

Policy enabling North Atlantic right whale reproductive health could save the species

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North Atlantic right whales (*Eubalaena glacialis*) risk extinction unless conservation measures not only reduce mortality but also enhance reproduction. Vessel collisions injure and kill by spinning propeller cuts or being hit with a blunt structure resulting in bone and soft tissue damage. Entanglement trauma includes sublethal injuries that can reduce their ability to reproduce, while lethal events include drowning, deep constricting wounds, and emaciation leading to death over months or years. Current regulations attempt to reduce mortality from vessel strikes and fishing gear entanglement off the eastern shores of the United States and Canada. However, sub-lethal stressors, especially entanglement, have exacerbated impacts from climate-driven food supply changes, resulting in a serious reduction in growth of individuals and calving rates. If consumers demand that their ship-borne goods and bottom-caught seafood be procured without serious welfare and health concerns for the whales, recovery is possible. We need the will to widely employ the tools of vessel speed restrictions and acoustic retrieval of bottom traps and nets without a persistent vertical line in the water column to reduce sub-lethal as well as lethal trauma. Thus, consumers should pressure legislators, endangered species managers, and suppliers for far broader protections than currently exist.

One-sentence summary: With ~340 left, North Atlantic right whales are close to extinction: for every calf born, three animals die. We know how to fix this; we just need to do it.

Keywords: consumer demand, mortality, right whale, sub-lethal trauma.

A previous “Food for Thought” (Moore, 2014) suggested that we have assumed the mantle of unintentional whalers. We indirectly kill whales while enabling the shipping and fishing industries to pursue our wants and needs. This includes ships moving goods, smaller vessels such as ferries, workboats, and recreational craft, and seafood harvested in traps and nets retrieved by lines in the water column. Subsequently, a proposal was made in a second “Food for Thought” (Moore, 2019) for a durable solution for the large whale entanglement problem involving the replacement of bottom trap and net endlines with acoustically triggered devices for “On-Demand” or “Ropeless” bottom gear retrieval. Here, the North Atlantic right whale (NARW, *Eubalaena glacialis*) is once again our focus as an example of the potential effects of anthropogenic trauma on all large whale species’ population growth in the Anthropocene. Efforts focused on reducing mortality are critical, but in addition, greater, enforced regulatory efforts to reduce the effects of sub-lethal trauma are essential for large whale population recovery.

Trauma incidental to consumer demand is maiming and killing North Atlantic right whales (NARW)

Primary stressors on the NARW have been 1000 years of direct whaling with harpoons, and more recent trauma and mortality from vessel strikes and line entanglement. Since the last recorded harpooning of a North Atlantic right whale mother and calf in 1967 off the Portuguese island of Madeira, the consumption of products moved by ships, coastal recreational boating, and the market for seafood caught in fixed gear fisheries using traps and gillnets have been the primary

drivers of lethal and sub-lethal right whale trauma. Whaling has been defined as the action, practice, or business of catching whales. Nothing about intent. Harpoon whalers served a primarily historic consumer demand for their whale products. The wants and needs of today’s consumers indirectly and unintentionally precipitate vessel strikes and entanglement of whales and are the ultimate cause of the death of these animals. Figuratively speaking, in a recent book, “We Are All Whalers” (Moore, 2021), I suggested that no industry thrives in a vacuum.

Between 1990 and 2010, North Atlantic right whales slowly increased their numbers from ~250 to just <500, and subsequently there began a steep species decline with increased mortalities in US and Canadian waters (NOAA, 2022; Pettis *et al.*, 2022). There are now ~340 remaining. Overall, the decline of females is much greater than that of the overall population, with only 72 reproductively active females remaining in 2018 (Reed *et al.*, 2022). Climate change has prompted more whales to migrate further north to the Gulf of St. Lawrence, Canada, areas that represent additional risks of vessel strike and entanglement. Furthermore, the increased strength of lines used in the trap and gillnet industries since the mid-1990s (Knowlton *et al.*, 2015) has increased entanglement severity.

Lethal vessel and rope trauma in right whales

The average time to death for a fin whale killed by an explosive harpoon is four minutes (Lambertsen and Moore, 1983). When a ship or smaller vessel fatally collides with a whale, death usually results within minutes, while fatally entangled right whales take six months to die on average (Moore *et al.*,

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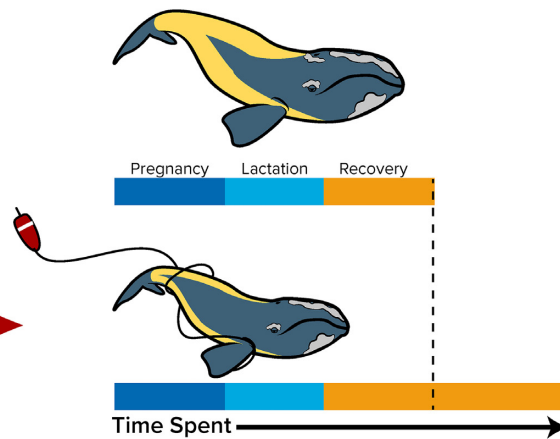
Human Impacts

(ex. Entanglements, Vessel Strikes, Climate Change)

Fewer impacts

More impacts

Body Size & Fat Stores



Calves Over Time

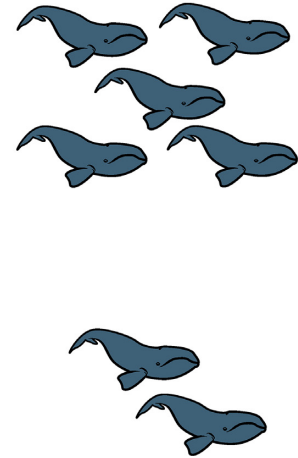


Figure 1. A summary of the impacts of human activities on North Atlantic right whale reproduction timeline, success, and growth (Stewart *et al.*, 2021, 2022) (© WHOI Creative).

2006). Thus, there is horrendous trauma, pain, and stress in all three cases, but of the three, the entanglement scenario is by far the most drawn-out. Were such prolonged trauma to be in plain sight on land, we would not tolerate it. For example, public outcry led to the banning or limiting of the use of leg-hold traps for foxes, coyotes, raccoons, wolves, lynx, and bobcats in some US states. Lethal whale trauma can include exsanguination, pneumothorax, major fractures of bones (such as the jaw, skull, and vertebrae), and starvation and extreme weight loss—the latter being a common and lethal end point for severe, chronic entanglements (Sharp *et al.*, 2019).

Sub-lethal trauma in right whales

Bottom-set traps for crab and lobster and nets for fish, with horizontal lines between traps or along nets, are often legally required to be marked with vertical lines running up to a surface retrieval buoy system. All rope in the water column within whale habitat risks entangling the animals. Repeatedly photographing rope scars on individually identifiable live whales has provided strong evidence for the rates and severity of damage from ropes of various kinds. Of 626 North Atlantic right whales photographed between 1980 and 2009, 83% were entangled at least once, and 59% more than once; 26% acquired new wounds or scars from fishing gear annually. The annual percentage of whales observed with rope on the body increased significantly during the study period (Knowlton *et al.*, 2012). Thus, entanglement in fishing gear is a common event for these animals. One whale had been entangled nine times (Amy Knowlton, pers comm, New England Aquarium, by email, 13 December 2022). Using visual appearance as a qualitative proxy for health, Knowlton *et al.* (2022) showed that severe entanglements decreased health, increased the risk of mortality, reduced birth rates, decreased calf survival, and increased calving intervals. However, unentangled whales also showed a health reduction through time, suggesting that food limitation is also currently significant, with the potential for a negative synergy between food and entanglement stressors (Knowlton *et al.*, 2022).

Whales have evolved a complex, delicate energy budget that balances food income against costs that include metabolism,

growth, migration, thermoregulation, diving, and foraging. In good years, females can also afford to breed, gestate, and suckle. However, the budget has not evolved to allow for unexpected costs, such as long-term or even short-term entanglement with associated tissue damage and rope drag (van der Hoop *et al.*, 2016). Entanglement in fishing gear can last for days to years and can impact blubber stores and require energy investment comparable to the energetic cost of gestating a calf or migration (van der Hoop *et al.*, 2017). Thus, recovery from such physiological stress and disturbance likely compromises an individual's future reproductive success, making entanglement a potentially significant contributor to fluctuations in population growth. In contrast, human-caused trauma is rarely observed in the congeneric southern right whales (*Eubalaena australis*) and, as a result, this species demonstrates much higher abundance and reproductive rates. NARW juveniles, adults, and lactating females were all in poorer body condition than southern right whales (Christiansen *et al.*, 2020), suggesting such poor condition in NARW had negative impacts on growth, survival, age at sexual maturity, and calving rates. A study of NARW growth (Figure 1) showed entanglement is associated with shorter whales, with average body lengths decreasing since 1981 (Stewart *et al.*, 2021). Larger whales had shorter inter-birth intervals and produced more calves per potential reproductive year (Stewart *et al.*, 2022). Between 2014 and 2018, mean annual deaths exceeded births by a factor of 3:1 (27.4/9.4) (NOAA, 2022; Pettis *et al.*, 2022).

The valuation of shipping and fishing industries ignores the costs of such trauma on both the welfare of individual whales and the conservation of species. Health is critical to the recovery of these species. The US and Canadian governments manage NARW by making attempts to mitigate mortality, but until we also promote actions to foster reproductive health, the recovery of this species will elude us.

A case study of North Atlantic right whale Snow Cone (Catalogue #3560)

In the 44 years since Snow Cone's grandmother was first photographed in 1978, a time span about half the life expectancy of a healthy right whale (70+ years), 12 of Snow Cone's 21

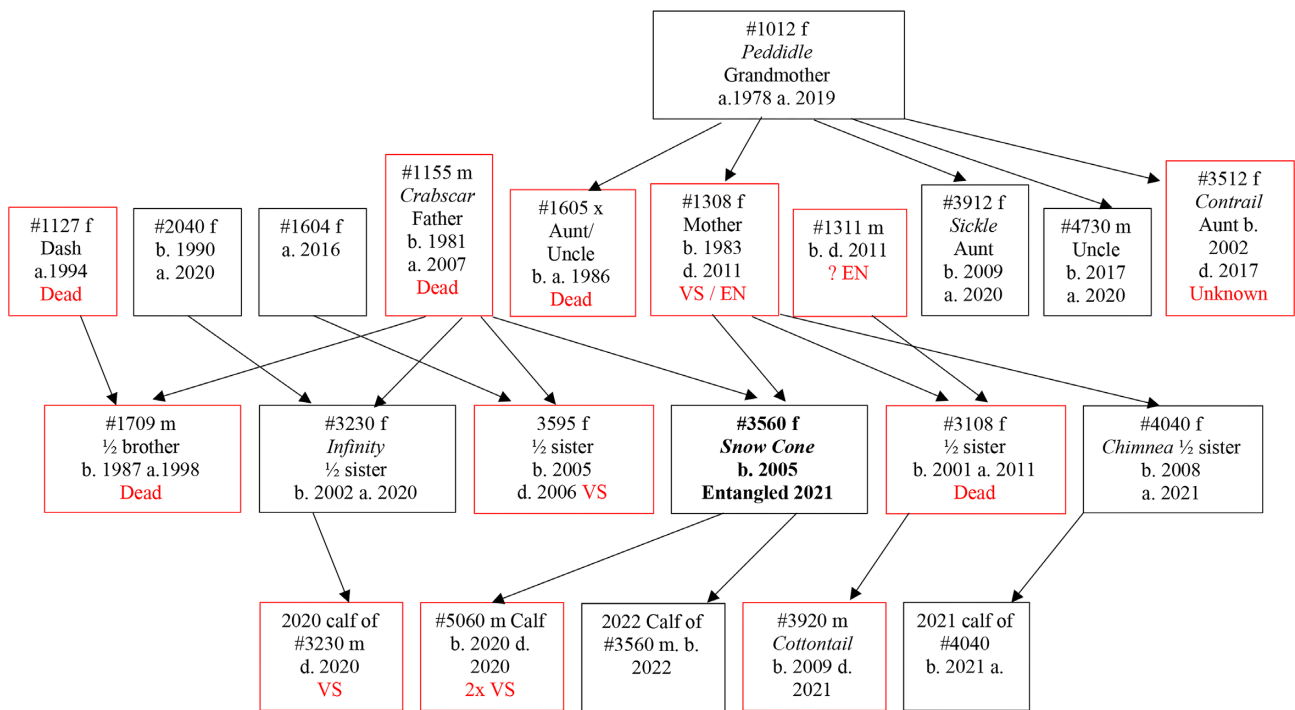


Figure 2. Family tree of the North Atlantic right whale, Snow Cone (Catalogue #3560), as of September 2022 (sighting data are incomplete after 2020). Not all animals are named. All animals receive catalogue numbers once they are individually identifiable. #: catalogue number. b: born; d: died a: alive; m: male; f: female; x: unknown gender; arrows: parent; red: dead (not seen >6 years); VS: Vessel Strike; EN: Entanglement.

first-order relatives (Figure 2) are known or thought to be dead (North Atlantic Right Whale Consortium, 2022). Of those with known causes of death, three had lethal or serious entanglements, and four were struck by vessels. Three of the five most recent calves of Snow Cone and her siblings died from vessel collisions. Snow Cone had her first observed calf in December 2019: it was hit by a vessel's propeller, causing serious wounds; it was then struck by another vessel, bled copiously, and died. Rope entangling Snow Cone was observed in March 2021. Her second calf was then born off Georgia in early December 2021. Snow Cone was sighted in July 2022, in the Gulf of St. Lawrence, but without her calf. She was next sighted on 21 September 2022, off Nantucket Island, MA, USA, substantially entangled in fishing gear, both from 2021 and a recent event, and in very poor health. This story highlights the extreme extent to which trauma can impact right whale lineages. It is also a unique story in terms of an entangled NARW giving birth successfully. As of December 2022, it is unclear if the calf survived beyond separation from its mother.

Solutions

Currently, US and Canadian management agencies focus on largely reactive solutions to reduce mortality. For vessel strikes, attempted solutions centre on reducing vessel speed and avoiding areas of high collision risk. For entanglement, efforts include decreasing the amount of rope in the water column, with a perceived stop-gap measure of reducing rope strength to minimize mortality from entanglements. However, the species will be lost without management measures that also substantially improve reproduction.

Consequently, we must proactively seek to change the market drivers through the adoption of ethical standards, such as

vessel speed limits and the removal of rope from the water column. Watchdog non-governmental organizations can have significant impacts on industry standards (Seafood Watch, 2022). Such consumer-driven demands can potentially create a balance with the actions of the seafood and maritime transportation lobbies within the realms of both politics and economics. However, public outcry may only come with a massive media campaign to educate the public about the trauma and death the whales face from fishing gear and ship strikes. Also, the whales' names and histories need to be provided. These stories and photographs will speak louder than any written words.

Measures to mitigate vessel strikes in Canada include dynamic slow zones in the shipping lanes, seasonal speed limit areas for ships and smaller vessels, restricted areas, and a voluntary slowdown in the Cabot Strait, the entrance to the Gulf of St. Lawrence in Canada. The US measures include limited seasonal speed limits for vessels >20 m (65') in length and voluntary dynamic areas for speed reduction as well as areas to be avoided. Also, in the US, proposed regulations aimed at implementing further mandatory measures including expanding speed restricted-areas and times, and to include vessels longer than 11 m (35') are under consideration (December 2022). Both countries have major unprotected areas through which whales must routinely travel to get to foraging hotspots. The US needs substantially more mandatory measures, paired with a programme of strong enforcement and significant penalties for violators. Voluntary measures do not work well (Wiley *et al.*, 2008). As was the case with the tuna-dolphin crisis, when pushed hard, fishers can find a way to solve the problem.

For entanglement risk reduction, Canada has 15-d area closures for all snow crab fishing and seasonal closures to vertical lines. The latter provide incentives for fishers to use traps

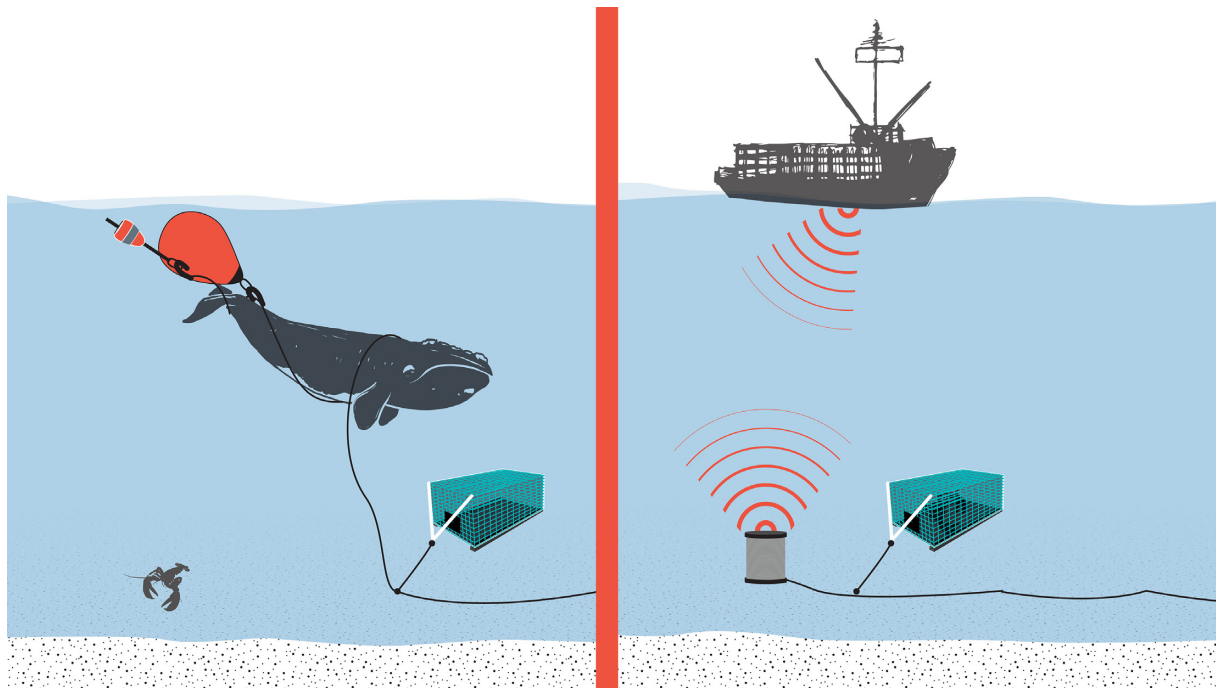


Figure 3. On-Demand fishing: left panel shows entanglement risk in traditional vertical lines; right the use of an acoustic trigger to retrieve traps with a bottom-stowed buoyant device for trap retrieval (© WHOI Creative).

that can be retrieved without vertical lines, such as by using acoustic triggers; this is so-called On-Demand or ropeless fishing (Figure 3). Similar seasonal areas open only to On-Demand fishing are in place in US state and federal waters; however, permits to do this in the US are hard to acquire because of bureaucratic and state/federal political challenges. However, in 2022, both lobster and crab were harvested without vertical lines. Providing support for the feasibility of sustainable fishing and healthy whales enabled by this new technology.

In 2020 and 2021, no mortalities were reported in Canada, while two vessel strike-related mortalities were documented in the US. However, injuries likely to be lethal continue in the waters of both countries, with at least five new right whale entanglements reported (NMFS, 2022). Furthermore, modelling has shown that we only document 1/3 of NARW mortalities (Pace *et al.*, 2021). Cryptic mortalities were more likely to be caused by entanglement than diagnoses from the examination of available carcasses would have predicted. Thus, recent efforts to reduce mortality have perhaps reduced the carnage to some degree; however, given the evidence for the severe effects of sub-lethal trauma on reproduction, until we manage for health as opposed to simply trying to keep them alive, recovery of the species is highly unlikely.

NARW are relatively common in foraging hotspots, such as Cape Cod Bay in the spring, southern New England throughout the year, and the Gulf of St. Lawrence in the summer; however, their movements between these areas are not risk-free. Protected areas need to be focused on avoiding both sub-lethal as well as lethal trauma while enabling industries to prosper. This would include broader, mandatory, and enforced vessel speed restrictions with the exclusion of all

lines from the water column. Canada has been attempting to do this by extensive real-time monitoring, mandatory dynamic closures, and aggressive enforcement. The US must expand mandatory seasonal measures, create mandatory dynamic measures, and include smaller vessels down to 11 m (35') in length in its rule-making. However, a key obstacle to progress is that potential improvements are invariably subject to endless and paralytic stakeholder and legal debate. The US Endangered Species Act was passed into law in 1972 with a provision to quickly protect listed species. Fifty years later, suit and countersuit, stakeholder consultations, and take reduction and implementation teams continue to jostle for priority among conflicting political and economic agendas, as some species continue their decline towards extinction.

Adoption of On-Demand fishing systems is essential in Canadian and US areas where NARW and fishing with static gear overlap in time and space. Major challenges include supply and demand for the gear, exempted fishery permitting delays, gear conflict avoidance, and the unit cost of the gear. In the US, the legal mandates to mark gear with surface buoys and the difficulty of obtaining permits to trial On-Demand gear, together with the understandable desire of many trap fishers to carry on with what works, hinder the advancement of this technological solution, which can enable the co-existence of fishing in whale hotspots. For instance, in 2022, an estimated 500 tonnes of snow crab were commercially harvested in areas closed to vertical buoy lines in the Gulf of St. Lawrence, Canada (Sean Brilliant, Canadian Wildlife Federation—<https://cwf-fcf.org/en/> pers. comm. by email, 5 December 2022). Harvesters seem to be increasingly motivated to gain access to otherwise closed areas.

The sad saga of the North Atlantic right whale has serious implications for other whale species around the world, which also face vessel collision and entanglement risks in addition to other species-specific issues. The NARW is a tragic case study of extremes, but we should learn our lessons and apply them more broadly. We have known the major threats to NARW for decades (Best *et al.*, 2001), but politics, economics, and woefully inadequate enforcement of existing regulations have caused endless delays in mitigation, and now the situation is dire. Ecosystem management to ensure adequate food and minimal trauma and other stressors for this and other whale species is critical to avoid further mortality and poor reproductive health.

The poor recruitment of NARW makes it very clear that management to minimize mortality is utterly inadequate to achieve a population that has good reproductive health, and hence a real chance at a robust recovery. Mitigation to minimize sub-lethal trauma would be largely achieved by more aggressive use of the tools already in place to reduce lethal trauma.

In summary, to enable whales and marine industries to coexist sustainably, consumers must demand that legislators and endangered species managers adopt and enforce regulations that reduce lethal and sub-lethal entanglement and vessel strike risks to endangered whales as they assist industries in operating sustainably. Consumers advocating support for ethical fixed-gear fishing and vessel speed restrictions can be the difference between saving an entire species and driving the North Atlantic right whales to extinction in a few decades. This is one small facet of a global policy realignment we can undertake. We must substantively change human behaviour to mitigate the widespread, growing threats of climate change, the more direct impacts of anthropogenic ecosystem disruption, and the consequent massive loss of biodiversity.

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Conflict of interest statement

No conflict of interest to declare.

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Data availability statement

See cited publications.

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