU-Spain Bottom Trawl Survey data were used for both because they allowed at sea verification of species identifications as well as categorization into size classes (e.g., small vs. large sponges). Recommended thresholds were selected using a precautionary approach and reflect the lowest density threshold values between VME and SiBA values determined in both areas (NRA and Canada).

Due to the lack of biomass thresholds for significant concentrations of other non-VME “common” coral species (e.g., soft corals, stony cup corals), no density thresholds are provided for these groups, but this may change in light of new science. Similarly, no threshold was provided for other non-VME “rare” species such as hydrocorals, but industry-collected observations, specimens, and data related to these rare species would be of interest to DFO Science, in order to improve our current knowledge on species diversity and distribution in the region.

Table 1. Coral and sponge significant density thresholds (N 100m-2) by gear efficient (%) developed from existing VME and SiBA biomass thresholds in the NAFO Regulatory Area (NRA) and in Canadian waters, respectively. ***Recommended significant density thresholds are in bold*** *and were selected using the precautionary approach. Best available knowledge of gear efficiency (e.g., for large sponges) was applied where available to refine significant density thresholds (detailed in Gullage et al. In press)[1].*

-	5% VME	5% SiBA	1% VME	1% SiBA
Sea pens	**4**	10	21	50
Large gorgonians	<1	<1	1	**1**
Small gorgonians	1	**2**	5	8
Black corals	<1	-	**1**	-
Large sponges (>5 cm)	2	1	10	**6**

These provisional significant density thresholds were calculated due to the lack of published thresholds that could be used to identify significant concentrations of corals and sponges in the NL Region from imagery data (i.e., pre-drilling seabed visual surveys). While previous thresholds used by the oil and gas industry seem to have been partially adopted from guidelines outlined by DNV 2013 based on *Lophelia pertusa* reefs, gorgonians, and coral gardens, there is no public information on how those values were calculated (e.g., 5+ large corals per 100 m^2). In this sense, the significant density thresholds presented here have the advantage of being based on regional data (including commonly local taxa), and VME and SiBA biomass thresholds already used by NAFO and Canada, respectively. Nonetheless, we caution that:

1. The gear efficiencies applied here did not account for the inherent variability associated with the patchy distribution of corals and sponges and other issues mentioned previously, in addition to external factors that could also influence both gear efficiency and selectivity;

2. Abundance estimates from trawl gear in this region have not yet been compared to estimates from imagery data, and these can differ and may need calibration;
3. The relationship between biomass and abundance is less clear for large gorgonians, as samples are often fragmented when brought onboard; and
4. The inclusion of Canadian RV survey as well as EU-Spain Bottom Trawl Survey data from additional sampling years might generate different density thresholds than those provided here.

Therefore, these significant density thresholds should be considered preliminary and reviewed as detailed *in situ* imagery data from special areas (VMEs and SiBAs) are collected.

Exploratory Drilling Activities

Depending on the results of the pre-drill survey, recommendations are made by FFHPP to avoid and/or mitigate the potential impacts of exploratory drilling. Recommendations for avoidance and mitigation techniques that are potentially suitable for use in the NL Region are presented Gullage et al. (in press)[1]. It is important to note that the suitability of a mitigation measure was defined based on its history of successful applications and its ability to withstand harsh weather conditions. It did not take into consideration the geological characteristics which may limit the application of some mitigation measures on a site-by-site basis, or the engineering requirements, human health and safety risks that could be associated with such measures.

Follow-up Monitoring

Follow-up monitoring can be required to either verify the predicted effects of exploration activities or determine the effectiveness of mitigation measures which were used during exploration. Baseline surveys may be used to ensure that changes in the chemical and biological aspects of the study area can be accurately recorded. Programs in Norway require baseline surveys before drilling occurs in new areas, as well as in areas where vulnerable benthic species and habitat are present or are believed to be present (Norwegian Environment Agency 2015). In addition, field-specific sites are selected for monitoring potential chemical or biological changes that result from exploration after drilling has begun. Some monitoring programs conducted in Canada suggest that the design would be based on the pre-drill survey, the potential zone of influence as described by dispersion models, and the sites location with respect to sensitive benthic habitats.

While there is an understanding that enhanced monitoring programs should be implemented for areas where coral and sponge species are likely to exist (Buchanan et al. 2003, Norwegian Environment Agency 2015), information on the specific methods that would allow for such enhancements are quite limited, particularly in the NL Region. Nonetheless, research from other regions provides information on some techniques for monitoring these communities that may be suitable. These are described below and summarized in Gullage et al. (in press)[1].

Although existing Norwegian guidelines suggest that acoustic surveys can be used in place of visual surveys (Norwegian Environment Agency 2015), the sole use of acoustic surveys in NL would not allow for the collection of information on the specific health of coral and sponge species. However, the addition of comprehensive visual surveys would provide a more detailed picture of the distribution of drill cuttings and mud in this region. At present, visual surveys are the primary mechanism for assessing coral and sponge species in the deep sea. Like pre-drill visual surveys, visual surveys for monitoring purposes can be performed using either an ROV, towfish camera, or AUV. Although scientific studies have had success with AUVs, ROVs are

generally preferred for detailed inspection applications because of their stability. While the use of high-resolution video equipment is recommended for visual surveys, existing research indicates that, even when using high resolution images, changes in polyp behaviour as a result of exposure to drill cuttings could not be identified (DNV 2013). Nonetheless, visual surveys allow for comparisons of a species' ability to cope with excess sediment (e.g., efficiency in removing sediment), changes in coloration, and changes in shape (e.g., loss of branches), which provide useful information about which species are most at risk to increased sedimentation. Comparisons between the pre-drill and follow-up visual surveys, particularly when they are performed using the same pattern (e.g., cloverleaf), are also helpful in validating dispersion models.

Other non-invasive techniques have been developed for use with subsea video, which allow coral health to be directly quantified from visual surveys. However, these techniques require a large amount of processing, making them quite onerous. To account for this, Underwater Hyperspectral Imaging (UHI) has been used to automate the process and involves the use of hyperspectral cameras which can record the full spectrum of reflected light, thus increasing the amount of information that a single image can provide. Although this work has proven to be promising for use in deep sea applications, it is not yet known if health impacts associated with drill cuttings can be measured using the same hyperspectral techniques described in existing literature. Furthermore, inadequate information on the baseline ("healthy") spectral reflectance of many species, and limited use on sponge species, suggest that its application in the NL Region may be limited at this time.

The techniques available for directly assessing coral and sponge health are quite limited and visual surveys are unable to detect the presence of chemicals used in drilling muds, therefore, existing guidelines also suggest that proponents conduct additional monitoring activities. DNV (2013) describes the importance of collecting current measurements, turbidity measurements, sediment traps, and sediment samples in the study area. Measurements of water currents are important to collect before and during drilling operations as they are key components in developing and testing accurate dispersion models. Turbidity measurements are most useful when collected during drilling operations to determine the amount of turbidity directly associated with drilling and to detect the presence and distribution of sediment plumes. Sediment traps can also be deployed throughout the drilling operation and in areas near coral and sponge assemblages, allowing for the direct measurement of drill cuttings. They can be compared to known PNET for corals and sponges and indicate the likely impact that drilling will have on these species throughout the study area. Lastly, recommendations indicate that using a corer to retrieve sediment samples both before and after drilling can assist in providing a detailed picture of where drill cuttings and mud have been distributed throughout the area. This can be used to validate dispersion models, as well as indicate areas where visual monitoring of corals and sponges should be focused.

Recommended Best Practices

Various recommended best practices have been identified to ensure that exploratory drilling activities in the NL Region can be performed while avoiding and/or mitigating the impacts on coral and sponge species. They are summarized below and have been organized to correspond with the decision-making framework (Figure 3). The recommended best practices and mitigation measures consider routine operations of exploratory drilling but exclude accidental events (e.g., spills) and cumulative effects with respect to corals and sponges and do not take into

consideration the engineering requirements, health and safety or costs associated with the specific activity.

- Relocation (Avoidance)
- Exploratory drilling activities should be relocated from areas that have been identified based on significant densities of corals or sponges, specifically SiBAs and VME habitats.
- Outside of SiBAs and VME habitats, exploratory drilling activities should only take place at least 2 km away from locations where pre-drill surveys have identified coral and/or sponge species at or above significant density thresholds. Drilling discharge dispersion models/zone of influence (1.5 mm PNET) predictions should be used to determine if a larger radius is necessary.
- The area of impact (1.5 mm PNET) should not overlap any existing special areas (SiBAs or VME habitats), as these can still be impacted through the dispersal of sediment and/or contaminants.

Dispersion Models (Pre-Drill Surveys)

- Dispersion models should be developed using the best available 3-dimensional current estimates.
- Dispersion models should consider seasonal and inter-annual variations of ocean currents.
- Dispersion models should track settlement of the largest possible fraction of suspended material.
- When available, previously validated drilling discharge dispersion models from relevant exploratory drilling sites should be used to inform model configuration for subsequent projects.
- Benthic boundary layer processes should be included in dispersion models.
- Sediment classes used in dispersion models should be representative of the proposed drill site.
- Sensitivity analyses should be performed on all relevant dispersion model parameters.

Baseline Survey (Pre-Drill Surveys)

- Baseline surveys should be conducted in previously un-surveyed areas, and in areas where coral and sponge species are present or are predicted to be present.
- Information on currents, turbidity, and sediment (rates and samples), should be collected as part of pre-drill surveys.
- Control sites (upstream/downstream) are recommended outside the expected zone of influence.

Visual Survey (Pre-Drill Surveys)

- All proposed drilling sites should undergo a thorough, high-resolution visual survey (e.g., HD of 4K resolution or best available technology).

- Pre-drill acoustic data (bathymetry and backscatter) should be collected at a high enough resolution that potential coral and sponge structures in the NL Region can be identified (e.g., Synthetic Aperture Sonar [SAS] or similar available technology).
- Potential coral and sponge habitat identified by acoustic surveys should be ground truthed through visual surveys.
- A hybrid survey should be completed that integrates 1) an acoustic survey that can identify bottom types (i.e., potential habitat for corals and sponges) and 2) a visual survey that can detect and identify corals and sponges.
- Visual surveys should consider the proposed footprint of positioning equipment and associated positional uncertainty (e.g., dynamic positioning transponders, anchors, mooring lines).
- Visual survey design should be conducted in a clover-leaf pattern and the length of transect lines should be based on the 1.5 mm PNET footprint identified by dispersion models. Video should be collected along the entire length of each transect line (i.e. maintaining video quality).
- Visual surveys should be designed to allow for measurement of abundance and density (e.g. consider camera angle, vehicle's altitude and speed) of corals and sponges surrounding a proposed drill site.
- Surveys should be conducted at suitable speeds (0.5 kts) with the camera 1–2 m above the seafloor and should be equipped for *in situ* measurement, taxonomic identification, and sample collection of reference specimens (i.e. that can confirm species identification from video).
- Due to the patchy nature of coral and sponge habitat, a qualified individual should review all video data (i.e. not just a portion of the video) collected prior to exploratory drilling and information regarding significant densities should be shared with DFO Science.
- Standardized training is recommended to qualify individuals to identify corals and sponges from visual survey data.
- Taxa should not be identified at the species level using visual imagery unless a reference specimen has been collected to verify identification.
- In cases where the video analyst has high confidence on the identification of common species from imagery, taxa can be tentatively identified at lower taxonomic levels.

Positioning (Mitigation)

- Positioning systems should reduce the potential for impact to corals and sponges as much as possible. If anchors are necessary, they should be deployed and retrieved by ROV when possible.
- If anchors are used, methods to reduce the impact that mooring lines will have (e.g., buoyancy) should be employed where possible.

Drilling (Mitigation)

- Methods that limit the amount of sedimentation during top hole drilling (e.g., not using water jetting) are recommended in areas where corals and sponges are present, where technically feasible.

- If cuttings transport systems (CTS) are used, the proposed equipment corridor, as well as the location of disposal site, should be subject to visual inspection to ensure significant densities of coral and sponge species are not present.
- If cuttings piles are generated, subsequent disturbance of these areas should be limited to prevent the redistribution of contaminated sediments.
- When possible, the selection of the type of drilling muds should be justified based on the least potential impact to corals and sponges.
- When possible, the release of drill cuttings at sea should be eliminated or reduced.
- When possible, selection of disposal methods for drill cuttings should be based on the least potential impact to corals and sponges.
- Back-up mitigation techniques should be identified in the event that the primary option is not performing as required.
- Mitigation techniques/tools should be tolerant to weather conditions in the Northwest Atlantic.

Abandonment (Mitigation)

- Instead of using grappling techniques for retrieving anchors, ROVs and pick-up buoys should be used where practicable and feasible to reduce bottom impacts.
- Impacts to corals and sponges should be minimized where possible when the well-head is being removed (e.g., utilize internal shearing if practicable).

Enhanced Monitoring (Follow-up Monitoring)

- Enhanced follow-up monitoring should be conducted in areas where coral and sponge species are present.
- Specific sites should be selected within the zone of influence and used to monitor physical, chemical, and biological changes that may occur while exploratory drilling is being conducted.
- Sites should be laid out in a radial pattern surrounding the proposed drilling site and consider the prevailing bottom current.
- Information on currents, turbidity, and sediment (rates and samples), should be collected during follow-up monitoring.
- Sediment cores should be collected to provide a detailed picture of sedimentation rates during drilling programs.
- Visual surveys, using ROVs, should be conducted as part of follow-up monitoring.
- Enhanced follow-up monitoring should implement the use of imagery analysis to potentially allow the assessment of changes in coral and sponge health over time.
- The same survey design and technique should be used in follow-up surveys as were used in pre-drill surveys to allow for comparison.
- Control sites (upstream/downstream) are recommended outside the expected zone of influence. Sites should be the same as those used in the pre-drill baseline survey.

Sources of Uncertainty

In general, comprehensive information relating to life histories, reproduction, distribution, and sensitivities of coral and sponge species in the NL Region is limited. Further, the specific impacts of exploratory drilling on coral and sponge species known to exist in the NL Region have not been well studied to date. As a result, the estimates of recovery time to pre-exploration conditions for coral and sponge species within the NL Region are uncertain given the limited available research. Therefore, research is required to gain a better understanding of the coral and sponges in these systems. It is recommended that research be conducted to identify a PNET based specifically on the sensitivity of coral and sponge species in the region and implement it for use in dispersion models.

The decision-making framework and provisional significant density thresholds were developed using a precautionary approach recognizing that there are knowledge gaps concerning several coral and sponge species in the NL Region, as well as the impacts of exploratory drilling on them. These mitigation thresholds should be reviewed and updated considering new information as it becomes available.

The recommended best practices and mitigation measures consider routine operations but exclude accidental events (e.g., spills) and cumulative effects. With increasing exploratory activity in the region, it will be important to consider cumulative effects on corals and sponges from anthropogenic activities, including exploratory drilling.

CONCLUSIONS AND ADVICE

This science advice, along with the detailed discussion in the accompanying Research Document (Gullage et al. in press)[1] provide a thorough review of the available information on corals and sponges within the NL Region as well as the potential impacts of exploratory drilling activities on corals and sponges. The avoidance and mitigation framework which was developed, along with provisional significant density thresholds, will provide an appropriate tool which can be used by management to provide guidance on the necessity for avoidance/mitigation with respect to concentrations of corals and sponges within the NL Region. Also, to ensure that exploratory drilling activities can be performed while avoiding and/or mitigating the effects to coral and sponge species, best practices are recommended for dispersion models, pre-drill (acoustic and visual) surveys, and follow-up monitoring to assist in avoiding and mitigating the effects of exploratory drilling activities on coral and sponge habitats.

There are still gaps in the knowledge of corals and sponges within the NL Region including species and their distributions. The potential impacts of exploratory drilling are also not fully understood at this time, including possible cumulative effects of anthropogenic activities. In light of the existing knowledge gaps, significant density thresholds and best practices should be reviewed as new information becomes available.

Following previous advice provided by DFO Science to limit impacts on corals and sponges, it is recommended that exploratory drilling activities (including the zone of influence) do not overlap SiBAs and VME habitats. These areas have higher concentrations of corals and are expected or known to be more vulnerable to anthropogenic activities with recovery times for corals and sponges expected to be long. It is also recommended that when significant densities of corals and sponges are identified in pre-drill surveys, the zone of influence from exploratory drilling activities should be at least 2 km away. Drilling discharge dispersion models/zone of influence (1.5 mm PNET) predictions should be used to determine if a larger buffer is necessary.

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This Science Advisory Report is from the January 28-30, 2020 Regional Peer Review Process on Coral and Sponge Mitigations in Relation to Exploratory Drilling Programs in the Newfoundland and Labrador Region. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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