Title	Assessing the Impact of Seismic Airguns on Commercially and Recreationally Important Fish
Administered by	Gulf of Mexico OCS Region
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Procurement Type(s)	Cooperative Agreement (but consider collaboration with industry)
Performance Period	FY 2020–2022
Date Revised	March 4, 2019
PICOC Summary	Write one or two sentences for each of the following elements, as appropriate.
Problem	Research into impacts to fish and fisheries from seismic surveys is limited, and conclusions are inconsistent. By necessity, our environmental analyses have relied on research with limited applicability and we have not had consistent conclusions about impacts to fish. It is important to obtain more information for species that occur on the U.S. Outer Continental Shelf (OCS) to better inform our analyses and management decisions.
Intervention	Observing the behavior of valuable reef fishes exposed to commercial seismic surveys would enable BOEM to better assess potential effects on biologically important behaviors. Such information would enable BOEM to meet statutory obligations to assess the level of impact and, as appropriate, propose mitigation measures to lessen or avoid such effects.
Comparison	Observe the movements of adult fish, and the potential physiological damage to larval fish, in response to a full seismic array.
Outcome	The outcome will address current gaps in our understanding of impacts to a commercially and recreationally important fish species: red snapper or grouper. Although the work would take place in the Gulf of Mexico (GOM), this research is relevant for both the Atlantic and GOM OCS Regions due to this species' wide geographic range. In addition, other snappers occur in other BOEM regions, so results may be extrapolated to similar species.
Context	Atlantic, GOM

BOEM Information Need(s): BOEM is required to consider the impacts of its activities on not just protected and managed species, but all species and ecosystems on the OCS. When it comes to seismic surveys, the most concerning impact-producing factor is noise. Noise can affect animals in a variety of ways—from physiological damage, to stress responses, to behavioral changes (Kight and Swaddle 2011). It is not clearly understood how fish (and their respective fisheries) are affected by such noise, particularly whether the effects are short term or long term. The fishing community has voiced its concern over pending seismic surveys, as they are unsure whether fish may vacate key fishing grounds or become damaged by the sounds. The International Association for Geophysical Contractors issued a statement assuring that impacts would only be short-term, but cite a lack of adequate research characterizing long-term impacts. Clearly this is a contentious issue and it would be prudent for BOEM to obtain a better understanding of this topic to ensure that its environmental reviews and assessments are adequate. It should be noted that a study of this nature was recently suggested by an external stakeholder. In addition, the Joint Industry Program announced in 2018 that one of their focal areas for the next phase of funding was "physical impacts to fish and larvae." Therefore, there may be possible avenues for collaboration with industry.

Background: Although initial concerns over noise were focused on marine mammals, there is mounting evidence that a wide range of marine taxa are sensitive to sound and could also be affected by anthropogenic noise. Early research on acoustic impacts focused on physiological effects, such as damage to air-filled structures or hearing loss. While such acute responses are indeed possible very close to the sound source, researchers are recognizing that other reactions, like a stress response or change in behavior, are more likely and would be more widespread. Repeated exposures to stressful events or disruption of key behaviors (*e.g.*, feeding) can have negative effects on critical life functions and overall fitness (Wright *et al.*, 2007).

The impacts of airgun noise on fish are potentially significant across all OCS regions. Impacts to fish with swimbladders are expected to be more widespread than those without, because the presence of this air-filled cavity can enable detection of acoustic pressure (a farther-range cue) rather than only particle motion (a shorter-range cue; Popper and Hawkins 2018). Red snapper, *Lutjanus campechanus*, is a common fish in the GOM and Atlantic, and supports important commercial and recreational fisheries. It serves as an ideal species for this type of study because it has a swimbladder, tends to aggregate in large groups, and is ecologically and economically relevant. Although sound production has not yet been demonstrated in red snapper, it is possible, considering that other snappers do produce sound (Fish and Mowbray 1952). If this is the case, it means that it may use acoustic signals to coordinate the timing of spawning (as in many other fish species), and such activities could be affected by the presence of airgun noise. Grouper would be another good candidate species group, as they too have a swimbladder and are known to be acoustically active (Sanchez *et al.*, 2017). The rest of this proposal focuses on red snapper, but a similar experimental design could be undertaken with grouper or other reef fish species. The decision about which species to focus on would depend on their prevalence at the sites that the seismic survey will cover.

Understanding the response of fishes to seismic airguns has important implications for the fishing industry, but research on impacts to commercial catch rates have generally focused on short-term impacts (*e.g.*, hours to days; Hirst and Rodhouse 2000). For example, Lokkeborg and Soldal (1993) found that catch rates of cod decreased near seismic surveys, but returned to pre-shooting levels within about 12 hours, suggesting that cod initially moved away from the survey area but were not permanently displaced. Skalski *et al.* (1992) showed an immediate significant decline in catch rates in a hook-and-line fishery, but the long-term reaction of rockfish was not measured. Engas *et al.* (1996) found that the density of cod and haddock decreased after seismic shooting, and while trawl catch rates did not return to pre-shooting levels within five days after acoustic exposure, longline catch efforts did begin to rebound. These studies demonstrate mixed results, and it is important to recognize that longer-term effects (*e.g.*, over weeks to months) have not been measured.

Finally, there has been little focus on potential effects of seismic airguns on fish larvae, and the research that has been done has not used a full-scale seismic array. Early studies examined the impacts of seismic airguns on fish eggs, larvae, and fry (*e.g.*, Booman *et al.*, 1996; Dalen and Knutsen 1987, Kostyuchenko 1996; Holliday *et al.*, 1987) but these studies generally focused on impacts at 10 m or less from the source (typically a single airgun). Given the recent finding that impacts to copepods may occur at > 1 km from an airgun, and the resurgence of attention on impacts to the planktonic community (McCauley *et al.*, 2017; Richardson *et al.*, 2017), this field warrants further study and additional research should focus on greater distances and/or water depths using a full-scale array.

Objectives: The objectives of this study are to:

- measure potential changes in behavior (*e.g.*, location, depth, schooling, duration of behavioral change) when free-swimming adult fish are exposed to seismic airguns;
- measure potential physiological changes to captive fish larvae that are exposed to seismic airguns; and
- frame these results in terms of potential impacts to the fishery.

Methods: Red snapper tend to aggregate at natural and artificial reefs in the GOM. We will focus this study on a reef that is expected to be surveyed or in the vicinity of a survey (within ~1–2 km) in the near future to measure impacts of a full-scale seismic array. Methods below could be replicated four times under the proposed budget.

<u>Method 1:</u>

An array of Vemco acoustic receivers will be deployed around the research site. Depending on water depth, some of these may be mounted on the bottom while some may need to be mounted on sub-surface buoys mid-way through the water column to maximize potential fish detections. These receivers can record data for approximately six months, so they will be deployed approximately three months before the survey is planned to take place. A passive acoustic recorder will be deployed within the approximate center of the Vemco array to measure the received level of the airguns at the center of the site. Although a single recorder cannot adequately sample the entire area, it can provide a basis of comparison for before-during-after the passage of the survey. A glider with a hydrophone can survey the entire site to help broaden spatial coverage of the sound field.

At least 50 adult snapper will be captured and tagged three months before the planned survey. Half of these animals will be tagged with traditional acoustic tags, which transmit their location when they pass within range of one of the receivers. The other half will be tagged with next-generation Vemco tags which transmit the fish's history of acceleration and depth. This information will be critical for understanding fine-scale movements as the survey passes overhead.

Approximately three months after the survey concludes, the receivers will be retrieved and movement data will be analyzed. Data analysis will focus on the individual- and population-level movements before, during, and after the passage of the survey. The receivers may also detect the presence of fish tagged from other telemetry studies, and likewise, our tagged fish here may be detected by other receivers; which could reveal other additional animal movement patterns.

Method 2:

Using light-traps, larval fish will be captured in the days immediately preceding the survey. It is likely that a variety of reef species will be captured, including the target species, so an assemblage of species will be tested. Fish larvae will be immediately transferred to mesh traps which will be deployed at different depths (*e.g.*, 10 m, 20 m, 30 m) from the ocean's surface in the immediate vicinity of the main research site (the receiver array). At least five replicate trap arrays (each with several depths) will be deployed around the site. In addition, five trap arrays will be deployed at a similar habitat type that is out of the acoustic range of the survey. These samples will serve as the controls.

Immediately after the passage of the survey, traps will be collected and larval samples will be preserved using vital red stain and formaldehyde. This will allow investigators to count the number of larvae that were alive *vs.* dead at the time of retrieval. Samples will be examined under the microscope for mortality and gross anatomical damage. Data analysis will focus on comparisons between the exposed *vs.* control samples and potential variation in anatomical damage with water depth and taxa.

Specific Research Question(s):

1. Do fish, specifically red snapper, leave the study area when the seismic vessel approaches?
    a. If so, how long does it take them to return to the area (if ever)?
2. Do fish exhibit a change in schooling behavior or depth as the survey passes overhead?
    a. If so, how long does it take them to return to natural (pre-seismic) behaviors?
3. Do fish larvae experience physiological changes in response to airgun noise?
    a. If so, how does this differ with water depth or distance from the source?

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