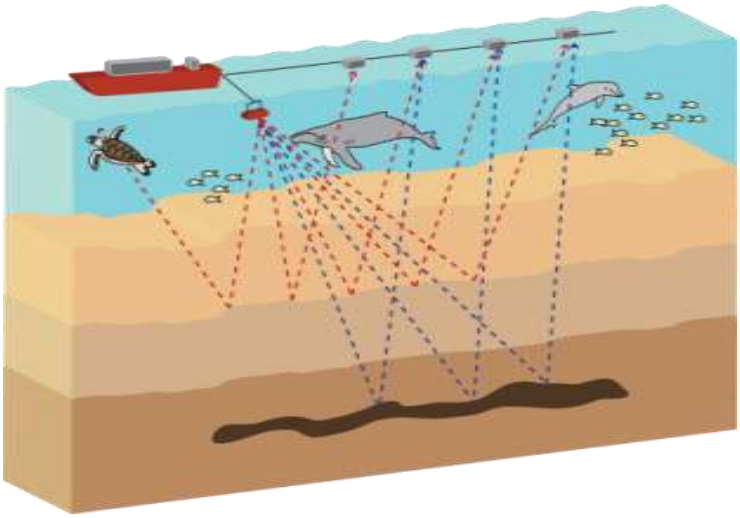
Seismic Testing for Offshore Oil and Gas Reserves

Seismic airgun blasting is a process which the oil and gas industry uses to identify and map oil and gas deposits under the seafloor. A typical seismic airgun survey involves a vessel traveling in successive parallel lines while towing one or multiple airgun arrays. The airguns used to conduct seismic surveys are the second largest source of noise energy in the oceans, behind explosives for military testing and shipping.[1]

How does seismic airgun blasting work?

Seismic airguns release pressurized air bubbles to create powerful sound waves that travel through the water column and seafloor[2] and provide information about the properties of geologic formations more than 6 miles below the seafloor.[3] These sound waves travel as echoes back to the sea surface, where they are captured by hydrophones.[4]



Seismic airgun testing characteristics:

- Loud blasts repeated every 10-12 seconds.[5]
- Repeated for days, weeks, or months at a time.[6]
- Approximately 12-48 individual airguns in one array.
- A single vessel can deploy up to 96 airguns.[7]
- Sea surface area covered by the largest towed seismic arrays is 21 times larger than the National Mall in Washington, D.C.[8]
- Seismic airgun sounds can be heard up to 2,500 miles from the source under some propagation conditions, farther than the distance from Washington, D.C. to Las Vegas.[9]

[1] Badelt, B. (2015). The Inventor of the Seismic Air Gun Is Trying to Supplant His Controversial Creation. *Hakai Magazine*.
[2] Seismic Surveys at Sea: The contributions of airguns to ocean noise. (2004) *Backgrounder*: Acoustic Ecology Institute.
[3] National Research Council. *Ocean Noise and Marine Mammals*. Washington, DC: The National Academies Press. (2003). doi:10.17226/10564.
[4] Seismic Surveys at Sea, 2004.
[5] National Research Council. (2003).
[6] Blackwell, S.B., et al. "Effects of Airgun Sounds on Bowhead Whale Calling Rates: Evidence for Two Behavioral Thresholds." *PLoS ONE* 10.6 (2015).
[7] National Research Council. (2003).
[8] Schuler, M. (2015). MV Sanco Sword Tows Record-Setting Seismic Streamer Spread. *gCaptain*. From http://gcaptain.com/mv-sanco-sword-tows-record-setting-seismic-streamer-spread/#.VoGysZfHIYA
[9] Nieukirk, S. L., Mellinger, D. K., Moore, S. E., Klinck, K., Dziak, R. P., & Goslin, J. (2012). Sounds from airguns and fins whales recorded in the mid-Atlantic Ocean, 1999-2009. *The Journal of the Acoustical Society of America, 131(2),* 1102-1112.

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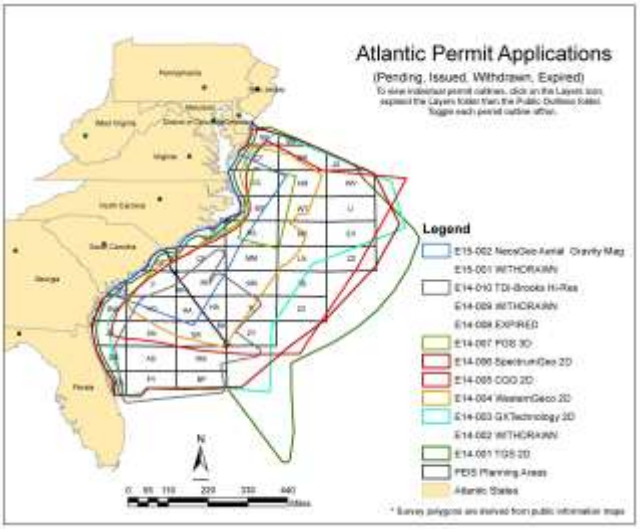
Why is seismic airgun blasting a problem?

Airgun pulses are loud, repetitive, explosive sounds. The produced sound can travel over large distances because of its low pressure and high amplitude.[10] Although seismic airgun arrays are designed to direct most of this sound vertically downwards, a significant amount of sound still travels horizontally away from the airguns.[11] Because sound travels so efficiently underwater, airgun pulses can be heard far from their sources – sometimes more than 2,500 miles away.[12]

Where is seismic airgun blasting being considered?

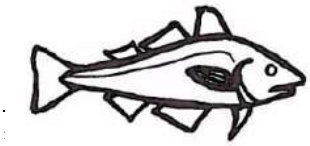
In 2014 the Bureau of Ocean Energy Management (BOEM) issued a Programmatic Environmental Impact Statement (PEIS) and Record of Decision to allow geological and geophysical (G&G) activities – including seismic airgun testing – to move forward in the Atlantic once additional environmental reviews are completed. The seismic testing permits being considered by BOEM would potentially allow temporally and spatially overlapping seismic surveys along the Atlantic coast that would result in cumulative impacts to marine life. This seismic testing would occur in an area twice the size of California,[13] 330,032 square miles, spanning from Delaware south to central Florida.



Permits for Atlantic seismic surveys being reviewed by BOEM.

The biological impacts of seismic airgun blasting

Fish



Fish species vary in their ability to detect and use sound, and seismic airgun noise therefore has a range of impacts on fish.

oth, E. (2010). Long range transmission loss of broadband seismic pulses in the Arctic under ice-free conditions. *The Journal of the Acoustical Society of America, 128(4)*, EL181-EL187.

[11] NRC. (2003). *Ocean Noise and Marine Mammals*.

[12] Nieukirk et al., 2012

[13] BOEM. (2012). Atlantic OCS Proposed Geological and Geophysical Activities Mid and South Atlantic Planning Areas Draft Programmatic Environmental Impact Statement (DPEIS), Vol I. Chapters 1-8. Section 4.2 Alternative A – The Proposed Action. pg. 177.

Numerous studies have shown that noise from seismic airgun testing negatively impacts fish.

Examples include:

- 40%-80% reduced catch rates in Atlantic cod, haddock, rockfish, herring, sand eel, and blue whiting.[14,15, 16, 17,18,19]
- Alarm response and damaged hearing structures.[20,21]
- Hearing system damage in pink snapper (Pagrus auratus).[22]

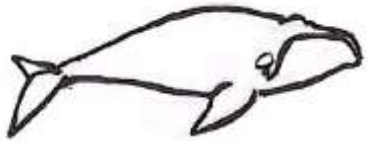
Invertebrates (i.e. bivalves)

Research indicates that some invertebrates are negatively impacted by seismic noise.

Examples include:

- Captive squid demonstrated strong startle responses and behavioral changes at approximately 2-5 km from an approaching seismic source.[23]
- Stress responses in bivalves[24] and crabs.[25]
- Developmental delays and body malformations in scallop larvae.[26]

Whales



Marine mammals rely on sound for feeding, communication, navigation and other behaviors necessary for survival. Studies found that seismic airgun noise can cause hearing impairment, physiological changes, and

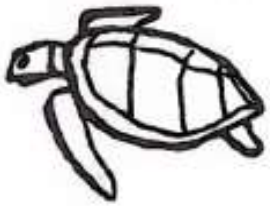
[14] Dalen, J., & Knutsen, G. (1987). Scaring effects in fish and harmful effects on eggs, larvae and fry by offshore seismic explorations. *Progress in underwater acoustics* (pp. 93-102): Springer.
[15] Engas, A., Lokkeborg, S., Ona, E., & Soldal, A.V. (1996). Effects of seismic shooting on local abundance and catch rates of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus). *Canadian Journal of Fisheries and Aquatic Sciences, 53*(10), 2238-2249. doi: 10.1139/cjfas-53-10-2238.
[16] Hassel, A., Knutsen, T., Dalen, J., Skaar, K., Lokkeborg, S., Misund, O., Ostensen, O., Fonn, M., & Haugland, E. (2004). Influence of seismic shooting on the lesser sandeel (Ammodytes marinus). *ICES Journal of Marine Science: Journal du Conseil, 61(7),* 1165-1173.
[17] Løkkeborg, S. (1991). *Effects of a geophysical survey on catching success in longline fishing.*
[18] Skalski, J., Pearson, W., & Malme, C. (1992). Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (Sebastes spp.). *Canadian Journal of Fisheries and Aquatic Sciences, 49(7),* 1357-1365.
[19] Slotte, A., Hansen, K., Dalen, J., & Ona, E. (2004). Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. *Fisheries Research, 67*(2), 143-150. doi: 10.1016/j.fishres.2003.09.046
[20] McCauley, R., Fewtrell, J., Duncan, A., Jenner, C., Jenner, M., Penrose, J., Prince, R., Adhitya, A., Murdoch, J., & McCabe, K. (2000). Marine seismic surveys: Analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. *Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, WA, for Austral. Petrol. Prod. Assoc., Sydney, NSW,* 8-5.
[21] McCauley, R., Fewtrell, J. & Popper, A. (2003). High intensity anthropogenic sound damages fish ears. *The Journal of the Acoustical Society of America, 113*(1), 638-642.
[22] McCauley, Robert D, et al. "High Intensity Anthropogenic Sound Damages Fish Ears." The journal of the acoustical society of America 113, no. 1 (2003): 638-42
[23] McCauley, R. D., et al. (2000)
[24] Moriyasu, M., et al. 2004. Effects of seismic and marine noise on invertebrates: A literature review. Canadian Science Advisory Secretariat. Research document 2004/126.
[25] DFO (Department of Fisheries and Oceans). 2004. Potential impacts of seismic energy on snow crab. DFO Can. Sci. Advis. Sec. Habitat Status report No. 2004/003.
[26] Aguilar de Soto, N., Delorme, N., Atkins, J., Howard, S.,Williams, J. and Johnson, M.2013. Anthropogenic noise causes body malformations and delays development in marine larvae. Scientific Reports 3: 283 DOI:10.1038/srep02831.

behavioral changes.[27] These include chronic stress, avoidance, displacement, communication masking, and vocalization changes.[28] Research studies demonstrate that seismic airgun noise can disrupt whale behavior.

Examples include:

- Bowhead Whale: change in surface respiration, avoidance, and call cessation.[29,30,31]
- North Atlantic Right Whale: Exposure to low-frequency ship noise may be associated with chronic stress in baleen whales.[32]
- Sperm Whale: Feeding rate decline.[33]
- Fin Whale: Altered singing and abandonment of habitat.[34]

Sea Turtles



Sea turtle hearing range overlaps with the higher frequency noises from seismic airguns. Studies show that seismic airgun noise can negatively impact sea turtles.

Examples include:

- Sea turtles show an alarm response to seismic noise.[35]
- Sea turtles show avoidance responses to seismic noise.[36]
- Turtles are at risk of becoming entangled in survey equipment.[37]

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[28] *Id.*

[29] Richardson, W., Miller, G., & Greene Jr, C. (1999). Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. *The Journal of the Acoustical Society of America, 106*(4), 2281-2281.

[30] Robertson, F, Koski, W., Thomas, T. Richardson, W., Würsig, B., & Trites, A. (2013). Seismic operations have variable effects on dive-cycle behavior of bowhead whales in the Beaufort Sea.

[31] Blackwell, S. Nations, C., McDonald, T., Greene, Jr, C., Thode, A., Guerra, M. & Macrander, A. (2013). Effects of airgun sounds on bowhead whale calling rates in the Alaskan Beaufort Sea. *Marine Mammal Science, 29*(4).

[32] Rolland, R. M., et al. "Evidence That Ship Noise Increases Stress in Right Whales." Proceedings of the Royal Society B-Biological Sciences 279, no. 1737 (Jun 22 2012): 2363-68.

[33] Miller, P., et al. "Using at-Sea Experiments to Study the Effects of Airguns on the Foraging Behavior of Sperm Whales in the Gulf of Mexico." Deep-Sea Research Part I-Oceanographic Research Papers 56, no. 7 (Jul 2009): 1168-81.

[34] Castellote, M., et al. "Acoustic and Behavioural Changes by Fin Whales (Balaenoptera Physalus) in Response to Shipping and Airgun Noise." Biological Conservation 147, no. 1 (3// 2012): 115-22.

[35] McCauley, R., Fewtrell, J., Duncan, A., Jenner, C., Jenner, M., Penrose, J., Prince, R., Adhitya, A., Murdoch, J., & McCabe, K. (2000). Marine seismic surveys: Analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. *Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, WA, for Austral., Petrol. Prod. Assoc., Sydney, NSW,* 8-5.

[36] *Id.*

[37] Weir, C. (2007). Observations of marine turtles in relation to seismic airgun sound off Angola. *Marine Turtle Newsletter, 116,* 17-20.