ICES Journal of Marine Science

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2019), 76(4), 781–786. doi:10.1093/icesjms/fsy194

Food for Thought

How we can all stop killing whales: a proposal to avoid whale entanglement in fishing gear

Michael J. Moore*

Biology Department, Woods Hole Oceanographic Institution, 266 Woods Hole Rd, Woods Hole, MA 02543, USA

**Corresponding author: tel: 508 289 3228; e-mail: mmoore@whoi.edu.*

Moore, M. J. How we can all stop killing whales: a proposal to avoid whale entanglement in fishing gear. – ICES Journal of Marine Science, 76: 781–786.

Received 26 October 2018; revised 21 November 2018; accepted 30 November 2018; advance access publication 10 January 2019.

Whales are federally protected by the Marine Mammal Protection Act; endangered species, such as the North Atlantic right whale, receive additional protection under the Endangered Species Act. However, their regulations have failed to satisfy conservation and animal welfare concerns. From 1990 to 2011 the North Atlantic right whale (*Eubalaena glacialis*, NARW) population grew at a mean of 2.8% annually. However, population trends reversed since 2011; the species is in decline, with only ∼100 reproductively active females remaining. This failure is driven by vessel collisions and increasingly fatal and serious entanglement in fixed fishing gear, whose rope strength has increased substantially. Chronic entanglement, drag, and associated morbidity have been linked to poor fecundity. Genuine solutions involve designating areas to be avoided and speed restrictions for ships and removing fishing trap ropes from the water column. A trap fishing closure for NARW habitat in the Cape Cod Bay (U.S.) area has been in place seasonally since 2015. 2017 mortalities in Eastern Canada elicited substantive management changes whereby the 2018 presence of NARW in active trap fishing areas resulted in an effective closure. To avoid these costly closures, the traditional trap fishery model of rope end lines attached to surface marker buoys has to be modified so that traps are marked virtually, and retrieved with gear that does not remain in the water column except during trap retrieval. Consumer demand for genuinely whale-safe products will augment and encourage the necessary regulatory changes so that trap fisheries conserve target and nontarget species.

Keywords: end line, entanglement, large whale, rope removal, trap.

In a previous "Food for Thought" titled "How we all kill whales" (Moore, 2014), I suggested that: "western countries have, through the development and increase in fishing and shipping in continental shelf waters, essentially resumed whaling as vessel speeds and fishing gear strength have increased in recent decades." Others have reviewed the effectiveness of whale/vessel strike mitigation (Silber *et al.*, 2012). Here, I will consider how we can stop killing whales with our seafood harvesting habits.

Ethical consumers are keen to ask where their seafood came from and how it was caught, hoping that the provider responds that the food source was certified sustainable by an entity such as the Marine Stewardship Council (MSC). At this point, the MSC product stamp is widely available and considered a sustainability standard. There is a general sense that the sustainable seafood movement has made remarkable progress and is now an integral part of running a modern seafood business, ultimately translating into healthier oceans. The business model of sustainable fisheries is expected to be viable and effective (Walton Family Foundation, 2017). However, the sustainable seafood movement has historically failed to consider bycatch when defining certification standards (O'Connell, 2017). This is beginning to be considered and should become a routine assessment.

On the U.S. and Canadian eastern seaboard, the number of mortalities and serious injuries of the North Atlantic right (*Eubalaena glacialis—NARW*) whale routinely exceed the "potential biological removal" (PBR) values set by the U.S.'s National Oceanic and Atmospheric Agency (NOAA) by factors of two to four. PBR, a biological reference point, is defined as the maximum number of animals that can be killed by anthropogenic causes each year whilst allowing that stock to reach or maintain its optimal sustainable population level. It is typically used to assess whether or not measures taken to protect a population are effective. PBR is regularly updated in NOAA Stock Assessment Reports (NOAA, 2018b).

The current status of the NARW population is best illustrated by the reduction in estimated abundance since 2010, with a disproportionate loss of females (Figure 1). This has occurred despite a range of regulatory changes aimed at achieving PBR (Pennisi, 2017). There has been an increasing number of entanglement mortalities since 2010 (Figure 2). Whereas many whale entanglements cannot be traced as to source fishery, given inadequate gear marking, the overwhelming nature of rope in the water column in whale habitat are endlines and floating groundlines from trap fisheries, especially American lobster (Boenish and Chen, 2018; Hayes *et al.*, 2018) and snow crab (Daoust et al., 2017; DFO, 2017). As can be clearly seen, if avoidance of whale morbidity and mortality are included in the definiton of “sustainable,” fisheries that harvest using traps with line in the water column, are far from sustainable.

NARW fecundity has also dropped since 2010 (Figure 3). No new calves were observed in 2018, the first time that no calves have been counted since scientists began monitoring the population more than forty years ago (Kraus *et al.*, 1986).

These and other data were summarized by a recent review (NMFS, 2017): “In many ways, progress towards NARW recovery has regressed.” The population has been declining since 2010 and has exhibited changes in habitat use (Pace *et al.*, 2017). During this period, NARW calving rates have remained below average (Hayes *et al.*, 2017) and body condition of the population has worsened (Rolland *et al.*, 2016). Important questions have developed in the scientific literature on energetic stressors on NARW, both from prey availability (Meyer-Gutbrod *et al.*, 2015) and the energetic costs of chronic, sub lethal entanglement (Knowlton *et al.*, 2012; van der Hoop *et al.*, 2017). In addition, between 7 June 2017 and 15 October 2018, NARW experienced a significant mortality event of ∼3% of the population (20 deaths). The diagnosed causes of death (12 in Canada and 8 in the USA) were entanglement and vessel strike (NOAA, 2018a).

In addition to its critical role in worsening the threat of extinction for the NARW, entanglement also poses a major animal welfare concern (Figure 4). Large whales that become entangled in fishing gear and are unable to break free take an average of six months to die (Moore and van der Hoop, 2012). Entanglement effects include: constriction, partial amputation, presumed chronic and severe pain, impaired feeding, drag and reduced fecundity.

Despite the negative population and calving trends described above, if anthropogenic impacts on NARW mortality and fecundity are successfully mitigated, their potential for recovery is great. The Southern right whale (*Eubalena australis*), a closely related species and pertinent comparison, has recently experienced intrinsic annual growth of 7% (International Whaling Commission, 2013). Thus, despite years of U.S. and Canadian federal management effort to conserve the species, there is every reason to also seek general public engagement in the success or failure of current efforts to prevent extinction of the NARW.

The relationship between large whales feeding on high density zooplankton prey patches and fixed trap fisheries for lobster and crab and other species is not intuitive to most seafood consumers. There seems to be no obvious direct resource competition except for space. As such, whale conservationists are likely the only consumers of lobster and crab who think of entangled whales as they dine. However, where the two resources do overlap (Figure 5), the conflict can be serious; and overlap is not uncommon: 85% of NARW bear scars from being entangled in gear once in their lives, and over half bear scars of being entangled two or more times (Knowlton *et al.*, 2012; Pettis *et al.*, 2017). Sustainable seafood certifiers, like MSC, can use their label to inform consumers of such conflicts, especially when they are not obvious. In March

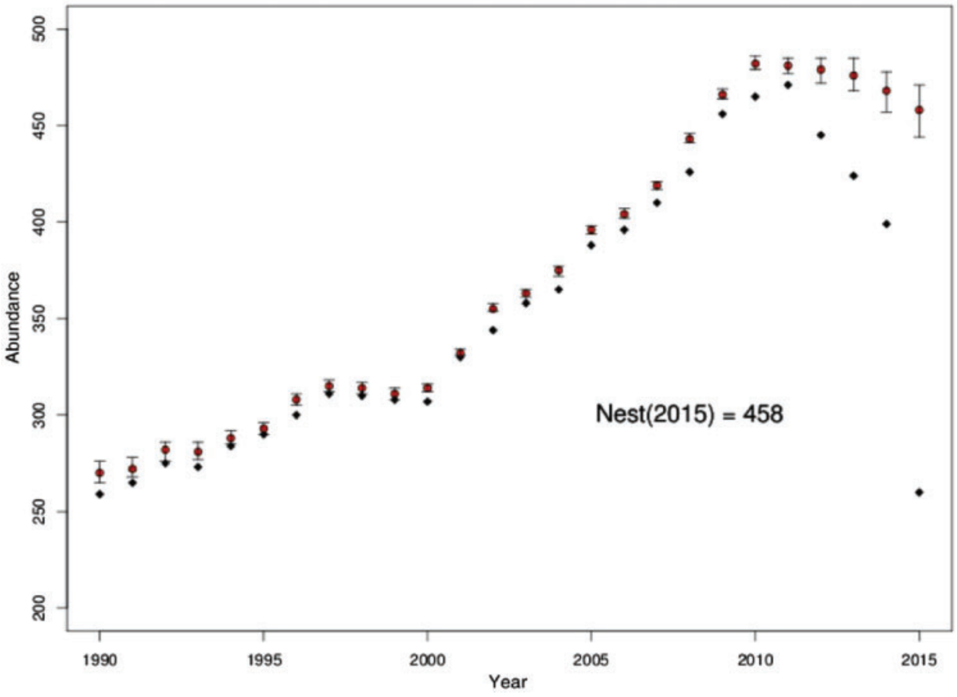

Figure 1. Abundance of North Atlantic right whale with recent disproportionate loss of females, many of which are never reproductively active (Pace *et al.*, 2017).

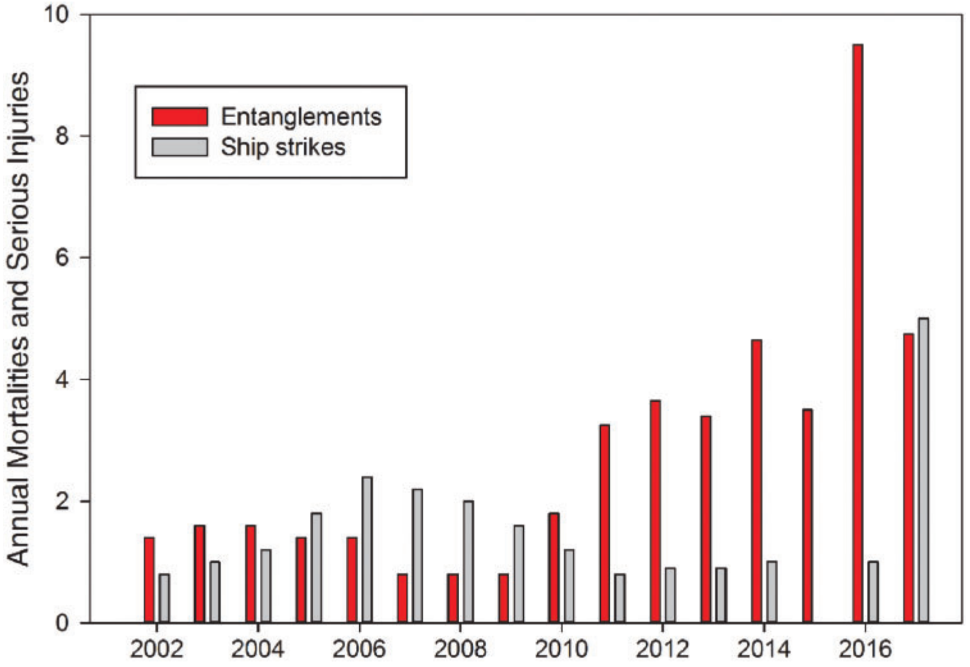

Figure 2. Diagnosed North Atlantic right whale vessel and entanglement mortality and serious injury (2002–2017). NOAA Stock Assessment Reports 2002–2014 (NOAA, 2018b), NOAA Preliminary Data 2015–2017 (Henry, 2017; North Atlantic Right Whale Consortium, 2018).

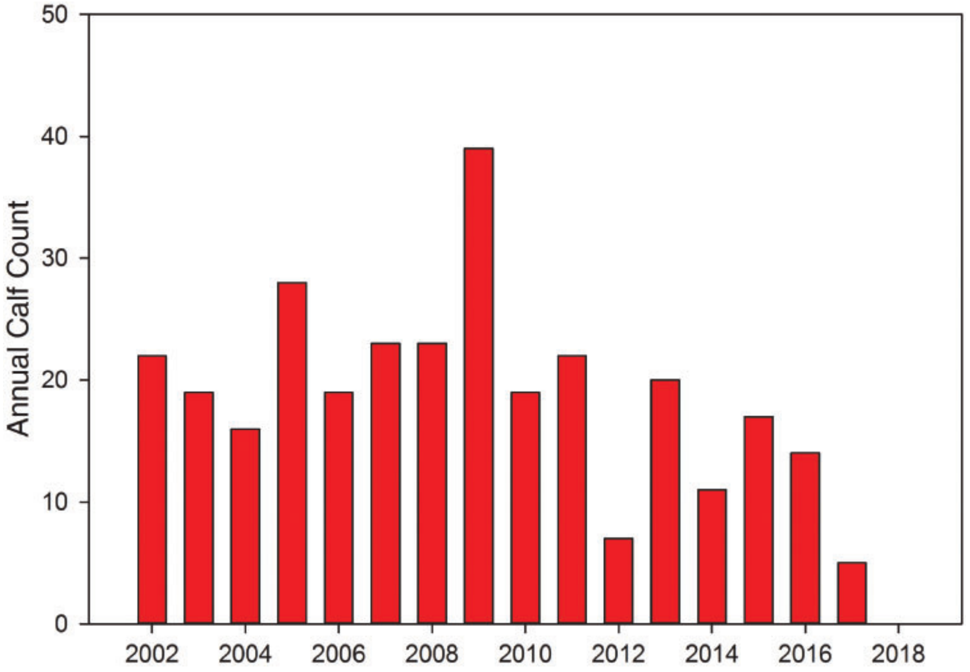

Figure 3. Annual North Atlantic right whale calf count (2002–2018). No calves were recorded in 2018. NOAA Stock Assessment Reports 2002–2014 (North Atlantic Right Whale Consortium, 2018; NOAA, 2018b).

2018, MSC chose to do so. It suspended the Gulf of Saint Lawrence snow crab fishery certificate due to fishery involvement in the NARW mortality event that occurred in the spring and summer of 2017 in the Gulf of Saint Lawrence.

Following the 2017 mortality event, the Canadian government also closed snow crab and lobster fisheries in the Gulf of Saint Lawrence and Bay of Fundy when NARW were sighted from April to June 2018. In contrast, April 2018 sightings of NARW from the beaches of Gloucester, Massachusetts and York, Maine in the USA, did not result in comparable closures. Thus far, there have been three entanglement-related NARW mortalities in Northeast U.S. waters in 2018.

The Canadian closures and an annual closure of Cape Cod Bay and adjacent waters have elicited substantial concern from the

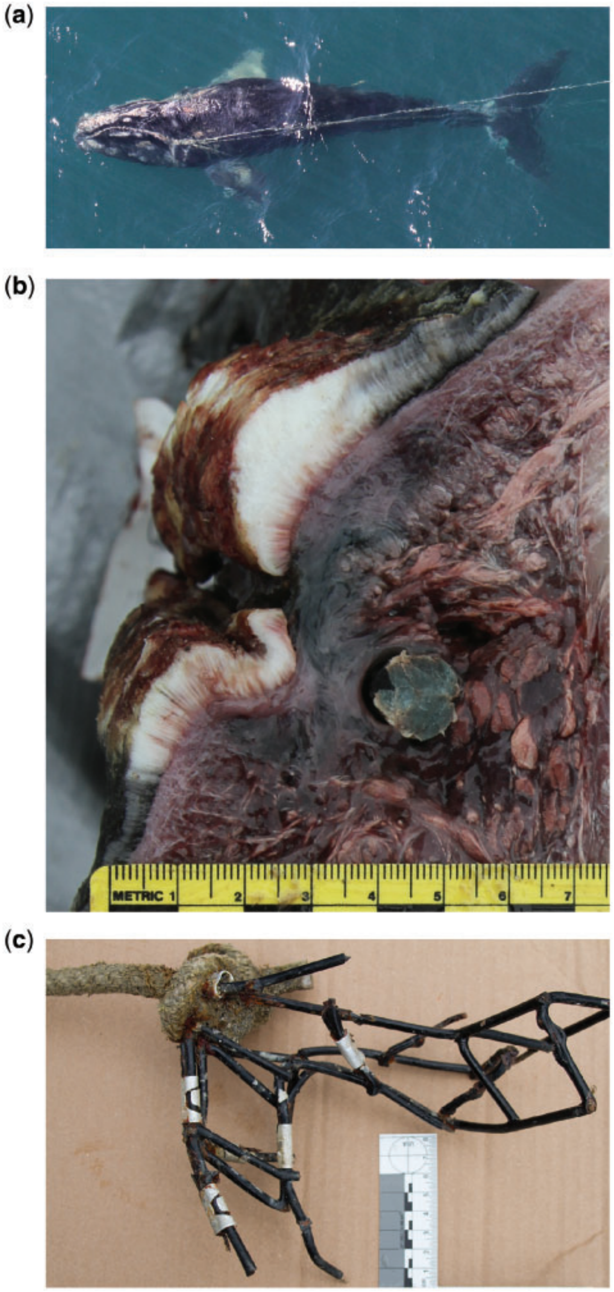

Figure 4. (a) Chronically entangled, emaciated North Atlantic right whale towing rope and a trap fragment (Moore *et al.*, 2013). This whale died two weeks after partial disentanglement. Florida Wildlife Commission, NOAA Permit #594-1759. (b) Section through lip of the same whale at necropsy showing segment of rope (arrow) that lacerated lip with resultant scar. The rope segment remained as a foreign body embedded in the lip. (c) Vinyl covered wire mesh trap fragment attached to a trap gangion, removed with 54 m of 11 mm diameter floating rope from animal whilst alive. Georgia DNR. B & C NOAA Permit 932-1905-01/MA-009526.

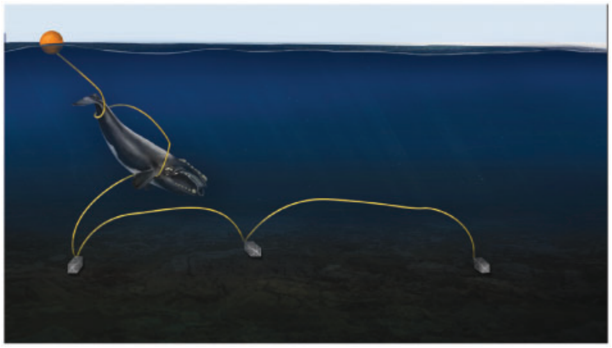

Figure 5. Illustration of a string of bottom traps (known as a trawl), linked by negatively buoyant ground lines, with a line from the end trap to a surface marker buoy. Filter-feeding North Atlantic right whales risk open mouth and appendage entanglements when swimming in fields of these vertical lines and buoys.

affected fishing industry sectors (CBC, 2018; WickedLocal.com, 2018) and spurred some willingness to trial alternative trap marking and retrieval options that are whale-safe (Ropeless Consortium, 2018), if doing so will reopen closed fishing areas. These whale-safe gear options, commonly referred to as "ropeless" or "buoyless" (no rope in water column in whale and turtle habitat, irrespective of source, except during trap retrieval if need be) would remove trap end lines from the water column, lowering the risk of entanglement substantially, leaving only risk from any ground line if traps deployed in a trawl. In this regard, the U.S. is planning an experimental fishery to harvest lobster without the use of end lines (Department of Commerce, 2018).

Previous mitigation measures such as weak links and sinking ground line (van der Hoop *et al.*, 2013), implemented in 2007, have led to no detectable overall decrease in entanglements. On the contrary, entanglement mortality has increased since these regulations have been in place (NMFS, 2017). Rules setting a minimum number of traps per trawl, designed to reduce entanglement risk by lowering the number of vertical trap lines in the water, not only failed to ultimately reduce the number of vertical lines, but may have had the unintended consequence of encouraging fishermen to use stronger lines to haul the longer trawls (Hayes *et al.*, 2018), resulting in an increase in the severity of injuries caused by entanglement (Knowlton *et al.*, 2016). A short term mitigation would involve fishing with reduced strength rope (Knowlton *et al.*, 2016). However, eliminating end lines in the water column by fishing with ropeless gear is the only long term option to end NARW entanglements. Obviously this recommendation could eventually involve a vast amount of lobster and crab habitat, in that passive acoustic surveys of NARW vocalization show their habitat to be very extensive in space and time (Davis *et al.*, 2017). It should start by developing ropeless approaches in currently closed NARW/trap fishing conflict hotspots in time and space, such as a closed lobster fishery in the Cape Cod Bay area in Massachusetts, USA, and the snow crab fishery in the Gulf of St Lawrence, Canada, where the industry will have the greatest incentive to gain access to areas from which they are currently excluded. The resulting product could sell for a significant sustainability premium. From there, as the technology becomes more affordable it should be encouraged to spread to other areas, because as climate change and consequent prey distribution shifts continue to change the nature of optimal whale habitat, the high mobility of both the whales and the relevant fisheries will result in ongoing entanglements unless ropeless technology is adopted over wide areas.

Similarly, disentanglement of large whales by humans has been used to mitigate large whale entanglement since the 1970s. It has

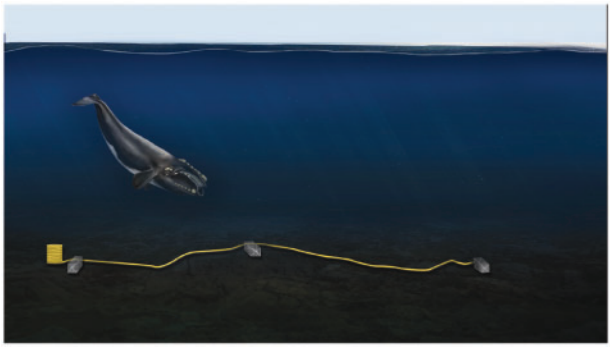

Figure 6. Without an end line and surface marker buoy there would be far less large whale entanglement risk in bottom trap fisheries. End lines would only be deployed for retrieval, either from the trap or the vessel, or not at all if a lift bag were used. The marker buoy role would be replaced by a virtual trap marker, visible on a screen on the vessel.

an obvious value to individual animals, and each individual is critical to the NARW population of <450 animals. However, only a minority of serious chronic entanglement cases are ever encountered (Hayes *et al.*, 2018). Disentanglement can only ever be palliative to the conservation risks faced by large whale species.

Therefore, the idea has grown that traditional fixed shellfish and finfish traps that have end lines and surface marker floats should be re-engineered to enable trap retrieval without line in the water column, except if needed during trap retrieval (Figure 6; Ropeless Consortium, 2018). An example of such a system would be to have bottom-stowed, acoustically released buoyant retrieval rope (Partan and Ball, 2016); or an acoustically triggered lift bag (https://www.smelts.org/line-less-technology; which avoids rope altogether); or to use a traditional grapple.

Whichever retrieval method is used, there also needs to be an alternative system to fulfil the surface buoy's role of enabling the trap owner and other vessels to know where traps are located on the bottom. Without this virtual marker, layovers of different strings of traps will be inevitable—and potentially dangerous in deeper waters. This requires development of a robust, affordable trap marker that acquires a GPS position before deployment, and then ideally updates its position by ranging from passing vessels equipped to communicate with the virtually marked traps. Where traps are attached to each other in a string or trawl, traps at each end of the trawl would be marked. An acoustic trap marker would also enable recovery of displaced traps, reducing ghost gear. There are a range of such transponders available for scientific and defence applications. The concept would need to be engineered specifically for trap marking, it would have to be affordable and durable, identifiable as to permit holder only by its owner and law enforcement and interfaced with vessel and cloud display systems.

The challenges to adopt these changes are substantial. Safety issues include avoiding layovers by different strings of traps. Layovers can be common where traps are fished in close proximity. Thus, an affordable, robust, virtual trap marker will be essential. Other vessels such as fish and scallop bottom trawlers will need to receive and display the virtual trap marks on their wheelhouse plotters as well. As this technology gains acceptance, economy of scale should increase affordability. In undeveloped countries this will be especially challenging, but there are relatively affordable ropeless options. Where bottom access is zoned, traps could be deployed without an acoustic marker, and strings of traps recovered by grappling, or using galvanic timed releases (Gagnon and Boudreau, 1991).

Where fisheries are not currently closed to mitigate whale entanglement, the motivation to adopt these more complex technological solutions will be weak, especially given that capital outlays and maintenance costs will exceed traditional approaches. Regulatory systems will also have to be updated to manage ropeless fishing. However, if regulations are introduced preventing trap fisheries from using end lines, then the fisheries will adapt and develop functional solutions.

There will be additional costs, but if ethical consumers demand genuinely sustainable, whale-safe lobster and crab products, this can all happen (Moore, 2018). There needs to be a solid, enforced regulatory framework, but a "nudge" to consumers (Mackay *et al.*, 2018) could make this happen. The time has come to seriously manage bycatch extinction risk and animal welfare concerns of whales in how we harvest seafood.

Acknowledgements

I thank Mark Baumgartner, Scott Kraus, Tim Werner, Amy Knowlton, Heather Pettis, Scott Landry, Stormy Mayo, Fred Penney, and Beth Casoni for discussions on this topic and Natalie Renier for drawing Figures 5 and 6. Funding was provided by the Woods Hole Oceanographic Institution Independent Research and Development Program.

References

Boenish, R., and Chen, Y. 2018. Spatiotemporal dynamics of effective fishing effort in the American lobster (*Homarus americanus*) fishery along the coast of Maine, USA. Fisheries Research, 199: 231–241.

CBC. 2018. 'Everybody's losing': crab fishermen prepare for more closures this week. https://www.cbc.ca/news/canada/new-brunswick/crab-fishermen-right-whales-1.4682433.

Daoust, P-Y., Couture, E. L., Wimmer, T., and Bourque, L. 2017. Incident Report: North Atlantic Right Whale Mortality Event in the Gulf of St. Lawrence, 2017. Collaborative Report Produced by: Canadian Wildlife Health Cooperative, Marine Animal Response Society, and Fisheries and Oceans Canada. http://publications.gc.ca/collections/collection_2018/mpo-dfo/Fs149-10-2017-1-eng.pdf. 1–256.

Davis, G. E., Baumgartner, M. F., Bonnell, J. M., Bell, J., Berchok, C., Thornton, J. B., and Brault, S. 2017. Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014. Scientific Reports, 7: 13460.

Department of Commerce. 2018. Proposed rulemaking. on modifying the. Massachusetts Trap/Pot Restricted Area and the Great South Channel Trap/Pot Restricted Area to allow trap/pot fishing that does not use vertical buoy lines. https://federalregister.gov/d/2018-21115.

DFO. 2017. Assessment of snow crab (*Chionoecetes opilio*) in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F) to 2016 and advice for the 2017 fishery. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/004. http://waves-vagues.dfo-mpo.gc.ca/Library/40597805.pdf.

Gagnon, M., and Boudreau, M. 1991. Sea trials of a galvanic corrosion delayed release mechanism for snow crab traps Canadian Technical Report of Fisheries and Aquatic Sciences No 1803. http://publications.gc.ca/collections/collection_2014/mpo-dfo/Fs97-6-1803-eng.pdf.

Hayes, S. A., Gardiner, S., Garrison, L. P., Henry, A. G., and Leandro, L. 2018. North Atlantic Right Whales – Evaluating Their Recovery Challenges in 2018 NOAA Technical Memorandum NMFS-NE-247 National Oceanic and Atmospheric Administration National Marine Fisheries Service Northeast Fisheries Science Center Woods Hole, Massachusetts. 1 + 24 pp.

Hayes, S. A., Josephson, E., Maze-Foley, K., and Rosel, P. E. (Eds.) 2017. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2016. NOAA Tech Memo NMFS NE 241. 274 p. https://www.nefsc.noaa.gov/publications/tm/tm241/

Henry, A. G. 2017. Entanglement injuries and mortalities. Power Point presentation at the Take Reduction Team Meeting of November 2017. https://www.greateratlantic.fisheries.noaa.gov/protected/whaletrp/trt/meetings/2017%20Nov/henry_2017_summary.pdf.

International Whaling Commission. 2013. Report of the IWC workshop on the assessment of southern right whales. Journal of Cetacean Research and Management, 149(Suppl.): 439–462.

Knowlton, A. R., Hamilton, P. K., Marx, M. K., Pettis, H. M., and Kraus, S. D. 2012. Monitoring North Atlantic right whale *Eubalaena glacialis* entanglement rates: a 30 yr retrospective. Marine Ecology Progress Series, 466: 293–302.

Knowlton, A. R., Robbins, J., Landry, S., McKenna, H. A., Kraus, S. D., and Werner, T. B. 2016. Effects of fishing rope strength on the severity of large whale entanglements. Conservation Biology, 30: 318–328.

Kraus, S. D., Moore, K. E., Crone, M. J., Watkins, W. A., Winn, H. E., and Prescott, J. H. 1986. The use of photographs to identify individual North Atlantic right whales, (*Eubalaena glacialis*). Report of the International Whaling Commission, 10: 145–151.

Mackay, M., Jennings, S., van Putten, E., Sibly, H., and Yamazaki, S. 2018. When push comes to shove in recreational fishing compliance, think 'nudge'. Marine Policy, 95: 256–266.

Meyer-Gutbrod, E. L., Greene, C. H., Sullivan, P. J., and Pershing, A. J. 2015. Climate-associated changes in prey availability drive reproductive dynamics of the North Atlantic right whale population. Marine Ecology Progress Series, 535: 243–258.

Moore, M. 2018. A Fix for the Imperiled North Atlantic Right Whale. TEDx Provincetown June 30 2018. https://www.youtube.com/watch? v=vhkY_Ny-sBA.

Moore, M., Andrews, R., Austin, T., Bailey, J., Costidis, A., George, C., Jackson, K., *et al.* 2013. Rope trauma, sedation, disentanglement, and monitoring-tag associated lesions in a terminally entangled North Atlantic right whale (*Eubalaena glacialis*). Marine Mammal Science, 29: E98–E113.

Moore, M., and van der Hoop, J. 2012. The painful side of trap and fixed net fisheries: chronic entanglement of large whales. Journal of Marine Biology, 2012: 1.

Moore, M. J. 2014. How we all kill whales. ICES Journal of Marine Science: Journal du Conseil, 71: 760–763.

NMFS. 2017. North Atlantic Right Whale (*Eubalaena glacialis*) 5-Year Review: Summary and Evaluation. https://www.greateratlantic.fisheries.noaa.gov/protected/final_narw_5-year_review_2017.pdf.

NOAA. 2018a. 2017-2018 North Atlantic Right Whale Unusual Mortality Event. https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2018-north-atlantic-right-whale-unusual-mortality-event.

NOAA. 2018b. Marine Mammal Stock Assessment Reports by Species/Stock. https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-species-stock.

North Atlantic Right Whale Consortium. 2018. NARWC Annual Report Card. https://www.narwc.org/report-cards.html.

O'Connell, K., *et al.* 2017. https://awionline.org/sites/default/files/uploads/documents/FINAL_letterMSC_19JAN2017.pdf.

Pace, R. M., Corkeron, P. J., and Kraus, S. D. 2017. State-space mark-recapture estimates reveal a recent decline in abundance of North Atlantic right whales. Ecology and Evolution, 7: 2045–7758.

Partan, J., and Ball, J. 2016. Rope-less fishing. Technology Development. http://www.bycatch.org/sites/default/files/Partan%26Ball_2016.pdf. 1–44 pp.

Pennisi, E. 2017. North Atlantic right whale faces extinction. Science. http://science.sciencemag.org/content/358/6364/703.full.

Pettis, H. M., Pace, R., Schick, R., and Hamilton, P. 2017. North Atlantic Right Whale Consortium 2017 Annual Report Card. Report to the North Atlantic Right Whale Consortium, October 2017. https://www.narwc.org/uploads/1/1/6/6/116623219/2017_report_cardfinal.pdf.

Rolland, R. M., Schick, R. S., Pettis, H. M., Knowlton, A. R., Hamilton, P. K., Clark, J. S., and Kraus, S. D. 2016. Health of North Atlantic right whales *Eubalaena glacialis* over three decades: from individual health to demographic and population health trends. Marine Ecology Progress Series, 542: 265–282.

Ropeless Consortium. 2018. https://ropeless.org/november-6th-2018-presentations/.

Silber, G. K., Vanderlaan, A. S. M., Tejedor Arceredillo, A., Johnson, L., Taggart, C. T., Brown, M. W., Bettridge, S., *et al.* 2012. The role of the International Maritime Organization in reducing vessel threat to whales: process, options, action and effectiveness. Marine Policy, 36: 1221–1233.

van der Hoop, J., Corkeron, P., and Moore, M. 2017. Entanglement is a costly life-history stage in large whales. Ecology and Evolution, 7: 92–106.

van der Hoop, J., Moore, M., Barco, S., Cole, T., Daoust, P-Y., Henry, A., McAlpine, D., *et al.* 2013. Assessment of management to mitigate anthropogenic effects on large whales. Conservation Biology, 27: 121–133.

Walton Family Foundation. 2017. Markets Strategy Summary – page 4. https://www.waltonfamilyfoundation.org/our-work/environment/oceans.

WickedLocal.com. 2018. South Shore lobstermen finally put traps in water. http://www.wickedlocal.com/news/20180516/south-shore-lobstermen-finally-put-traps-in-water.

Handling editor: Howard Browman