Marine Policy 78 (2017) 68–73

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Seismic survey noise disrupted fish use of a temperate reef

Avery B. Paxton[a,b,*], J. Christopher Taylor[c], Douglas P. Nowacek[d,e], Julian Dale[d], Elijah Cole[e], Christine M. Voss[a], Charles H. Peterson[a,b]

[a] Institute of Marine Sciences, University of North Carolina at Chapel Hill, Morehead City, NC, United States of America
[b] Department of Biology, University of North Carolina at Chapel Hill, Chapel Hill, NC, United States of America
[c] National Ocean Service, National Centers for Coastal Ocean Science, National Oceanic and Atmospheric Administration, Beaufort NC, United States of America
[d] Nicholas School of the Environment, Duke University Marine Laboratory, Beaufort, NC, United States of America
[e] Pratt School of Engineering, Duke University, Durham, NC, United States of America

ARTICLE INFO

Keywords:
reef fish
airgun
oil and gas exploration
fish abundance
marine conservation

ABSTRACT

Marine seismic surveying discerns subsurface seafloor geology, indicative of, for example, petroleum deposits, by emitting high-intensity, low-frequency impulsive sounds. Impacts on fish are uncertain. Opportunistic monitoring of acoustic signatures from a seismic survey on the inner continental shelf of North Carolina, USA, revealed noise exceeding 170 dB re 1μ Pa peak on two temperate reefs federally designated as Essential Fish Habitat 0.7 and 6.5 km from the survey ship path. Videos recorded fish abundance and behavior on a nearby third reef 7.9 km from the seismic track. During seismic surveying, reef-fish abundance declined by 78% during evening hours when fish habitat use was highest on the previous three days without seismic noise. Despite absence of videos documenting fish returns after seismic surveying, the significant reduction in fish occupation of the reef represents disruption to daily pattern. This numerical response confirms that conservation concerns associated with seismic surveying are realistic.

1. Introduction

Marine seismic surveys emit high-intensity (up to 260 dB re 1μ Pa rms @ 1m), low-frequency (5-300 Hz peak spectral levels) sounds from airgun arrays downward into the water column [1]. The resultant sound waves penetrate the seafloor to provide imagery of the underlying geology. These surveys can detect reservoirs of oil and natural gas, determine site-specific suitability for installation of offshore renewable energy infrastructure, evaluate sources of minerals for commercial extraction or sand for use in beach nourishment, and/or provide information on the continental substructure for geological research. Noise from seismic surveying can alter marine mammal vocalizations and foraging rates, and can lead to marine mammal displacement [2–4]; however, there remain unanswered questions regarding how wild fish respond to seismic survey noise. Understanding whether fish are affected through alterations in behaviors associated with feeding, growth and survival has conservation and management implications.

Acute impacts to individual fish from seismic noise, including damage to sensory ear hair cells, can occur with close-range exposure to low-frequency, high-intensity sounds in laboratory settings [5,6]. Impulsive sounds similar to those from seismic surveys, such as noise made by pile driving, can cause mild to lethal injuries ranging from swim bladder rupture to hematoma and hemorrhaging [7–9]. Behavioral responses of fish to impulsive noise are more difficult to quantify but may include changes in abundance in particular habitats [10], changes in swimming patterns or feeding [11,12], as well as physiological stress even leading to mortality [7]. In contrast, in two studies that were specific to noise associated with seismic surveying, there were no marked changes in fish physiology or behavior [6,13]. Reductions in fish catches can persist for up to five days after seismic activity [10,14,15]. Aside from those mentioned previously, most studies testing fish response to seismic noise occurred in laboratory settings; underwater observations of fish in their natural environment during seismic surveys are rare [7]. Wardle et al. (2001) experimentally exposed fish *in situ* to noise from three synchronized airguns and observed startle responses in some fish but did not detect other changes in behavior or abundance. Although fish in their natural environment may be expected to respond to seismic surveys based on laboratory experiments and reduction in fisheries catch [17], no previous study has documented such an *in situ* behavioral response.

Opportunistic monitoring of a seismic survey offshore of North Carolina (NC) during September 2014 determined whether reef-

* Corresponding author.
E-mail address: abpaxton@live.unc.edu (A.B. Paxton).

http://dx.doi.org/10.1016/j.marpol.2016.12.017
Received 18 November 2016; Received in revised form 21 December 2016; Accepted 22 December 2016
Available online 20 January 2017

associated fishes in their natural environment respond to marine seismic surveying. The academic objective of the seismic survey was to study the formation and evolution of the Eastern North American Margin [18], which involved use of an airgun array of similar volume to those used during oil and gas exploration. The majority of the survey occurred in deep (> 1000 m) waters off the continental shelf, although it continued across the shelf and into shallow (< 35 m) inner continental shelf waters of northeastern Onslow Bay, NC (Fig. 1). This area supports hardbottom reefs that sustain an abundance of fish representing a diverse community, including tropical, subtropical, and warm-temperate species [19–21]. Fish use the temperate reefs for spawning and foraging, as well as for nurseries and refugia, qualifying them as Essential Fish Habitat under the Magnuson-Stevens Fishery Conservation and Management Act (2007).

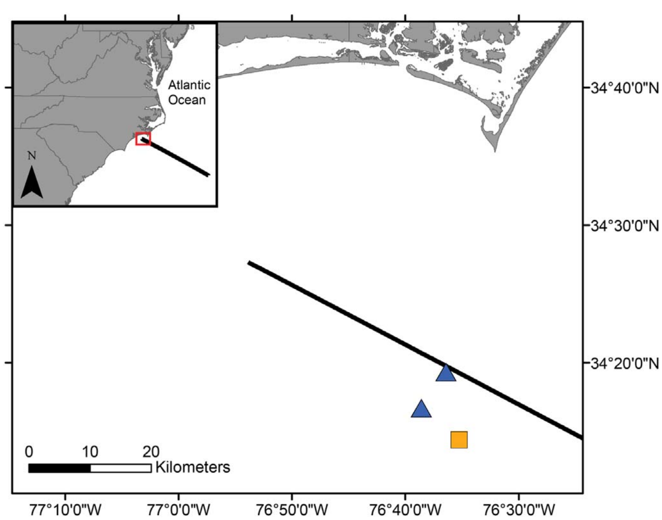

Fig. 1. Track of seismic survey vessel (black line) relative to three monitoring reefs on the inner continental shelf of NC: two outfitted with hydrophones (blue triangles) and one with video camera (orange square).

2. Materials and Methods

As an empirical test of whether noise from seismic surveying can elicit a response from reef-associated fishes, such as a change in abundance, passive underwater monitoring stations were opportunistically established on three temperate reefs during September 2014 (Fig. 1). The reefs, ranging from 25 to 33 m deep, were located 0.7, 6.5, and 7.9 km from the path of the vessel continuously conducting the seismic survey. The reefs were selected based on their proximity to the seismic survey track and because they have been the focus of various marine fisheries and ecological studies for several decades and have been documented to have notable abundances of fish in the federally-managed snapper-grouper complex and other commercially and recreationally important fishery species [20,21].

The two reefs located closest to the survey track, a natural rocky reef and an artificial reef, were equipped with hydrophones (SoundTrap 202 recorders, Ocean Instruments, New Zealand) that documented the acoustic signatures of the surveying noise (Audio S1-S2). Hydrophones sampled continuously at 16-bit, 96 kHz. A video camera recorded fish abundance and behavior on the third reef, a naturally occurring rocky reef, farthest from the survey path (Videos S1-S2). The video camera (GoPro, USA) was outfitted with an intervalometer (cam-do, USA) to record 10-sec videos every 20 min. These monitoring instruments were mounted on conical metal frames (0.5 m high, 0.3 m base diameter), anchored with 60-80 kg of lead, and deployed on each reef on September 17, 2014 so that the instruments could record before and during seismic surveying. Video cameras deployed at the two reefs outfitted with hydrophones malfunctioned. Logistical constraints prevented collection of data following seismic surveying.

Acoustic data from the two hydrophones were processed and then five shots were aggregated for each of nine selected time points. Shots were processed in groups of five to obtain a 'local average' to smooth fine scale variation that occurs in the propagation conditions. The time points were chosen relative to the closest point of approach (CPA) on both the landward and seaward components of the survey path. The five shots closest to the CPA that were not clipped were processed, and other locations were chosen to compare the received signals from the reefs, e.g., the more distant sampling locations gave similar propagation paths to the reefs, while the closer locations were subject to very different parts of the non-uniform source beam pattern [22]. On acoustic recordings from the reef located 0.7 km from the path of the

Video S1. Video recording from reef located 7.9 km from closest approach of the seismic surveying vessel during the evening one day prior to seismic surveying on the inner continental shelf. A video clip is available online.Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.marpol.2016.12.017.