SAVING THE

North Atlantic Right Whale

Produced in collaboration with researchers Michael Moore, Mark Baumgartner, and Dan Zitterbart, Woods Hole Oceanographic Institution

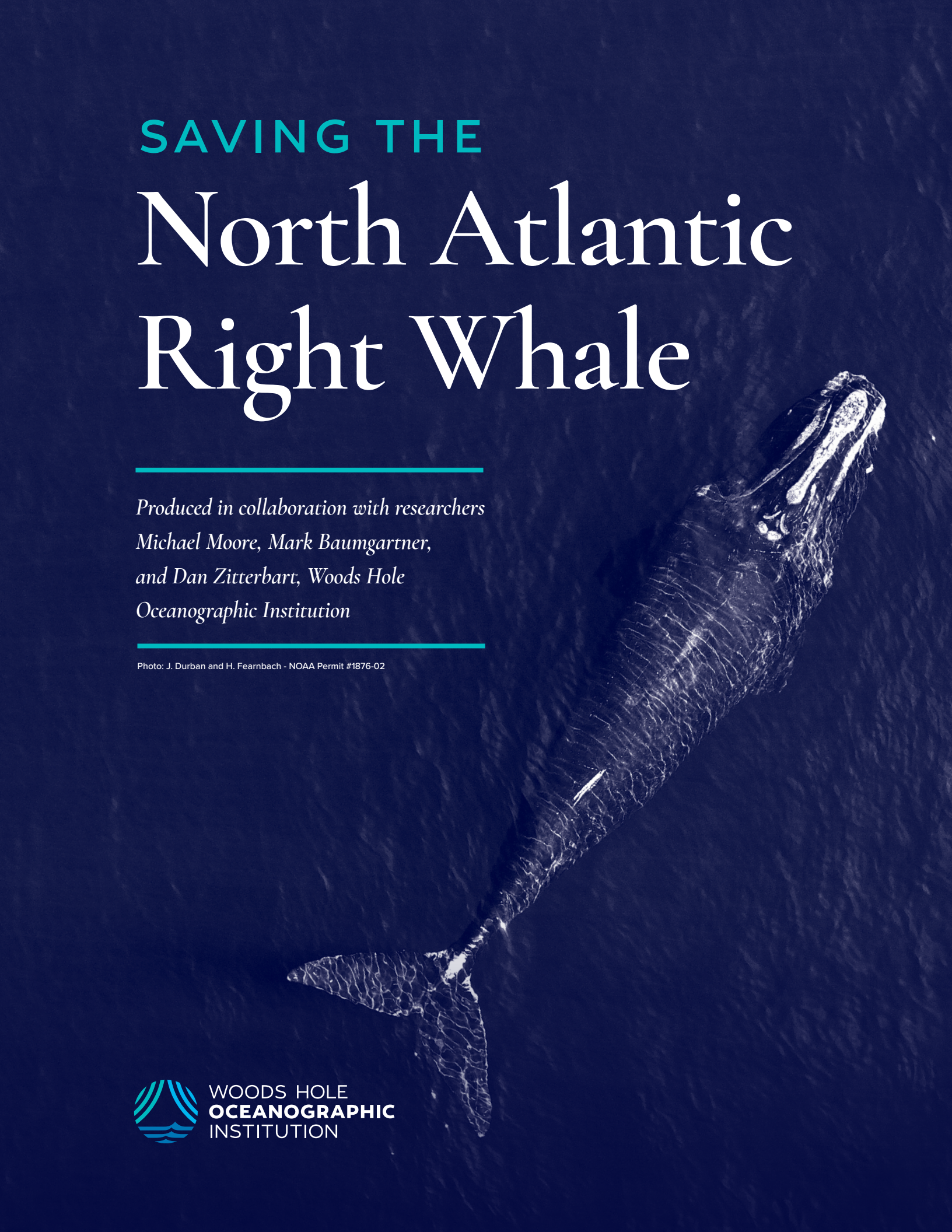


Photo: J. Durban and H. Fearnbach - NOAA Permit #1876-02

WOODS HOLE
OCEANOGRAPHIC
INSTITUTION

The North Atlantic right whale is one of the most endangered whales in the world. There are currently approximately 360 right whales swimming in North Atlantic waters. This report from Woods Hole Oceanographic Institution (WHOI) examines the top three threats facing the North Atlantic right whale and explores actions being taken by the scientific community and concerned organizations to ensure the long-term survival of this critically endangered species.

North Atlantic Right Whales in Crisis

The North Atlantic right whale (*Eubalaena glacialis*) is a critically endangered whale species that is protected under the U.S. Endangered Species Act, the Marine Mammal Protection Act, and Canada's Species at Risk Act. These animals are often found within 50 miles of the East Coast of North America, making them vulnerable to human activities.

By the time whaling was declared illegal in 1935, the North Atlantic right whale was close to extinction. By 1992, an estimated 295 were alive.[1] Their numbers rebounded by 2.8 percent per year between 1990 and 2010,[2] which brought the population up to 481 individuals.[3] But in 2017, National Oceanic and Atmospheric Administration Fisheries declared an Unusual Mortality Event (UME) for North Atlantic right whales, which continued into 2020. Within three years, 42 whales in Canada and the United States had been found dead and eleven were documented with serious injuries.[4] Compounding the problem, the number of calves born to roughly 90 breeding females cannot keep pace with the number of human-caused deaths. With approximately 360 North Atlantic right whales remaining, each casualty represents a significant blow to this critically endangered species.

The purpose of this report is to explore the top three critical threats facing the North Atlantic right whale: fishing gear entanglements, vessel strikes, and noise pollution. Importantly, this report will also focus on the crucial efforts underway to develop the most effective and pragmatic solutions for addressing these risks and supporting the recovery of the North Atlantic right whale population.

Why aren't they flourishing?
An aerial view of an adult North Atlantic Right Whale and calf. Photo: WHOI, NOAA Permit #17355

Whale Entanglements

The Problem

In trap/pot fisheries that target lobster, crab, and fish along the U.S. and Canadian eastern seaboards, fishermen use long vertical ropes or "lines" that connect traps on the ocean bottom to floats on the water surface—a system that allows fishermen to locate their traps and haul them back up. These ropes, which are suspended in the water column, pose a critical danger to North Atlantic right whales as whales are easily entangled in the lines and, at times, cannot escape.

Whales that become entangled can drag the heavy gear around for months, expending more energy and gradually losing weight. The ropes can constrict body parts, impair the ability to feed, and slice into flesh and bone—causing abrasions, infections, and sometimes partial amputations. Whales snarled in gear can have trouble swimming, diving, and breathing, and those that survive may not have the energy reserves needed to reproduce.

Research suggests that fishing gear entanglements are becoming increasingly critical. From 2010 to 2015, 85 percent of diagnosed North Atlantic right whale deaths were due to entanglements.[5,6] And despite efforts to reduce accidental kills of whales in fishing gear, both nonfatal and lethal entanglement rates have increased.[7, 8, 9] A study that examined all available photographs of North Atlantic right whales taken from 1980 to 2009 found that out of 626 individual whales, 83 percent showed scars caused by ropes or nets, and 59 percent had been entangled more than once.[10]

A tangled web
When a whale becomes entangled, fishing gear can cut into its flesh, impede its ability to dive and feed, and create a drag that exhausts its energy supply. Photo: EcoHealth Alliance, NOAA Fisheries Permit #594-1759

Diagnosed North Atlantic right whale deaths

1970–2009 [11]

44% Vessels

35% Entanglements

2010–2015 [12, 13]

15% Vessels

85% Entanglements

Solutions

ROPELESS FISHING GEAR

Ropeless fishing technology presents a possible solution that could be both safe for the North Atlantic right whale and viable for the Atlantic fishing industry. Several prototypes are currently under development and some fishermen are partnering with scientists to test different ropeless fishing traps.

One approach that is currently used commercially in Australia replaces the static line in the water column with a coiled rope and buoy that are inside a weighted bag attached to the trap on the ocean bottom. Fishermen can send an acoustic signal to the trap, which triggers a release, sending the buoy and rope floating to the surface where they are immediately hauled aboard.

Another ropeless technology is based on an inflatable buoy that is attached to the trap. An acoustic trigger inflates the buoy, which rises with the trap to the surface. Although not yet adopted in North America, these two options are being tested in both U.S. and Canadian waters.

Going ropeless

WHOI engineers have developed a ropeless technology that uses an acoustic signal to release a line from a trap.

In collaboration with federal, non-governmental, and fishing industry consultants, WHOI researchers continue to work on improving ropeless gear. With support from the SeaWorld & Busch Gardens Conservation Fund, they are testing offshore ropeless systems from 2020 to 2023.

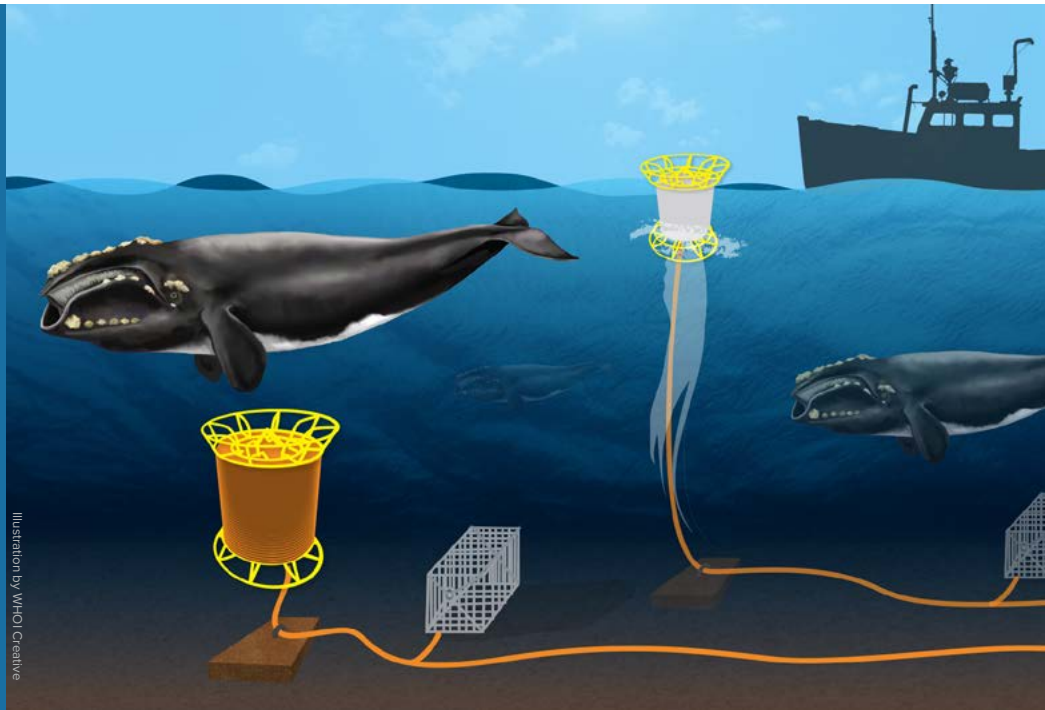


Illustration by WHOI Creative

FISHING LESS, PROTECTING MORE

Though it seems counter-intuitive, WHOI researchers and collaborators found that reduced fishing efforts could result in a more profitable U.S. lobster industry, while vastly reducing the potential for right whale entanglements. [14] The study also found that fishing area closures in Cape Cod Bay led to greater overall catches for Massachusetts lobster fishers. Restrictions on the number of traps and the length of the season for Canadian lobster fishers resulted in the same size landings as their American counterparts, with 7.5 times less effort. By increasing the profitability of the lobster and crab fisheries, researchers hope to reduce the hazards right whales face as they navigate through nearly a million fishing gear end-lines in northeastern U.S. waters.

DISENTANGLEMENT EFFORTS

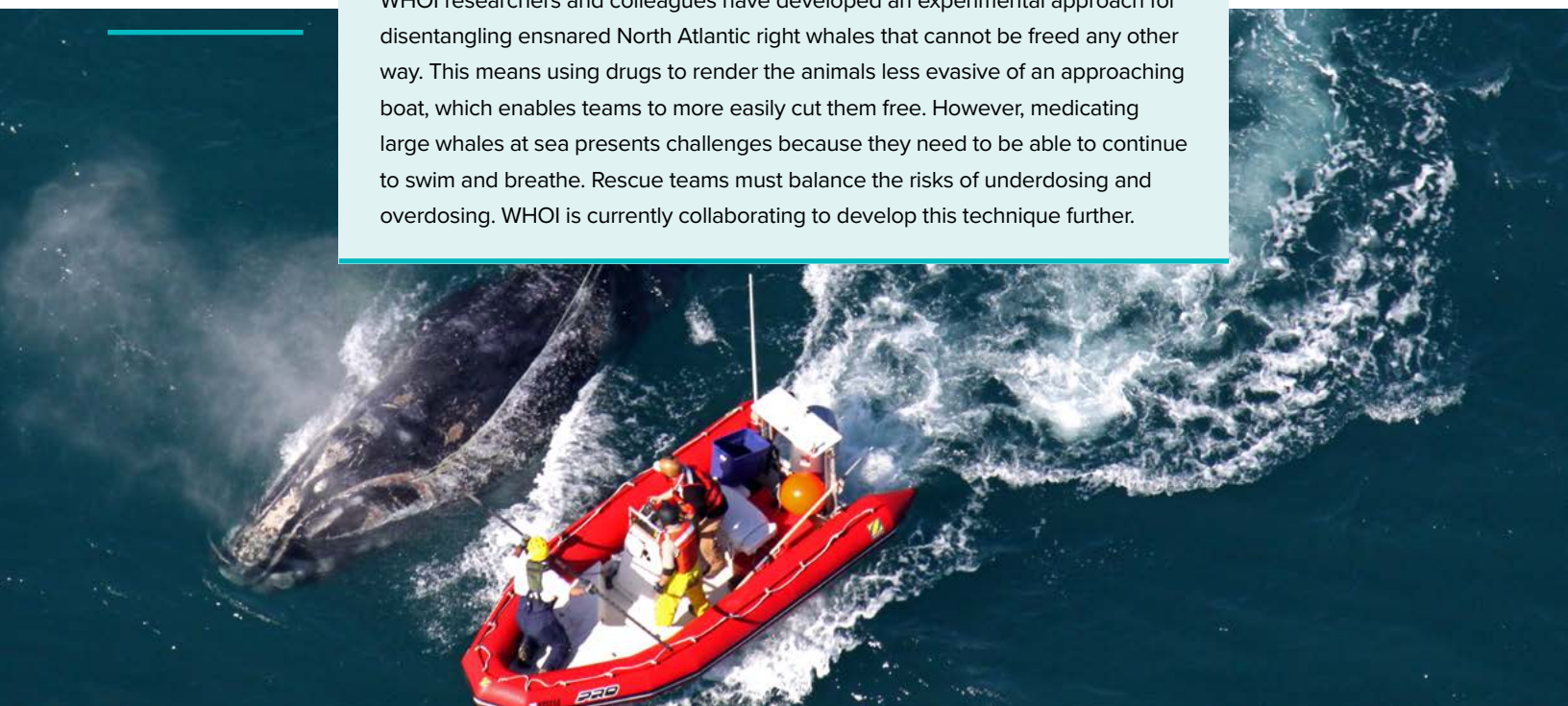
Disentanglement efforts have been successful at freeing hundreds of large whales that have become caught in fishing gear. Disentanglement operations along the East Coast of the U.S. are spearheaded by the Atlantic Large Whale Disentanglement Network, which comprises highly-trained emergency responders from 20 public and private organizations.

Removing fishing lines that are wrapped around the whales is both challenging and dangerous. Teams approach the whales in small inflatable boats and use grappling hooks to grasp the tangled gear. Buoys that can be easily removed are then attached to the fishing lines to slow the whales down, allowing the rescuers to move closer. Once they are within reach, the disentanglement team uses a custom-designed tool attached to a long pole to cut away the fishing gear. After the whale is disentangled, the team again uses the grappling hooks to remove the debris from the water.

North Atlantic right whales, in particular, can be harder to disentangle than other whales due to their strength, endurance, and their need for more personal space, which often makes them more difficult to approach.

Sedation technique for whale disentanglement

WHOI researchers and colleagues have developed an experimental approach for disentangling ensnared North Atlantic right whales that cannot be freed any other way. This means using drugs to render the animals less evasive of an approaching boat, which enables teams to more easily cut them free. However, medicating large whales at sea presents challenges because they need to be able to continue to swim and breathe. Rescue teams must balance the risks of underdosing and overdosing. WHOI is currently collaborating to develop this technique further.



A noose in the deep blue
A disentanglement team attempts to free a right whale from fishing gear. Photo: EcoHealthAlliance, NOAA Permit #932-1905.

COMPUTER MODELING

Evidence suggests that most North Atlantic right whales become entangled in fishing gear at some point in their lives. However, little documentation is available that shows how entanglement happens when the whales encounter fishing gear. To better understand how entanglement occurs, scientists from BelleQuant Engineering, Duke University, and the Anderson Cabot Center for Ocean Life at the New England Aquarium collaborated on the development of a simulator that recreates whale entanglements. Users navigate a virtual whale through a water column containing fishing gear, allowing scientists to study how North Atlantic right whales move and react when encountering different types of fishing gear configurations.[15]

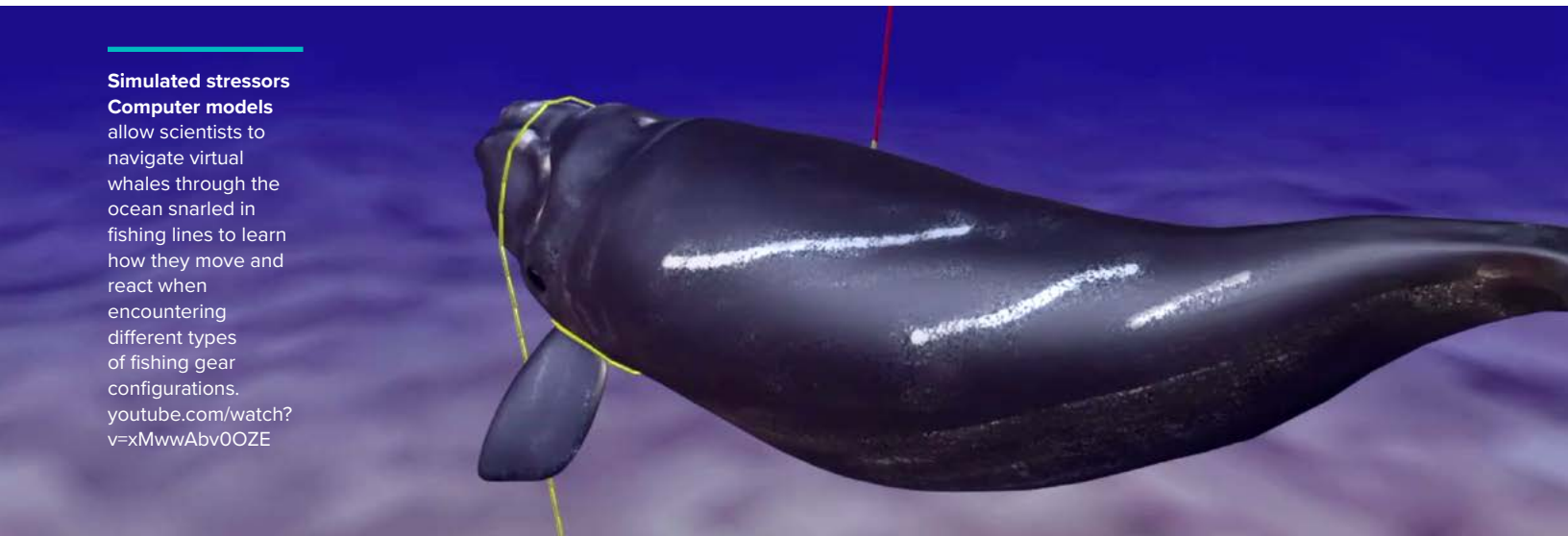
The simulated North Atlantic right whale model was designed based on a morphologically accurate representation with realistic swimming motions. The goal of the simulator is to develop a better understanding of the dynamics of entanglement to help prevent it from happening. By recreating the way ropes wrap around North Atlantic right whales, scientists hope to determine how to change fishing gear to reduce entanglement risks.

REDUCED-BREAKING-STRENGTH ROPE

A possible near-term solution to address fishing gear entanglement is the use of reduced-strength lines that break more easily. Although entanglements may not be prevented, the number of injuries and deaths could be reduced if North Atlantic right whales were better able to break free from entangling ropes.[16] Reduced-strength ropes offer the added advantage of preserving the fishing industry's current fishing methods.

WHALE-SAFE LABELING

As a strategy to help incentivize more widespread adoption of ropeless fishing gear for reducing entanglements, efforts are underway to include ropeless fishing technologies with certification programs and "Whale-Safe" labeling that recognizes sustainable practices within wild-capture fisheries and aquaculture operations. These efforts also extend to nongovernmental organization seafood ratings, which acknowledge whether seafood was caught using fishing practices that cause little harm to habitats or other wildlife.



Simulated stressors Computer models allow scientists to navigate virtual whales through the ocean snarled in fishing lines to learn how they move and react when encountering different types of fishing gear configurations. youtube.com/watch?v=xMwwAbv0OZE

Vessel Strikes

The Problem

Another major threat to the survival of the North Atlantic right whale is injuries resulting from vessel collisions with whales. Because right whales mostly migrate along the coast between Florida and eastern Canada—near major ports and numerous shipping lanes—they're especially susceptible to vessel strikes.

From 1970 to 2009, vessel strikes were the leading cause of diagnosed North Atlantic right whale mortalities.[17] Between 2003 and 2018, the U.S. National Marine Fisheries Service (NMFS) confirmed that 70 North Atlantic right whales were killed by human-caused trauma, at least 16 of which were due to vessel strikes.[18] Many more strikes go undetected.

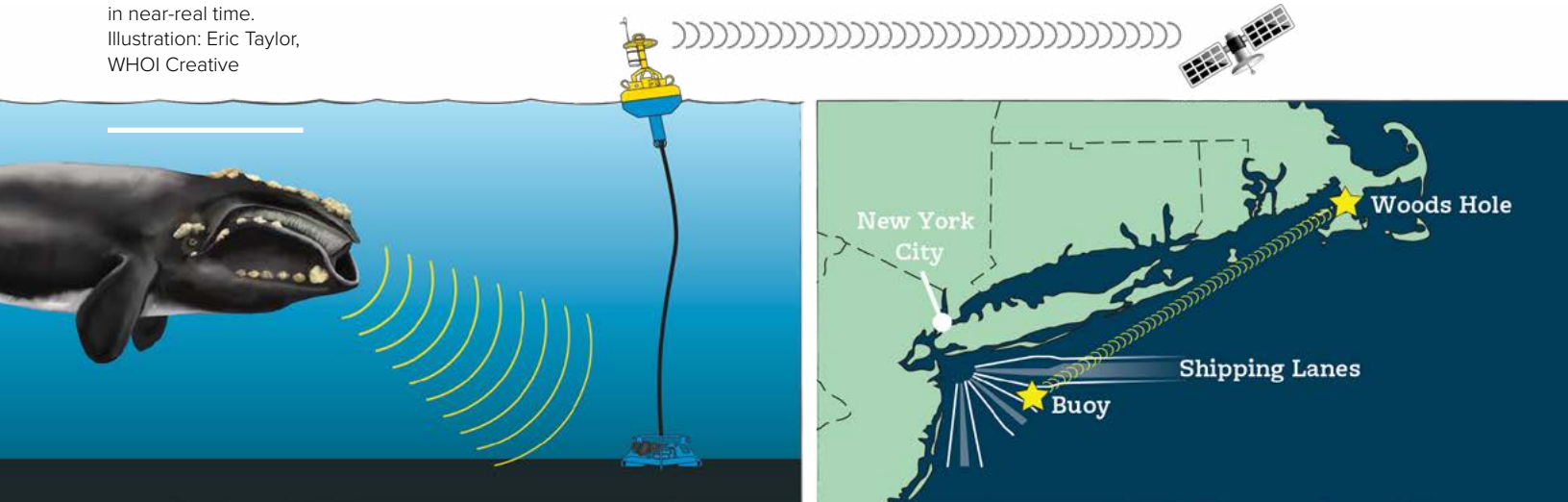
In 1999, coastal managers began to systematically use planes and boats to spot North Atlantic right whales so they could give advisories to vessels. But these methods can't be used at night or in bad weather. Nor can they find whales when they aren't swimming near the surface.

Solutions

WHALE DETECTION BUOYS

To help vessels avoid lethal collisions with endangered North Atlantic right whales, WHOI biologists and engineers have developed a passive acoustic technology to make near real-time detections of whales. Known as the digital acoustic monitoring (DMON) instrument, the device is equipped with underwater microphones called hydrophones that listen for whale sounds. Information collected by the DMON is transmitted every two hours via satellite back to a lab at WHOI. The data is then reviewed by an analyst and posted on the publicly-accessible website *robots4whales.whoi.edu*.

For several years, acoustic buoys have successfully detected whales in near real-time off the east coast of the U.S. and Canada, alerting regulators, scientists, industry, and the public about the presence of whales.[19] More recently, Robots4Whales data from an acoustic buoy has been used by *Whale Safe*, which monitors for ships and a variety of whale species— including the endangered blue whale—in the Santa Barbara Channel off the coast of southern California.



A buoy that listens DMON (Digital acoustic MONitoring) buoys detect whale calls and transmit information about them from the seafloor up the cable to the buoy, which relays the information to a satellite and ultimately to scientists in near-real time. Illustration: Eric Taylor, WHOI Creative

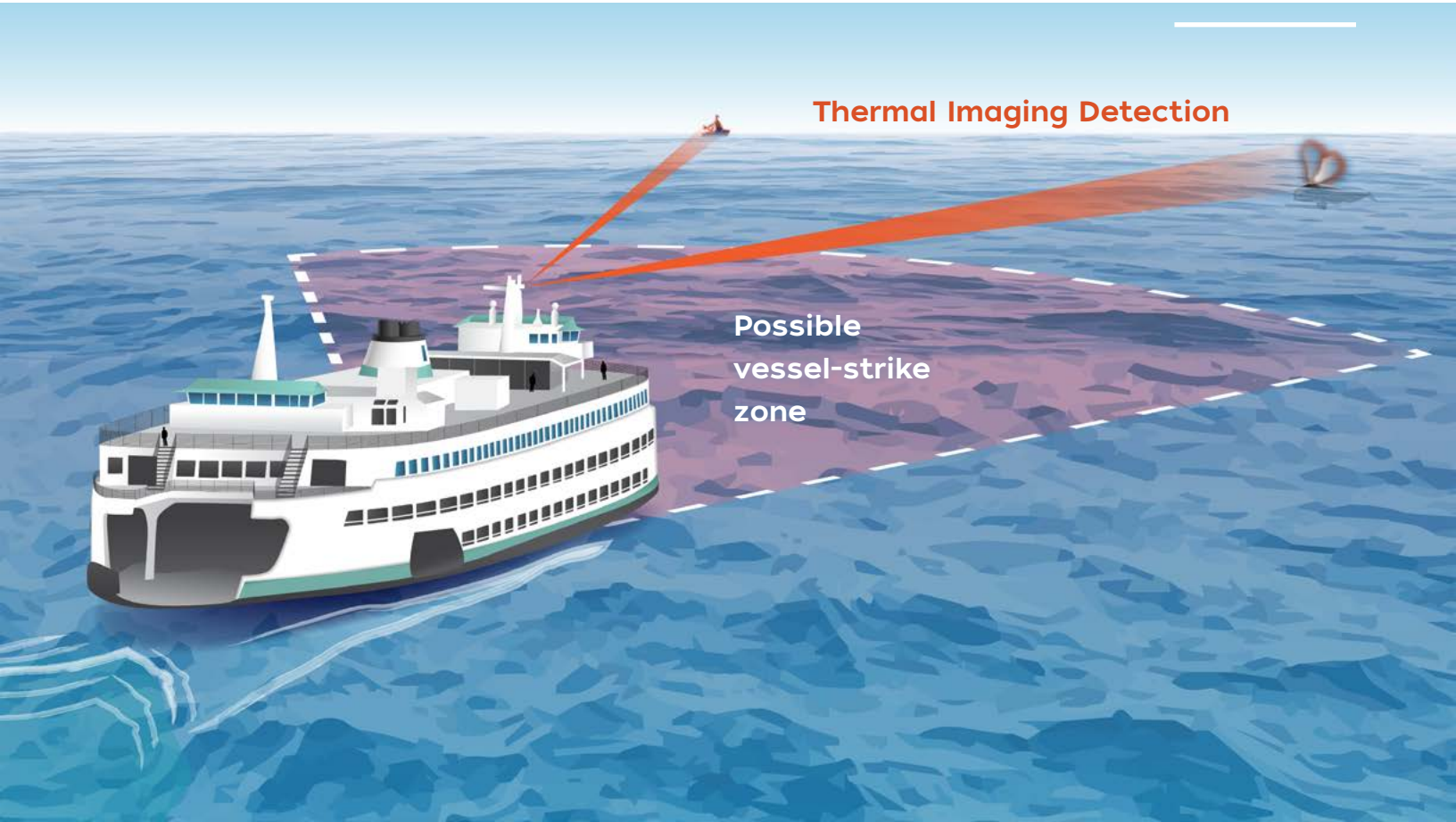
WHALE DETECTION GLIDERS

Fixed-location moorings are useful in shipping lanes near busy ports, but highly migratory species such as right whales require more mobile technologies to enable detection throughout their range. In collaboration with NOAA's Northeast Fisheries Science Center and others, WHOI researchers have also placed DMON technology on gliders, autonomous underwater vehicles that "listen" for whale calls as they seesaw through the ocean for days or weeks at a time.[20, 21] If a glider detects a right whale or other species of interest, it sends an email or text message to scientists and regulators, who may then send out an aerial survey for further verification, issue a warning to ships and fishermen, or even impose fishery closures or mandatory ship speed limits.

The passive acoustic whale detection system developed at WHOI is now part of a comprehensive surveillance and dynamic management effort to protect right whales along the U.S. and Canadian east coasts, as well as blue whales off the coast of California. In the U.S., a new NOAA program called Right Whale Slow Zones asks mariners to voluntarily reduce speed in areas where right whales have been detected. In Canada, acoustic detections trigger mandatory closures of fishing grounds and ship speed limits.

THERMAL IMAGING CAMERAS

To help mitigate the potential for vessel strikes, WHOI researchers are developing next-generation whale detection systems that use thermal infrared (IR) cameras to monitor for the presence of whales in shipping lanes. If they are mounted high enough—such as on wind farm turbines—these systems are able to detect whales up to ten kilometers away. Installed



Eyes on the horizon Thermal imaging camera systems mounted on ferries and ships are able to detect moving objects several miles away. If a whale is identified, the system sends an alert within seconds, giving the captain enough time to slow down or change course. Illustration by Natalie Renier, WHOI Creative

on ships, the systems can automatically alert shipping captains to the presence of whales up to several kilometers away within seconds, enough time for most vessels to slow down or change course.

Thermal imaging cameras detect whales by measuring the apparent temperature difference between the animal and the surrounding water and air when they surface and exhale, or "blow." Unlike human observation from planes and boats, these cameras don't require ambient light, so they can spot whales around the clock. The cameras are linked to Artificial Intelligence software that has been trained on examples of waves, vessels and whales. These detection algorithms filter out images of boats and birds and only alert the ship's crew of probable whale detections.

In the summer of 2020, a lightweight and stabilized version of the camera system was tested on a research vessel in Stellwagen National Marine Sanctuary, off the coast of Massachusetts. In 2021, WHOI researchers and colleagues plan to continue these trials and also install the system on a passenger ferry in the North Atlantic to evaluate unattended performance of those systems. They are working on a second verification step to further reduce false positives.

The thermal imaging system is a powerful new tool in real-time whale detection. Used alone or in conjunction with acoustic monitoring, this technology could significantly reduce the risk of vessel strikes for all whale species.

A huge threat
Right whales are found all along the eastern seaboards of the U.S. and Canada, making them susceptible to vessel strikes. Photo: iStock.

VESSEL SPEED RESTRICTIONS

In 2008, NOAA's National Marine Fisheries Service enacted a series of vessel speed restrictions along the U.S. East Coast. According to the restrictions, all vessels 65 feet (19.8 meters) or longer must travel at 10 knots or less in Seasonal Management Areas along the U.S. Atlantic seaboard at certain times of the year. The 10-knot speed restriction also extends out to 20 nautical miles around major mid-Atlantic ports. Since the regulations were implemented, deaths from vessel strikes have declined.[22, 23] In response to recent vessel strikes in the U.S. and the declining population size of right whales, the extent and duration of these vessel speed limits are currently being assessed for their efficacy, and there is growing interest in expanding them to further reduce vessel strike risk.

VESSEL ROUTING RECOMMENDATIONS

Several regulatory measures have been implemented to route vessels in a manner that reduces the probability of collisions. Beginning in 2001, NMFS, in cooperation with the U.S. Coast Guard, began developing a vessel-strike reduction strategy that was mainly based on routing vessels through areas where North Atlantic right whales were less likely to be. The first measure implemented in the U.S. under the strategy was the designation of new shipping lanes off ports adjacent to the right whale calving grounds in 2006.[24] Other regulations to route vessels for protecting the North Atlantic right whale include:

- In 2003, the International Maritime Organization moved shipping lanes in the Bay of Fundy away from an area with the highest density of North Atlantic right whales to an area of lower density;
- In 2006, NOAA established a set of recommended vessel routes to reduce vessel strikes in four important Eastern U.S. right whale habitats;
- In 2007, and again in 2009, NOAA changed the Traffic Separation Scheme (i.e., shipping lanes) servicing Boston to reduce vessel collisions with right whales and other whale species;
- In 2009, NOAA designated certain waters in the Great South Channel off Cape Cod as an "Area to Be Avoided" by vessels;
- *The Roseway Basin "Area to be Avoided" region* in Canada.

Since vessel speed restrictions were implemented, deaths from vessel strikes have declined.

Noise Pollution

The Problem

Underwater noise pollution is a significant threat to the survival of the North Atlantic right whale. Right whales communicate with one another by making calls, which can cover distances of more than 20 miles. The calls let whales stay in touch, share information about food, help mates find each other, and keep groups together while traveling.[25] However, rising levels of ocean noise, primarily from increasing vessel traffic, are interfering with their ability to communicate. Other forms of human-caused underwater noise pollution that impact the whales' communications include vessel sonar, the use of seismic air guns for offshore drilling exploration, and construction activities associated with offshore wind turbines.

To compensate for the escalating background noise, right whales are increasing the amplitude of their calls in an effort to be heard. In one study,[26] a team of researchers found evidence that exposure to low-frequency vessel noise may be associated with chronic stress in whales, which has implications for the recovery of the endangered North Atlantic right whale population. In addition, the authors found that underwater noise levels would get so high that right whales could not increase their call amplitude enough to compensate.

Solutions

ALTERNATIVES TO SEISMIC AIR GUNS

To explore for deposits under the ocean floor, the oil and gas industry employs seismic air guns that fire loud pulses by releasing air that is under extremely high pressure. The guns are arranged in arrays on vessels and are fired repeatedly into the water every 10– 12 seconds around the clock for months at a time. The noise from seismic surveys can be heard almost continuously in some areas for distances of up to 4,000 kilometers.[27]

An alternative method of seismic surveying to seismic air guns is marine vibroseis, which has been used successfully in land-based seismic exploration for many years.[28] Instead of a sharp- onset, loud, intense "shot," vibroseis uses the same energy but spread over a longer duration, thus eliminating the sharp rise time (sounds quickly increasing in loudness) and high peak pressure (volume or amplitude) of air guns—two characteristics of sound thought to be the most injurious to living tissues.[29]

The acoustic footprint, as measured in terms of both peak pressure and sound exposure level, is substantially smaller for marine vibroseis than that of air guns for the same geophysically useful energy output, providing an environmentally safer alternative to air guns without compromising effectiveness for seismic exploration.[w]

QUIETING VESSEL ENGINES

Vessel-quieting technologies and solutions are available to help reduce the underwater noise continually generated by the propellers, motors, and gears of large commercial vessels. Propellers, which cause cavitation (formation and rapid collapse of bubbles), are the main source of underwater sound generated by vessels, but the shape of a vessel's hull can also influence propeller performance and the resulting noise production. Machinery onboard vessels—such as engines, turbines, and generators as well as where that machinery is located on the vessel—are also factors that affect how sound emits from vessels to the surrounding waters.

Technologies such as low-noise propulsion systems—which use larger and slower-spinning propellers to minimize cavitation—and mounting systems that raise engines off the engine room floor to reduce vibration, have allowed NOAA to reduce the noise levels from some of their vessels. Vessels can also reduce the amount of machinery noise by using equipment with inherently low noise and vibration levels or by installing vibration isolators that use elastic materials within the machinery.

The International Maritime Organization has established guidelines for marine noise, but the guidelines are not mandatory. Turning these guidelines into mandates would represent a significant step forward.

Drowning in sound Exposure to low frequency ship noise may be associated with chronic stress in whales. Photo: Dreamstime

How you can help

NOAA Fisheries lists ways that the public can help save the North Atlantic right whale:

Report a Right Whale Sighting

Please report all right whale sightings from Virginia to Maine to (866) 755-6622, and from Florida to North Carolina to 877-WHALE-HELP (877) 942-5343). Right whale sightings in any location may also be reported by ship radio to the U.S. Coast Guard via channel 16 or through the *Whale Alert* iPhone/iPad app.

Stay 500 Yards Away

To protect right whales, NOAA Fisheries has regulations that prohibit approaching or remaining within 500 yards (1,500 feet) of a right whale—500 yards is the length of five football fields. These regulations apply to vessels and aircraft (including drones), and to people using other watercraft such as surfboards, kayaks, and Jet Skis. Any vessel within 500 yards of a right whale must depart immediately at a safe, slow speed.

Report Marine Life in Distress

Report a sick, injured, entangled, stranded, or dead animal to make sure professional responders and scientists know about it and can take appropriate action. Numerous organizations around the country are trained and ready to respond. These include:

- Northeast Marine Mammal and Sea Turtle Stranding and Entanglement Hotline: (866) 755-6622
- NOAA Fisheries Southeast Marine Mammal Stranding Hotline: (877) 942-5343

Report a Violation

Call the NOAA Fisheries Enforcement Hotline at (800) 853-1964 to report a federal marine resource violation. This hotline is available 24 hours a day, seven days a week for anyone in the United States.

The view from above
Aerial image of the open mouth of a skim feeding right whale. Photo: J. Durban and H. Fearnbach, NOAA Permit #17355

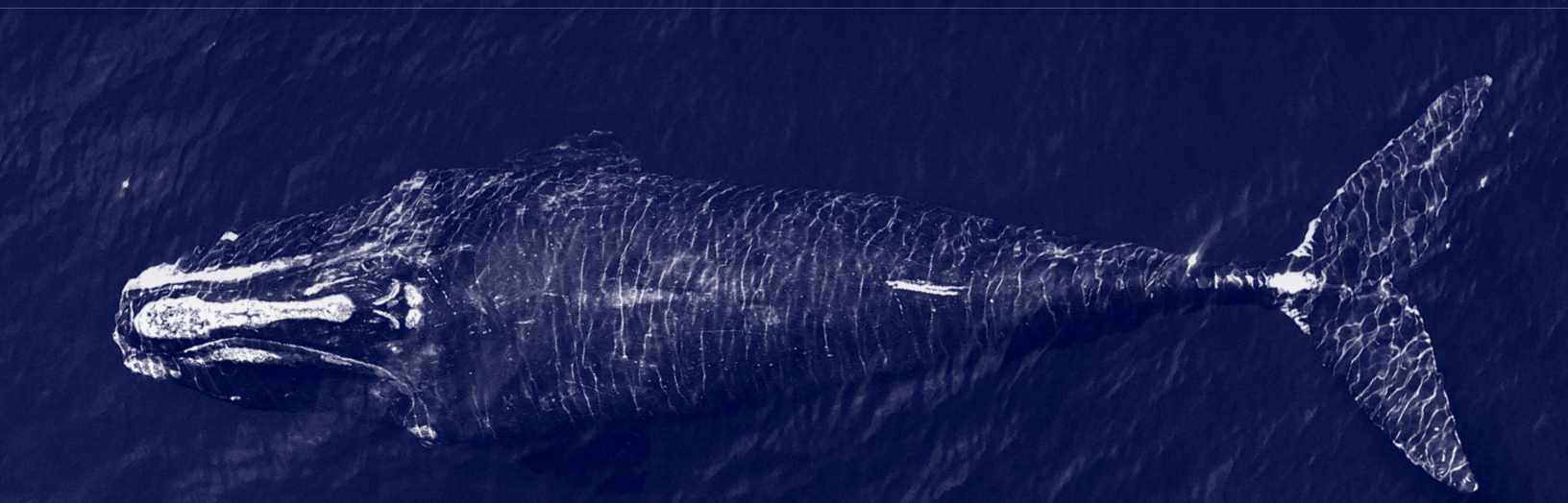
References

1. A. R. Knowlton, S. D. Kraus, and R. D. Kenney, "Reproduction in North Atlantic right whales (Eubalaena glacialis)," Canadian Journal of Zoology 72 (1994): 1297–1305, doi: 10.1139/z94-173.
2. G. T. Waring, E. Josephson, K. Maze-Foley, and P. E. Rosel, eds., US Atlantic and Gulf of Mexico. Marine Mammal Stock Assessments – 2015, NOAA Technical Memorandum NMFS-NE-238 (2016).
3. H. M. Pettis and P. K. Hamilton, North Atlantic Right Whale Consortium 2015 Annual Report Card, report to the North Atlantic Right Whale Consortium (November 2015). Retrieved from https:// www.narwc.org/uploads/1/1/6/6/116623219/pettis.pdf
4. NOAA Fisheries. (2020, October 23.) 2017-2020 North Atlantic Right Whale Unusual Mortality Event. Retrieved from https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2020-north-atlantic-right-whale-unusual-mortality-event.
5. Pettis and Hamilton, North Atlantic Right Whale Consortium 2015 Annual Report Card.
6. Waring et al., US Atlantic and Gulf of Mexico. Marine Mammal Stock Assessments – 2015.
7. L. A. Arthur, W. A. McLellan, M. A. Piscitelli, S. A. Rommel, B. L. Woodward, J. P. Winn, et al., "Estimating maximal force output of cetaceans using axial locomotor muscle morphology," Marine Mammal Science 31 (2015): 1401–1426, doi: 10.1111/ mms.12230.
8. A. R. Knowlton, J. Robbins, S. Landry, H. A. McKenna, S. D. Kraus, and T. Werner, "Implications of fishing rope strength on the severity of large whale entanglements," Conservation Biology 30 (2015): 318–328, doi: 10.1111/cobi.12590.
9. A. R. Knowlton, P. K. Hamilton, M. K. Marx, H. M. Pettis, and S. D. Kraus, "Monitoring North Atlantic right whale Eubalaena glacialis entanglement rates: A 30-year retrospective," Marine Ecology Progress Series 466 (2012): 293–302, doi: 10.3354/ meps09923.
10. J. M. van der Hoop, M. J. Moore, S. G. Barco, T.V.N. Cole, P.-Y. Daoust, A. G. Henry, et al., "Assessment of management to mitigate anthropogenic effects on large whales." Conservation Biology 27 (2013): 121–133, doi: 10.1111/j.1523-1739.2012.01934.x.
11. van der Hoop et al., "Assessment of management to mitigate anthropogenic effects on large whales."
12. Pettis and Hamilton, North Atlantic Right Whale Consortium 2015 Annual Report Card.
13. Waring et al., US Atlantic and Gulf of Mexico. Marine Mammal Stock Assessments – 2015.
14. H.J. Myers, M. J. Moore, "Reducing effort in the U.S. American Lobster (Homarus americanus) fishery to prevent North Atlantic right whale (Eubalaena glacialus) entanglements may support higher profits and long-term sustainability,", Marine Policy (2020).
15. Howle, Laurens E. Howle, Laurens E., Scott D. Kraus, Timothy B. Werner, and Douglas P. Nowacek. "Simulation of the entanglement of a North Atlantic right whale (Eubalaena glacialis) with fixed fishing gear." Marine Mammal Science (2018).
16. Knowlton et al., "Implications of fishing rope strength on severity of large whale entanglements."
17. van der Hoop et al., "Assessment of management to mitigate anthropogenic effects on large whales."
18. Sharp, S.M., et al., Gross and histopathologic diagnoses from North Atlantic right whale Eubalaena glacialis mortalities between 2003 and 2018 https://doi.org/10.3354/dao03376. Diseases of Aquatic Organisms, 2019. 135(1): p. 1-31.
19. Baumgartner. M.F., J. Bonnell, S.M. Van Parijs, P.J. Corkeron, C. Hotchkin, K. Ball, L.-P. Pelletier, J. Partan, D. Peters, J. Kemp, J. Pietro, K. Newhall, A. Stokes, T.V.N. Cole, E. Quintana, and S.D. Kraus. 2019. "Persistent near real-time passive acoustic monitoring for baleen whales from a moored buoy: system description and evaluation." Methods in Ecology and Evolution 10:1476–1489, doi: 10.1111/2041-210X.13244.
20. Baumgartner, M.F., D.M. Fratantoni, T.P. Hurst, M.W. Brown, T.V.N. Cole, S.M. Van Parijs, and M. Johnson. 2013. "Real-time reporting of baleen whale passive acoustic detections from ocean gliders." Journal of the Acoustical Society of America 134:1814-1823.
21. Baumgartner, M.F., J. Bonnell, P.J. Corkeron, S.M. Van Parijs, C. Hotchkin, B.A. Hodges, J. Bort Thornton, B.L. Mensi and S.M. Bruner. 2020. "Slocum gliders provide accurate near real-time estimates of baleen whale presence from human-reviewed passive acoustic detection information." Frontiers in Marine Science 7:100, doi: 10.3389/fmars.2020.00100.
22. D. W. Laist, A. R. Knowlton, and D. Pendleton, "Effectiveness of mandatory vessel speed limits for protecting North Atlantic right whales," Endangered Species Research 23 (2014): 133–147, doi: 10.3354/esr00586.
23. J. M. van der Hoop, A.S.M. Vanderlaan, T.V.N. Cole, A. G. Henry, L. Hall, B. Mase-Guthrie, et al., "Vessel strikes to large whales before and after the 2008 Ship Strike Rule," Conservation Letters 8 (2015): 24–32, doi: 10.1111/conl.12105.
24. Marine Mammal Commission, Ship Strikes and Right Whales, October 2015.
25. Right Whale Listening Network, Bioacoustics Research Program. The Cornell Lab of Ornithology.
26. M. R. Rolland, S. E. Parks, et al., "Evidence that ship noise increases stress in right whales," Proceedings of the Royal Society B. Volume 279, Issue 1737 (2012).
27. S. L. Nieukirk, D. K. Mellinger, S. E. Moore, et al. (2012), "Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean, 1999–2009," Journal of the Acoustical Society of America 131 (2012): 1102–12.
28. L. Weilgart, Alternative Quieting Technology to Seismic Airguns for Oil & Gas Exploration and Geophysical Research, brief for
Global Sustainable Development Report – 2016 Update (2016).
29. B. L. Southall et al., "Marine mammal noise exposure criteria: initial scientific recommendations," Aquatic Mammals 33 (4) (2007): 411–522.
30. Weilgart, Alternative Quieting Technology.

A North Atlantic right whale breaches the surface southeast of Cape Cod in May 2015. Photo courtesy the NOAA Teacher at Sea Program, NOAA Ship GORDON GUNTER; NOAA/NEFSC/KAD

WOODS HOLE
OCEANOGRAPHIC
INSTITUTION

Woods Hole Oceanographic Institution is dedicated to advancing our knowledge of the ocean. For our planet and our future.



Get Involved

SUPPORT OUR RESEARCH
www.whoi.edu/givenow

FOLLOW US ON SOCIAL MEDIA
@WHOI
@WoodsHoleOcean
@Woodshole_ocean

JOIN OUR EMAIL LIST
www.whoi.edu/signup

www.whoi.edu

Woods Hole Oceanographic Institution, 2020. Saving the North Atlantic Right Whale. Produced in collaboration with Michael Moore, Mark Baumgartner, and Dan Zitterbart, Woods Hole Oceanographic Institution.
Woods Hole (MA): WHOI, 15 pp. DOI 10.1575/1912/24708