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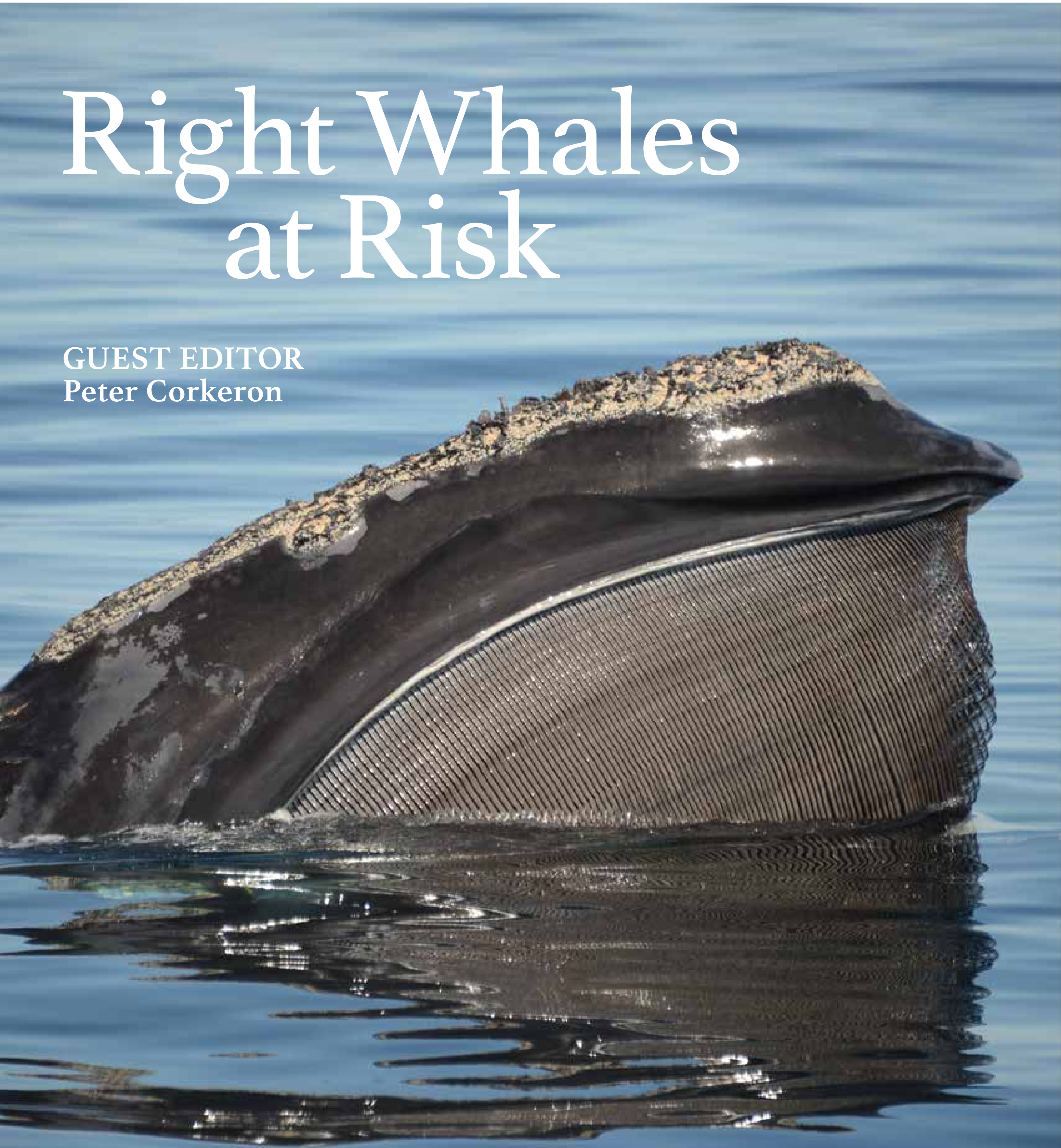
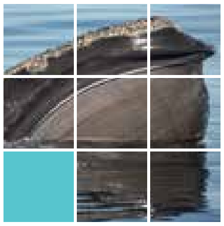


Right Whales at Risk

GUEST EDITOR
Peter Corkeron

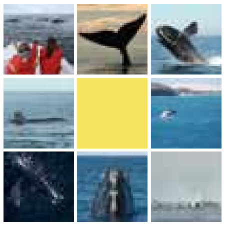
AMERICAN CETACEAN SOCIETY
P.O. Box 51691
Pacific Grove, CA 93950
acsonline.org



FRONT COVER

Fourteen year old male #3125 skim feeding in Cape Cod Bay. Right whales position the widest part of their open mouths where the plankton layer is densest– in this case that is at the surface.
Photo Credit: Anderson Cabot Center/New England Aquarium. Collected under NMFS Permit #14233.

BACK COVER



Top Left: Aquarium researchers Marilyn Marx and Cynthia Browning, aboard the R/V Calisto, work a right whale SAG in the Bay of Fundy.
Top Middle: Whale Porcia (#3293), a nine year old first-time mother lifts her flukes high.
Top Right: One-year-old male (#4143) breaches.
Middle Left: Sebastian (#4650), a male calf, does a head lift in front of his mother Clipper (#3450).
Photo Credits: Anderson Cabot Center/New England Aquarium. Collected under Fisheries and Oceans Canada SARA permit.
Middle Right: Head of the Bight.
Photo provided by Peter Corkeron.
Bottom Left: Twelve year old mother Couplet (#2123) with her first calf (#3323) off Talbot Island, GA.
Photo Credit: Anderson Cabot Center/New England Aquarium. Collected under NMFS Permit #775-1600-2.
Bottom Middle: Whale Sliver (#1227), a 25+ year old male, head lifting as part of an underwater acoustic display called "gunshot".
Bottom Right: The Aquarium's crew aboard the R/V Nereid photograph a large SAG.
Photo Credits: Anderson Cabot Center/New England Aquarium. Collected under Fisheries and Oceans Canada SARA permit.

Mother Harmonia (#3101) with first calf #3901 off Talbot Island, GA.
Photo Credit: Anderson Cabot Center/ New England Aquarium. Collected under NMFS Permit #655-1652-01.

LETTER FROM THE PRESIDENT UKO GORTER

"49. B. glacialis. N. Sild-Qval, Lille-Hval, Nord-Kaper."

This short cryptic sentence by the Danish naturalist Otto Friedrich Müller, penned in his *Zoologiæ Danicæ* in 1776, serves as the original description of the North Atlantic right whale (*Eubalaena glacialis*). It is a rather underwhelming and unceremonious entry into the scientific world for such a large magnificent cetacean, which may well be regarded as THE quintessential whale.

Already known and hunted, first by the Basques from the 11th Century, and later by the British and Dutch in the early 1600s and onward, it was nearly extinct by the mid-nineteenth Century. These days, harpoons have given away to more insidious human-caused threats, like ship-strikes and entanglements in fishing gear.

We currently recognize three distinct right whale species. The North Atlantic right whale (*Eubalaena glacialis*), the North Pacific right whale (*Eubalaena japonica*), and the Southern right whale (*Eubalaena australis*). While the two Northern Hemisphere species are faring the worst, the southern species is generally doing better. Yet, all face many continuing human-caused pressures.

It was high time for us to dedicate a special *Whalewatcher* journal issue to right whales. As a matter of fact, a number of years ago we contemplated and planned a special right whale issue, which unfortunately did not materialize back then. Finally, we are now immensely pleased that this right whale issue of our journal has been published.

We are deeply indebted to Dr. Peter Corkeron, who graciously accepted to serve as our guest editor for this special right whale issue. As the Senior Scientist and Chair of the Kraus Marine Mammal Conservation Program of the Anderson Cabot Center for Ocean Life, we could scarcely find anyone better to help guide this issue.

Peter has brought together 14 expert scientists and biologists to contribute articles for our right whale issue. While the focus is much on the endangered North Atlantic right whale, we have included important articles highlighting the Southern right whale, and the lesser-known and endangered North Pacific right whale.

Our profound gratitude to Dr. Peter Corkeron, and all the authors who have so generously donated their time and effort to this special *Whalewatcher* journal.
Thank you!

Uko Gorter, president

Female Slash (#1303) raises her flipper as she rolls to be belly up in a 59 whale Surface Active Group (SAG) in the Bay of Fundy.
Photo credit: Anderson Cabot Center/New England Aquarium. Collected under Fisheries and Oceans Canada SARA permit.

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Top Left: Nine year old mother #2301 and her newborn calf #3310 off Amelia Island Florida. *Photo by: Lindsay Hall. Photo Credit: Anderson Cabot Center/New England Aquarium. Collected under NMFS Permit #775-1600-2.* Bottom Left: Whale #3812 skim feeding south of Plymouth, MA. At least 11 other right whales can be seen skim feeding in the background. A blow sample was collected from this whale at this sighting to measure his hormone levels. *Photo Credit: Anderson Cabot Center/New England Aquarium. Collected under NMFS Permit #14233.* Right: Whale Trellis (#1331) in the foreground of a large, 59 whale Surface Active Group (SAG) in the Bay of Fundy. This is one of the largest SAGs on record. *Photo Credit: Anderson Cabot Center/New England Aquarium. Collected under Fisheries and Oceans Canada SARA permit.* Page 5: The Aquarium's crew aboard the R/V Nereid photograph 24 year old mother Columbine (#1408). *Photo Credit: Anderson Cabot Center/New England Aquarium. Collected under Fisheries and Oceans Canada SARA permit.*

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EDITOR'S INTRODUCTION

STORIES OF RIGHT WHALES

PETER CORKERON

Top Right: Right whale calf breaching at the Head of the Bight.

Page 6: Researchers photo-identifying a right whale at the Head of the Bight, with the Bunda Cliffs as a backdrop. Only permitted research vessels are allowed on the water in the calving area.
All photos in this article are courtesy of Prof. Rob Harcourt, Macquarie University.

Desert Whales

Flat desert ends at vertical limestone cliffs, dropping to the Southern Ocean. I get out of the four wheel drive, look down on a dozen female right whales, each alongside by her calf, lazing in the water about 100 yards below me. All I can do is jump up and down in excitement. Like a five year old. With Steve Burnell, I'd come to establish a project of behavioral observations on undisturbed right whales– the early days of what has become a 30-year research program.

I was at the Head of the Bight, at the eastern edge of the Bunda Cliffs, miles of vertical limestone forming the southern arch of Australia. It feels a long way from anywhere. Certainly far from the cities and industry that we whitefellas value so highly. For the Yirgala Mirning people, the traditional owners of this land and sea country, it is, of course, home. And for those Mirining people who have whales as their totem, their extended family includes these right whale mothers we see below us– raising their babies, dotted along a few hundred yards of coast, tucked in right by the cliff. They barely move. Back in 1991, the whales were protected by distance from our intrusions. Now there's a marine park adding protection, and the whales of south-western Australia have thrived. Thirty years ago, 18 calves were born at the Head of the Bight. By 2017, there were about one hundred, calves born, so many that now mothers have overflowed this nursery, some calving now at Fowlers Bay, 90 miles or so to the east.

Several of the articles in this issue, and many others like it, start with theses sorts of personal reflection. But we authors are scientists, ostensibly dispassionate. Why the personal reflections? For most of us–certainly the contributors to this issue–we're dedicated to using the scientific method to understand the world, and in doing so, furthering marine wildlife conservation. Most of us could have easier, better paid careers if we'd chosen differently, but we didn't. And so here we tell our tales of right whales from around the globe, doing what we can to change the world, make it safer for whales. Because these days, the data speak to serious problems. We are failing at whale conservation.

We Know What's Happening

North Atlantic right whales are a species in serious trouble. Decades of slow, sporadic increase from a minuscule population of the survivors of centuries of whaling meant that by 2010, we now know that their numbers peaked at a little under 500. They've been in back in decline since then. We're in the process of finishing what the whalers started, wiping out the final remnants of this species. We know why they are declining. Both their relatively slow increase– about 2% per year, when some populations of southern right whales have been increasing at around 6% per year– and their decline are due to deaths and injuries caused by human activities. Whales are killed and injured by entanglements in the ropes attached to fishing gear (pots set for lobsters and crabs), and the fishing gear itself (gillnets); and being hit by vessels. Were it not for the close collaboration between so many researchers, sharing data for the photo-identification Catalog, described by Amy Knowlton and Philip Hamilton in their article, and managed and overseen through the North Atlantic right whale Consortium, as Heather Pettis and Scott Kraus describe, we wouldn't know so much about these whales. Bill McLellan describes the heartbreaking (and backbreaking) necropsy work that he and so many other dedicated professionals have devoted their time to conducting. The decades of dedication by people like Bill, and Michael Moore, and their work ensuring that their results are shared with the wider community are why we know so much about how these whales die.

We also understand the quirks of their biology that makes North Atlantic right whales so prone to these insults. Right whales live in inshore waters and so encounter people's industries more than most other whale species. And the inshore North Atlantic is heavily industrialized, particularly by fishing and shipping. More importantly, right whales are ram feeders, meaning that they graze, swimming slowly with mouths open, filtering their planktonic food out of the water, for miles at a time. Field researchers sometimes refer to them "mowing the lawn", and the description is apt. Although most baleen whales gulp their food in just a few seconds, right whales' foraging behavior is more akin to that of dugongs and manatees, the other marine grazing mammals. So when we place millions of ropes in the water column where right whales feed, we put them at greater risk than other baleen whales that use the same patches of ocean. And when they feed close to the surface, they spend hours at a time at a depth where they're vulnerable to being hit by vessels.

We understand an extraordinary amount about what's happening with North

Top Left: Female right whale at the Head of the Bight.

Page 9: Researchers approaching a right whale at the Head of the Bight.

Peter Corkeron Cont.

Atlantic right whales. We can confidently state that their numbers have declined over the past decade. Even when their numbers peaked they were still very rare at less than 500 individuals. That we can do such a great job describing right whales' plight is a ringing endorsement of the community of scientists who work together, and have worked together for decades, to share data and analyses. As well, we can give context to our understanding of North Atlantic right whales knowing about their close relatives: the North Pacific, and Southern, right whales.

Perspective Matters

There are several populations of Southern rights, scattered through the Southern Ocean. Most of them, although not all, have been recovering their numbers since whaling at rates that initially astonished scientists. Southern rights show a counterfactual– how right whales can thrive in oceans that are less industrialized. And their multiple populations give us the opportunity for something rare in whale research– the capacity to make inference from replicate studies. While the different populations are aren't true replicates, they do help us describe how different populations of right whales are doing, and provide some information on the processes driving those differences. Will Rayment's article tells the story of what is probably the most remote population of southern rights. Julia Dombrovski's gives us a comparative view of North Atlantic and Southern rights, and Fredrik Christiansen's throws mathematics at another comparison. On the other hand, Jess Crance's piece on the eastern population of North Pacific right whales shows that whales living somewhere that seems unimaginably remote is no guarantee of protection.

Having studied Southern rights in Australia, I found that initially, working on North Atlantic rights was astonishing. One project that I was involved in was helping Roz Rolland, Scott Kraus, and their colleagues analyze the hormone levels of right whales from fecal samples. Understanding physiology from hormones gives us an amazing insight into the internal lives of whales, but it helps to understand the life history context of the whale from which the sample is obtained. What's the whale's sex? How old is it? If female, could she be pregnant, or is she nursing? Is she entangled? We had just over 100 samples of different individuals from a species numbering less than 500. For each one of these samples, we knew what area the sample came from, which individual whale it came from, that whale's age and likely reproductive state, and whether it was entangled– at the time that the sample was collected. When I first saw the data available, my initial comment was "this is cheating". To know so much about an entire species of whales, that we could have samples from about a quarter of the individuals and we knew who they were? Magical, only of course, there's nothing magic about it, just decades of constant, focused field and laboratory work.

Another, different example comes from the health assessment work that Amy and Philip mention in their article. I sat with Heather and Scott, and they showed me their photographic health assessments. As we scrolled through the various indicators they have to determine right whales' health, I kept saying "nope, never seen that". After they'd finished, my first remark was, "but where are the healthy ones?". I was still waiting to see what I was used to in the southern Hemisphere, huge, shipping-container, blocky whales with great rolls of fat behind their blowholes, and flat-backed bodies. In my experience, a Southern right whale mother up close has a back like a table. North Atlantic rights are more curved, like other whales. (An aside– the Icelandic name for *Eubalaena glacialis* is Sléttbakur, or flat-backed whale. This suggests that North Atlantic rights can be chubby too.) To me, North Atlantic rights just looked kinda crap compared to the right whales of my experience. Julia's article makes the same point, and also notes how striking it is.

"Kinda crap" isn't very scientific. In recent years, the time between calves has increased for each female North Atlantic right whale, and the age at which females start calving has grown older. The photo-identification health assessment work shows that North Atlantic rights have been losing body condition, both as individuals and overall. The time between calves for most Southern right mothers is usually three years, so how do their northern cousins look in comparison? Several years ago, at a conference of the Society for Marine Mammalogy, the indomitable Peter Best from South Africa posed this question at the population level– the real question isn't that Southern rights can increase at around 6% a year, it's why don't North Atlantic rights do the same?

For me, one of the fun parts of doing science is when I get to sit around with colleagues over coffee or a meal, and throw ideas around. At the Society for Marine Mammalogy's Biennial conference in 2015 in San Francisco, a group of us working on right whales around the world got together to discuss how we could set up a comparative study. The rapid advances in our ability to measure large whales

with accuracy and precision, using cheap, simple drones, opened up an opportunity. Fredrik Christiansen's article in this issue shows where that dinner conversation led.

So we can now put numbers to "kinda crap". Fredrik has been able to quantitatively demonstrate that North Atlantic females that have a calf (who are in better condition than adult females who aren't in good enough condition to even have a calf) are in far worse shape than female Southern rights that calve. More than that, from his work at the Head of the Bight, Fredrik has shown that bigger female Southern rights have bigger calves that grow better than do smaller, (relatively) skinnier females. Other work, led by Josh Stewart in a program run by John Durban, Holly Fearnbach and Michael Moore, has compared photogrammetric data collected on North Atlantic rights decades ago with them now, showing that the right whales here are now smaller than they were. And the one variable that can explain some of that change is whether or not a whale has been entangled, or whether its mother was entangled while pregnant.

For perspective, in 1991 there were 18 calves born at Australia's Head of the Bight, and by 2017 there were about one hundred (not counting the spillover to Fowlers Bay). In 1991, 17 North Atlantic right whale calves were born, in 2017 there were five, and this year there were 18. Here, this is seen as almost a bumper year for calves. Given that none were born in 2018, that could be seen as fair. What the comparative work shows clearly is that if we restrict our perspective to just North Atlantic rights, we fail to see how their world could be, were we not shortening their lives (with vessel strikes and entanglements), and impacting their health and reducing their capacity to calve (entanglements).

Conservation Science

Our societal conversation about North Atlantic right whales is anchored in the findings of scientific research. The expectation that we can and will understand so much about what's happening with right whales is so ingrained that we've lost sight of how extraordinarily complete our knowledge is.

To summarize:

- The number of North Atlantic right whales is in decline. We detected this decline, of a tiny number of whales at sea, within a few years of the decline starting. It's done using sophisticated modern versions of mark-recapture models, working with decades of photo-identification data shared across many research institutions;
- At the scale of the east coast of North America, North Atlantic right whales have changed their distribution post-2010. Susan Parks' article explains how, via a different collaboration, one of many researchers studying the acoustics of right whales;
- Where cause of death has been determined, all the deaths of the dozens of juvenile and adult North Atlantic right whales have been due to human actions;
- Fishing gear entanglements have serious negative impacts even when whales are not killed. The energetic costs of serious entanglements impede females' reproduction, and stunt the growth of both entangled whales, and their calves.
- Entanglements are physiologically stressful for whales, from work done using hormones extracted from fecal samples, and baleen;
- North Atlantic right whales are scrawny compared with some populations of Southern right whales, and visible indicators of their health have deteriorated over the past decades;

Top Left: Right whale pectoral fin, Head of the Bight
Top Right: Right whale calf breaching at the Head of the Bight.

Page 11: Grey morph right whale calf breaching, showing the end of the Bunda Cliffs and sandhills to their east.

- North Atlantic right whales have moved into new areas that lack the protection offered in more "traditional" areas occupied previously;
- Finally, management is not reacting quickly enough to these changes to ensure this species' survival.

It's this last point that shades out all the rest. Yes, we've done a fantastic job of using science to inform the societal conversation about the plight of right whales. But, as is made clear by the articles by Kyla Bennett, and by Sean Brillant and Kim Davies on the US and Canadian management responses (respectively) - it's not enough. In the US, we're still trapped in a management cycle of too little being done much too late. As Sean and Kim demonstrate, the on-water actions taken by the Canadian government have been demonstrably better than the sluggardly pace of the US. Canadian actions really do seem to have helped, after the disasters of 2017 and 2019. Given that those of us producing this science are doing it for the express purpose of whale conservation, what more can we do? Right now, particularly in the USA, we're failing North Atlantic right whales.

Some Numbers

We could resort to arguing the detail of management approaches. To pick one example, the latest rules released for consideration by NOAA suggest they're aiming for a 69% reduction in right whale mortality as a result of the first tranche of their rules. The legal requirement is to get mortality under what's known as the Potential Biological Removal (PBR), a limit reference point stipulated in US legislation (for more, see Kyla's article). But is 69% valid? From NOAA reports, they estimate that 39 right whales were found dead between 2010 and 2017. Over that same period, the rate at which right whale carcasses were recovered is estimated (in a recent scientific paper led by a NOAA scientist) was estimated at 29%. If 39 whales were found, representing 29% of the real number of deaths, then 39/.29 =134, or 16.8 deaths per year for that 8 year period. PBR is currently 0.8 whales per year, ca. 4 whales dead every 5 years, given that it's difficult to kill four-fifths of a whale. A PBR of 0.8 is 5% of 16.8 (per year), so from NOAA's own data, mortality needs to be reduced by 95%, not 69%. It may be argued that PBR as implemented refers only to US fisheries, although in the original scientific papers developing PBR, there is no distinction between the various sources and origins of mortality caused by human activities.

And see what I did there? I presumed a nit-picky rejoinder from someone, parsing out the minutiae of the argument. Why did I do this? Because we've been having exactly those back-and-forth arguments over the detail of data and analyses for years now. It is far more important to examine how we got to the current narrative. I'll give an example.

It's been memory-holed now, but for a few years prior to 2017, a major question being discussed in right whale conservation circles was "where have they gone"? The discovery of the aggregation in the Gulf of St Lawrence (first indicated in 2015, but confirmed in 2017), coincided with the discovery that they were in decline, and so the decline gets the attention. But when right whales seemingly disappeared prior to 2017, there was strong pushback from within NOAA to the idea that the changes were due to a decline, rather than that the whales had simply gone elsewhere. (I ran the large whale research program at NOAA's Northeast Fisheries Science Center (NEFSC) from 2011 to 2019, so am very well aware of what was happening inside NOAA at the time.) The reduced calving, poor condition, and increased proportion of individuals with severe injuries– indicated a decline was likely. But because the whales' distribution had also changed at the same time, fewer observations of whales in traditional habitats were made. Within NOAA, there was a preference for assuming that all was still well, it was just that whales had moved. In 2015, when some of us at the NEFSC raised concerns about the status of right whales, we encountered strong opposition. The pushback continued right up to 2017 when the paper demonstrating that right whales were in decline was accepted for journal publication. As late as 2016, senior NOAA staff were still referring to North Atlantic right whales

as an exemplar of NOAA's conservation successes. A major reason that Richard Pace developed his sophisticated mark-recapture model of right whale abundance was to overcome this internal NOAA resistance. What happened next? NOAA established a team to oversee how to respond to the right whale crisis. The team included the nay-sayers, and none of the people who'd sounded the warning that right whales were in trouble. Since then, Richard has produced more ground-breaking science on right whales, in particular the proportion of whales that have died and aren't found. Rather less has emerged from the work directed by the right whale oversight team. We won the battle but lost the campaign.

What's the solution? We now have agreement that there's a serious problem, yet the manner in which science is being used to solve the problem is cause for disagreement. The changes that have been proposed by managers, when they're finally implemented, are unlikely to be sufficient. Will further argument over detail provide resolution? Science is iterative, so undoubtedly there will be new studies that improve our understanding if exactly what's going on. That's necessary. Is it sufficient?

Narratives, and Narrative Control

There was a time when whales were seen a giant living tubs of oil. To exploit them for commercial gain was unquestionably appropriate. The early modern era of Antarctic whaling was possibly the most lucrative industrial exploitation of wildlife in all human history. But that view of whales as commodities for the killing has, in most countries, lost its social license. People don't think it's acceptable. That change in mindset didn't come about from arguments over data. The mathematics of exploitation was argued, and eventually won, at the meetings of Scientific Committee of the International Whaling Commission. But that's not what stopped whaling. Peoples' view of what whales were, and what they meant for humanity's vision of our place in the world, changed utterly. That didn't happen by accident. It is the crowning achievement of the social movement for whale conservation.

So why are North Atlantic right whales in such trouble? We are killing them off, and we are also changing their lives. We know that smaller, scrawnier whales have greater difficulty successfully raising calves. Through entanglements, we are not just killing them and shrinking them– we're making it harder for them to have healthy calves that stand a good chance of surviving to adulthood. And we're making adulthood harder to achieve, as the age at which females are having their first calf– assuming they live that long– is getting later. We're changing what it means to be a North Atlantic right whale.

In theory, strong protective legislation should make conservation simple. Why isn't it? I suspect there are a few interlocking issues at play. Right whales deaths are not intentional. Unlike whaling, or drive hunting, there's no clear villain deliberately trying to kill whales. But inadvertent and unexpected are different things. When we add over a million ropes to the ocean that is home to a species, we must expect them to encounter these ropes. When vessels, of any size, travel fast in areas where whales are, some collisions must occur. What do we do?

Dealing with the problem of vessel strike is more straightforward than entanglement. Slowing vessels, and not just large vessels, in places where right whales occur will help. Accomplishing it is simply a matter of will.

Entanglement is more complex. There have been a series of attempts to solve the problem of entanglement, all of which have obviously been inadequate. The most successful have been those enacted by Canadian managers in the Gulf of St Lawrence. Timing the opening and closure of a fishery so it overlaps as little as possible with whales' presence is clearly a good idea. Then, rolling closures triggered by whale detections, when coupled with sufficient survey effort, appears to have helped as well.

Disentanglement efforts are necessary, but wildly insufficient. Over 90% of entanglements are never observed, and even when found, many whales are not completely disentangled. There's a presumption that the entanglement problem must have a technical solution but none implemented in the US to date have provided any measurable protection. Currently, hope lies in developing and implementing technology to remove ropes on fishing gear. But the applicability of ropeless gear is now trapped in the culture war clashes that bedevil so much of the discourse in the USA, to the detriment of whales. And returning to counterfactuals– there has been little interest in the US in the fact that comparable trap/pot fisheries in peer nations (e.g. Canada, Australia) use vastly less traps (and rope) for the value of catch landed.

What to do? The science is clear– without significant robust change in fishery and shipping management, extinction of the North Atlantic right whale is certain. Our perceptions as a society about what is appropriate behavior in the ocean need re-calibration. Strewing miles of rope through the ocean in order to catch invertebrates commercially is assumed to be appropriate. The way that the lobster industry is currently prosecuted in the USA demonstrates that this is questionable. Shipping foreign goods into North America to support our demands is assumed to be appropriate, but do we need to get it at high speed? Another question is: As a society, are we comfortable with allowing two industries–fishing and shipping– to dictate so much about ocean use? Under current conditions, right whales will go extinct due to our desires for rapid delivery of inexpensive consumables and lobster rolls.

These questions could be being raised by the wider conservation community, but they're not getting much air time. Why not? First, many in the conservation community are now so busy working through the courts to try to get NOAA to act according to conservation law that they lack the time to devote to other issues. It's an opportunity cost problem. Second, some conservation NGOs seem very content staying within the bounds of the current paradigm. Perhaps, as some of them employ people from government, it's a reflection of those peoples' true loyalties– ensuring that the world does not see any more great paradigm shifts in conservation thinking, whether or not right whales go extinct. Perhaps those people don't even realize that's how they think. Thirdly, it's not somewhere that most scientists will go. Many see this as stepping outside their scientific objectivity. Some of us, however, see working at the science-policy interface as important and valuable.

All of us hold the our planet and its environment, including the ocean, somewhere central inside us. How we place ourselves in what was once nature, and now is the planet we are obliged to save, says much about us. And it speaks to who we are as a society. Clearly, most people of North America have a transactional view of ocean. It's there entirely for people to exploit. North Atlantic right whales are victims of this worldview and they will remain so until that view changes, or the whales die out.

I'm a long way from the Head of the Bight, physically and spiritually. I still believe that we can use science to conserve the ocean. This issue tells stories that inform that process. But we scientists can't be the ones alone who save the whales, we just pass on the information that makes saving them possible. It's up to all of you reading this to take the next steps. Prove us right. Go out and save right whales.

Above: Right whale mother and calf at the Head of the Bight, with the Bunda Cliffs in the background. The viewing platform for whale observation is visible on the cliffs.

Above: Consortium members socializing at the end of the day. Informal conversations after the formal meeting are important for strengthening relationships and developing new project ideas. Two authors, Drs McLellan and Parks, are visible. *Photos courtesy of Heather Pettis and Scott Kraus.*

THE NORTH ATLANTIC RIGHT WHALE CONSORTIUM:

COORDINATING SCIENCE FOR THE CONSERVATION OF AN ENDANGERED SPECIES

HEATHER PETTIS AND SCOTT KRAUS

Research collaborations on all aspects of a species' biology throughout its geographic range are critical for effective marine mammal conservation, particularly for those whose ranges are large and/or compounded by multiple state, federal and/or international oversight. Approaches to such collaborations have varied for marine mammals globally, with varied levels of success. One framework in particular is recognized for its success in such endeavors: The North Atlantic Right Whale Consortium (NARWC). Currently, the NARWC is comprised of more than 200 individuals, research and conservation organizations, shipping and fishing industries, technical experts, U.S.

and Canadian government agencies, and state and provincial authorities, all of whom are dedicated to the conservation and recovery of the North Atlantic right whale. The Consortium, managed by an Executive Board, is internationally recognized and has been identified as a model for establishing other species related consortia.

The origins of the North Atlantic Right Whale Consortium (NARWC) predate the organization as we know it today by more than a decade. In the mid 1980's, John Prescott (a Commissioner at the Marine Mammal Commission and Executive Director at the New England Aquarium), Dr. Howard Winn (a professor at the University of Rhode Island), and Dr. Robert Hofman (the Scientific Program Director at the Marine Mammal Commission), realized that marine mammals had no support for research or management from the relevant government agencies. Despite the passage of the Endangered Species Act (ESA) in 1973, and the Marine Mammal Protection Act (MMPA) of 1972, no funding was allocated in the National Marine Fisheries Service budget for marine mammal research in the Atlantic. By the late 1970's, there were only small-scale Southeastern US Tursiops studies, and the Minerals Management Service (MMS) was conducting occasional surveys in the Gulf of Mexico.

Prescott and Winn took it upon themselves to lobby congress for marine mammal funding, and ultimately were successful when congress allocated $250k for Atlantic research. Separately, in 1977, the Bureau of Land Management (the predecessor to the Minerals Management Service, which was predecessor to the current Bureau of Ocean Energy Management) issued a call for marine mammal research related to oil and gas exploration off the Northeast coast of the US. Professor Winn gathered a large group of collaborators to bid on the work. These included Prescott (at NEAq), Dr. Steve Katona (College of the Atlantic), Dr Charles Mayo (Center for Coastal Studies), Mr. William Watkins (Woods Hole Oceanographic Institution), David and Melba Caldwell of Marineland of Florida), and a number of other colleagues under the umbrella of the Cetacean and Pinniped Assessment Program (CePAP). The CePAP program conducted surveys, collected sightings and stranding records, and developed new study methods for marine mammals along the east coast, with a focus on the waters between Cape Hatteras and Nova Scotia. The CePAP program ran for 5 years, ending in 1982.

In 1979, Prescott and Dr. James Gilbert (University of Maine) hosted a workshop on East Coast/Gulf Coast Cetacean and Pinniped Research, which laid out the status, threats, and biology of the known species, and developed a road map for research and monitoring for relevant federal agencies to follow in meeting the requirements of the MMPA and the ESA. With this roadmap in hand, congress continued to support marine mammal research via the National Marine Fisheries Service (NMFS) in the interim, leading to the discoveries of North Atlantic right whales in the Bay of Fundy and the calving ground off the southeastern US. In 1984, under pressure from scientists and environmental groups, congress upped the funding for NMFS marine mammal programs. Bureaucratic wrangling slowed contracting, but finally in 1986, the original iteration of the Right Whale Consortium was funded. Titled: “Integrated Program for Research on the Northern Right Whale off the Eastern United States”, this research

Top Right: The more formal part of the Consortium meeting, from years past. This year and last, the meetings have been virtual, in response to the ongoing pandemic.

Page 14: Whale Calvin (#2223) with her third calf #4523 in Roseway Basin off the southern tip of Nova Scotia on September 17, 2015. It is rare to see mothers with calves in this area. *Photo Credit: Anderson Cabot Center/New England Aquarium. Collected under Fisheries and Oceans Canada SARA permit.*

collaboration ran from 1986 to 1994, with support from the NMFS.

This early work of the combined institutions demonstrated that #1) right whales existed in small but apparently growing numbers, and #2) that great scientific advances could be made with an integrated data-sharing approach. Such an integrated approach facilitated a broader understanding of North Atlantic right whale biology and conservation needs, including critical information on distribution, reproduction, mortality, and anthropogenic impacts. Dozens of foundational peer-reviewed publications on right whales resulted from these early relationships (see Kenney *et al* 1986, Kraus *et al* 1986, Kraus et al 1986a, Stone et al 1988 Kraus 1990, Hamilton and Mayo 1990, and Mayo and Marx 1990 for examples of some of these important publications), and elevated the issue of right whale conservation to one of international recognition and importance. Despite these early successes, in 1993, NMFS broke the right whale contracts up into separate components; database management went to the University of Rhode Island, the Photo-Identification Database (Catalog) went to the NEAq, and small fieldwork programs annually supported researchers in different Atlantic regions. Philip Hamilton and Amy Knowlton's article in this issue describes the workings of the Catalog in detail.

When the funding for the integrated right whale program ended in 1994, and the norm became contracts between the government and lead researchers at different institutions, communication and collaboration between right whale researchers became less common. Those of us in the field at the time felt that loss acutely, but more importantly, it was clearly a loss for the species, as studies of science and conservation of a large, cryptic, highly migratory species is nearly impossible from a single location or by a single scientist. Researchers were still hard at work studying the species and making important discoveries (i.e. population modeling, genetic sampling and analyses), but the working collaborations became dormant. Collaborations between small research groups still existed, but as new researchers, state and federal managers, and conservationists emerged and engaged in right whale work, much of it was done independently and without knowledge of the historical efforts and existing programs. Coincidentally, this was also a time during which the North Atlantic right whale was showing signs of reproductive and health declines and increased impacts from human activities.

Recognizing the need to "regroup" and work towards developing a unified strategy to address emerging scientific and conservation issues, researchers at the New England Aquarium hosted a meeting on right whale science in the fall of 1997. There were only a few dozen attendees at this meeting, but it was clear that such a gathering was long overdue. A follow up meeting was held in the fall of 1998, with ~80 participants, representing researchers, industry stakeholders, and state and federal managers in attendance. At this 1998 meeting, the right whale community agreed that a more formal and expanded organization of right whale science and conservation efforts was needed. Just a few weeks after the meeting, the North Atlantic Right Whale Consortium as we largely know it today was established. It included data curators, a chair, a secretary, and a voluntary board that reviewed data requests, and assisted the secretary with the annual meeting agenda and presentations

The formalization of the North Atlantic Right Whale Consortium was predicated upon a few simple, but pioneering notions. First and foremost, the NARWC set forth to be, above all else, a data and knowledge sharing group. The founding partners of the NARWC had experienced first-hand the value of shared data in producing the most robust and informative scientific findings and sought to maintain this practice with the expansion of the organization. Several key right whale databases were developed and curated by founding partners in the NARWC's early years, including the Catalog (New England Aquarium) and Sightings Database (University of Rhode Island). These databases represented the foundation of much of the effort to study and manage North Atlantic right whales, and the original contributions to them were voluntary and primarily from founding members. With the decision to expand the NARWC came a commitment to encourage a wider contribution to, and access of, the databases for scientific and educational purposes, while also developing protocols that protected the rights of contributors.

Though it has always been the modus operandi for the NARWC, extensive data sharing among unaffiliated researchers and organizations is largely novel and unpracticed in biological studies of single species. A more typical practice is for researchers to hold quite tightly to their data, maintaining proprietorship in perpetuity or sharing only once analyses have been completed and published. For the NARWC, the process is nearly reversed. Submission to the NARWC databases is voluntary, yet comprehensive and database frameworks include well-defined QA/QC protocols that are evaluated and modified annually with input from data contributors and database curators. These protocols and modification processes ensure that data capture and processing are streamlined, efficient, and thorough. Research and survey teams collecting right whale data typically submit to NARWC Catalog and Sightings Database shortly after the conclusion of their field season and/or projects. And, organizations for whom field seasons stretch over several month often submit more frequently. These submissions are mutually beneficial. Databases are updated with critical information on distribution, demographics, impacts of human activities that inform both short- and long-term research and management efforts.

For example, near real time monitoring of impacts of human injury on right whale health are critical to detecting emerging threats and threat areas. Such monitoring efforts are only made possible because survey teams forward sightings and photographs of injured right whales immediately upon detection. Assessments of these injuries are forwarded to management agencies throughout the right whale range and inform critical mitigation efforts, including real time responses. Researchers, too, benefit greatly from contributing to NARWC databases. The right whales detected during their survey efforts are identified to individuals and contributors have direct access to all associated data linked to their sightings, including demographics and behavior. Moreover, several data contributors have mutual agreements whereby they have direct access to each other's data, allowing for regionally focused assessments and collaborations by these groups.

The North Atlantic Right Whale Consortium's commitment to data sharing extends well beyond those groups actually collecting the data. Data sharing protocols, initially developed with the expansion of the NARWC and modified over time in response to community and contributor needs, guide access to databases under NARWC curation. Anyone, from students, to researchers, to managers, to industry stakeholders, to conservation and educational organizations, is able to submit a request for access to the databases. The access protocols are bound by relatively simple and straightforward conditions; the request must be for a bona fide purpose, the data may be used only in accordance with the intentions set forth in the request, the data are not to be shared with third parties, and data contributors and the NARWC must be acknowledged at an appropriate level (be it as coauthor or acknowledgment in resulting data products). Each request is reviewed by database curators and/or voluntary Board members to ensure that duplication of effort is minimized, that proposed analyses are appropriate, and that potential coauthors are identified. The review also provides an important opportunity for the NARWC to provide feedback and clarity on the request and data caveats, both of which ultimately strengthen the science behind the end product for the requester.

> "...the data sharing model employed by the NARWC is the single most important resource in the North Atlantic right whale conservation toolbox."

The NARWC data sharing framework is critical to the long-term survival of the North Atlantic right whale. Without it, our detailed knowledge about this species, including the dire conservation crisis it currently faces, would not exist. In the first year of its expansion, the NARWC received five requests for data access. In 2020, it received 72. Between 2005-2020, more than 450 requests were made and at least 250 publications and reports cited North Atlantic Right Whale Consortium data, including pivotal papers on species abundance and trajectory, distribution, feeding ecology, genetics, acoustic behavior, and anthropogenic impacts on health, reproduction, and survival. In short, the data sharing model employed by the NARWC is the single most important resource in the North Atlantic right whale conservation toolbox.

The second most important resource for right whale conservation is the commitment of North Atlantic Right Whale Consortium members to an open exchange of information. To that end, the NARWC has held annual meetings since 1997 at which members gather to share research results, forge new collaborations, and engage in directed and productive discussions about right whale conservation. The meeting also provides a venue whereby strategies for advancing new initiatives to benefit the species can be vetted and initiated. Meetings feature presentations of research stemming from data access requests, providing data contributors and others an opportunity to experience first-hand the impact of the NARWC data sharing framework. Working groups and open discussion forums are also regular features of these meetings and have led to significant advances in right whale conservation, including the development of the Right Whale Annual Report Card (narwc.org/report-cards), the engagement of bilateral federal management agencies (U.S. and Canada), and the formation of the Ropeless Consortium (ropeless.org). Interest and participation in these Annual Meetings have grown substantially over time, from a few dozen participants in 1997 to nearly 430 in 2020. What began as a gathering of a primarily right whale researchers, a few NGOs, and regional management offices has transformed into a comprehensive stakeholder event at which scientists, fishermen, environmentalists, and managers participate.

In its 2001 report on the workshop entitled "Comprehensive Assessment of Right Whales: A Worldwide Comparison" the International Whaling Commission noted that the "foundation of the North Atlantic Right Whale Consortium in 1986 had provided the framework for a collaborative and uniform approach to the research and conservation of right whales in the western North Atlantic" and went on to suggest that it serve as a model for the creation of a similar Consortium for southern right whale populations (IWC 2001). Such suggestions have not been limited to right whales. Research groups for other species, including southern resident killer whales, Pacific Coast Feeding Group grey whales, and the Franciscana dolphin, have sought NARWC guidance on the creation of single species consortia for their research

Above: Heather Pettis doing fieldwork. Heather is the organizing energy behind many years of successful Consortium meetings.

communities. In discussions with each of these groups, one of the principal challenges encountered is getting research communities to buy in to and adopt the core principle of the NARWC – that of the data sharing framework. These challenges may be insurmountable for some, but in our experience, this approach benefits both the species and the researchers.

For the people who established the NARWC data sharing and collaboration protocols, the survival and recovery of this endangered species holds priority over all self-interests. In the beginning, it was probably helpful that the group was small, and many researchers were already working with one another. At the heart of their efforts and those of the NARWC today, is the notion that collaboration enhances, not harms, the advancement of independent research initiatives. The future of this endangered species is entirely dependent upon a community of individuals, whose dedication to the survival of the North Atlantic right whales against significant odds remains a powerful force on their behalf. Because of this community dedication, we think the omens for right whales are good.

Acknowledgements

Thanks to Dr. Robert Kenney for dusting off the memory banks to help inform the summary of the pre and early NARWC days. We would also like to thank all the North Atlantic Right Whale Consortium data contributors and members for their continued commitment to data sharing and a collaborative approach to conserving North Atlantic right whales.

References

Hamilton, P.K. and Mayo, C.A., 1990. Population characteristics of right whales (*Eubalaena glacialis*) observed in Cape Cod and Massachusetts Bays, 1978-1986. *Reports of the International Whaling Commission, Special Issue*, (12), pp.203-208.

International Whaling Commission. 2001. Report of the workshop on the comprehensive assessment of right whales: A worldwide comparison. J. Cetacean Res. Manage. Spec. Issue 2, pp 1-60.

Kenney, R.D., Hyman, M.A.M., Owen, R.E., Scott, G.P. and Winn, H.E. 1986. Estimation of prey densities required by western North Atlantic right whales. Marine Mammal Science, 2: 1-13. https://doi.org/10.1111/j.1748-7692.1986.tb00024.x

Kraus, S.D., Prescott, J.H., Knowlton, A.R. and Stone, G.S., 1986. Migration and calving of right whales (*Eubalaena glacialis*) in the western North Atlantic. *Report of the International Whaling Commission*, 10, pp.139-144.

Kraus, S.D., Moore, K.E., Price, C.A., 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*). *Rep. int. Whal. Commn*, pp.145-51.,

Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*). Mar. Mamm. Sci. 6(4):278-291.

Mayo, C.A. and M.K. Marx. 1990. Surface foraging behaviour of the North Atlantic right whale, *Eubalaena glacialis*, and associated zooplankton characteristics. *Canadian Journal of Zoology*. 68(10): 2214-2220. https://doi.org/10.1139/z90-308

Stone, G.S., Kraus, S.D., Prescott, J.H., and Hazard, K.W. 1988. Significant aggregations of the endangered right whale, *Eubalaena glacialis*, on the Continental Shelf of Nova Scotia. The Canadian Field Naturalist 102(3):471-474.

THE POWER OF KNOWING THE INDIVIDUAL– THE NORTH ATLANTIC RIGHT WHALE CATALOG

PHILIP HAMILTON AND AMY KNOWLTON

Philip

I have been using photo-identification to study North Atlantic right whales for over 35 years and I still find it challenging to convey how exciting and rewarding it is to know most of the individuals of a species. Photo-identification is the process of using images of an animal's natural markings to distinguish one individual from another. For me, there is something innately compelling about being out on the water, seeing a whale come to the surface to breath, and immediately recognizing who it is, knowing her sex, where she's been seen in the past, who her calves are. When I first started matching photographs of the callosity patterns on the heads of right whales in the mid 80's, I had no training. I didn't know how much that pattern could change, how stable the outlines of skin sloughing were, how glare could be mistaken for a bright, white scar. This lack of knowledge added to the mystery and my sense of discovery and those qualities have compelled me ever since. One of my more memorable recognition events was early on in my career. I was working as a naturalist on a whale watch boat when we came across a right whale in Cape Cod Bay in September. This is a very odd time of year to find a right whale in the Bay and the whale was showing very little of its head as it rested at the surface. I saw a very faint propeller scar behind the blowholes and knew immediately that it was #1034- a calving female due to give birth the following year. I was so excited that I became completely tangled in the microphone cord as I spun around taking photographs, writing down data, and explaining to the passengers with a voice trembling with excitement how interesting this sighting was. Clearly I was hooked!

Since that time, I have helped shepherd the North Atlantic Right Whale Catalog through many transitions. This database of all known photographed right whale sightings serves as the cornerstone for what we know about this species. Through its 86,000 plus sightings, we have learned that: right whales give birth at 10 years of age on average; mothers can wean their young as early as six months and as late as 18 months; and some individuals are seen both frequently and regularly, while others are rarely seen and seem to use habitats others than those that are well studied. While most right whales remain within 100

Caption. *Photos courtesy of Philip Hamilton and Amy Knowlton.*

miles of the coast of eastern North America, some take fascinating walkabouts- Porter, an adult male who swam from Cape Cod to the northern tip of Norway; or Pico, an adult female who swam to the Azores one January; or Mogul, and adult male who swam to Iceland one year and France and Newfoundland the next. Imagine if we couldn't recognize the individuals. We would think there was a remnant population in the eastern North Atlantic rather than whales from the western North Atlantic showing tremendous plasticity in their movements.

Over the years, this Catalog has transitioned from being stored in dBase (remember that old black screen with the dot prompt!), to MS Access, to SQL. And the images, which used to be slides and prints stored in rows and rows of filing cabinets, transitioned to digital stills and, increasingly, video. The photo-identification process itself has changed from leaning over a hot light table using a jeweler's loop to carefully inspect a 1" x 1" slide transparency to using a computer screen with the ability to zoom in to the point of excessive pixilation. This latter transition required completely new software which we developed with a grant from the National Science Foundation. And that's just where the cataloging process stands now. As technology advances, so does the Catalog. The next steps are to build a fully web-based system with integrated video. We have also been collaborating with the team at *FlukeBook* who have used A.I. to develop right whale automated matching. These advances with A.I. are exciting, but, call me old school, I don't think it can ever take the place of humans in the cataloging process. We code each image and sighting with detailed information. Some of that coding is used to train the automated matching routines. That coding also allows researchers to locate very specific marks to make difficult matches that A.I. could likely not make. Our minds are able to hold and integrate information from many images showing different angles and body parts which helps us make difficult matches. And frankly, I would be sad if teams in the field were no longer able to recognize old whale friends on the water- a skill that would definitely be lost if we all stopped poring over thousands of images and instead let the machines do the work for us.

I cannot emphasize enough the importance of knowing the individual. I'll give one specific example to illustrate. On June 21, 2007, a female right whale was found dead and entangled in fishing gear in the Gulf of St Lawrence. That is all we would know without the Catalog. With the Catalog, we know that this was Starboard (#3603), born in 2006 to mother #1503 (Trilogy) and father #1712. We know that her mother Trilogy was last seen in 2010 entangled in a gillnet and we suspect she is dead. We know

Starboard's grandmother Baldy #1240 has had nine calves over a 40 year period (see family tree) and is responsible for at least 23 whales joining the species. We know that Starboard lost part of her fluke to an entanglement when she was just one. We know that she had eight aunts/uncles (not all living): Baldy's 1974 calf (not cataloged), 1241 (Bugs), 2140 (Peanut- also died in GSL in 2017), 2740, 3240 (Orion), Baldy's 2005 calf (not Cataloged), 3930, and Baldy's 2014 calf (not cataloged). She has three siblings: 2503 (older sister Boomerang), 3303 (older sister), and 3903 (younger sister). She has at least nine nieces and nephews by Bugs, Boomerang, and Orion. She was just 11 years old when she died and had not had her first calf yet. The loss of potential recruitment to the population caused by her death is significant- especially in light of her grandmother's contribution to the species. This is just one example of the context which the Catalog provides to a single event.

There are several remarkable aspects of the North Atlantic Right Whale Catalog that make it truly unique. It is one of the longest running Catalogs, with continuous data coming in since 1980 (with some historical images going back as far as 1935). It includes all individuals of the entire species with very few non-calf whales "discovered" each decade. Also, because there are so few right whales in the species (currently less than 400 even though there are over 700 whales in the Catalog), we keep every image contributed to the Catalog. Some catalogs focus on just one "type" image for a sighting or an individual; having all the images in the right whale Catalog allows for a myriad of additional analyses (described below). Finally, and perhaps most importantly, the right whale community is extremely collaborative and has the well-structured North Atlantic Right Whale Consortium (described in the next article) to foster cooperation and data sharing. It is thanks in large part to the Consortium that all the images taken by over 500 individuals and organizations, have made their way to us at the Aquarium. Just think what we would be missing if the photos of Porter, Pico, and Mogul were never submitted! Right whales, and those of us who study them, are extremely lucky to have such cooperation.

Some think of the Catalog as simply about identifying an individual whale and documenting that it was alive (or dead) and present somewhere at a point in time. It is much more than that. The reason we keep all the images submitted is that the images tell many different stories and serve as permanent proof for those stories. To name just a few, the images allow us to 1) track scars left from past entanglements and determine how frequently new entanglements occur; 2) track changes in body condition and other external indicators of health; 3) document and analyze behaviors such as the frequency with which whales swim to the bottom and return with mud on their heads, or the roles different whales play in mating groups; 4) analyze association patterns; and 5) identify dead whales floating belly up with no callosity showing (something that A.I. is unlikely to ever achieve). Amy discusses some of these topics in more detail below. Finally, the power of the Catalog is magnified when linked to a myriad of other databases. More than 80% of the species has been genetically sampled, and when the resulting genetic data are linked with identifications from the Catalog, provide information on sex, paternity, inbreeding, reproductive success, and survival. Data from samples of whale breath, feces, baleen, and skin/blubber biopsies provide hormone data on individuals that reveal pregnancy, sexual maturity, and various different health factors including stress. Photogrammetry measurements linked to individuals and their sighting histories are used to develop growth curves and track changes in growth over time. The ways that individual identification data can be leveraged is practically endless. How could anyone not be captivated by photo-identification and all we can learn from it?!?

Amy Knowlton pictured.

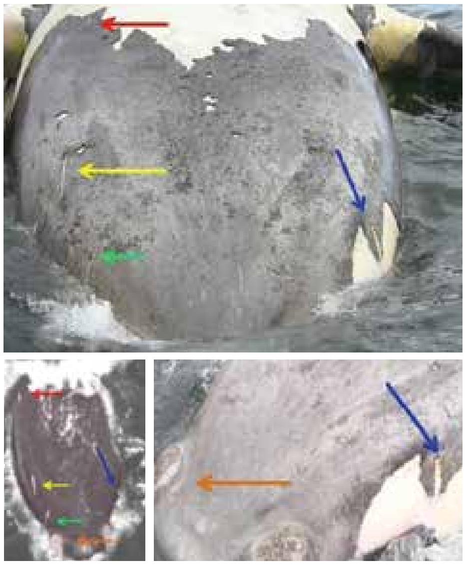
Page 21: Left: Caption.
Top Right: Caption.
Bottom Right: Caption.

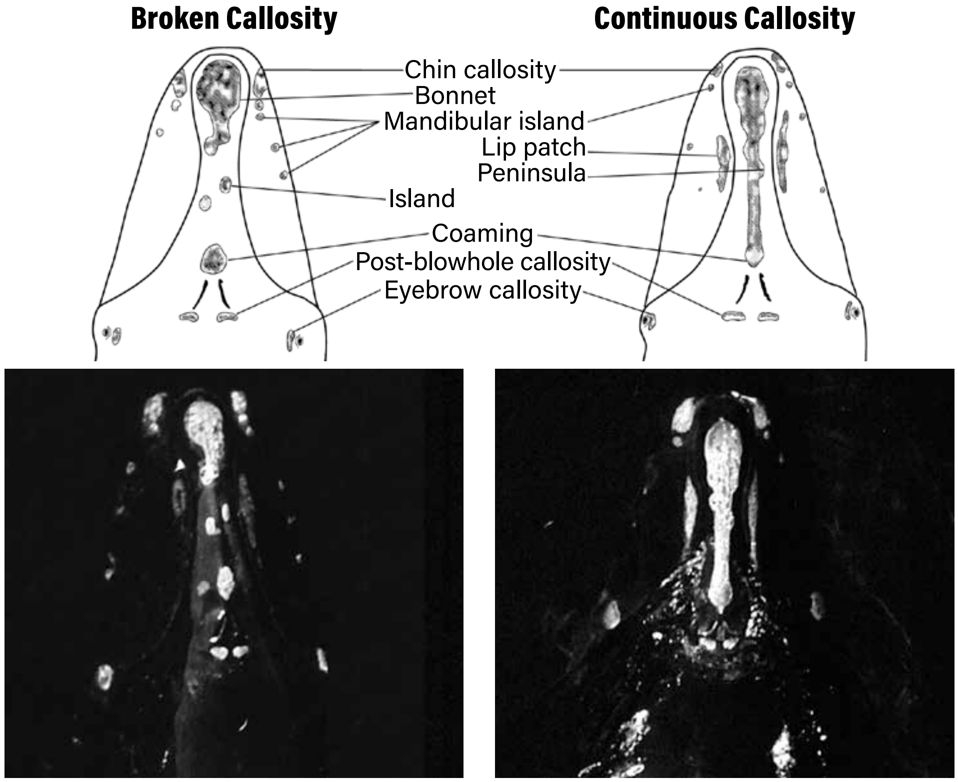
Amy

When I was young, I didn't dream of becoming a cetologist [whale biologist] as I didn't even know that was a possibility. I was following a more traditional track thinking that I wanted to become a medical doctor but once I got to college, my life took on a new direction after I was exposed to the environmental field and realized there were ways to follow my passions of being on the ocean and amongst wildlife. As I reflect back on my youth, I now realize there were some signals that suggested I might be a good fit for the right whale catalog work that has been a big part of my career. During the summers, starting when I was around 7 years old, I was busy cataloging the pennies in the penny jar that my parents kept "hidden" in their closet. I had a small notebook where I listed every year in order and added a checkmark if I had a penny of that year. I still have the notebook but the pennies are long gone, surreptitiously spent on penny candy. Then in 4th grade, in art class, I sculpted two whales - a mother and baby - that look uncannily like right whales [add picture?]. At that time, in the 60's, whales were just beginning to infiltrate into dialogs in my home as TV shows and National Geographic articles that I avidly watched and read became accessible. Fast forward to the early 1980's and after graduating from college with a geography degree, I quickly realized that doing office temp work to earn a living was not going to satisfy my soul and I soon found myself volunteering part time at the New England Aquarium. Because of my experience operating boats, I was placed at the outset on the right whale project despite the fact I knew nothing about the species. Once I joined this effort, and especially once I saw a right whale in the flesh when I joined the team in the Bay of Fundy, I was hooked for life!

It has been a career that has both fulfilled and challenged me. The fulfillment comes from the extensive knowledge we have gained of this critically endangered species through the dedication and collaboration that have been the mainstays of the right whale community. Right whales have given us a unique opportunity to understand how they live. We have learned about how right whales use the water column including interactions with the seafloor as evidenced by frequent observations of mud on their heads. We have documented that surface active groups typically are comprised of one female and multiple males attempting to mate with her, an apparent mating strategy that we assume means that the strongest male is the most successful. We have carefully monitored health of individuals over time using external visual indicators and have documented that mothers nursing their calves lose body condition over the course of that year until the calf is weaned and the mom can start regaining her fat stores to ideally give birth again two years later. And the Catalog has been used by many researchers beyond our team at the New England Aquarium as the knowledge of individual life histories provides a rich storyline to integrate into those studies including those looking at population status effects of climate change, and effects of human activities on health to name just a few.

The challenging aspect of this career has come from witnessing all the insults and impacts that this species endures living along this heavily industrialized coastline. Since my first day in the office in February 1983 when I heard about the fatal vessel strike off New Jersey of a two-year-old male named Friend to the recent vessel strike and entanglement deaths still plaguing this species in 2021, it has been a daunting





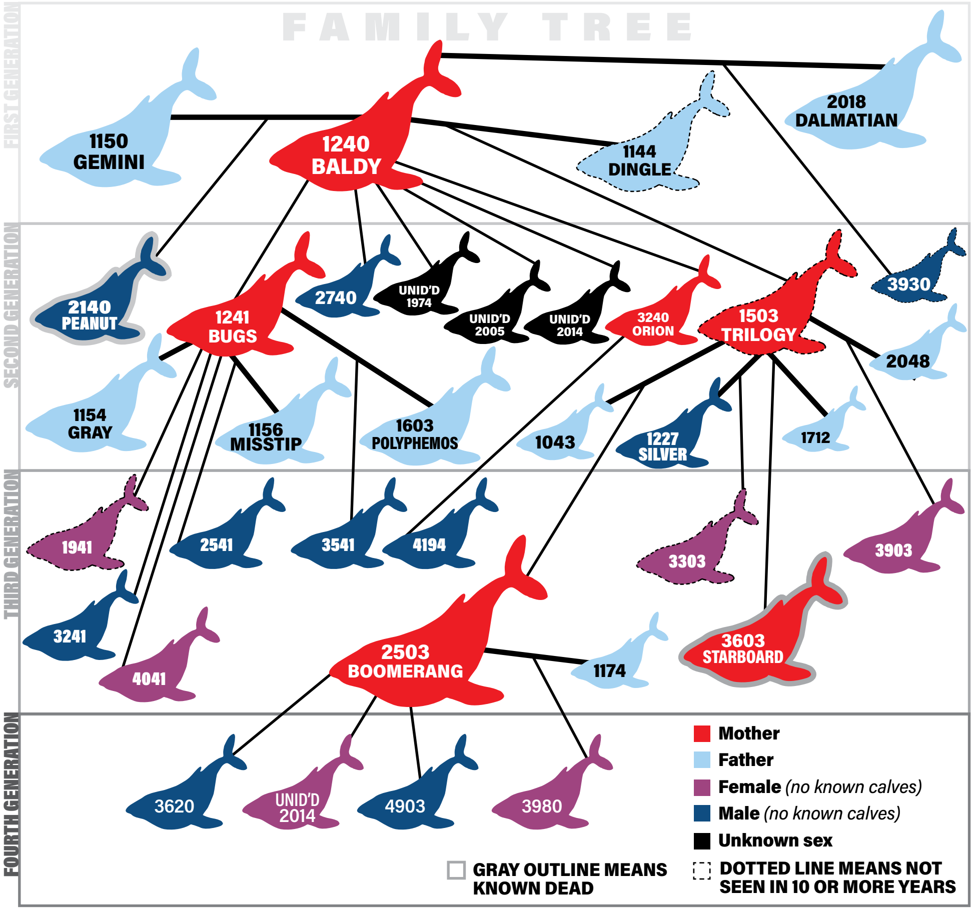
Top Left: Examples of how small details can lead to successful matches. Matches like this can only be accomplished when all aspects of a whale are photographed and cataloged. This includes photographs that are obscure, distant or even out of focus.
Top Right: Caption.

Philip Hamilton and Amy Knowlton Cont.

task to first understand why, when, and where these interactions with human activities are happening, and then assess whether and how such interactions could be mitigated. The Catalog has been an incredible resource for describing what right whales experience. By reviewing every image of each individual taken each year, we conduct a painstaking assessment and review each part of the whale's body to determine if any new scars exist. Entanglement scars are described as scars that wrap around different body areas including the mouth, flippers, and flukes. And in a limited number of entanglement cases, we also observe attached fishing gear. From documenting evidence of over 1600 entanglements in more than 40 years, we have determined that 87% of the species has endured at least one entanglement event and some individuals have experienced as many as 8 entanglements. But not every entanglement has the same effect. Some entanglements result in minor, superficial scars akin to skinning one's knee. But in recent decades (since around 2000), more of the entanglements are resulting in moderate to severe injuries and more complexity when gear remains attached. We've also linked these entanglements to the visual health assessments and show that the more severe the injury, the greater effect on health, especially in reproductive females who already deal with body condition fluctuations because of calving and nursing. We have also been able to look at retrieved gear from four large whale species, including 28 identified right whales. That work indicated clear patterns of smaller species and younger right whales entangled in lower breaking strength ropes than adult right whales. In one journal article we recommended that 1700 lb breaking strength ropes be used throughout fixed gear fisheries to ensure whales could successfully break free from the bottom gear without experiencing a complex entanglement and severe injuries. This "solution" is being implemented broadly in the US and Canada and is what we deem an interim option as ropeless gear, the ultimate solution to this threat, continues to be developed and implemented. As 1700 lb ropes become integrated into fisheries, we will carefully monitor the outcome to right whales to assess whether this weaker rope is working as intended.

For vessel strikes, many whales die from the strike as a result of blunt force impact or deep propeller cuts. We use the Catalog to determine who died, which is not always a straightforward task if the whale is badly decomposed. But we use many different clues beyond just the callosity pattern on top of the head. It can be the pattern of mandibular islands or crenulations of the lower lip ridge or the presence of a tiny scar on the body that can help us cinch a match to the Catalog. For those whales that survive a strike, they are typically left with a suite of propeller cuts. We use the Catalog images to estimate the dimensions of these cuts which gives us insights into the relative size of the vessel involved in the strike, which then can inform management measures. And we also monitor their health over time to see how they respond to these non-lethal strikes.

The situation for North Atlantic right whales is not a happy story as too many are dying from our human activities on the ocean. The possibility of extinction looms with each untimely death. Because of the Catalog and the tremendous level of collaboration involved, we have insights into what it will take to keep this species going - broader vessel speed restrictions with more intensive enforcement of speed violations and a dramatic shift in how fixed gear fishing is prosecuted, with an expeditious transition to ropeless fishing and weaker ropes in the interim. These are proven solutions that if implemented could turn the downward trajectory of the North Atlantic right whale around.


FAMILY TREE
FIRST GENERATION
SECOND GENERATION
THIRD GENERATION
FOURTH GENERATION
1150 GEMINI
1240 BALDY
1144 DINGLE
2018 DALMATIAN
2140 PEANUT
1241 BUGS
2740
UNID'D 1974
UNID'D 2005
UNID'D 2014
3240 ORION
1503 TRILOGY
3930
2048
1154 GRAY
1156 MISSTIP
1603 POLYPHEMOS
1043
1227 SILVER
1712
1941
2541
3541
4194
3303
3903
3241
4041
2503 BOOMERANG
1174
3603 STARBOARD
3620
UNID'D 2014
4903
3980
Mother
Father
Female (no known calves)
Male (no known calves)
Unknown sex
GRAY OUTLINE MEANS KNOWN DEAD
DOTTED LINE MEANS NOT SEEN IN 10 OR MORE YEARS

Caption.

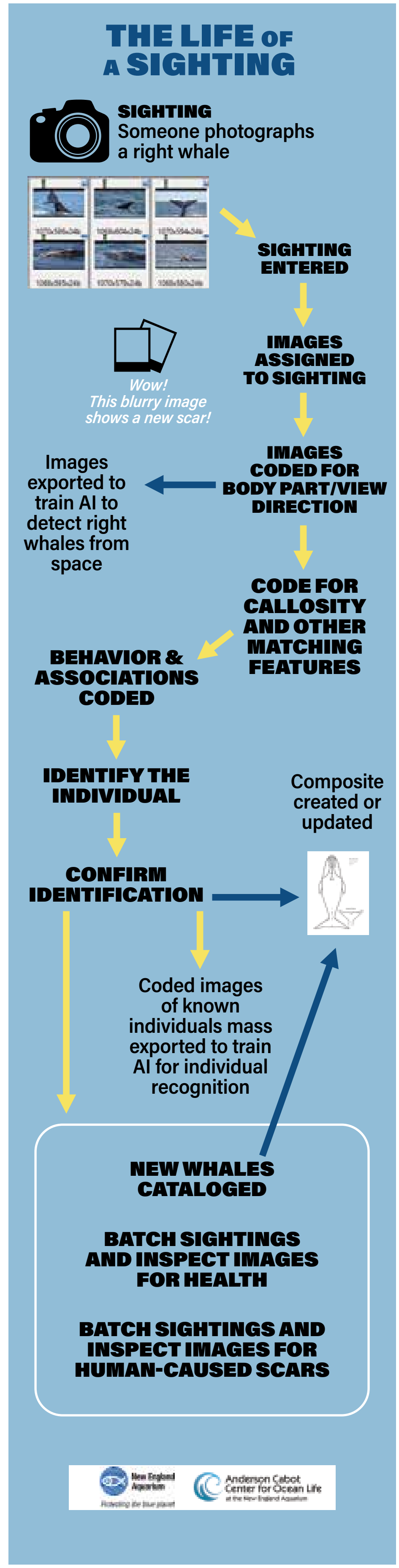

THE LIFE OF A SIGHTING
SIGHTING
Someone photographs a right whale
SIGHTING ENTERED
IMAGES ASSIGNED TO SIGHTING
Wow! This blurry image shows a new scar!
IMAGES CODED FOR BODY PART/VIEW DIRECTION
Images exported to train AI to detect right whales from space
CODE FOR CALLOSITY AND OTHER MATCHING FEATURES
BEHAVIOR & ASSOCIATIONS CODED
IDENTIFY THE INDIVIDUAL
Composite created or updated
CONFIRM IDENTIFICATION
Coded images of known individuals mass exported to train AI for individual recognition
NEW WHALES CATALOGED
BATCH SIGHTINGS AND INSPECT IMAGES FOR HEALTH
BATCH SIGHTINGS AND INSPECT IMAGES FOR HUMAN-CAUSED SCARS
New England Aquarium
Anderson Cabot Center for Ocean Life

Figure 4. The live north Atlantic right whale stranded on a small sand spit off Cape Lookout, NC on January 2009. The author is standing at the head of the whale monitoring respirations and any response to loud whistles directed at the whale. The whale shows an obvious bend in the peduncle, that during the necropsy was found to be from a fractured vertebral column. *Image from UNCW Marine Mammal Stranding Program.*

WHY DO NORTH ATLANTIC RIGHT WHALES DIE AND HOW DO WE DETERMINE THAT?

WILLIAM MCLELLAN

The adult female North Atlantic right whale (*Eubalaena glacialis*) (NARW) swims slowly south into the warm subtropical waters. The ubiquitously distributed primate *Homo sapiens* has named this area offshore of Amelia Island, Florida as part of the protected calving and nursery area, just south of the Georgia/Florida border. They have also given this NARW the nickname "Lucky" and the specific catalogue identification Eg#2143. She is the daughter of Eg#1243 and she could be thinking of a fateful day seven years ago in colder northern waters. Lucky was born in 1991 and suffered a vessel strike when she was less than one year old. The vessel's propellor sliced three deep gashes into her left abdomen which she survived, although those wounds did heal slowly over time. She matured and became pregnant in 2004 with what was thought to be her first calf. After a summer and fall of feeding nearly non-stop, her abdomen swelling with her developing calf, she slowly traveled south. As she arrived off Florida, the waters calmed - she had arrived at the site where she would, like so many NARW before her, deliver her calf. But as she swam south and her abdomen swelled, the scarred-over propellor wounds began to stretch and eventually to open. The loss of structural stability of her abdominal wall allowed seawater to seep into her abdomen, which ultimately led to septicemia and her, and her calf's, death. How was this step-down of terrible consequences determined? By conducting a thorough necropsy of Lucky and her fetus to determine the cause of death of each individual whale.

When an animal dies it is often said that an autopsy was conducted, but we only conduct *auto*psies of us (*auto* meaning self, similar to we drive an *auto*mobile). We conduct a necropsy on all other animals. A necropsy technically means the study of death, but in whales, and most other marine mammals, a necropsy (sometimes called a postmortem exam) is also an opportunity to collect stored information about the individual's life, all the way from birth to death. The extent of these postmortem investigations is limited only by the condition of carcass, the data and samples that are collected, and the time available and conditions under which those inclusive investigations are conducted. As NARWs are highly endangered, we strive to maximize the information that we collect from these well-known individual whales by collecting data and samples on the cause of death, but also data on the health status and history of the animal's life. After the necropsy is completed on the beach, and samples are run in the lab, a cause of death is determined and scored as suspect, probable or confirmed (Moore *et al.* 2013). A thorough necropsy of an adult NARW may take two full days of work, from fresh tissue sampling to investigating the entire skeleton. As many as 25 people may be on the beach over the course of the necropsy and the area often resembles a construction site with large equipment moving back and forth across the beach and trucks packed with gear ringing the site (*see Figure 1 on page 26*).

The troubling truth of investigating NARW mortalities is that, in most events, the cause of death does not require extensive investigations or the running of vast numbers of tests on possible viruses or biological toxins. This quote in a recent publication that reviewed all NARW mortality investigations from 2003 - 2018 (Sharp *et al.* 2019) makes the point - "no natural mortalities were identified in adult or juvenile NARWs". All mortalities that were not newborns, where cause of death could be determined, were due to human interactions from vessel strikes or entanglement in fishing gear. All NARW postmortem investigations, from a neonatal "failure to thrive" to an adult entanglement in commercial fishing gear, requires as much time to be spent on the external exam as is spent on sampling organs for disease. With that introduction, let's walk through three NARW postmortem investigations led by teams along the US Atlantic coast. These cases will illustrate the procedures that are conducted on the beach and analyzes in various laboratories in the following weeks, months and/or years.

CASE 1: November 2004 Outer Banks of North Carolina

On 24 November 2004, the carcass of a large whale was spotted in the surf on the Outer Banks of North Carolina. The high winds and waves kept the carcass from "sanding in" as it slowly bumped down the coast over the course of the day. The local stranding responder was able to collect images that allowed the North Carolina stranding network to confirm the carcass was that of an adult NARW. That species ID initiated a coast-wide effort to pull together a team to investigate this event, and a number of people with specific large whale necropsy experience grabbed their "go bag" and headed out the door on Thursday 25 November- yes, Thanksgiving Day. The afternoon of Thanksgiving was spent collecting external images, initial morphometrics (measurements of the size of the body and appendages) and organizing sampling equipment.

The morning of 26 November started early with two large excavators being offloaded from their tractor trailers and clamoring down to beach to the site where the whale had been finally anchored in the surf the day before. It became apparent that the left fluke blade was missing and all that remained was tattered connective tissue attached to the caudal vertebral column as the fluke blades contain no bones (Figure 2). To avoid damaging that large lesion (a lesion is a region of an organ or other tissue that is damaged from trauma or disease), the two excavators worked in tandem to roll the 15m long, approximately 50,000kg carcass up the beach and above the high tide line to the site chosen for the necropsy. If it helps to visualize their immense size, an adult NARW approximates the length and width of tractor-trailer truck. Teams finished morphometrics and external images and immediately transitioned to start sampling and opening the carcass.

A necropsy is a detailed examination of the entire carcass of an animal, which documents not only lesions and pathologies, but gathers data and samples from all organ systems to describe fully the condition of the individual. A thorough necropsy is regularly performed on a mouse! The process on a NARW is more challenging, because the heart could be the size of a washer and dryer and each lung the size of a large refrigerator. To be accessed, organs must be prosected from the carcass, cut away with large knives and pulled out with tow straps or line, subsampled, then subsampled again to fit in the "standard" tissue processing cassettes. Nearly the entire world of histopathology, infectious disease and bio-toxicology is conducted with samples smaller than your pinky fingernail- which is the definition of downsizing while conducting a NARW necropsy.

During the Outer Banks necropsy, two teams started working on opposite ends on the carcass. One prosecting team focused on describing and collecting samples from the torn/severed left fluke blade. As mentioned above, the massive connective tissues that "attach" the fluke to the vertebral column had been torn off completely. The large arteries that supply blood to the fluke to maintain that tissue, but also act as the radiator to cool the entire animal, were torn

open as well. Collecting small pieces of the arteries and tissue surrounding the arteries, and fixing them in 10% neutrally buffered formalin, ultimately allowed the pathologist to confirm the animal was alive at the time of that traumatic event. Working on the head end, the other prosecting team set about documenting and sampling a deep laceration across the rostrum. Soft tissue was sampled and fixed, then a bone saw was used to saw into the left and right premaxillae bones (facial bones that form part of the rostrum) to investigate the depth of the lesion. Bone is a difficult tissue to investigate histologically because it must be decalcified before it can be fully processed. This tissue does, though, provide an excellent metric of the force required to break it/lacerate it. With those two critical lesions at opposite ends of the body sampled, the team then moved on to opening the large carcass.

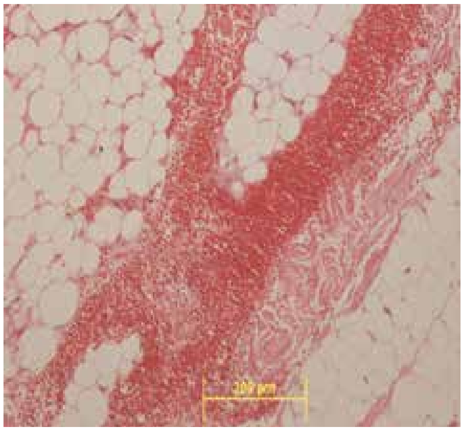
The next step was to remove the entire head from the body using long knives and heavy equipment. This process allowed the head to be moved away from the rest of the carcass, so it could be investigated and sampled in detail by one team. Heavy equipment assisted in elevating the rostrum and skull which opened the oral cavity and exposed the palate, baleen, tongue, and esophageal opening. The tongue of an adult NARW is similar in shape and size to a VW beetle! No lesions were noted in the oral cavity, which is where much of the damage seen in entangled whales is usually documented (see case description below). Working from the fluke forward, the other team opened the abdomen along the ventral midline and collected fecal and urine samples to run tests for biotoxins and stress hormones. The reproductive tract was fully exposed to document reproductive condition. Sadly, the size of the uterus suggested that this adult female was pregnant, and a fetus was found free floating in the abdomen. Samples were collected from the remaining organs that could be identified (decomposition acts fast inside a large whale) and the necropsy then moved to investigating the entire remaining skeleton. That process required disarticulating the ribs and sections of the vertebral column and moving them onto tarps where they were dissected cleanly, and any fractures or other lesions documented. The entire head was also dissected leaving a final organized "pile" of skeletal elements that were loaded onto a truck and trailer (in the middle of a howling snowstorm) and trucked north to be prepared to be exhibited.

After the team washed up (and ate a HUGE vat of lasagna), the gear was cleaned, stowed and folks traveled back to their homes. Over the following days and weeks, the investigation of this event continued. Images that were collected of the rostrum, bearing its unique callosity pattern, allowed ID specialists at the New England Aquarium to conform that this was Eg#1909 and that she was 15 years old. Histological analyses confirmed that the fluke lesions were perimortem (at the time of death). And critically, a large vessel reported that they had struck a whale a few days prior to the stranding while steaming out from the Chesapeake Bay. The timeline they described matched the calculated blood loss from the large arteries torn from the fluke leading to unconsciousness and death. The skeleton arrived in western Massachusetts where it was prepared and now is mounted in the New Bedford Whaling Museum's Jacobs Family Gallery exhibit "Skeletons of The Deep". The exhibited specimen is the first to include the skeleton of a fetal whale and is in the appropriate position, folded in half in mom's caudal abdomen.

CASE 2: December 2010 off northeast Florida

This case fully illustrates the extensive efforts that are undertaken to remove and resolve entanglements and the follow-up necropsy investigations when they are not successful. On 25 December 2010, a live NARW was spotted by the Florida Wildlife Commission's aerial survey team operating off the northeast coast of Florida. The team stayed with the whale to document its identification and to assess its health and discovered that the animal was entangled in line. At the next weather window, a team from Georgia Department of Natural Resources responded on the water and removed a large portion of the entangling line, but there was still line that could not be safely pulled free from the whale. The whale was monitored to see if it could shed the remaining gear itself, but it did not, and after two weeks a new procedure was undertaken. The new procedure was to sedate the free-swimming whale to allow the response team to work right beside the animal to cut as much line free as possible. The sedation procedure, which had taken years of collaborative planning, was a success, and more gear was removed while the animal swam. But despite these heroic efforts a small amount of line remained around the rostrum, in the mouth and around the flipper. Sadly, on 1 February 2011 the animal was found floating dead and was towed into St. Augustine Beach where a thorough necropsy was conducted.

As there was a team of veterinarians that developed and conducted the new sedation procedure, the decision was made to have the necropsy conducted by a separate team to ensure that an independent investigation of potential impacts of the sedation and



Top Left: *Figure 3.* A thin histopathology sample stained with chemicals that identify proteins. The yellow scale bar is approximately the maximum width of one human hair. The round areas on the upper left side are adipocytes, the red dots in the middle are red blood cells, and the pink swirls in the right are connective tissue. Histology preparations like these are used to determine if trauma occurred before death (pre-mortem) or after death (post-mortem). Here, the red blood cells are found outside of an artery suggesting trauma caused a rupture of the circulatory system spilling cells into surrounding tissues which can only occur while alive with normal blood pressure.
Image from Dr. Dave Rostein.

Top Right: *Figure 2.* The left missing fluke blade that was torn from Eg #1909 in November 2004. The whale is lying with its back down on the beach and the large tendons from the axial muscle are apparent on the side of the terminal vertebral column.
Image from the UNCW Marine Mammal Stranding Program.

Page 26: *Figure 1.* The scene on the beach while investigating Eg #3911 on St Augustine Beach, Florida on 2 February 2011 (Case #2). The whale and necropsy team is ringed by yellow "police tape" and the public has lined to on the shore edge to watch. The large green excavator provides the controlled force required to delicately dissect the specimen to collect both cause of death information and biological samples. The red and blue tents provide shelter to process samples collected form the carcass, out of the icy rain that fell that entire day.
Image from National Marine Fisheries Service, Southeast Regional Office.

disentanglement effort was conducted. The necropsy began early on the morning of February 2, when the carcass was pulled up onto the beach and external images and morphometrics were collected. The investigation process followed a similar path as described above. A team started to work on the head by removing the lower mandibles (lower jaws), and large tongue in one piece using heavy equipment that was brought to the beach. The entangling lines that had been worked on tirelessly by disentanglement teams on the water were found to be tied in knots inside and outside of the baleen and no amount disentanglement effort could have removed them (*see Figure 2*). A piece of line found trailing along the tongue had been swallowed by the whale, continuing deep into the esophagus. This finding made the necropsy team think of how horrible it would be if one swallowed an end of dental floss while flossing one's teeth, and it remained lodged in the pharynx and esophagus. The line that was found knotted around the baleen and down the esophagus was the proof needed to determine that entanglement had led to the long-term demise of this NARW. But it was the team working at the other end of the animal that discovered what had delivered the coup de' grace for this animal.

The entangling line had been wrapped around portions of the entire animal from head to flukes, and although large pieces had been removed by the disentanglement team, the line cut deep abrasions on the ventral peduncle near the fluke insertion of this emaciated and debilitated whale. The wounds were deep and likely were bleeding, which must have attracted one or more great white sharks to investigate what was at the end of the blood trail in the ocean. Two large bites were found on the ventral peduncle that severed the large arteries and veins that supply and return blood from the flukes (Cassoff *et al.* 2011). Again, histology samples collected from the wound site allowed the pathologist to confirm that the bites were perimortem and the weakened NARW quickly bleed to death on one of the last days of January (*Figure 3*). An extensive review of the disentanglement, sedation, tagging and necropsy results was published on this case and can be found in Moore *et al.* (2012).

CASE 3: Off Cape Lookout North Carolina

The third case begins when the US Coast Guard, returning in a large helicopter from offshore and passing over the shoaling sands off Cape Lookout, NC, reported a live stranded whale to the state stranding network on 28 January 2009. Two members of the network met the helicopter when it landed and immediately transited back out to the site 5km off the coast to view the whale. Their initial assessment confirmed a NARW was grounded on a small sand bar, but the whale was still alive. After that initial assessment it was decided to allow the whale to go through the high tide overnight to see if it would refloat and to assess it again the following day. The Coast Guard made a quick trip out to the site in a surf boat early the following morning and confirmed the whale was still there. With that news the team members got underway from NC State University, NC Maritime Museum, National Oceanic and Atmospheric Administration, Virginia Aquarium and Marine Science Center and UNC Wilmington and gathered in Morehead City, NC on 29 January. There they loaded gear into two small boats that could land on the sand bar and set out just after noon.

The team arrived an hour later to find a live NARW that had carved a deep trough into the soft sand of an island, approximately 100 meters across, which was only exposed at low tide. There were multiple gulls on the whale that had pecked holes into the blubber and across the head. The whale had a noted bend and offset of the caudal peduncle a couple of meters in front of the flukes (Figure 4). In the low-tide window available to the team, an assessment of the whale's condition and the probability that it could successfully refloat was conducted. The assembled team had hundreds of live cetacean responses and thousands of hours on beaches under its collective belt and reached the conclusion that the whale was in distress, would not recover, and that euthanasia (from the Greek "easy death") was appropriate. With the decision made, sedatives and analgesics were administered, and a combination of chemical and physical methods ended the suffering of this whale (Harms *et al.* 2014).

Nearly all NARWs have a life story that we follow from birth to death, and this whale was no different. He was the calf of Eg#2640 and had been photographed by the New England Aquarium in August of 2007 with deep line abrasions surrounding the peduncle at the insertion of the flukes. The lines were not entangling the animal anymore, but any possible internal damage remained undetermined. Two and a half years later, that entanglement played a tragic role in the deterioration of this young whale.

As sedatives were being administered to the whale, the team also collected blood samples from the flukes that would prove to be instrumental in our understanding of this whale's condition. After the animal's humane death, a full set of external data and samples were collected before we were forced off the sandbar by the rising tide. We were back on the tiny island on the following falling tide and immediately began the internal examination. As there was no equipment available on the sandbar, blubber was removed by lines toggled through it and pulled by teams of two to three "pullers". The necropsy was conducted completely by hand and samples were collected of post-mortem blood, urine and feces to provide ground truthing for all of the past (and future) samples collected from other carcasses, and of floating poop samples discovered by the famous "poop-sniffing dogs". More specifically to this case, the matched live blood and post-mortem fecal samples were published (Rolland *et al.* 2017) and showed among the highest levels of stress hormones ever tested in a whale. The ultimate reason for this animal's chronic stress was rooted back in that entanglement in 2007 that did damage to the vertebral column of the young calf.

"A taxing decision was made on that island to end this animal's suffering– little did we know how extreme that suffering likely had been."

As we exposed the vertebral column on that tiny island it became apparent that the "offset bend" seen when the animal was alive was due to chronic trauma that resulted in large scale deformation of a region of the vertebral column, axial muscles and connective tissues in the caudal peduncle. We collected a large section of the vertebral column whole, froze it in a walk-in freezer and transported it entirely as a wrapped specimen north to the Woods Hole Oceanographic Institution. There, the vertebral column was CT scanned intact and then dissected. These investigations illustrated that multiple vertebrae had suffered traumatic damage to the intervertebral discs, allowing vertebrae to rub bone on bone and to crumble apart. Ultimately, multiple vertebrae were fused together into one scoliotic mass. Clearly, this condition hampered and ultimately stopped this whale from swimming effectively and likely caused it to experience extreme pain with every up and down of the flukes (Cassoff *et al.* 2011). A taxing decision was made on that island to end this animal's suffering-little did we know how extreme that suffering likely had been.

The cases described above illustrate the extent to which these endangered NARWs are examined to determine both the cause of their death and their accumulated experiences while alive. As stated above, these investigations have revealed that all juvenile and adult NARWs examined over the past 15 years, when cause of death could be determined, died because of human activities. These necropsies have delivered the important, detailed information required to reduce, or better yet eliminate, these mortality factors. Now all that remains to do is the hard work of protecting these whales so that recovery can take place over the coming years and decades.

Acknowledgements

I would like to thank the numerous individuals that I have worked with on NARW mortality investigations along the US and Canadian Atlantic coasts. These events have required everyone to immediately drop what they were doing and run to the site where the whale will be landed, either on a beach, in a marina or in a dump and in the snow, rain or heat of summer. Each case has taken over the responders lives for days, weeks or months as the samples and data are collected, written up in expansive Gross Necropsy Reports, managing and shipping out samples and managing data returning from numerous laboratories. Individuals that need special recognition are, Amy Knowlton, Sue Barco, Deb Fauquier Teri Rowles, Alex Costidis, Craig Harms, Dave Rostein, Michael Moore and special2 recognition of my life partner Ann Pabst for always keeping the wheels on the wagon when I was "out the door" and her excellent editing skills!

References

Cassoff, R., McLellan W.A., Barco S.G, Touhey Moore K, Moore M. J. 2011. Lethal entanglement in baleen whales. *Diseases of Aquatic Organisms*. 96:175-185.

Harms, C.A., McLellan, W.A., Moore, M.J., Barco, S.G., Clarke, E.O., Thayer V.G., and Rowles, T.K. 2014. Mysticete euthanasia: Low residue euthanasia of stranded mysticetes. *Journal of Wildlife Diseases*, 50(1):63-73.

Moore, M.J., van der Hoop, J., Barco, S.G., Costidis, A.M., Gulland, F.M., Jepson, P.D., Moore, K.T., Raverty, S. and McLellan, W.A. 2013. Criteria and case definitions for serious injury and death of pinnipeds and cetaceans caused by anthropogenic trauma: underwater entrapment, chronic entanglement, sharp and blunt vessel, and gunshot. *Diseases of Aquatic Organisms*. 103:229-264.

Moore, M., Andrews, R.D., Austin, T., Costidis, A.M., George, C., Jackson, K., Landry, S., Ligon, A., McLellan, W.A., Pitchford, T., Rotstein, D., Rowles, T. Slay, C., Smith, J., Walsh, M. 2012. Rope trauma, sedation, disentanglement, and monitoring tag associated lesions in a terminally entangled North Atlantic right whale (*Eubalaena glacialis*). *Marine Mammal Science*. DOI: 10.1111/j.1748-7692.2012.00591.x

Rolland, R.M., McLellan, W.A., Moore, M.J., Harms, C.A., Hunt, K.E. 2017. Fecal glucocorticoids and anthropogenic injury and mortality in North Atlantic right whales (*Eubalaena glacialis*). *Endangered Species Research*. 34:417-429.

Sharp S.M., McLellan W.A., Rotstein D.S., Costidis A.M., Barco S.G., Durham K, Pitchford T.D., Jackson K.A., Daoust-P.Y., Wimmer T., Couture E.L., Bourque L., Frasier T., Frasier B., Fauquier D., Rowles T.K., Hamilton P.K., Pettis H., Moore M.J. 2019. Gross and histopathologic diagnoses from North Atlantic right whale (*Eubalena glacialis*) mortalities between 2003 and 2018. *Diseases of Aquatic Organisms*. 135:1-31.

A TALE OF FLOPPY TAILS:

RIGHT WHALE FEMALE-CALF PAIRS, CALVING AND NURSING

JULIA R.G. DOMBROSKI

If you ever encounter a female right whale with her calf, your heart will skip a beat. Those who have had this opportunity would agree. Referred to as mother-calf, cow-calf or female-calf pairs, the group formed by a female and her offspring are treasures of whale biology. The complex and fascinating relationship between a right whale female and her offspring depends on many variables including parental care, behavioral ontogeny, and nursing. The relevance of right whale female-calf pairs, however, goes beyond the bond between a

Grey morph southern right whale (*E. australis*) calf off southern Brazil. *Photo Credit: Lucía Martina Martín López, 2018. Permit SISBIO-60324 issued to J. Dombroski. Photos courtesy of Julia Dombroski.*

Julia R.G. Dombroski Cont.

Southern right whale (*E. australis*) calf tail slapping. When calves are born, their tails look floppy. Floppy flukes are emblematic sightings on calving grounds. *Photo Credit: Lucía Martina Martín López, 2018. Permit SISBIO-60324 issued to J. Dombroski.*

female and her offspring. Reproductively active females and calves are vital components of any population; by adding new individuals to the population pool, females hold the biological fuel for population maintenance, viability and recovery conditionally on the survival of calves. Right whale populations were severely depleted by whaling. After the international moratorium that regulated whale harvest across the globe, Southern right whales (*Eubalaena australis*- SRW) and North Atlantic right whales (*Euabalena glacialis*- NRW) have been showing distinct recovery paths. Southern right whales have been recovering throughout the southern hemisphere. Nevertheless, locally, in each calving ground, populations might be considered endangered due to increasing anthropogenic pressure from expanding urbanization and intensive use of coastal habitats. After a brief period of positive growth, when the population reached a little under 500 individuals, the abundance of North Atlantic right whales, once more, dramatically plunged. When this article was written, estimates pointed to fewer than 400 NRW individuals left. From those, fewer than 100 were presumed to be reproductively active females, suggesting that the power of promoting population growth by adding new individuals is greatly reduced. Moreover, females and calves seem to be particularly impacted by effects of climate change and anthropogenic activities aggravating the alarming status of the critically endangered NRW. Any threat to females' and calves' normal behavior, health and survival could affect SRW and NRW recovery. Therefore, investigating, understanding and protecting female-calf pairs is not only scientifically captivating; it is an essential task to inform right whale management and conservation.

Like other baleen whale species, NRW and SRW are migratory. During the summer, they feed at higher latitude feeding grounds. During winter and spring, right whales breed and calve in mid-latitude coastal calving grounds. In the Southwestern Atlantic, southern right whales travel from the Antarctic Peninsula and South Georgia to aggregate by two main calving areas in Argentina and Brazil. In the North Atlantic, North Atlantic right whales leave the Northeast coast of the United States and southeast Canada toward one known calving ground for the species in the western Atlantic, the Southeast United States (SEUS). The calving grounds are the first habitat right whale calves will know. During the 4-month stay in these warmer shallower waters, a female will solely care for their developing calf. Therefore, calving grounds are the stage of fascinating events in the life of a right whale and to study mother-calf pairs on these areas is an absolute privilege.

Most of the information, as well as the inspiration for this article, comes from my experience working off Brazil and off SEUS. Off southern Brazil, in the state of Santa Catarina, surfers and right whales share space between the waves, above sandy bottom beaches along the coast. Numerous mother-calf pairs, sometimes over 20 concentrated in a single bay, aggregate only a few hundred meters from shore. The whales` arrival is celebrated by local small businesses who support land-based whale watching and thrive with visitors attracted by the possibility of sighting a right whale.

Calves are a crowd favorite with their floppy tails and uncoordinated movements.

In comparison to southern Brazil, the coast along the SEUS is heavily urbanized and right whale sightings are sparser. Despite the army of managers and scientists looking from them, several days might go by before a female-calf pair can be found, if found at all. It is easier to find gigantic cargo ships on the horizon, pods of common dolphins, and even great white sharks than it is to find right whales. Investigating right whales on calving grounds in two hemispheres gave me the opportunity to observe how southern and north Atlantic right whales are similar but also quite different, nurturing my enthusiasm to investigate female-calf pairs on calving grounds. Throughout this article, when I refer to right whales, I will be discussing aspects that are shared by SRW and NRW. By referring SRW or NRW, I will indicate when information is related to one species or when the study I am referring to was conducted specifically on *E. australis* or *E. glacialis*. I will use these terms to share some of my favorite aspects of female-calf biology and behavioral ecology.

Every right whale calf (SRW and NRW) is cherished and celebrated by devotees, naturalists, and scientists. However, few have witnessed a female right whale giving birth. For both species, most calves are born on the calving grounds. The rare birth descriptions suggest that NRW females give birth alone; the expulsion of the calf takes less than five minutes, and while the female is below the surface blood clouds can be seen surfacing before the new-born calf emerges. All these aspects of NRW right whale parturition are in accordance with birth descriptions from other cetacean species. However, the two NRW females observed delivering calves chose distinct locations to give birth and behaved differently before and after calves were sighted. Births were observed in offshore and coastal waters on the calving ground off SEUS; while one report described of the female milling, conducting shallow dives and tail slapping before expelling the calf, another reported the female vigorously thrashing her body and rolling onto her side; while a calf was left alone at the surface for a few minutes, the other was immediately reached by the female. For right whales, like other great whales, the details of normal birthing behavior remain to be investigated. Nonetheless, the report of a calf that did not survive or perhaps was born dead, might offer clues on what is abnormal parturition behavior. An SRW off the calving grounds in Argentina was sighted belly up at the surface, amongst other whales, producing loud blows with the calf half expelled from her body. The calf was partially expelled and retracted from the female's body multiple times over two hours suggesting intense distress. The same female was sighted alone approximately two weeks after the event, and therefore, the calf was presumed dead.

> "...interactions are usually correlated with high calling rates, frequent pectoral waves, tail slaps and loud blows."

When right whale calves are born, they weigh ~1 ton and are 3-5 m in length; their flukes are limp due to their positioning in the uterus and their skin might be peeling due to differences between the chemical and physical characteristics of the in utero and ocean environment. When newborn calves are active at the surface, it is sometimes possible to notice their floppy flukes. For me, these floppy flukes are the most iconic sightings on calving grounds. Calves also have a sharp angle between their blowholes and the upper jaws which gives them a shoe-y appearance. As they grow older, the angle becomes shallower until they reach the well-known shape of an adult right whale.

By observing calves in calving grounds, you will see the origin and development of features that characterize right whales, such as callosities and skin color. Callosities are rough skin patches around some areas in the rostrum populated by cyamids (*Cyamus sp*), used to identify individual right whales. Calves are born without callosities or with smooth callosity patterns that are not populated by cyamids. Over time, cyamids are transferred from mother to calf during tactile interactions. The first species of cyamids to occupy calves' callosities are orange (*C. erradicus*); when a calf with orange callosities is sighted, we presume it is only a few days old. Over the course of few days, the orange lice are replaced by the typical white species that populates the callosities of the adults (*C. ovalis and C. gracilis*).

Most right whale calves are, like most adults, black with occasional ventral or lateral white patches. However, SRW calves might be white with black patches. White right whale calves are called grey morphs. These animals have a genetic mutation that reduces the number and size of melanocytes and the amount of melanin produced by affected individuals with no other known health effects. Unlike the white patches of normal calves, the white skin of grey morphs will turn darker with time; therefore, adult grey morphs are either dark grey or dark brown.

Despite being born able to move, breathe, and nurse independently, right whale calves depend on the female's parental care for survival. Females provide their calves protection from other whales and predators, opportunities for behavioral development, and nutrition. On calving grounds, SRW female-calf pairs spatially segregate from adults and juveniles occupying shallower waters, possibly to avoid harassment from juveniles and adult whales, and to minimize probability of interacting with predators, such as killer whales. Another strategy females might use to mitigate predation is to maintain physical proximity to calves. To do so, NRW females change their dive behavior – they increase surfacing interval and decrease dive depth when accompanied by calves. Following the physiological development of the calves, a female with an older calf has shorter surface intervals than a female with a younger calf. On calving grounds, the female and calf engage in behaviors involving consistent physical contact between them. For example, calves can be observed rolling over and riding the female's back (sometimes referred to as back riding), being carried on the female's rostrums or resting on the mother's belly at the surface. These behaviors might not only strengthen the bond between female and offspring, but they might also help the calf conserve energy by reducing costs of swimming.

In addition to bonding behavior between a female and her calf, a female-calf pair might also interact with other pairs. On the calving grounds in the southwest Atlantic, these interactions are favored by high female-calf pair density. Initiated for instance by a curious calf approaching a resting pair, interactions between female-calf pairs can involve more than two groups. These interactions are usually correlated with high calling rates, frequent pectoral waves, tail slaps and loud blows. The function of these interactions remains

Julia R.G. Dombroski Cont.

Aerial view of a mother and calf.

unknown, but it is possible that they provide opportunities for the calves to practice social and mating behavior.

During interactions between pairs, observers have a hard time tracking which calf belongs to which female. This raises the question of whether and how females and calves recognize and keep track of each other. The high value of calves and high-density aggregations of mother calves should, in theory, favor the development of a recognition system between mother and offspring. Nevertheless, documented cases of non-offspring nursing (mostly of lone potentially orphaned calves), calf swapping, and adoption of both southern and North Atlantic right whales put in check this assumption. Due to impending migration to feeding grounds, calves must develop quickly during their stay on calving grounds. Increasing frequency of separation events between a female and her calf as well as the occurrence of aerial and surface-active behaviors over time are indicators of the motor and physiological development of the calf. To preserve her valuable energy stores the female tends to assume and remain primarily in low-energy behavioral states.

Right whale females fast on calving grounds; all the energy necessary to maintain the female's metabolism comes from her internal reserves. The female also supports the calf's rapid growth exclusively with her energy reserves which are transferred to the calf through nursing. The constant production of lipid-rich milk requires massive energy investment by females causing rapid body mass decline during lactation. A female may lose 25% of her body volume during her stay on calving grounds. Evolutionarily, the massive energy investment needed to support the rapid postnatal growth of calves and the time needed for the females to restore their energy reserves may explain the long intervals between pregnancies (~3 years) of mature right whale females. On the other hand, calf growth is proportional to the female's energy investment. Southern right whale calves are estimated to gain over 450% body volume and grow 3.2 cm a day (~1 m per month) in the 3 months after birth relying exclusively on nursing as a source of energy. The rapid growth may increase the probability of SRW and NRW calf survival while decreasing their vulnerability to predation. With increasing body size, the calf's energy demands grow. Therefore, throughout the calving season, the frequency and duration of nursing bouts also increase, increasing the toll on the female's body. Whether nursing is mediated by acoustic or other communication cues is unclear. Observers often presume nursing based on the calf's positioning in the water column slightly under the females' body, facing the region that corresponds to the mammary glands' location. However, time spent under the female might not correspond to time spent nursing. Because milk transfer happens below the surface, under the female's body, it is challenging to verify if a calf is, in fact, drinking milk. Misclassifying nursing could affect estimates of energy transfer between females and calves. To decrease uncertainty in such estimates, nursing should be verified with evidence of milk transfer. Although there is no record of visual confirmation of nursing in right whales, these data are available for humpback whales. By using

handheld underwater cameras and video-enabled biologging technology, researchers visually confirmed nursing behavior in humpback whales, advancing understanding of mother-calf energy transfer dynamics. Details of right whale nursing remain to be described.

"Why is she so ...small?" was my first thought when I first spotted a female NRW accompanied by her calf off the SEUS calving ground. Despite good health, the first North Atlantic right whale I had ever seen was not as chubby as the females I was used to sight in Brazil. Neither was the second, the third, or any of them. A few years later, research by Christiansen *et. al.* would corroborate what I, and others before and after me, had anecdotally noticed: NRW lactating females have lower body condition scores compared to SRW mothers. The body condition score translates the relationship of physical structure and energy reserves and suggest that, compared to SRWs, NRW have less energy available to maintain their metabolism and to support the growth and development of the calf. This conclusion is worrisome due to potential implications for the critically endangered NRW population. Even small changes in energy reserves available to females could lead to major effects on calving intervals, probability of pregnancy, and age of first parturition. The calf`s health, and consequently their survival, could also be affected by the female`s deficit in energy reserves. For example, North Atlantic right whales born in the past decade grow up to 1 m smaller than whales born in the 1980's; this trend follows the declining body condition of females. If smaller calves are less likely to survive, these effects could seriously harm the recovery of the NRW population.

For a right whale researcher, there's nothing like a female-calf sighting. For a few seconds, time stops. While you wait for your heart to recover from that skipped beat, you can enjoy the company of a pair of the most amazing creatures on the planet. However, the wellbeing of females and calves are at risk and we must act to ensure that female-calf sightings will enchant the future generations. Throughout habitats, right whales (SRW and NRW) are exposed to a myriad of human-related threats and the cumulative impacts of this exposure on individuals and populations are already being seen. The critically endangered status of the NRW illustrates the severity of these effects. To mitigate the effects of anthropogenic threats, we must understand the right whale behavioral ecology and physiology. Our understanding of the costs of lactation for females, as well as our ability to measure body condition and growth of females and calves, represent important scientific advances that will inform impact assessment on females and calves.

However, important knowledge gaps about female-calf pairs' behavior, right whale calving, and nursing remain to be filled; for example, what communication cues mediate their interactions?, how nursing, in fact, happens?, and what are the long-term effects of poor health condition of the females for the survival of calves? Given the importance of females and calves to the right populations, baseline research on this group should be a priority topic in the right whale scientific agenda. As such, I can only hope our efforts will contribute to right whale conservation and will continuously provide us amazing, inspiring and magical sightings of female-calf pairs, from North to South, for many years to come.

Southern right whale (*Eubalaena australis*) female-calf pair off the calving ground in southern Brazil. Female-calf pairs are fascinating research models and vital components of right whale populations. *Photo Credit: Lucía Martina Martín López, 2018. Permit SISBIO-60324 issued to J. Dombroski.*

Selected References

1. Christiansen F, Vivier F, Charlton C, Ward R, Amerson A, Burnell S, Bejder L. 2018 Maternal body size and condition determine calf growth rates in southern right whales. *Mar. Ecol. Prog. Ser.* 592, 267–281. (doi:10.3354/meps12522)

2. Christiansen F *et al.* 2020 Population comparison of right whale body condition reveals poor state of the North Atlantic right whale. *Mar. Ecol. Prog. Ser.* 640, 1–16. (doi:10.3354/meps13299)

3. Taber SM, Thomas PO. 1984 Mother-Infant Interaction and Behavioral Development in Southern Right Whales, Eubalaena Australis. *Behav* 88, 42–60. (doi:10.1163/156853984X00470)

4. Taber S, Thomas P. 1982 Calf development and mother-calf spatial relationships in Southern right whales. *Animal Behaviour* 30, 1072–1083. (doi:10.1016/S0003-3472(82)80197-8)

5. Zani MA, Taylor JKD, Kraus SD. 2008 Observation of a Right Whale (*Eubalaena glacialis*) Birth in the Coastal Waters of the Southeast United States. *aquatic mammals* 34, 21–24. (doi:10.1578/AM.34.1.2008.21)

6. Foley HJ, Holt RC, Hardee RE, Nilsson PB, Jackson KA, Read AJ, Pabst DA, McLellan WA. 2011 Observations of a western North Atlantic right whale (*Eubalaena glacialis*) birth offshore of the protected southeast U.S. critical habitat. *Marine Mammal Science* 27, E234–E240. (doi:10.1111/j.1748-7692.2010.00452.x)

7. Sironi M, Marón CF, Pettite L, Guevara J, Martorel JP, Rowntree V. 2019 First record of an unsuccessful parturition of a southern right whale (*Eubalaena australis*) at Península Valdés, Argentina. *Mar Mam Sci* 35, 1587–1596. (doi:10.1111/mms.12594)

8. Fortune SME, Trites AW, Perryman WL, Moore MJ, Pettis HM, Lynn MS. 2012 Growth and rapid early development of North Atlantic right whales (*Eubalaena glacialis*). *J Mammal* 93, 1342–1354. (doi:10.1644/11-MAMM-A-297.1)

9. Meyer-Gutbrod E, Greene C, Sullivan P, Pershing A. 2015 Climate-associated changes in prey availability drive reproductive dynamics of the North Atlantic right whale population. Mar. Ecol. Prog. Ser. 535, 243–258. (doi:10.3354/meps11372)

I CAN HEAR YOU NOW:

HOW LISTENING TO RIGHT WHALES CAN HELP PROTECT THEM FROM HARM

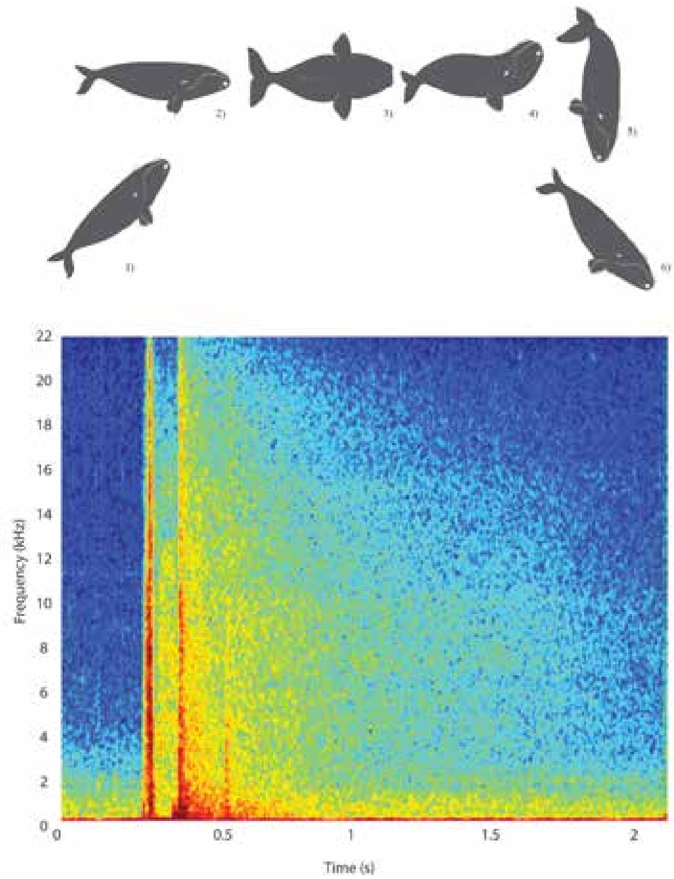
SUSAN PARKS

My Start with Whale Acoustics

Some people find their calling for their careers early in life. Some of my earliest memories are of standing with my toes buried in the sand, staring out to sea as the breaking waves rushed past my feet on the beaches of Galveston, TX. I have always been fascinated by animals, and their communication, from a very young age. From the mockingbirds singing outside my window, to the frogs in our yard, I was constantly exploring the sounds around my neighborhood growing up. My first introduction to the sounds of whales came when I was 11 years old. My father was an Electrical Engineering Professor at Cornell University and he had brought home sound clips from another researcher he had met, Chris Clark, to help in analysis of the signals. I remember listening to the whoops and squeaks from the recordings, and wondering what the whales were saying. When I went to college, Chris Clark showed up to give a guest lecture in my Animal Behavior class, outlining the fascinating world of underwater communication for these species. From that point on, I have been hooked on trying to understand what whales are 'saying' and how understanding these sounds can give us insights into their lives, and in turn contribute to their conservation. Looking back on these early experiences now, it seems unsurprising that I ended up dedicating my career to trying to unravel the mysteries of the lives and languages of whales, which remain an enduring and satisfying puzzle to be worked out.

A Brief History of Right Whale Acoustics

Some of the earliest documented recordings of baleen whale sounds, by Bill Schevill and Bill Watkins, included recordings of North Atlantic right whales off of Martha's Vineyard in Massachusetts in the 1950s and made available to the public in 1962 through their record, "Voices and Whales of Dolphins". Despite this early start, the study of whale vocalizations grew slowly as an area of research, as the tools and equipment necessary to explore the sounds they produced became more widely available to scientists in the field. A number of researchers published descriptions of observations from a variety of species in the late 60's and early 1970's. The publication of the descriptions of humpback whale songs in 1971 by Roger Payne and Scott McVay was really the first time that whale sounds captured the public's attention. Without the benefit of complex and structured song, right whale vocalizations remained mostly a mystery of belches and low frequency moans. Arguably the most significant advance in our understanding of right whale acoustics came from the graduate research of Chris Clark, the same guest lecturer whose dynamic lecture pulled me into studying whale communication when I was in college. Based on over 200 days of observation and over 1500 hours of acoustic recordings, he was able to tease apart the diversity of sounds used by right whales on their calving grounds in Argentina. He published a comprehensive study of the southern right whale repertoire, along with detailed observations of the context of sound production in the early 1980s. Despite over twenty years passing between the early reports from Schevill and Watkins, very little additional information was available about the sounds produced by North Atlantic right whales when I started my Ph.D. in 1998, working with Peter Tyack at the Woods Hole Oceanographic Institution. From my undergraduate start working in the Bioacoustics Research Program at Cornell University, I made connections with Chris Clark and Kurt Fristrup. They in turn put me in touch with Peter Tyack when I was looking into options for graduate school. At the Woods Hole Oceanographic Institution, I had the opportunity to meet Bill Watkins during my first years as a graduate student. His office was inside an old house just off the main street in Woods Hole, MA. I remember my first meeting with him, walking down a narrow corridor to enter his office where he was surrounded by piles of scientific papers and sitting in front of a vault which contained an archive of original acoustic recordings. These recordings, which provide a valuable historical record of the earliest recordings of whales, are now housed at the William



Top Right: Image showing the sequence of repetitive behaviors observed in adult male North Atlantic right whales when producing gunshots; 1-surfacing; 2-at surface; 3- flipper slapping; 4- head push with gunshot production; 5- slow dive; 6- between surfacing events. The lower panel shows a spectrogram of a gunshot sound recorded from a right whale in the Bay of Fundy. The first vertical band is produced by the whale, and the subsequent vertical bands are the surface and bottom reflections of the very loud signal.

Page 34: Image of five right whales in a Surface Active Group in the Bay of Fundy. *Photo Credit: Collected under DFO Permit. Photo by: Susan Parks. Photos courtesy of Susan Parks.*

A. Watkins Collection of Marine Mammal Sound Recordings and Data at the New Bedford Whaling Museum, where anyone can access the recordings online at: whalingmuseum.org/collections/highlights/watkins-marine-mammal-sound-recording

My meetings with Bill Watkins and Peter Tyack over the first summer of graduate school were the start of my research career studying the sounds and behavior of North Atlantic right whales. They both generously shared their time and experience to help me plan a study to shed light on the function of right whale sounds. Despite the location of my Ph.D. program in Woods Hole, only a few miles from the location of the earliest right whale recordings, my own research took place in the Bay of Fundy in Canada. A region with some of the highest tidal range in the world, and incidentally some of the fastest moving fog I've seen in my life. I spent the 5 years of my Ph.D. work collaborating with the New England Aquarium right whale research team that had been studying right whales in the Bay of Fundy since the early in 1980s. This group of amazing scientists taught me both about right whales and about conducting field research with whales, as I became part of their team to assist with visual surveys and photo-ID before I went on to collect my own behavioral and acoustic observations with their assistance (and patience!).

What do North Atlantic right whales have to say?

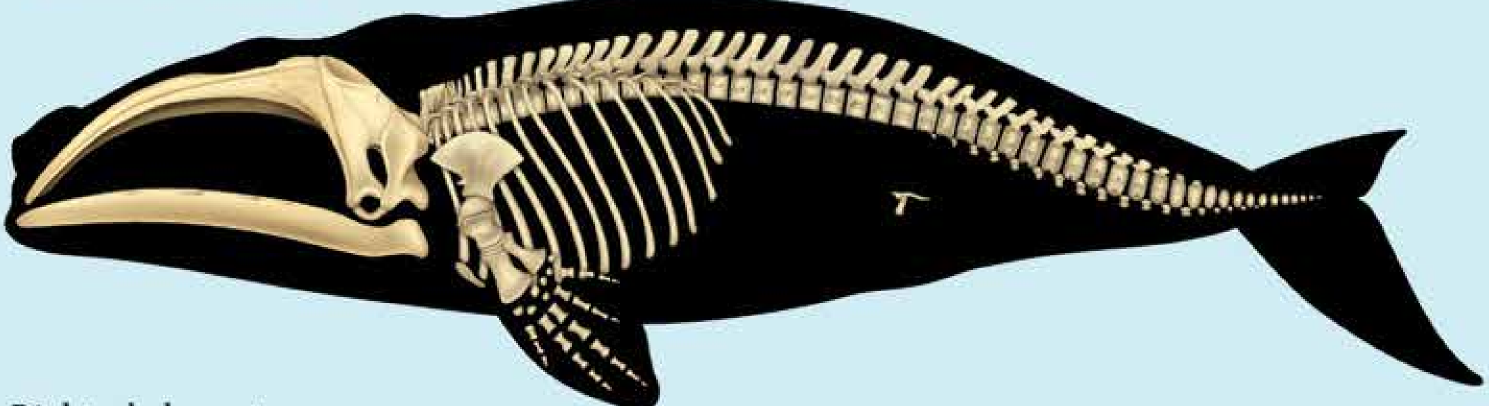
Upcalls

Most of the time, the answer to this question is "Not much". Unlike the much more loquacious humpback whale, North Atlantic right whales, particularly when alone, rarely make sounds. All research to date points to right whales using sounds primarily for social communication and they make the most sounds when they are in the largest social groups. The best known signal, included on the 1962 recordings by Schevill and Watkins, is the upcall, a simple, short ~1 second signal sweeping from about 70-150 Hz. This signal was described in southern right whales as a contact call by Chris Clark, produced by animals during separation and reunion events. In the North Atlantic, the upcall is also the only known signal to be produced by both sexes, and all age classes, from calves as young as 6 months of age.

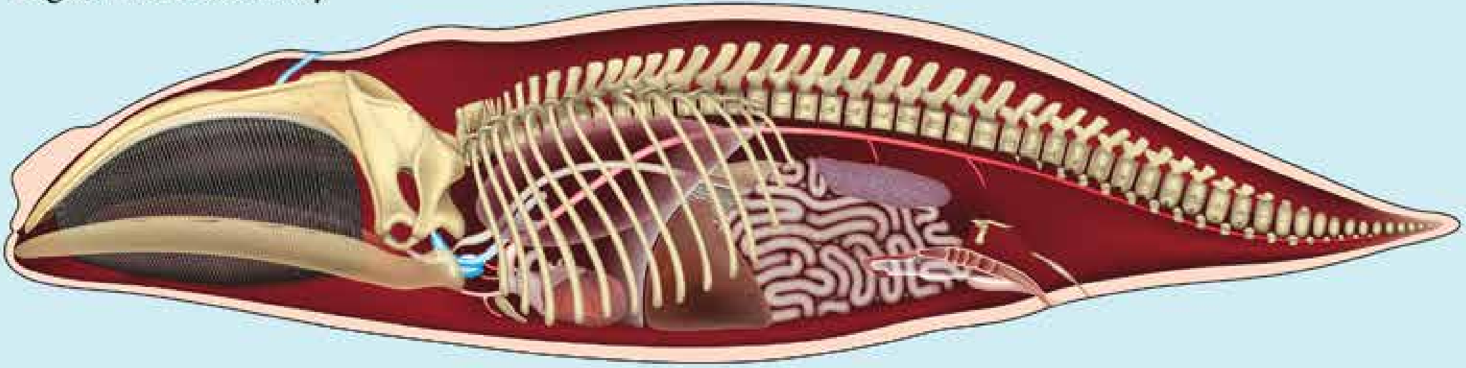
SUSAN PARKS CONTINUES ON PAGE 38

Right Whales

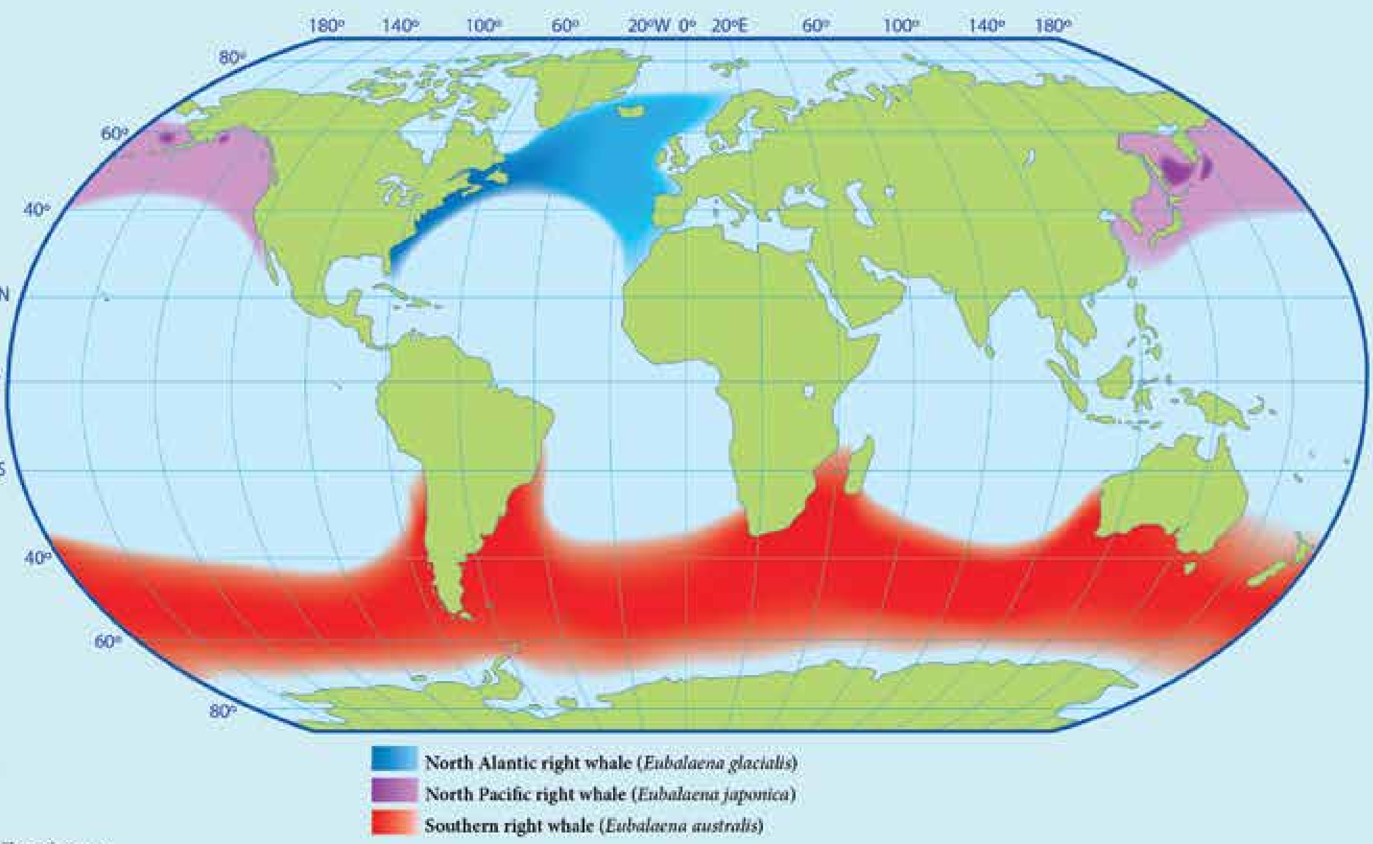
Right whale osteology

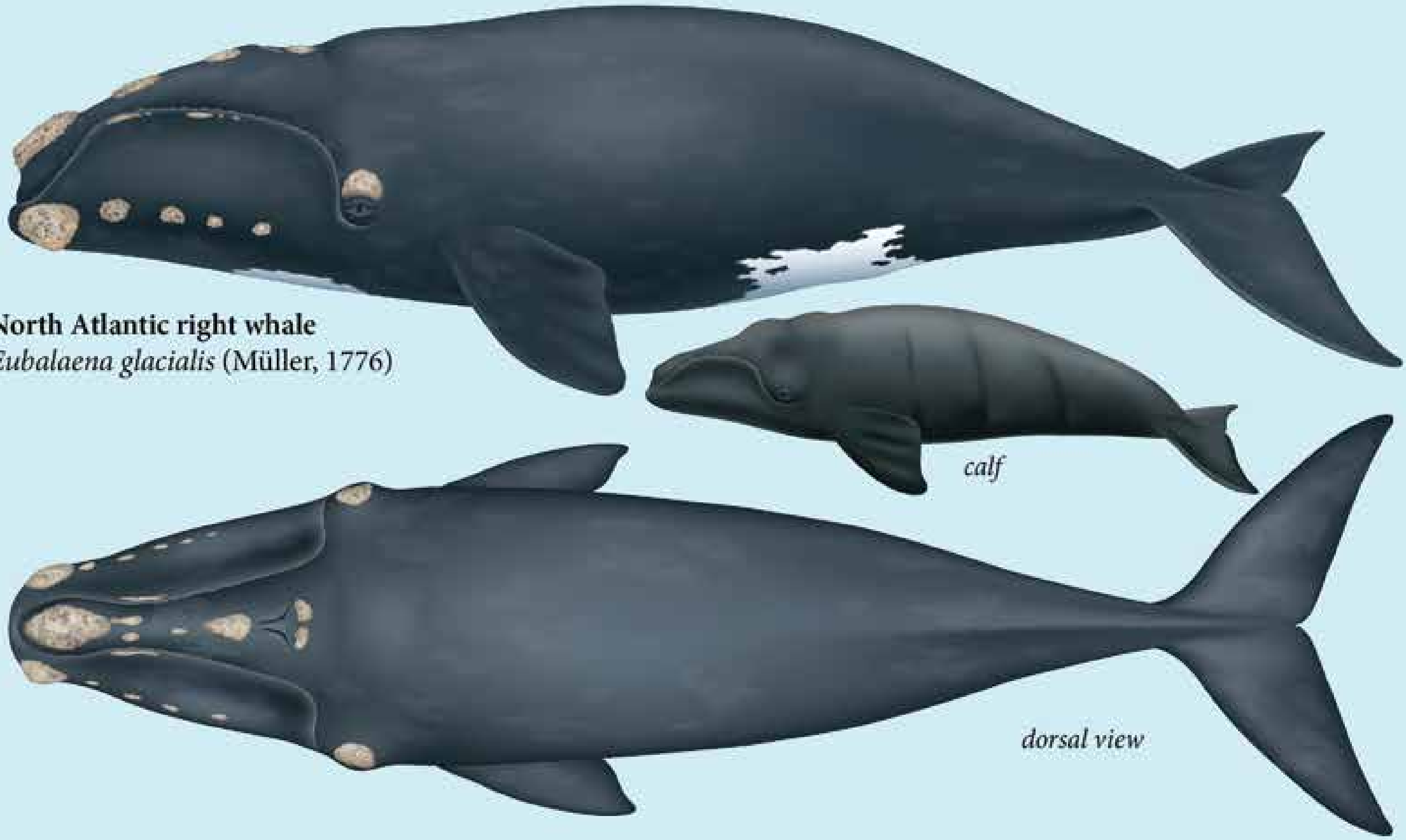


Right whale anatomy

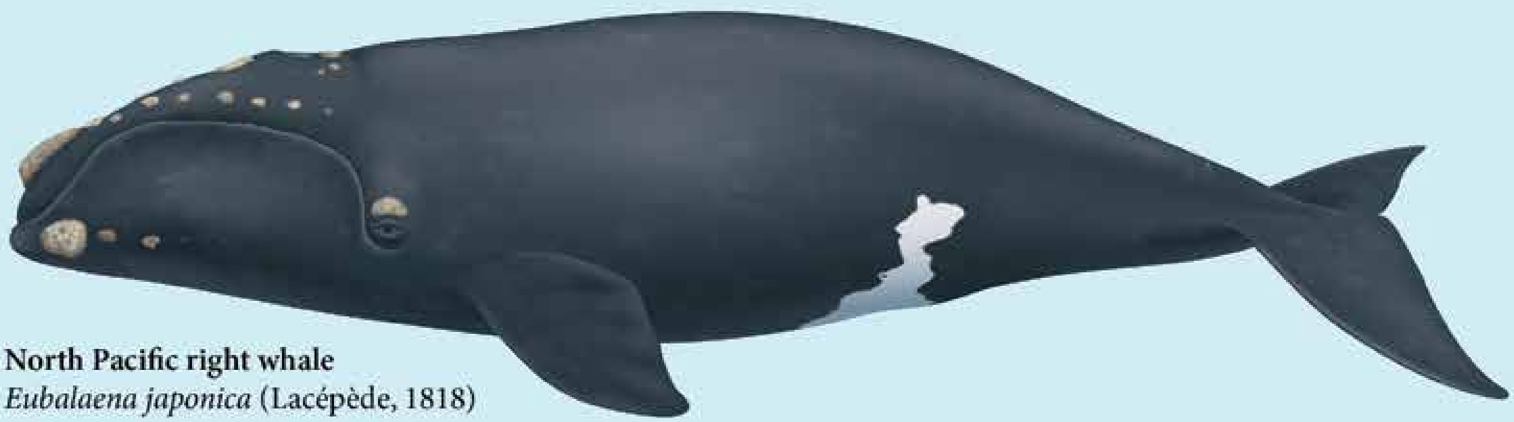


Range map





North Atlantic right whale
Eubalaena glacialis (Müller, 1776)



North Pacific right whale
Eubalaena japonica (Lacépède, 1818)

Southern right whale
Eubalaena australis (Desmoulins, 1822)

Surface Active Group Tonal Calls

Right whales do make a variety of other signals, in what is considered a graded repertoire of call types that blend across a continuum of purely tonal calls to more harsh pulsed or non-linear calls where the call energy is spread across a wide range of frequencies. Most of these more complex signals are produced in social groups, referred to as surface active groups, where groups of right whales come together to interact. These groups in the North Atlantic have been observed with as many as 40 whales in a single group and can last for several hours. In the Bay of Fundy, my first research project explored they hypothesis put forward by Scott Kraus that the central female in these groups was responsible for producing most of the sounds. I conducted playbacks of North Atlantic right whale surface active group recordings, which attracted adult males and used hydrophone arrays to confirm that most of the tonal signals are produced by the female in the group, and most vocalizations cease after the central female departs. Other sounds, including upcalls and the 'gunshot' signal are also produced in these groups and are associated with animals other than the central female joining the groups.

The 'Gunshot' Signal

Another distinctive signal produced by right whales is a loud, very short broad-band impulse signal. Chris Clark referred to this as an 'underwater slap' given its similarity to the sounds made by flippers or flukes hitting the water's surface. In the North Atlantic, this signal was referred to as the 'gunshot' as the signal and its echo in the Bay of Fundy are reminiscent of a rifle being fired. In the North Atlantic, individuals documented producing this signal on the feeding grounds have been documented over the past four decades have all been adult males. Surface observations of these males include descriptions of the whale's body jiggling like a shaking bowl of Jell-O when the sound is produced. Some individuals produce the gunshot sounds in prolonged bouts, accompanied by a repeated movement pattern of surfacings, flipper slapping and head pushing. Recently, similar repetitive bouts of gunshots recorded from North Pacific right whales have been proposed to function as a form of 'song' in that species, which would be consistent with the observations reported for North Atlantic right whales for the prolonged bouts of signals produced. Right whales also clearly use this signal in an aggressive context when they are annoyed. In surface active groups, when multiple males are jostling for position around a central female, multiple gunshot signals can be heard. Similarly, descriptions of mother's with young calves have been reported making this signal when other right whales get too close in North Atlantic right whales on the calving grounds.

> "The application of passive acoustic monitoring has allowed for a deeper understanding of right whale habitat use…"

Mother-calf Communication

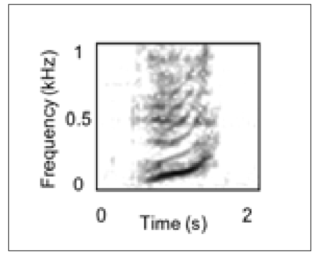
A number of recent studies have documented the sounds of right whale mother-calf pairs from shortly after birth through the summer feeding grounds. The most distinctive finding has been that mother-calf pairs rarely vocalize when outside of social situations, and they mostly keep to themselves when the calves are very young in the North Atlantic. The mothers instead produce a very quiet short grunt-like sound that allows them to keep in touch with their young calves in the murky water, without letting nearby eavesdroppers know that they are there. A link to listen to these sounds can be found at asa.scitation.org/doi/full/10.1121/1.5115332. As the calves grow, and spend more time away from their mother's and migrate up to the spring and summer feeding grounds, the call types and call rates increase as their social interactions increase. Interestingly, there is evidence that North Atlantic right whale mothers have experienced 'swapped at birth' exchanges of calves when calves are very young, suggesting that vocal recognition between the mother and calf takes time to develop.

Passive Acoustics: Listening to Know if Right Whales Are in an Area

The biggest growth in the area of right whale acoustics over the past 20 years is the use of passive acoustic monitoring, or listening, to find out when right whales are in an area. Despite relatively low rates of calling, when individual whales or groups of whales are present in an area of the ocean, acoustic recorders can document their presence by capturing their calls. The upcall has been primarily targeted as a signal for detection, given how broadly it is used by all whales in the species and its function as a long-range contact call, meaning it is the most likely signal to capture a right whale presence. This approach of passive acoustic monitoring has grown from deployments of a few recorders for relatively short periods of time in the early 2000's to the development and deployment of a range of near-real time buoys to help monitor for right whale presence in high traffic areas, such as the shipping lanes headed into Boston. These near-real time monitoring stations have expanded in use overtime from initially a Cornell based website with daily updates on right whale detections, to a now multi-region web-based application to provide ship captains real-time updates on the current conservation status and detections of both right whales near Boston harbor on an app called *WhaleAlert*, but also now other endangered whales in other regions of the world: whalealert.org.

Over the past decade, mobile platforms such as underwater autonomous vehicles called gliders have been sent out to do passive acoustic surveys of areas, and report back when right whale calls are detected. These near-real time monitoring efforts use either cellular connections or satellite connections to alert scientists on shore when right whale upcalls are detected. These tools are multi-purpose, as they can aid scientists in locating aggregations of right whales for focused research efforts, as well as inform conservation agencies and ocean users of the potential for right whale presence in a particular area.

The application of passive acoustic monitoring has allowed for a deeper understanding of right whale habitat use, including evidence for right whale presence year-round in the northern habitats that were previously thought to function as summer foraging grounds. A recent review combining over 10 years of long-term acoustic recordings along the East Coast of the United States has documented a shift in the timing and habitat use of right whales that occurred in 2010, when there was a major change to the Gulf of Maine ecosystem that impacted the food chain that right whales depend upon. Right whales



Left: Members of the New England Aquarium Right Whale Field team on the front steps of the field house in Lubec, Maine in August 2000. Back row from left: Susan Parks, Alicia Windham-Reid; 2nd row from left: Christopher Slay, Heather Pettis, Beth Pike; 3rd row from left: Lisa Conger, Amy Knowlton, Stephanie Martin, 4th row from left: Jackie Ciano and her nephew.

Right: Spectrogram image of a right whale upcall, showing frequency on the y-axis and time on the x-axis. The energy of the signal is indicated by the darkness of the shading on the image.

are now spending more time in the Mid-Atlantic regions than they did before 2010 and have shifted farther North during the peak feeding season to Canadian waters in the Gulf of St. Lawrence. This shift coincided with a marked increase in right whale mortalities. The right whales moved in large numbers into areas with fishing and shipping activity that was did not have conservations efforts in place to minimize interactions with right whales due to their previously infrequent use of the area. Future conservation efforts for right whales must rely on passive acoustic detections to identify these shifts in distribution that are likely to become more frequent with climactic shifts in the ocean habitat, so that conservation efforts can be put in place to avoid unnecessary deaths that occur when right whales show up in unexpected places at unexpected times.

While these passive acoustic monitoring efforts have given us an increased understanding of right whale habitats and improved our understanding of when they are in a particular area in need of protection, this is not a perfect solution. Passive acoustic monitoring requires right whales to make a sound for us to detect them. Focused behavioral studies make it clear that mothers with young calves, and whales not engaged in social interactions (such as whales actively feeding), rarely make sounds that would be picked up by monitoring devices. This makes it important to remember that while detecting a right whale call means a right whale is present, NOT detecting a call does not confirm that they are absent from a habitat area. Other methods of detection, such as visual surveys, are needed to supplement acoustic surveys.

Closing

Looking back, I feel like it is unsurprising that right whales ended up being the primary study species in my career thus far. From early interactions with Chris Clark, the world's expert on Southern right whale acoustics, to fortuitously crossing paths with Bill Watkins at the Woods Hole Oceanographic, I had some of the earliest pioneers of right whale acoustics as guides and inspiration. This was a path that I started on over 30 years ago when I had the chance to listen to whale recordings on my father's computer. I have spent my career chipping away at the unanswered questions about their communication. Though much of the research progress has been slower than I would wish, due to their endangered status and small population size, I am thankful to be part of the scientific community contributing to the conservation of this critically endangered species.

References

Baumgartner, M. F., Fratantoni, D. M., Hurst, T. P., Brown, M. W., Cole, T. V., Van Parijs, S. M., & Johnson, M. (2013). Real-time reporting of baleen whale passive acoustic detections from ocean gliders. *The Journal of the Acoustical Society of America*, 134(3), 1814-1823.

Clark, C. W. (1982). The acoustic repertoire of the southern right whale, a quantitative analysis. *Animal Behaviour*, 30(4), 1060-1071.

Clark, C. W. (1983) Acoustic communication and behavior of the southern right whale (*Eubalaena australis*). U: Communication and Behavior in Whales. Ed. R. Payne. : 163-198.

Crance, J. L., Berchok, C. L., Wright, D. L., Brewer, A. M., & Woodrich, D. F. (2019). Song production by the North Pacific right whale, *Eubalaena japonica*. *The Journal of the Acoustical Society of America*, 145(6), 3467-3479.

Cummings, W. C., Fish, J. F., & Thompson, P. O. (1972). Sound Production and Other Behavior of Southern Right Whales, *Eubalena glacialis*. San Diego Society of Natural History.

Davis, G.E., et al., (2017). Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014. *Scientific reports*, 7(1), pp.1-12.

RG Dombroski, J., Parks, S. E., AC Flores, P., Martín López, L. M., Shorter, K. A., & Groch, K. R. (2020). Animal-borne tags provide insights into the acoustic communication of southern right whales (*Eubalaena australis*) on the calving grounds. *The Journal of the Acoustical Society of America*, 147(6), EL498-EL503.

Gerstein, E. R., Trygonis, V., McCulloch, S., Moir, J., & Kraus, S. (2014). Female North Atlantic right whales produce gunshot sounds. *The Journal of the Acoustical Society of America*, 135(4), 2369

Parks, S. E. (2003). Response of North Atlantic right whales (*Eubalaena glacialis*) to playback of calls recorded from surface active groups in both the North and South Atlantic. *Marine Mammal Science*, 19(3), 563-580.

Parks, S. E., & Tyack, P. L. (2005). Sound production by North Atlantic right whales (*Eubalaena glacialis*) in surface active groups. *The Journal of the Acoustical Society of America*, 117(5), 3297-3306.

Parks, S. E., Hamilton, P. K., Kraus, S. D., & Tyack, P. L. (2005). The gunshot sound produced by male North Atlantic right whales (*Eubalaena glacialis*) and its potential function in reproductive advertisement. *Marine Mammal Science*, 21(3), 458-475.

Parks, S.E., Brown, M.W., Conger, L.A., Hamilton, P.K., Knowlton, A.R., Kraus, S.D., Slay, C.K. and Tyack, P.L., 2007. Occurrence, composition, and potential functions of North Atlantic right whale (*Eubalaena glacialis*) surface active groups. *Marine Mammal Science*, 23(4), pp.868-887.

Parks, S. E., Searby, A., Célérier, A., Johnson, M. P., Nowacek, D. P., & Tyack, P. L. (2011). Sound production behavior of individual North Atlantic right whales: implications for passive acoustic monitoring. *Endangered Species Research*, 15(1), 63-76.

Payne, R. S., & McVay, S. (1971). Songs of humpback whales. *Science*, 173(3997), 585-597.

Schevill, William E., Watkins, William A., "Whale and porpoise voices : a phonograph record", 1962, https://hdl.handle.net/1912/7431

Van Parijs, S. M., Clark, C. W., Sousa-Lima, R. S., Parks, S. E., Rankin, S., Risch, D., & Van Opzeeland, I. C. (2009). Management and research applications of real-time and archival passive acoustic sensors over varying temporal and spatial scales. *Marine Ecology Progress Series*, 395, 21-36.

CANADA'S CRITICAL ROLE IN NORTH ATLANTIC RIGHT WHALE CONSERVATION

SEAN BRILLANT AND KIM DAVIES

Myself and Dr. Moira Brown photographing a right whale in the Gulf of St Lawrence. *Photo Credit: Canadian Whale Institute/New England Aquarium/University of New Brunswick. Photos courtesy of Sean Brillant and Kim Davies.*

In recent years, North Atlantic right whale (hereafter NARW) presence has increased in Canadian waters through both longer seasonal presence, and a broader geographic range. As Canada has worked to adapt protection measures to these changes, the number of coastal communities affected by NARW conservation has increased, as have the number and types of fisheries, fishing areas and shipping routes. The work Canada has undertaken to protect NARW is not clearly understood to many Canadians and even less so by many in US who are invested in or affected by the steps being taken to ensure the survival of this species. This paper is intended to provide a general explanation of what has occurred in Canada to protect this species, thoughts about what motivated these efforts, and speculation about what Canada may do in the immediate future related to NARW.

Late to the Game

The North Atlantic right whale was designated as Endangered Species in Canada in 1980 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and formally protected by law when the Species At Risk Act (SARA) came into force in 2002. Prior to 2017, Canada had created a federal (i.e., SARA) Recovery Strategy for NARW through which two critical habitats were identified, modified shipping patterns around these critical habitats to reduce risk of vessel strikes, and supported efforts by fisheries in the Bay of Fundy to find and to share the locations of NARW during fishing seasons. Beyond this, little else was done to reduce the risks they faced from their greatest threats then, and now; entanglement in fishing gear and strikes by ocean-going vessels.

Beginning in 2010, NARW calving rates began to decline precipitously and the number of sightings of NARW in the Canadian critical habitats began to decrease. Several recent studies have shown that these events coincided with notable changes in circulation of the North Atlantic, a warming of deep waters in the Gulf of Maine, and a large decline in the productivity of *Calanus finmarchicus*, a copepod that is an important food source for NARW. Acoustic surveys during this time suggest that NARW were dispersed throughout Atlantic Canadian waters until 2014, but in 2015 acoustic detections began to increase in the southern Gulf of St. Lawrence (GSL). Aerial surveys of the southern GSL began in 2015 and large numbers of NARW were immediately detected, including the first NARW carcass. More NARW were detected in the southern GSL in 2016, but the elevated mortalities were not discovered until 2017.

On June 6, 2017, the carcass of a NARW was seen floating in the GSL. By the end of that summer, twelve NARW had been found dead in Canadian waters and five others were entangled, but still alive. The Government of Canada was attentive to the situation from the beginning, but after the sixth carcass was found within eight days it began a series of unprecedented actions intended to reduce the mortality event that was emerging. This included first limiting the area of the snow crab fishery in the southern GSL then implementing an early end of season for the fishery, and eventually imposing speed restrictions on cargo vessels (> 300 gross tonnage) traveling through the GSL.

Since 2017, Canada has continued to revise management measures each year to manage our fishing and shipping activities, facilitated the development of

substantial monitoring programs to support these measures, and invested heavily in research, stewardship, engagement, and risk mitigation activities both within and outside government. Canada's management measures for fisheries and vessel traffic are unique sets of annual rules that are reviewed, revised, and announced early each year, prior to the start of the NARW seasonal occupancy period. Although these measures appeared to be successful in 2018, and again in 2020 and 2021 as there were no detected NARW deaths during these years, in 2019 a second period of elevated mortalities occurred and nine more NARW were found dead in Canadian waters.

Why the Change

Several factors likely contributed to the initial and ongoing historic attention and effort by Canada to protect this species. The decision in late-2016 by the US to enforce marine mammal bycatch reduction standards of the Marine Mammal Protection Act (MMPA) on countries importing seafood into the US was, however, a powerful motivation. For Canadian lobster and snow crab fisheries, this represented more than 90% of their market of almost $3 billion of landed seafood value. Suddenly Canada had to act. Other reasons that may have prompted these historic efforts likely included the growing interest from US scientists to survey the GSL, the establishment of a new Canadian parliament in late-2016, and an unfavourable 2018 audit of Canada's responsibility to protect marine mammals by the Office of the Auditor General's Commissioner of Environment and Sustainable Development. Another likely reason was that a highly trained volunteer whale entanglement response specialist was killed while removing gear from an entangled NARW in the GSL in 2017. This sad and tragic event brought to light the risks that these responders had been facing for many years with little support from the federal government. Regardless of the reason, by limiting its fisheries and shipping activities on a large scale, Canada began momentous efforts in 2017 to prevent harm to NARW and this effort continues today in 2021.

Signs of Commitment

Canada appears to be establishing a long-term commitment to protect this species most evident by its unprecedented investment in assets relevant to this issue since 2017. For example, the federal government has hired many more marine mammal scientists and specialists in recent years, there have been large acquisitions of equipment (e.g., hydrophones, aerial drones, underwater autonomous vehicles) and vehicles (i.e., aircraft) for surveillance, and the number of government funding programs supporting science and management for whale conservation (e.g., Canada Nature Fund for Aquatic Species at Risk, Marine Mammal Response Program, Canadian Space Agency Smart Whales Initiative, National Science and Engineering Research Council Whale Science for Tomorrow) has increased from the single program (Habitat Stewardship Program) prior to 2017.

It is likely the MMPA requirements for US market access is still motivating Canada's efforts to eliminate risks to NARW, and that this will continue into the future. A decision on Canada's comparability to US MMPA bycatch standards for seafood imports is currently expected in 2022, and Canada has been striving to meet these standards, but it is likely these will need to be adhered to in the years to come. Economic sustainability of the most valuable fisheries in Canada is now clearly all about their ecological sustainability.

Conservation efforts for NARW may also be sustained in Canada because of the ongoing and growing knowledge and attention by the public on this issue. News agencies, NGOs, and even researchers are providing an increasing amount of public information about the situation. Documentaries are being created, and general knowledge by the public about the situation is deepening. Everyone sees that the situation is wrong and that the harm caused to NARW by our ocean activities must not continue. This is not simply a case of the diminishing numbers of a distant, rarely seen animal. The declining population of NARW is a situation about our inattentiveness causing suffering, and about the need for our country and its ocean industries to act in a responsible manner to prevent needless damage to our wildlife heritage.

Knowing Now What We Didn't Know

Our knowledge of the situation with NARW has improved considerably since 2017. The abrupt disappearance of NARW from their established feeding areas in the Gulf of Maine– western Scotian Shelf region, and their increased occurrence in a previously unknown, and more northerly, habitat (the Gulf of St. Lawrence) has been the critical factor driving this situation. This abrupt distributional shift has effectively resulted in a significant range expansion of the NARW population in Canadian waters, and has, therefore, increased the area over which NARW require protection in our waters. These changes are related to climate change impacts on the entire North Atlantic Basin, which predictive models suggest will continue in the present direction, eventually making the Gulf of Maine region permanently unsuitable habitat for *Calanus* (i.e., right whale prey). It would be wise to anticipate that there may be further changes to the distribution of NARW and other whales in the future in response to a rapidly changing ocean. The nature of these changes is difficult to predict because we do not have good sampling of NARW prey throughout their range. As we can expect this will continue as our oceans change, this means more fisheries, shipping routes, and communities will be affected by the presence of these animals in the future.

Our knowledge of the sources of risk that NARW face has also improved. For example, we are learning that it is not only active fishing gear that can harm NARW, but that fishing gear that is lost or left behind after the end of a fishing season is a larger problem than expected. We have also learnt that the growth of individual NARW and reproductive rates of the entire population are both stunted compared to other right whale species, and this is likely due to the numerous harmful, but non-lethal stresses inflicted on them by our ocean activities. Entanglements and ship strikes have long lasting harmful effects even if the animal survives the ordeal. The survival of this species is, therefore, not only about reducing the number of animals we kill each year. We need to reduce the harm we are causing them as they are struggling to survive in this changing, and food-limited ocean.

Myself and my technician deploying oceanographic instrumentation to measure right whale food in the foraging habitat in the Gulf of St. Lawrence.

Canada's Transformation

Today, Canada is better prepared to respond to and to prevent another mass mortality event like those in 2017 and 2019. Since 2017, there have been tremendous efforts by the Canadian government and its allies in industry, academia, the non-governmental sector, and the public to prevent NARW injury and death by ocean activities in Canada. Ice breakers have been commissioned to clear harbours of ice to allow fisheries to begin sooner in early spring to ensure more quota is landed, and thus more gear is out of the water before the NARW arrive. A large surveillance effort to detect NARW occurs from spring through autumn (April – November) each year. Tens of thousands of square kilometres of the GSL have been closed to fishing each year since 2017 to prevent entanglements. Complex and dynamic speed management measures have been imposed on international shipping traffic through the GSL. And the entire management system for fisheries and vessel traffic management have been changed to incorporate efforts to protect NARW. Most importantly, the Canadian government has demonstrated itself to be adaptive, collaborative, and focused on prevention, rather than entanglement mitigation or alleviation, in addressing threats to these whales.

Much Work Remains

Despite these efforts, NARW continue to become entangled in fishing gear in Canadian waters, and the population continues to decline as of 2021. We have presented evidence that Canada is committed to protecting NARW, but there is no binding legal commitment by the Canadian government to maintain the new NARW management measures or new monitoring programs in the long term. The situation remains fragile. Canada must continue the collaborative and adaptive path we set out on after the 2017 mortality event, particularly as it is likely Canada will have to take on a more critical role for the survival of the NARW in the future. It is our hope that Canada and all nations will see that efforts to reduce incidental harm from our ocean activities is the best way to serve our people, and to respect and to protect the benefits we gain from our oceans.

Above: A different marine mammal. Wild ponies, Assateague Island. *Photos courtesy of Kyla Bennett.*

CAN WE SAVE THE NORTH ATLANTIC RIGHT WHALE?

KYLA BENNETT

"You can do the best science in the world but unless emotion is involved it's not really very relevant. Conservation is based on emotion. It comes from the heart and one should never forget that." —Conservationist and biologist Dr. George Schaller.

I always knew that I wanted to spend my life saving animals and their habitats. After getting a bachelor's degree in animal behavior, I pursued my PhD in Ecology and Evolutionary Biology, assuming that a doctorate would prepare me for work in wildlife conservation. For my dissertation, I studied wild pony behavior on Assateague Island, which meant living in a

Kyla Bennett Cont.

tent nestled in windswept dunes for four months each year. I spent so much time with the ponies that one of the stallions, John, would herd me with his mares every time he wanted to move down the beach. John thought I was part of his harem. Luckily, having me with hang out with him and his herd was all he wanted from me.

In the fourth year of my five-year field work on Assateague, the National Park Service (NPS) decided that there were too many ponies on the small barrier island, and that the herds should be culled. Several of the herds had territories that overlapped with the two campgrounds on the island, and these ponies were unafraid of people. They learned to raid coolers for watermelon and beer, turn on outdoor taps to get fresh water to drink, and even pull hamburgers off hot grills to eat. Culling these animals would be easy; the NPS proposed luring them into trucks with bags of chocolate chip cookies or doughnuts – their favorite treats – to be relocated elsewhere.

Unfortunately, the NPS planned to cull the ponies without any regard to the herds' social structure. If they removed the stallion, or the dominant mare, the herd would struggle, and probably fall apart. If they took a mother who was still nursing her foal, it could mean foals starving to death. It would have also ruined years of research, including my own, but my primary concern was the ponies themselves. So I did what I had to do – I contacted the press, and threatened the NPS with a lawsuit. I ended up on the local television station, and ultimately, under pressure from the public, the NPS reversed their decision and abandoned their plan to cull the herds.

While I had saved the ponies, I got myself in hot water at graduate school. Someone called my advisor, and told them I was "too emotional," and that it was clear I could not conduct unbiased research. My advisor lectured me sternly – there was no place for emotion in research, and getting too close to your study animals was unacceptable. Good scientists – especially good *male* scientists – never got emotionally involved with their research subjects. They were just animals, after all.

I knew I wanted to advocate for wildlife, and clearly, academia was not the place to do that. I decided then and there to go to law school, so I could protect animals without being accused of being an emotional woman who cared too much about her subjects. After law school and a decade-long stint at the U.S. Environmental Protection Agency (EPA) saving wetlands, I wound up in an animal welfare organization working on, among other things, the North Atlantic right whale.

Which is how I found myself, twenty years ago, on a research vessel in the Bay of Fundy, surrounded by roughly ten percent of the entire right whale population, a hydrophone broadcasting their vocalizations to surrounding whale watch boats. Curious whales approached us, and as I gazed into the eyes of these magnificent, sentient creatures, I knew that the only way to get people to care about their plight was to get them to love the whales. To get emotional. As Jacques Cousteau once said, "You can't save what you don't love, and you can't love what you don't know." We must know – and love – right whales in order to save them.

Save the Whales

"This planet is threatened with destruction, and we who live in it, with death. The heavens reek, the waters below are foul..." These chilling words were spoken by biologist Barry Commoner, on the very first Earth Day, April 22, 1970. Citizens concerned with oil spills, polluting factories, rivers catching on fire, pesticides killing bald eagles, the destruction of wilderness, and extinction of wildlife, gathered forces around the world to draw attention to a planet in peril. The fear was bipartisan, and it resulted in a heyday for the environmental movement: the EPA was

Top Right: Wild pony, Assateague Island.

Page 44: Kyla Bennett and a research assistant engaged in observational study of wild ponies, Assateague Island.

formed, the Clean Air Act, Clean Water Act, the National Environmental Policy Act, and the Endangered Species Act were all passed, and in 1975, the environmental non-profit Greenpeace introduced its "Save the Whales" campaign. Suddenly, whales became the face of the environmental movement.

Roughly 50 years later, despite the fact that commercial whaling had ceased in the United States and most other countries around the world, whales are still in peril from pollution, climate change, fishing, ships, seismic testing, and ocean noise. North Atlantic right whales (*Eubalaena glacialis*) were hunted to near extinction by the 1890s. Called the black whale, nordcaper, sletback, or seven-foot bone whale, eventually humans settled on the name "right whale" because they were the "right" whale to kill due to their thick layer of blubber which made them float when slaughtered. Right whales have been listed as endangered under the Endangered Species Act since 1973, and they are currently Critically Endangered according to the International Union for Conservation of Nature (IUCN) Red List, the comprehensive inventory of the global conservation status of species around the world.

North Atlantic right whales live in the Atlantic Ocean, migrating to the warm waters of Georgia and Florida to give birth, and up into Canadian waters in warm summer months. The species has never quite recovered from commercial whaling, and today, they are facing extinction due to entanglement in fishing lines and vessel strikes. The population has dropped to roughly 350 animals. Virtually all mortality where we know the cause of death is from entanglements or ship strikes. In other words, because of humans.

The Laws Purporting to Protect Right Whales

In the USA, right whales are protected by two major federal laws, the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). Both laws are supposed to protect marine species and their important habitats from harm. Specifically, the ESA protects and implements recovery of imperiled species and the ecosystems upon which they depend. The MMPA protects *all* marine mammals (whether they are listed as threatened or endangered under the ESA or not) and their habitats by maintaining the health and stability of the marine ecosystem. The North Atlantic right whale is therefore protected under both laws, because it is a marine mammal, and because of its endangered status. Because right whales are a marine species, their recovery is overseen by the National Oceanic and Atmospheric Administration (NOAA), located in the Department of Commerce. Ironically, NOAA is tasked with a conflicting dual mandate: to regulate and sustain marine fisheries, *and* to protect endangered marine species and their habitats.

Both the ESA and the MMPA have provisions making it unlawful to "take" protected species. The word "take" is defined broadly to include not just physical harm, but also harassment, and also covers both intentional and unintentional harms. Entanglement in fishing gear, therefore, is considered a "take" under both statutes. NOAA can authorize what is known as an "incidental take," or an unintentional take, under certain circumstances, and after following the procedures set out in the laws.

The Endangered Species Act

Specifically, the ESA allows NOAA to approve incidental takes of right whales so long as such take does not jeopardize the continued existence of a threatened or endangered species, or adversely modify critical habitat. Therefore, NOAA has a duty to ensure that any action it or any other federal agency takes is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of the species' designated critical habitat. If a proposed action "may affect" a listed marine species, the agency taking such action must consult with NOAA.

This consultation results in NOAA issuing a Biological Opinion, which is a formal finding as to whether the proposed action results in jeopardy to the species. NOAA can issue a "no jeopardy" finding, which means the action can proceed, or it can find jeopardy, which prohibits the action from occurring.

Whenever a fishery management involves utilization of gear known to interact with an ESA listed species, there is the potential for adverse effects. When an ESA consultation is required for a Fishery Management Plan, NOAA acts as *both* the agency taking the action (i.e., authorizing a fishery), and the consulting agency. In other words, NOAA consults with itself, and when it does, it looks for win-win solutions that simply do not exist.

The Marine Mammal Protection Act

Under the MMPA, NOAA can authorize some incidental takes of right whales during commercial fishing operations. Before issuing such a take permit,

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NOAA must find, among other things, that mortality and serious injuries caused by commercial fishing will have a negligible impact on the stock. NOAA issues annual reports on the status and trends of each population of marine mammals, and contained in these reports is a number that represents the "potential biological removal" (PBR), or the number of individuals that can be lost due to human causes without undermining the sustainability of the stock. If the commercial fishing causes more mortality and serious injury than the PBR level, NOAA cannot conclude that fishing will have a "negligible impact" on the species.

However, if a population is listed under the ESA, as is the right whale, NOAA can mitigate impacts by developing Take Reduction Plans to prevent depletion of the population from interactions with certain fisheries. These Take Reduction Plans are supposed to reduce mortality and serious injury of the population within six months such that it is reduced below the PBR. And, within five years from its implementation, the Take Reduction Plans are supposed to reduce mortality and serious injury from the commercial fishery to insignificant levels.

In NOAA's most recent MMPA Report for 2019, which covers the years 2013 to 2017, the annual PBR for right whales was estimated at 0.8. This means that NOAA estimates if less than one right whale dies each year from human activity (such as entanglements or ship strikes), the species will still be able to reach its optimum sustainable population.

This fact is worth repeating: NOAA, the federal agency tasked with saving the critically endangered right whale, estimates that less than one individual can die each year from entanglements and ship strikes.; As right whales have experienced much higher human-caused mortality than this over the past two and a half decades, they have not recovered from whaling as they could, or should, have. This, in turn, has meant that when conditions worsened for them since 2010, there has been less buffer protecting them from the extinction risk that they now face.

Are the ESA and the MMPA Protecting the North Atlantic Right Whale?

Despite the fact that right whales are ostensibly protected by these two powerful environmental laws, the federal government is failing miserably to protect this iconic species from entanglements and ship strikes. A deep dive into these threats show us why.

Entanglements in Fishing Gear

Fixed fishing gear is used in several fisheries, including the groundfish fishery using sink gillnets, and the lobster fishery using traps and pots. This gear is placed or anchored on the ocean floor and connected to a buoy at the water's surface by vertical lines in the water column. These vertical lines form a gauntlet through which right whales have to swim; because right whales tend to roll when they hit one of these lines, entanglements are inevitable. Unfortunately, right whale deaths due to entanglements have increased in the last decade as the lines have gotten stronger and the gear on the ocean floor has gotten heavier. There are an estimated one million vertical lines in right whale habitat during prime fishing season. Entanglements are most common in the mouths, appendages, and tails of right whales. As Philip Hamilton and Amy Knowlton note in their chapter, from Catalog data, scientists estimate that 87% of right whales have experienced one or more entanglements.

To make matters worse, these chronic entanglements have contributed to vastly reduced calving rates – where an average female previously calved once every three to four years, she only calves once every nine to ten years now. So not only do entanglements kill right whales outright, the stress of entanglements reduces their fecundity.

NOAA conducted its first ESA consultation for the lobster fishery in 1988, where it surprisingly found that lobstering was unlikely to adversely affect the species. And, in 1994, NOAA issued a Biological Opinion concluding that the lobster fishery would not result in jeopardy to the right whales. But in 1995, five right whales were found dead, and another eight perished in 1996 – five of these deaths were known to be due to entanglements. NOAA had no choice but to issue another Biological Opinion, and this time, they found that the lobster fishery was likely to jeopardize right whales. Unfortunately for the right whale, NOAA also concluded that seasonal prohibitions on lobstering were enough to avoid this jeopardy. So lobstering in right whale habitat continued.

A Take Reduction Plan was created, and NOAA created the Atlantic Large Whale Take Reduction Team (ALWTRT), a team of people with expertise in the species of concern, or expertise in the fisheries impacting the whales. The ALWTRT published its first Take Reduction Plan (ALWTRP) in 1997, focused on reducing whale entanglements with fishing gear. Over the years, NOAA made gear modification requirements as suggested by the ALWTRT, and instituted seasonal closures for certain fisheries, including the lobster fishery. And at first, it seemed to be doing some good – the right whale population grew to an estimated 481 individuals by 2011.

But then, the right whale population started declining, with deaths outpacing births. In 2017, NOAA declared an "Unusual Mortality Event (UME)," an unprecedented number of deaths. The statistics are horrifying: 17 confirmed dead right whales in 2017; three in 2018; ten in 2019; two in 2020; and to date in 2021, two more dead. Since 2017, then, roughly 10% (34) of the entire population of right whales have been found dead, with countless more never found. A 2021 paper estimates that observed right whale carcasses only accounted for 36% of all estimated death from 1990 to 2017, which means that the vast majority of right whale deaths are never seen. In fact, NOAA estimates that on average, 21 right whales die each year, almost exclusively from entanglements in fishing gear and vessel strikes. The UME is still in effect.

And, to make matters worse, entanglements in fishing gear is not the only threat faced by these whales. The film *Entangled* provides a detailed look into what entanglements and climate change are doing to North Atlantic right whales: entangled-film.com.

Ship Strikes

Because right whales are a coastal species, preferring areas within 50 miles of shore and feeding close to the surface, their habitat overlaps with extremely busy shipping lanes. While right whales travel generally in a north/south direction, ships are approaching the coast in an east/west direction, and collisions seem unavoidable. In 2008, after a decade of negotiation, NOAA developed a ship strike reduction rule, which required vessels to slow their speed in specific areas in specific seasons, where right whales were known to occur in shipping lanes.

NOAA developed two types of speed limits: mandatory speed limits in seasonal management areas, where speed limits are automatically imposed certain times of the year in areas where right whales have been previously documented; and dynamic management areas, which are imposed when right whales are seen from aerial surveys and reports from vessels in the area. These latter dynamic area speed limits are voluntary. All vessels larger than 65 feet in length must reduce their speeds to 10 knots (roughly 11.5 miles per hour) when whales are in the seasonal management areas.

However, NOAA has never modified these speed rules in any significant way since 2008, despite requests from conservationists and scientists to broaden the rule to include smaller vessels, to expand the areas where speed limits are in place given that right whales are utilizing new areas for feeding, or to make the voluntary restrictions mandatory. Since 2013, at least 12 right whales have been hit by vessels. In fact, in 2020, two of ten calves born that year were known to have died within months of their birth, killed by vessels.

A recent report on compliance of these speed limits showed that non-compliance is almost 90% in the mandatory speed zones, and roughly 85% in the voluntary areas. In other words, the vast majority of vessels simply ignore the rule. Despite this, NOAA continues to do nothing more than "request" that mariners slow down, as shown in a recent tweet from this summer.

What Should NOAA Be Doing?

Remember that the PBR for the North Atlantic right whale is 0.8, which means we cannot afford to lose even one animal each

Bottom Right: A tweet from NOAA, requesting vessels slow down for right whales.

Page 46: Kyla Bennett with one of her study subjects.

year from entanglements and ship strikes . And yet, the same agency that develops this PBR acknowledges that 21 individuals die each year, primarily for human activities. What is going wrong?

NOAA is not following the science. NOAA has a plethora of excellent scientists researching right whales and publishing peer-reviewed papers on the plight of the species and what can be done. Unfortunately, the majority of this research is ignored when NOAA goes through rulemaking purported to help save the right whale. These include:

- A 2017 article co-authored by a NOAA scientist found that the area south of Martha's Vineyard is important for right whales, and that 30% of calving females utilize this area. More recently, scientists have documented right whales' increased use of ocean waters in New England, south and east of Nantucket, for feeding and socializing. Right whales, like all animals, follow their prey, and climate change is forcing them to hunt for tiny crustaceans called copepods in different areas. Research published in 2021 - with several NOAA coauthors - demonstrates that scientists are seeing right whales using this area south of the islands year round. Despite this, NOAA's latest rule only closes that area to fisheries in February to April. More disturbingly, this area is now slated for massive industrial wind development.
- A 2020 peer-reviewed paper found that the U.S. lobster fishery in Maine expends approximately 7.5 times as much effort as the Canadian lobster fishery in a particular area. Specifically, Canadian lobstermen and women catch roughly 3.7 times more lobsters per trap than Maine lobstermen and woman. The researchers concluded that reduction in the number of traps, and therefore reduction in the number of lines that could possibly entangle whales, does not necessarily result in fewer lobster landings and a negative economic impact. However, NOAA does not attempt to get U.S. lobster fisheries to reduce the number of traps being fished.
- A 2016 article, authored by the top marine mammal scientists from institutions such as the New England Aquarium, the Woods Hole Oceanographic Institute, and Duke University (that NOAA works with on a daily basis related to right whale conservation), stated, "Right whales need immediate and significant management intervention to reduce mortalities and injuries from fishing gear... Failure to act on this new information will lead to further declines in this population's number and increase its vulnerability to extinction." To date, NOAA has declined to make any significant management interventions.

> "It has become impossible for NOAA to advocate for both the fisheries and the whales."

- A 2017 article, authored and co-authored by two NOAA whale scientists discusses increasing rates of entanglements in fishing gear and "evidence that previous management interventions have not measurably reduced entanglement or entanglement-related mortality" and that "it is likely that impacts on morbidity are increasing." Again, NOAA refused to implement rules that would significantly reduce entanglements.
- A 2017 article co-authored by NOAA employees showed that right whales have changed their distribution patterns since 2010 (likely due to climate change), and consideration of these new patterns are "imperative for the conservation of this species." However, NOAA is not taking these changing distribution patterns into account.
- Studies show that vessels are not complying with mandatory or voluntary speed limits, and ship strikes continue to kill right whales. NOAA has not taken any steps to improve compliance with speed limits, or convert voluntary speed limits into mandatory speed limits.
- Perhaps most importantly, virtually all scientists agree that ropeless fishing gear is the only hope we have of reducing entanglements while allowing the lobster fishery to flourish. This ropeless gear has traps that are virtually marked, and held down at the ocean floor with no vertical line in the water column. When the owner of the trap wants to retrieve it, it sends a signal to inflate a buoy, or release a rope, and bring the trap up to the surface. And yet, NOAA's latest rule published this summer states that ropeless gear is too expensive, and therefore they will loan out the gear such that, "[b]y 2025, we anticipate ... [ropeless gear] would allow up to 33 fishermen to fish with up to 10 trawls each." There are roughly one million vertical lines in the water in peak fishing season. Removing lines from 33 fishermen will not save the right whales.

Is There Hope?

It has become impossible for NOAA to advocate for both the fisheries and the whales. Both before and during the UME, NOAA has attempted to walk a line of keeping fisheries profitable, while taking tiny steps of gear modifications, speed limits, and seasonal closures purported to help right whales. Each of these small steps was met by fury and protest on behalf of many in the fishing and shipping industries. While some insisted they wanted to find a way to save the whales, others were more blunt: if it was a choice between their way of life and survival of the right whale, the right whale had to die.

NOAA's dual mandate means it neither protects the right whale or the fisheries well, and both the fishing industry and conservationists are angry. North Atlantic right whales are plummeting toward extinction, and NOAA has been sued countless times for failing to protect the species.

Ropeless gear and enforceable, mandatory speed limits for all vessels are possible solutions, but NOAA's reluctance to embrace them is problematic. The right whale will not survive these entanglements and ship strikes, exacerbated by their unpredictable movements due to warming oceans and shifting prey. Protection of the critically endangered right whale must be removed from NOAA's purview and given to another agency that does not have conflicting missions. People have to be educated about these whales, and what the true costs are of their cheap lobster rolls. NOAA appears committed to putting a good face on an unquestionably dire situation, and we cannot allow that to stand. We must learn to love right whales, and make necessary sacrifices, in order to save them.

Above: A rare sight. Two North Pacific right whales in the Gulf of Alaska. *Photo Credit: NOAA under MML permit #20465. Image credit: Jessica Crance.*

RIGHT ON THE EDGE: CAN THEIR PACIFIC COUSINS BE SAVED?

JESSICA CRANCE

Their dark history

They once numbered in the tens of thousands throughout the North Pacific. Today, fewer than 500 exist; in the U.S., only around 30

Top Right: A North Pacific right whale lunging, in the waters off Kamchatka. *Image credit: Vladimir Burkanov*.

Page 51: Another image of the same two North Pacific right whales in the Gulf of Alaska. *Photo Credit: NOAA under MML permit #20465. Image credit: Jessica Crance.*

animals are thought to remain. Two distinct stocks are currently recognized: the western stock, thought to number in the low hundreds, and the eastern stock, that has only tens of individuals remaining. The tale of the North Pacific right whale (*Eubalaena japonica*) is dark; and for the eastern stock, the outlook is bleak. Once abundant in Alaskan and eastern North Pacific waters, they are now so rare that single observations have warranted publication.

So named for being the "right" whale to kill (being slow, having thick blubber, and floating when killed), right whales in all oceans quickly became the target of commercial whaling. Hunted for oil, meat, and baleen (used for corset stays, umbrellas, carriage springs, and other accessories), it is estimated that between 21,000 - 30,000 right whales were taken in the North Pacific in a single decade. By 1900 they were already considered commercially extinct – meaning their numbers were so low they weren't worth the effort of trying to catch. Although low numbers of catches continued into the early 20th century, they weren't protected by law until 1935.

Although not numerous, reasonable numbers of right whales continued to be seen in the North Pacific, particularly in the Bering Sea, Aleutian Islands chain, and the Gulf of Alaska, until 1964 when their numbers dropped dramatically, seemingly overnight. Despite an increase in searching effort, there were only 60 sightings total in the entire eastern North Pacific from 1964 to 2001. And for decades, the cause of their disappearance remained unknown.

Then in 1993, Professor Alexei Yablokov, then the Special Advisor for Ecology and Health to Russian President Boris Yeltsin, gave a presentation at the 10th Biennial Conference on the Biology of Marine Mammalogy in which he revealed to the world the fact that the Soviets had been conducting large scale illegal whaling in all the world's oceans since 1948. While some scientists had suspected several countries of falsifying their catch records, the extent of the Soviet harvest was unknown until that moment. Traveling across the world's oceans, they took anything that crossed their bow, leaving "a desert in their wake". When they moved their fleet into the North Pacific in the early 1960s, they decimated what remained of the North Pacific right whales, dropping numbers in the eastern population to the tens of animals, making them the most critically endangered large whale population in the world. While the western population of North Pacific right whales is doing slightly better, even their numbers remain in the low hundreds.

The Problem

Despite being ESA-listed as Critically Endangered and having federally designated critical habitat, there are no regulatory measures or management policies in place. Several legislative policies (e.g., vessel speed restrictions) have been implemented for the congeneric North Atlantic right whale (*Eubalaena glacialis*) that have aided conservation efforts. The North Atlantic right whale, however, is widely in the public's eye. Thanks to their preferred coastal habitat and ease of access, scientists have a keen understanding of the population status and trends of "the urban whale", and the overlap between this population and various human activities is well understood. And importantly, it is comparatively easy to understand the cause of North Atlantic right whale injury or mortality; their coastal distribution means animals that are struck or entangled often wash up on shore.

For their North Pacific counterparts, the picture isn't nearly as clear. There are only an estimated 30 individuals left in US waters, and that number was based on data that are now 15 years old. With only 30 individuals remaining, finding North Pacific right whales would be a challenge even if they were right along the west coast in plain view. But when their historical distribution is in a remote region with notoriously bad weather, finding even a single animal becomes a search for the proverbial needle in a haystack. With re-sights of individuals happening at most every few years (or at worst, never happening), it's impossible to say whether this critically endangered population is remaining stable, rebounding, or declining. While researchers have seen very little evidence of entanglement or ship strike scars in images collected of North Pacific right whales to date, given its location it is unlikely that any incident would be noticed. Either the animal washes up on shore somewhere along the hundreds of miles of uninhabited coastline, or it sinks – taking with it any knowledge of the direct impacts of human activities on the population. And with the small population size and an estimated 2:1 male-biased sex ratio, the loss of even a single animal, especially a female, would be detrimental.

The eastern population of North Pacific right whales can be found in summer months in the productive waters of the Gulf of Alaska and Bering Sea, where they feed on the abundant zooplankton. But where they go when they leave these productive waters remains a mystery.

Being commercially extinct prior to the keeping of many scientific records, scientists must rely heavily on old whaling logbooks for information on their pre-whaling distribution. But even the most comprehensive of whaling logbooks did not note sightings of calves or mating behavior, some going so far as to say "there was little to no evidence of breeding grounds". While this could be a result of biased effort at certain times of year, no calves have been sighted since 2004. It's assumed that North Pacific right whales migrate south to lower latitudes in the winter like other baleen whale species, but very little evidence of migratory pathways exists.

In recent years, there have been more sightings of right whales off the coast of British Columbia, Canada, occurring in May or June and October. Perhaps these sightings correspond with animals migrating to and from the Gulf of Alaska or Bering Sea. In April of 1997, a North Pacific right whale was sighted off Hawaii; three months later, that same individual was seen in the Bering Sea. While an exciting discovery, this remains the first and only high to low latitude match of an individual since the beginning of photo-ID records in the late 1970's. There have been about a half dozen sightings off southern California and Baja Mexico over the past several decades that also suggest these animals may move south for winter. Unfortunately, these are usually sightings of a single adult animal, and are so few and far between that they are often identified as other species. This was the case with a right whale sighted off La Jolla, California in 2017; originally misidentified as a gray whale, it wasn't until drone footage circulated around social media that it was correctly identified as a right whale.

The Research

Given the lack of knowledge about even the basic life history of this population, much of the research being conducted is simply trying to answer the *where*– where are their migration routes or breeding grounds, and where is their current distribution relative to their historic distribution. Unfortunately, answering even these most simple of questions is difficult. But despite the challenges, several surveys over the past couple decades have been successful in locating, photographing, biopsying, and deploying satellite tags on right whales. Detailed movement data were collected from the satellite tags, which provided great insight into habitat use in the Bering Sea. Unfortunately, all tags fell off before the animals left the southeastern Bering – leaving the question of where they go (or if they leave) unanswered.

While large scale surveys are the best way to obtain population structure and individual-specific information (i.e., from photo-ID photographs or biopsy samples), they have often been cost-prohibitive. Passive acoustics, however, provides a relatively inexpensive means of monitoring the population year round, during times when vessel surveys are not possible. Right whales make several stereotyped calls, most notably the gunshot and the upcall, so by detecting these call types at various locations throughout the year, we can determine the spatio-temporal distribution of right whales. Currently, the NOAA Fisheries - Marine Mammal Laboratory (MML) at the Alaska Fisheries Science Center has 20 long-term bottom mounted recorders deployed throughout Alaskan waters, where we've been able to monitor for right whales since 2007. These data have shown that right whales are being detected farther north in the Bering Sea than in years previous, a fact which is supported by recent sightings of a right whale near St. Lawrence Island that was re-sighted two weeks later in Chukotka. Whaling logbooks do show a few takes of right whales in the northern Bering in June and July (in both Russian and U.S. waters), although there is some question as to the validity of species ID and whether they may have actually been bowhead whales misidentified as right whales. Whether correct or not, it remains to be seen whether these detections and sightings are a sign of a return to pre-whaling distribution grounds, or a shift in distribution as a result of climate change. The Bering Sea oscillates between two different environmental states, shifting from cold regimes where extensive remnant winter water in the bottom layer (referred to as a cold pool) concentrates prey in the southeastern Bering Sea, to warm regimes where there is reduced sea ice and a reduced or absent cold pool, resulting in prey being more widely distributed. Right whales tend to utilize a more spatially constricted habitat during cold pool years. It's possible, therefore, that the recent detections and sightings in the northern Bering are a result of a shift to a warm pool, and perhaps indicative of how the population may respond to climate change and the increased reduction in sea ice.

The passive acoustic monitoring, while providing invaluable data on changes to their spatio-temporal distribution, does come with its own complications. Not only do both humpback (*Megaptera novaeangliae*) and bowhead whales (*Balaena mysticetus*) make similar upcalls, bowheads also make gunshots – and overwinter in the southeastern Bering. When the calls from both species are aurally and spectrographically indistinguishable, how do you differentiate between the two and ensure accurate species attribution? We're hopeful that a recent discovery will help with that. A couple years ago, we made an unexpected recording of a North Pacific right whale singing. Comprised almost entirely of gunshots, these songs have a hierarchical structure and a stereotypy (a patterned repetition) on par with the songs of humpbacks. Interestingly, however, right whale songs have a temporal stability that is unheard of with humpback songs. The four song types described for North Pacific right whales thus far have remained constant over eight years of recordings. And to date, these songs are unique to

North Pacific right whales. While this undoubtedly raises more questions than it answers (why does the most critically endangered population of right whales sing?), it does mean that if these songs are detected, that is an unequivocal sign of a vocalizing right whale, and therefore can be used to detect right whales outside their known habitat. If detections occur in the eastern North Pacific, or along the west coast of the US, that may provide insight into their migration routes or overwintering grounds.

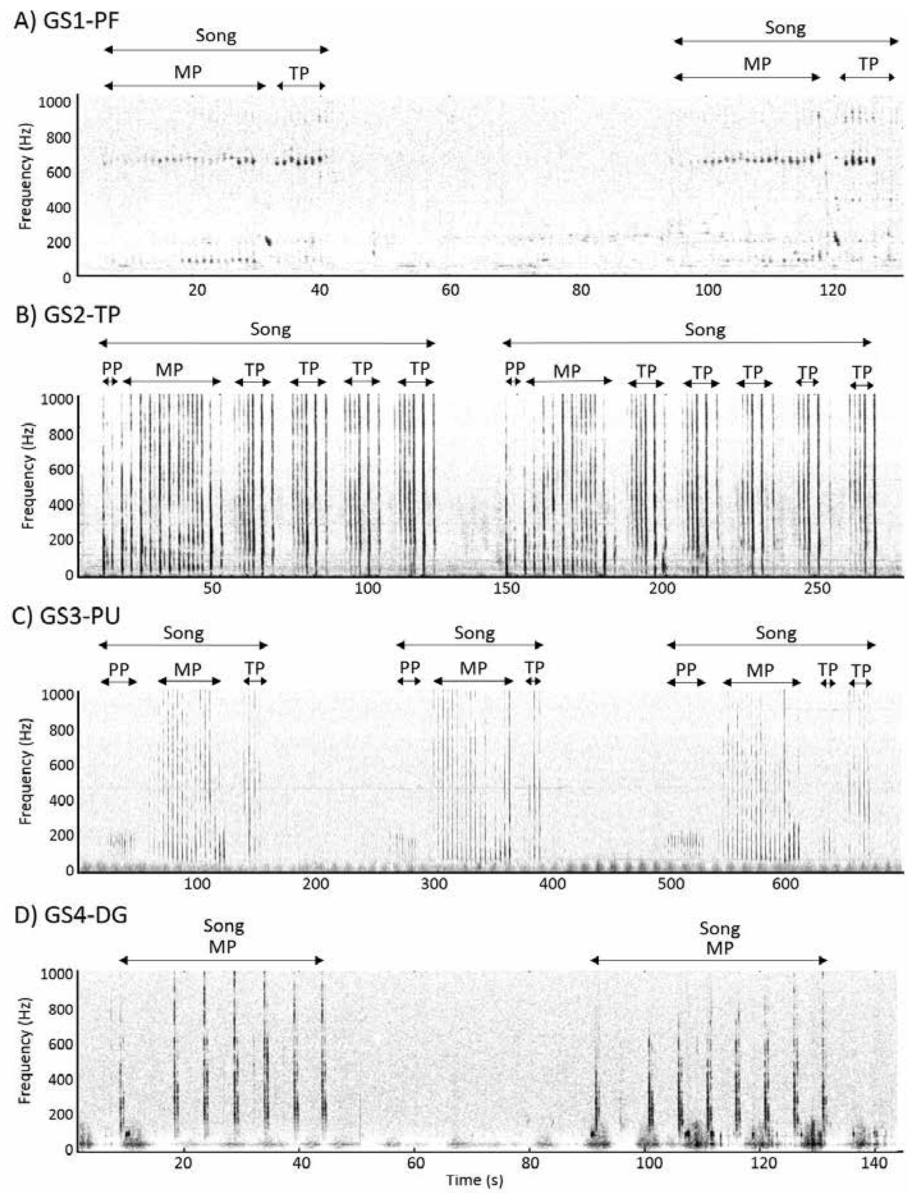
Although aurally and spectrographically similar, species identification may be possible using novel techniques to analyze propagation characteristics of call types. Current research being conducted by Aaron Thode of Scripps Institution of Oceanography, Julien Bonnel of Woods Hole Oceanographic Institution, and Dana Wright, Ph.D. candidate with Duke University, is looking at determining the calling depth of an animal based on varying arrival times of modes evident in propagation distortion effects. By using a technique called nonlinear dynamic time warping, the estimated source depth of a call can be determined. Preliminary results from this study showed that right whale gunshots were typically produced in only a few meters depth. These results coincide with what is known about North Atlantic right whale calling behavior; bowhead whales, however, are thought to call at greater depths. By comparing calling depths of gunshots from the two species, we hope to see a separation in gunshot calling depth between the two species that can then be used to attribute gunshots to species and determine whether right whales are remaining in the Bering Sea overwinter.

To help identify possible migration routes, MML is currently working with the Department of Fisheries and Oceans Canada (DFO) in a collaborative study to detect right whale calls along the British Columbia coast using custom call detection and classification software (INSTINCT) designed by Dan Woodrich. Because right whales have been seen more frequently in recent years off British Columbia, DFO and MML are working together to analyze data from the DFO long-term recorders deployed along the BC coast to determine if right whales are using this area as a migratory corridor.

In another attempt to shed light on the mystery of their breeding or overwintering grounds, Dana Wright is conducting research involving biogeochemical tracers, called stable isotope ratios, in museum specimens of baleen plates from the whaling era. These plates are sheets of inert keratinous tissue, made from compounds similar to those in our hair and fingernails, that grow from the upper jaw of baleen whales and allow them to filter feed small organisms from the water column. Just like our hair, baleen grows continuously throughout the animal's life and due to their length (150+ cm) can record a time-series of the last 5+ years of ecological history of an individual North Pacific right whale. Consequently, this tissue may shed light on a myriad of poorly known information about this species, including migratory patterns and site fidelity, diet and trophic level reconstruction, as well as physiological inference. In addition to baleen, Wright is also analyzing stable isotope ratios from skin samples collected via remote biopsy starting in the early 2000s. Together, the skin and baleen data provide an opportunity to compare historical and contemporary right whale niche and habitat use, which may aid management and conservation efforts for this species.

While these studies help us gain insight into migration and movement patterns, vessel-based surveys are still the best means for obtaining information on individuals and population structure. In 2017, the International Whaling Commission's Pacific Ocean Whale and Ecosystem Research (POWER) cruise surveyed the eastern Bering Sea, and

NPRW SONG TYPES



Top Right: Two North Pacific right whales in the Gulf of Alaska
Photo Credit: NOAA under MML permit #20465. Image credit: Jessica Crance.

included passive acoustics (via sonobuoys) for the first time to aid in the detection of North Pacific right whales. During the 60 day survey, a total of twelve different right whales were photographed (an estimated 15 were seen), and biopsy samples were collected from three animals. This was the largest number of right whales seen during a single survey since 2004. The 2018 POWER survey in the Central Bering added three additional right whales to their total, with three accompanying biopsy samples. All told, four right whales were confirmed new and added to the catalog, with two other animals also possibly new individuals. And remarkably, all six biopsy samples were from individuals of previously unknown sex. Unfortunately, analysis results of the six biopsy samples collected during those two years resulted in five males and only one female. These bleak results indicate that the sex ratio in this population may be far more male-biased than the current estimated 2:1 ratio would suggest. But despite having all the odds stacked against them, there is still reason for hope.

The Glimmer of Hope

The first right whale sightings off British Columbia in over six decades occurred in June and October of 2013. In the past four years alone, three additional sightings have occurred off Haida Gwaii and Vancouver Island. Could this be indicative of an increase in numbers, or perhaps a return to their historical range? Or are these animals a different sub-population than those in the Bering Sea, and utilizing different migratory routes? In either case, the increase in sightings in recent years, plus the 15 different right whales sighted in only two years (2017, 2018) provides hope that all is not yet lost. This is perhaps best illustrated by the sighting of two non-adults. The June 2013 sighting off Haida Gwaii and one of the individuals seen during the 2017 POWER survey were estimated to be a juvenile; even more exciting, the Haida Gwaii animal was a female. Despite their critically low population size, at least one female is still reproducing; because of this, we named the 2017 juvenile "Phoenix".

I'm currently out at sea in the Gulf of Alaska as I write this. It's taken four different surveys over the past eight years, but I finally saw right whales in the Gulf of Alaska. Four right whales were seen in two separate encounters, which is the most sightings ever in a single survey in the Gulf of Alaska. One of the animals, sighted in Barnabas Trough, was sighted off Haida Gwaii just two months ago in June by James Pilkington and Jared Towers of DFO. Another individual (seen just south of the Trinity Islands) was matched to the MML right whale catalog and identified as MML 71, an individual first seen in Barnabas Trough in 2006. And amazingly, two of the four animals were confirmed new individuals. Even after decades of looking, we are still finding new individuals. And with each new sighting comes another surge of hope, and a renewed determination.

But most importantly, with more sightings in recent years has come more articles in the news, more press releases, and more exposure. The more the general public is aware of this species, the more extralimital sightings we will get – which could be instrumental in helping understand the migration routes of these rare animals. As such, increasing awareness about this species is a key step in the conservation of a population. Because people save what they love, and they love what they know, we need to make the North Pacific right whale as common a household name as their North Atlantic cousins. And by continuing our important research, we can hopefully fill in some of the current gaps in knowledge regarding the spatial distribution of the most critically endangered large whale stock, and help guide research and conservation efforts to give these animals their best chance at recovery.

The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author and do not necessarily reflect those of NOAA or the Department of Commerce.

References

Berzin, A., 2008. The truth about Soviet whaling: a memoir. *Marine Fisheries Review*, 70(2).

Crance, J.L., Berchok, C.L., Wright, D.L., Brewer, A.M. and Woodrich, D.F., 2019. Song production by the North Pacific right whale, *Eubalaena japonica*. *The Journal of the Acoustical Society of America*, 145(6), pp.3467-3479.

Filatova, O.A., Fedutin, I.D., Titova, O.V., Meschersky, I.G., Ovsyanikova, E.N., Antipin, M.A., Burdin, A.M. and Hoyt, E., 2019. First Encounter of the North Pacific Right Whale (*Eubalaena japonica*) in the Waters of Chukotka. *Aquatic Mammals*, 45(4), pp.425-429.

Ford, J.K., Pilkington, J.F., Gisborne, B., Frasier, T.R., Abernethy, R.M. and Ellis, G.M., 2016. Recent observations of critically endangered North Pacific right whales (*Eubalaena japonica*) off the west coast of Canada. *Marine Biodiversity Records*, 9(1), pp.1-7.

Ivashchenko, Y.V., Clapham, P.J. and Brownell Jr, R.L., 2017. New data on Soviet catches of blue (*Balaenoptera musculus*) and right whales (*Eubalaena japonica*) in the North Pacific. *Journal of Cetacean Research Management*, 17, pp.15-22.

Kennedy, A.S., Salden, D.R. and Clapham, P.J., 2012. First high-to low-latitude match of an eastern North Pacific right whale (*Eubalaena japonica*). *Marine Mammal Science*, 28(4), p.E539.

Scarff, J.E., 2001. Preliminary estimates of whaling-induced mortality in the 19th century North Pacific right whale (*Eubalaena japonicus*) fishery, adjusting for struck-but-lost whales and non-American whaling. *Journal of Cetacean Research Management Special Issue* 2, pp.261-268.

Thode, A., Bonnel, J., Thieury, M., Fagan, A., Verlinden, C., Wright, D., Berchok, C. and Crance, J., 2017. Using nonlinear time warping to estimate North Pacific right whale calling depths in the Bering Sea. *The Journal of the Acoustical Society of America*, 141(5), pp.3059-3069.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica*, 19, pp.1–50.

Wade, P.R., Kennedy, A., LeDuc, R., Barlow, J., Carretta, J., Shelden, K., Perryman, W., Pitman, R., Robertson, K., Rone, B. and Salinas, J.C., 2011. The world's smallest whale population?. *Biology letters*, 7(1), pp.83-85.

Woodrich, D., Berchok, C., 2020. INSTINCT: Infrastructure for Noise and Soundscape Tolerant Investigation of Nonspecific Call Types. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-412, 58 p.

Wright, D.L., Berchok, C.L., Crance, J.L. and Clapham, P.J., 2019. Acoustic detection of the critically endangered North Pacific right whale in the northern Bering Sea. *Marine Mammal Science*, 35(1), pp.311-326.

Zerbini, A.N., Baumgartner, M.F., Kennedy, A.S., Rone, B.K., Wade, P.R. and Clapham, P.J., 2015. Space use patterns of the endangered North Pacific right whale *Eubalaena japonica* in the Bering Sea. *Marine Ecology Progress Series*, 532, pp.269-281.

STUDYING RIGHT WHALE PHYSIOLOGY AND BIOENERGETICS WITH DRONES

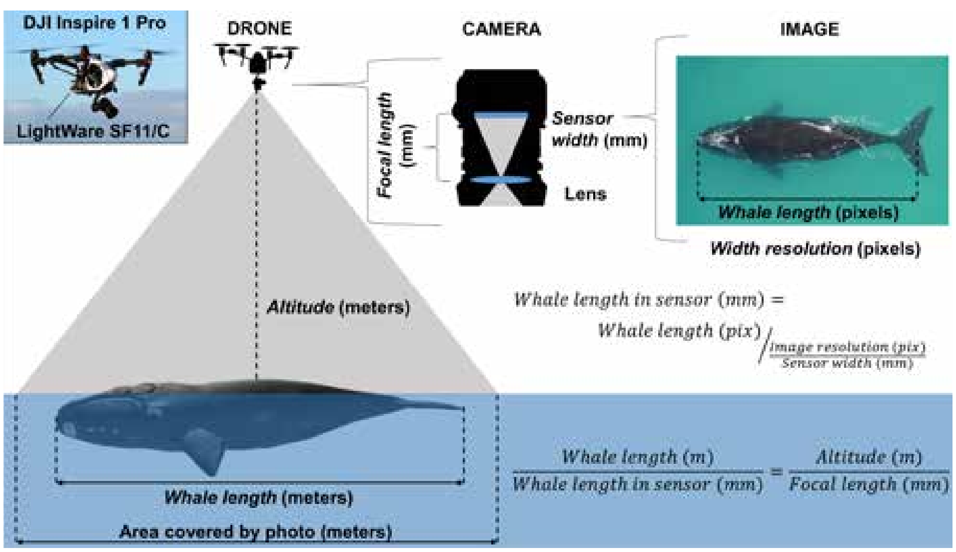
FREDRIK CHRISTIANSEN

Measuring the Size of the Largest Animals on the Planet

Baleen whales, which includes the right whale, are the largest animals on the planet. A large body size offers several advantages for whales, including protection from predators, reduced heat loss, increased foraging and diving capacity, and increased locomotion. Large whales also have low mass-specific metabolic rates (the energy required to support 1 kg of body mass), which enables them to quickly build up large amounts of fat reserves from the surplus energy they obtain when feeding in prey rich feeding grounds. These fat reserves can then be utilized later during extended periods of fasting while the whales migrate 1,000s of km's to nutrient poor breeding grounds in winter where they mate and give birth. Being large and fat is hence key to both the survival and reproductive success of baleen whales, which in turn will influence population growth and viability, as well as resilience to environmental and anthropogenic disturbance. In light of this, studying the size and body condition, or fatness, of large whales is of great importance for conservation and population management.

Due to their large size, it is logistically challenging to study baleen whale physiology and bioenergetics (how animal acquire and allocate energy to survival, growth and reproduction over their lifetime), since conventional methods cannot be applied. As a result, most of our knowledge of large whale physiology and bioenergetics comes from historical whaling, where measurements were taken from animals that had been killed for commercial or scientific purposes. With commercial whaling being internationally banned since the late 1980s, and the practice not being ethically or economically supported by many nations, this is no longer a viable option to study whales, especially not vulnerable populations such as the North Atlantic right whale (*Eubalaena glacialis*) which would not be able to sustain such an invasive sampling. As a result, scientists have been working hard over the last decades to develop new non-lethal alternatives to study baleen whale physiology and bioenergetics.

One of the most promising and rapidly growing approaches to study whale



Top Image: Fredrik Christiansen pictured.
Bottom Image: *Figure 1.* Graphic illustration of drone photogrammetry of right whales and the parameters needed to convert whale length measurements from pixels to meters.
Photos courtesy of Fredrik Christiansen.

physiology and bioenergetics is drone-based photogrammetry. Photogrammetry is a technique that measures the size of real-world objects from photographs. Aerial photogrammetry was introduced in whale research already in 1978 by Hal Whitehead and Roger Payne, who used this technique to measure the body length of southern right whales (*Eubalaena australis*) in Península Valdés, Argentina. By taking a zenithal photograph of a whale at a known altitude, the size of that whale can be estimated through basic trigonometry by measuring its pixel length in the photograph and knowing the image resolution, camera sensor size and focal length (*Fig. 1*). In the following decades, this technique was used to measure the growth rate of southern right whales in South Africa, and compare body shape between North Atlantic right whales and southern right whales. Despite this promising avenue, aerial photogrammetry did not gain much popularity until the recent advent of commercially available drones, or unmanned aerial vehicles (UAVs). Drones offers several advantages over conventional aircraft in being much cheaper and safer to use. Multirotor drones can take-off and land vertically, and hence be flown from small vessel (or from land) in remote locations far from any airfield. By attaching a laser range finder, or altimeter to the drones, the altitude above sea level can be recorded for every photo, which can be used to scale the images from pixels to meters (*Fig. 1*).

The introduction of drones in large whale research has opened up new avenues to study whale physiology and bioenergetics and the intention of this chapter is to highlight some of these areas of research and show the benefits of this new technology. Since much of the recent work with drones have been focused on right whales, this chapter also offers an insight into the physiology and bioenergetics of these fascinating creatures.

Do Drones Disturb Whales?

Before discussing the many benefits of drone-based research on right whales, it is important to highlight the potential costs of this technology in terms of animal welfare. When studying animals, in particular their behaviour, it is important that the researchers themselves do not negatively affect the study animal, as this could bias results and lead to incorrect conclusions. Does the noise or presence of drones negatively affect whales? This question is warranted, since studies have shown that drones can negatively affect both birds and terrestrial mammals. To address this question, some colleagues and I carried out an experiment at the Head of Bight in South Australia in 2016, a major breeding/nursing ground for southern right whales in South Australia. Taking advantage of the tall limestone cliffs that characterize this area, we recorded the breathing and movement patterns of mothers and calves from land with the help of a theodolite. We recorded the undisturbed (control) behaviour of the whales for 30min, after which we flew a drone (a DJI Inspire 1 Pro) from the cliffs down over the whales, which then hovered over the head of the focal mother for up to 10min. After this, the drone returned to land, and the whale was left alone. When comparing the behaviour of the whales in the presence and absence of the drone, we could not detect any changes in breathing rates, swim speed or movement pattern. In a separate study we also investigated the underwater noise level of drones when flown at different altitudes above sea level, and found that when flying at >10m altitude the noise of the drone was below that of ambient (background) noise level in many shallow water habitats. From these studies, we concluded that the drones did not cause any noticeable disturbance to the whales, and offered a non-invasive way to study right whales.

Measuring the Fatness of Whales

The body condition of an animal is a measure of its relative fatness, or the amount of energy reserves an individual has relative to its structural size (body length). Since whales require large amounts of energy to reproduce, the body condition of an individual can give a valuable indication of its reproductive potential (its ability to 'produce' offsprings). Further, since body condition relates to the ability of an individual to fast (a fat individual can fast for longer than a thin individual), it gives an indication of the survivability of that individual. In humans, a common metric for relative body fatness is the body mass index (BMI). An individual's BMI is calculated by dividing his or her weight (in kg) by the square height (in meters) and a similar formula can be used to calculate the body condition of whales.

Whales are able to store fat, or lipids, in most of their body tissues. Most lipids, but also a large number of proteins, are stored in a specialized subcutaneous layer of fat, called the blubber layer, which surrounds the body of whales and which is composed of densely

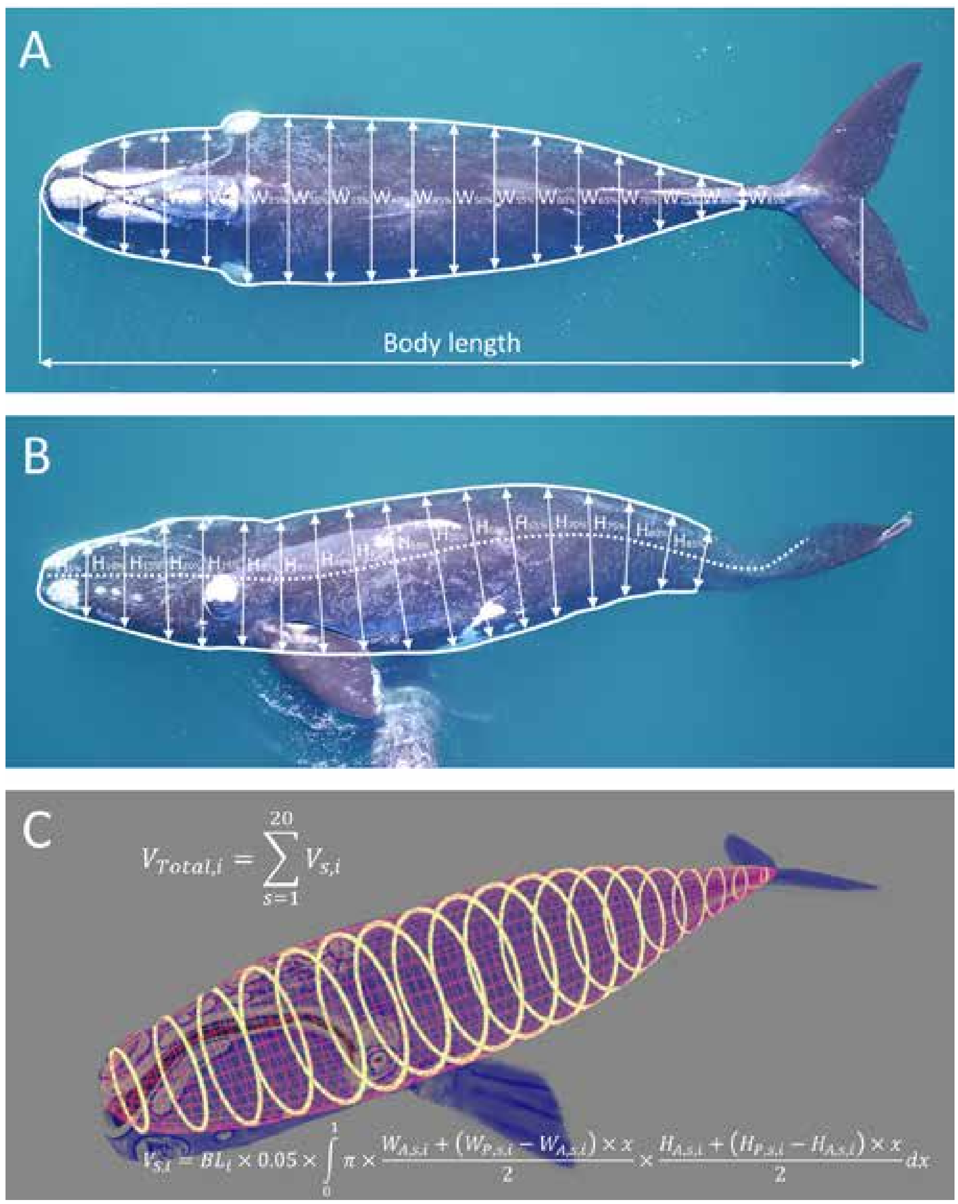


Figure 2. (A) Aerial photographs of the dorsal surface of a southern right whale, used to measure body length and width (W) at 5% increments along the body axis from 5% to 85% body length from the rostrum (white arrows). (B) Lateral side of the same whale, used to extract body height (H, dorso-ventral distance) along the same measurement sites. (C) A 3D model of the same whale, used to estimate body volume. The cross-sectional ellipses illustrate the variation in height-width ratio across the body of the whale. Figure modified from Christiansen et al. (2019).

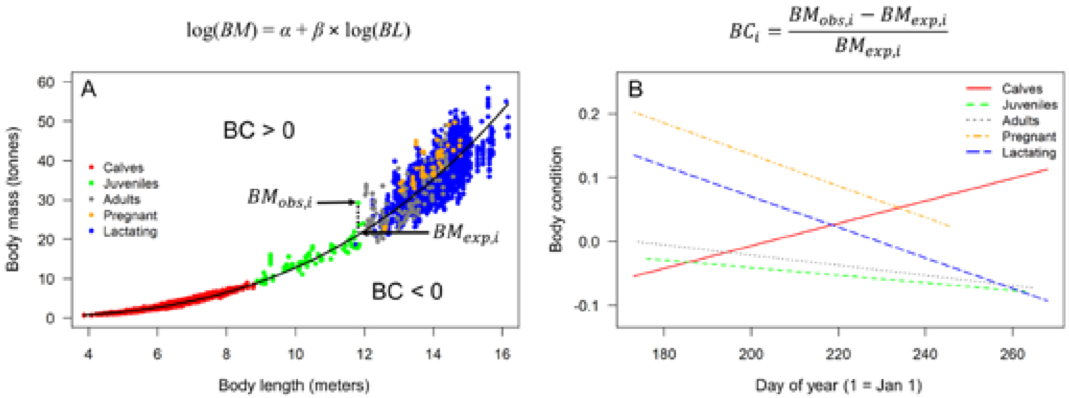


Figure 3. (A) Relationship between body mass (BM) and body length (BL) in southern right whales in South Australia. The black line represent the average, or expected, body mass (BMexp) of a whale of a given length. The deviation (vertical distance) in measured, or observed, body mass (BMobs) of individual whales (points) is used to estimate the body condition (BC). Points above the solid line represent whales in better than average condition (BC>0), whereas points below the solid line represent whales in poorer than average condition (BC<0). (B) Seasonal changes in body condition of different reproductive classes (see key) of whales over the breeding season. The figure highlights the rapid decline in body condition of late-pregnant and lactating females compared to adult and juvenile whales. Calves are nursing through the breeding season, which is shown by the increase in body condition over the season.

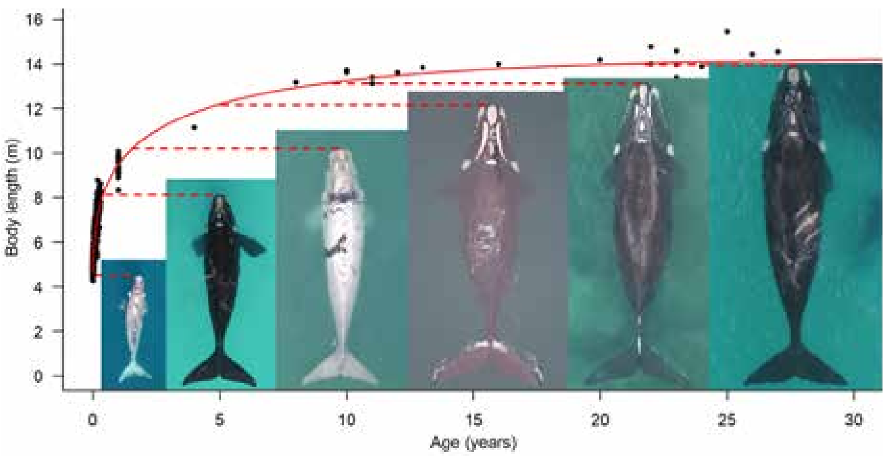


Figure 4. Length-at-age curve (solid red line) of southern right whales derived from drone photogrammetry data of known-aged individuals from South Australia. Example photos of known sized individuals are shown for reference.

vascularized adipose tissue. In addition, whales can store large amounts of lipids and proteins in their muscle, in and around their organs (visceral fats), and even in their bone marrow. While the lipid and protein content of any of these tissues could in theory be used as a measure of body condition, it is more practical to use a single measure of body condition that encapsulates all these tissues together. Common metrics used to study body condition in large whales is hence body girth (circumference), body volume or body mass, relative to the structural size of the animal, most often expressed by its body length. Drone photogrammetry can be used to estimate all three of these metrics by measuring the body length, width and height (dorso-ventral distance, or body depth) from aerial photographs taken of the dorsal (back) and lateral (flank) side of the animal (*Fig. 2*). By measuring the height-width ratio across the body of the whale, the body volume can be calculated by modeling the core body shape of the whales as a series of truncated elliptical cones (*Fig. 2*). By knowing the average tissue density of the whales, which can be obtained from historical whaling records (the tissue composition of the species) or from animal-borne tags (from the buoyancy of the whale when gliding underwater), it is possible to calculate the body mass of whales.

The body condition of individual whales can be calculated by plotting the metric of interest (e.g. body mass) against body length (its structural size), and fitting a regression line through the data (*Fig. 3A*). This line will represent the average (expected) body volume of an individual of a given length. The deviation of individual data points (whales) from this line indicate their relative fatness, or body condition. If an individual ends up above the line, it is fatter than an average whale of similar length, and if it falls below the line, it is in poorer condition than average (*Fig. 3A*). This standardized measure of body condition can be used to track an individual's body condition over time and compare different reproductive classes of whales, and even populations. Since the callosity pattern of right whales makes it possible to identify individual whales from the air, drone photogrammetry offers the perfect tool to monitor the growth and body condition of individual right whales over time.

Estimating the Cost of Growth

Like most baleen whales, southern right whales grow rapidly in size from birth until sexual maturity, which for some individuals can occur as early as five years of age. This rapid growth no doubt incur large energetic costs for right whales. By using drone photogrammetry to measure the body length of known-aged right whales obtained from long-term monitoring programs, it is possible to create length-at-age growth curves from free-living whales. By converting these length curves to mass, and estimating the energetic content of the different tissues that comprise the body of the whales, it is possible to estimate the daily cost of growth of right whales through their lives.

At birth, the body length of southern right whales calves are ~35% the length of their mothers, which means that larger mothers will give birth to larger calves. Consequently, the birth size of calves varies widely, from 3.7 to 5.5m, with a mean of 4.7m (1360kg) (*Fig. 4*). After birth, the calf will stay with its mother for approximately one year, growing on average 1.3cm/day (28.3kg/day), until it reaches a body length of ~9.5m (11,500kg) and is weaned (*Fig. 4*). Juvenile southern right whales grow at an average rate of ~70cm/year (3,100kg), until reaching the minimum length at sexual maturity at ~12m (24,000kg) (*Fig. 4*). After reaching adulthood, the growth rate slows down markedly, to about 13cm/year (835kg/year), until the whale reaches its average (or asymptotic) length of 14m (38,000kg) at approximately 20 years of age (*Fig. 4*). It is believed that right whales, similar to other whales, keep growing throughout their lives, but at a much slower pace, and can reach maximum lengths above 16m. While their longevity is unknown, their closest relative, the bowhead (*Balaena mysticetus*), can live for up to 200 years, thus making it plausible that right whales can reach ages of >70 years.

Estimating the Cost of Staying Alive

While southern right whales needs a lot of energy to grow large, a far larger amount is required to stay alive. Even at rest, a mammalian body requires energy for key processes such as basal metabolism, repairs, digestion and thermoregulation. While larger animals require a larger absolute amount of energy to stay alive, the mass-specific cost declines with increased body mass. Hence, another benefit of being large is that baleen whales have a very low mass-specific energy cost. Measuring the daily cost of maintenance is however challenging, since conventional methods (e.g. doubly labelled water or respirometry techniques) cannot be utilized for animals weighing up to 40,000 kg and which migrates 1,000s of km's each year. Instead, drone photogrammetry, combined with behavioural data on can be used to approximate the costs of maintenance. Since all metabolic processes require oxygen, the respiration rate (the frequency of breathing) of whales can be used to infer the relative energy demand of an individual. By measuring the respiration rate of southern right whales across their size range (from 4.7m at birth to 16m as adult), a clear decline in respiration rate is visible with increasing body length (*Fig. 5*). This decline represents the reduction in mass-specific metabolic rate of individuals as they grow in size. In addition, the activity of an animal will influence its energy demands, and by measuring the respiration rate of southern right whales across different swim speeds, this rate of increase can also be estimated (*Fig. 5*). Drones with long flight times (>20min) offers a great tool to record the fine-scale behaviour of southern right whales without disturbing them. With the latitudinal and longitudinal position of the drone being recorded several times per second, it is possible to estimate the swim speed of the focal whales by flying the drone above the centre of its body and mimicking is horizontal (2D) movement. In addition to breathing rates and swim speed, many interesting behaviours can be captured by the drone, such as suckling, the proximity between mothers and calves, mating behaviours, breaching and pectoral slapping (*Fig. 5*).

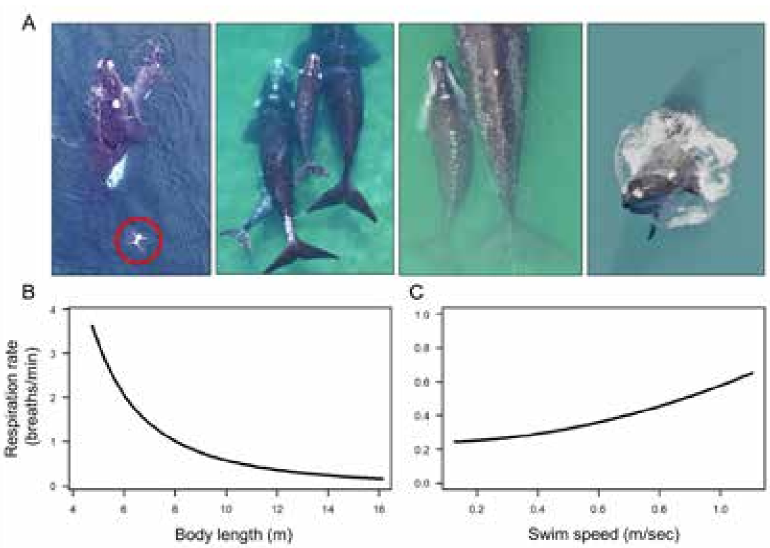


Figure 5. (A) Examples of southern right whale behaviours observable during drone-based behavioural focal follows in Península Valdés, Argentina. A DJI Mavic Pro drone with a flight time of >20min, suitable for focal follows, is visible in the left still frame (red circle). (B) Respiration (breathing) rates of southern right whales as a function of body length and (C) swim speed, based on data obtained from drone-based focal follows.

Estimating the Cost of Reproduction

With right whales making annual migrations between summer feeding grounds and winter breeding grounds, they have evolved a reproductive cycle that closely follows their annual migratory cycle, with both gestation and lactation being completed within a year each. The energy needed to support the rapid growth of the foetus and calf comes from the mother, either as a direct nutrient transfer (via the placenta) to the foetus, or through the milk that the mother produces after the calf is born. Since right whale females are fasting during the last month of gestation and first 3-4 months of lactation, this energetic burden has a visible effect on their body condition. By taking repeated drone measurements of body volume of females and calves over the breeding season in South Australia, I was able to estimate that southern right whale females lose on average 25% of their body volume over 3 months of lactation. This equals an average volume loss of 120 litres/day for a female, which resulted in a calf growth rate of 80 litres/day, or a 3.2cm/day growth rate in body length. Larger and fatter females were able to invest more energy into their calves, which consequently grew faster and could leave the breeding grounds earlier. Hence, being large and fat is of great benefit for right whales.

A Global Health Assessment for Right Whales

With body condition determining the reproductive potential of right whales, drone photogrammetry offers a great tool to assess and compare the health status of populations. In 2015, researchers from several countries came together to try to make a global assessment of the body condition of right whales. The motivation for the comparative study came from the recent decline in abundance of the North Atlantic right whale, where reproductive failure due to malnourishment is believed to play a major role. In the following years, drone photogrammetry was used to measure the body condition of the North Atlantic right whale population, as well as three seemingly healthy (growing) populations of SRWs in Argentina, Australia and New Zealand. The results showed that juvenile, adult and lactating

ARGENTINA AUSTRALIA NEW ZEALAND NORTH ATLANTIC

Figure 7. Drone aerial photographs of southern right whales from Argentina, Australia and New Zealand, compared and a North Atlantic right whale, highlighting the poorer body condition of the latter population. Photos taken by the author (left & centre-left), Stephen M. Dawson (centre-right), John W. Durban and Holly Fearnbach (right). Reproduced from Christiansen et al. (2020).

females were all significantly thinner in the North Atlantic compared to their southern counterparts (*Fig. 7*). The magnitude of this difference was substantial, with North Atlantic right whale females at the start of lactation (just after they give birth) being of similar condition as southern right whale females after three months of nursing their calves (just before they depart the breeding grounds). Less available energy means that North Atlantic right whale calves and juveniles will grow slower. This was confirmed in a recent study, which showed that the body length of North Atlantic right whales have been decreasing over the past four decades as a result of human activities. Slower growth means that individuals will reach sexual maturity later, while poor body condition means that mature females will take longer to recover between calving events, which will increase calving intervals and reduce reproductive rates. Poorer condition also means that individual whales are more likely to starve to death during prolonged periods of disturbance, such as entanglements in fishing gear.

Conservation and Management Benefits

Drone-based photogrammetry and behavioural sampling has revolutionized the field of large whale physiology and bioenergetics, and many more applications of these technologies are expected to arise in the coming years and decades. Aside from research benefits, drone-based research also has huge potential for conservation and wildlife management. With whales being increasingly exposed to human activities, including vessel noise and climate change, understanding how changes in behaviour can lead to population level consequences is of growing importance. Bioenergetics offers a pathway to explore the relationship between behaviour, energetics (energy expenditure and acquisition), body condition and vital rates (survival and reproduction). As I have demonstrated in this chapter, drone photogrammetry offers a great tool to inform some of these different relationships in a non-invasive way that is suitable for vulnerable populations, such as the North Atlantic right whale. By measuring individual whales and populations over time, we will be able to determine the effect of both anthropogenic and environmental factors on right whales. By comparing populations facing different levels of exposure to human disturbance, we will be able to evaluate how single and multiple stressors can impact right whale populations, and what management actions are needed to reverse negative trends. Finally, by monitoring the health of right whale populations over time, we will be able to measure the effects of gradually changing ocean conditions due to climate change, which in turn will help us predict future impacts of climate change on whale populations, to aid conservation.

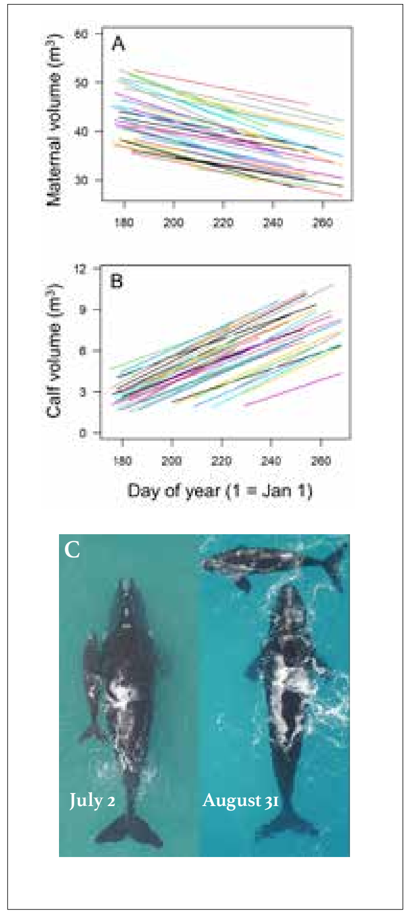


Figure 6. (A) Seasonal loss in maternal body volume and (B) growth in calf body volume of 40 southern right whale mother-calf pairs in South Australia. Each line represent a single individual and was estimated from repeated drone measurements of the same individual over a 90 day period. (C) The same mother and calf pair observed on July 2 and August 31, 2016, showing the growth in calf size and reduction in maternal body condition over that period. Figure modified from Christiansen et al. (2018).

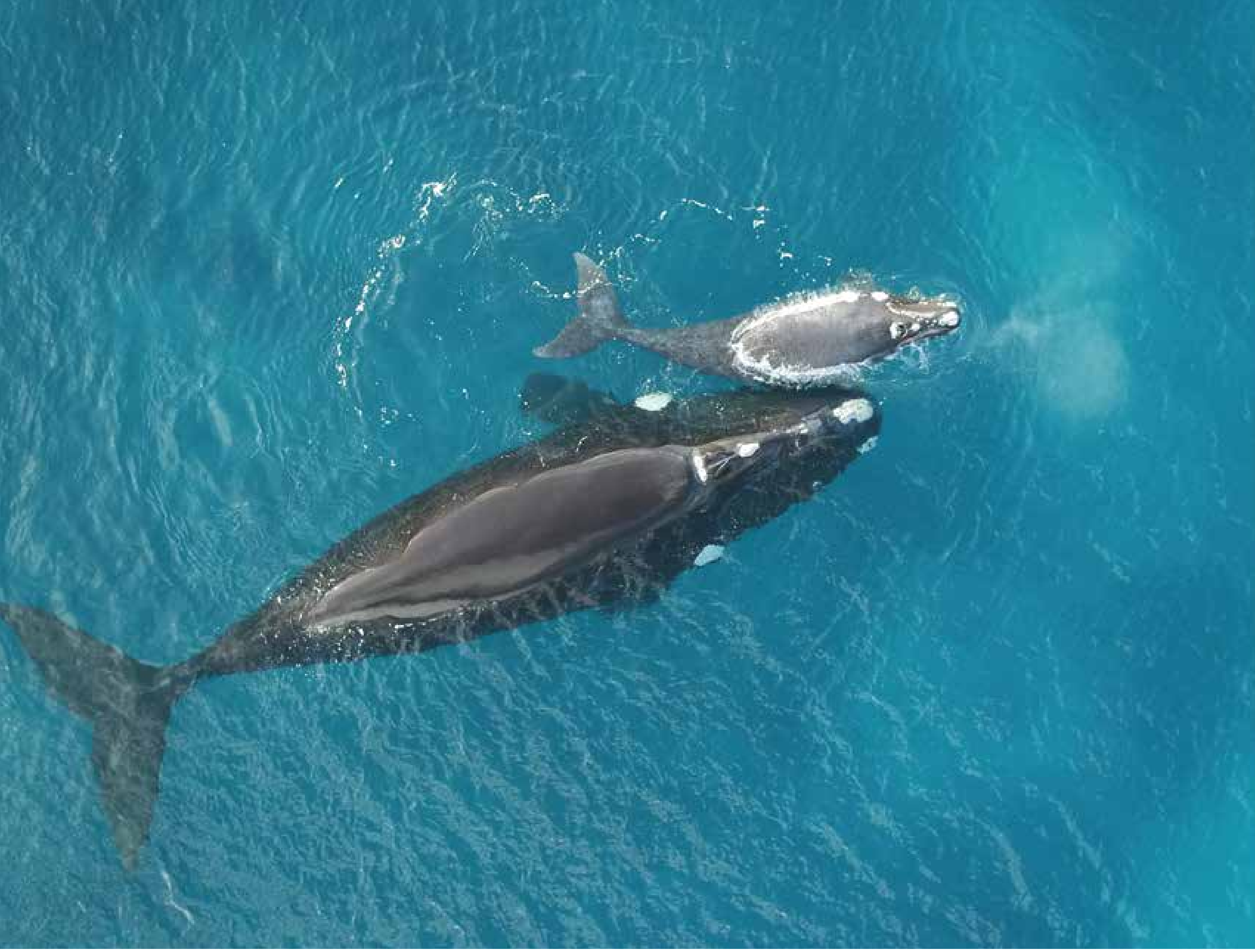
A curious right whale checks out the stern of R/V Polaris II at anchor.
Photo Credit: Prof. Steve Dawson.

BACK FROM THE BRINK:

RECOVERY OF SOUTHERN RIGHT WHALES AROUND AOTEAROA – NEW ZEALAND

WILL RAYMENT

A persistent green smudge on the RADAR screen is the only indication that we are approaching the Auckland Islands. I peer out of the wheelhouse of R/V Polaris II, the University of Otago's research vessel, to see that the wind is still howling, the seas are still wild and there is no sign of land beneath the dark grey clouds that hug the horizon. Few people have heard of the uninhabited Auckland Islands, and even fewer have been there. Most assume that they lie somewhere near the city of the same name, in the mild, almost sub-tropical, northern part of New Zealand. In reality, they are 450 km south of the mainland, deep in the Southern Ocean, at latitudes ominously nicknamed the Furious



Will Rayment Cont.

Fifties. And we have chosen to come here in the middle of winter. Why? Because the Auckland Islands are a haven for southern right whales.

Port Ross, named for polar explorer James Clark Ross, is a harbour at the northern end of the Auckland Islands archipelago, and during July and August is literally bulging with southern right whales, or tohorā, in the native Māori language. The whales are so densely spaced that navigating a safe course down the harbour requires a diligent watch, and frequent slaloms around the seemingly oblivious giants. Many of the whales are mature females, choosing Port Ross as a relatively calm, undisturbed haven in which to give birth and nurse their calves. The mums seem keen on keeping themselves to themselves, content to float quietly in the shallow margins of the harbour, while their calves either suckle, or play boisterously around them. But Port Ross is not just a nursery area. A good chunk of the whales in the harbour are juveniles. What they are doing there is a bit of a mystery, as they are not yet of breeding age and Port Ross is far from their productive foraging areas. But they certainly seem to be having a good time. Southern rights are among the most demonstrative of the large whales, and can be seen repeatedly breaching, spy-hopping, lobtailing and waving their enormous pectoral flippers in the air. The teenagers are into all of it, and on top of that seem to have an insatiable curiosity towards new visitors to their playground. It's not unusual for the nosey whales to approach our small boats, give us a friendly nudge, or even gently lift us temporarily from the water's surface. On occasions a particularly curious juvenile will follow the vessel around, seemingly wondering why we aren't reciprocating their playful advances. It all adds up to a magical scene; a remote harbour providing shelter from both the wild weather and the destructive impacts of humans, and chock full of healthy, playful southern right whales.

Of course, it hasn't always been this way. At the start of the 19th century, when commercial whalers turned their attentions from the massively depleted northern populations to the abundance of the southern hemisphere, it is estimated that there were between 30,000 and 50,000 southern right whales in New Zealand waters. At this point, right whales were abundant all around New Zealand's coastline. The mature females would come inshore during the winter and nurse their calves in and around the sheltered bays

Top RIght: Female southern right whale and her calf in the sheltered waters of Port Ross. *Photo Credit: Dr. Will Rayment.*

Page 62: A playful right whale calf and its mum. Aerial images like these have helped us to understand the relative health of the population. *Photo Credit: Prof. Steve Dawson.*

and harbours, particularly along the east coast of the South Island. There are stories from early European settlers that it was hard to get an uninterrupted night's sleep because of the cacophonous noise made by the plentiful whales so close to shore. This behaviour was part of their downfall. Once again, the *Eubalaena* species was targeted because they were the "right" whales to hunt; the trusting giants were easy to kill and provided a wealth of oil and baleen to fuel markets in Europe and America. Their decline was spectacular. After the first shore whaling stations appeared in southern New Zealand in the late 1820s, and with catch rates accelerated by bay whaling and the pelagic fleet, the population was reduced to probably just a few hundred individuals by the 1870s. No longer a commercially viable option, the whalers switched their focus elsewhere, but continued to take southern right whales opportunistically when they encountered them. This drove the population to an estimated minimum of about 100 whales in 1915. Fortunately New Zealand right whales managed to hang on until they were protected by the whaling regulations of the 1930s. Since then there has been an agonisingly slow recovery, punctuated by illegal Soviet whaling in the 1960s, during which it is estimated that another 300 right whales were taken from New Zealand waters. This sad story, familiar the world over, sets the scene for the recovery of southern right whales in the sub-Antarctic islands, and hopefully beyond to the coast of mainland New Zealand.

Having once been so plentiful, it was thought that southern right whales may have become locally extinct in New Zealand; there was a period of 35 years in the mid 20th century when not a single whale was sighted around the mainland. That view changed from the 1980s onwards when reports of consistent aggregations of right whales started trickling in from the remote sub-Antarctic islands. The first systematic surveys, starting in 1995 and involving a collaborative effort between researchers from University of Auckland, Australian Antarctic Division and Department of Conservation, among others, revealed that the population was well and truly recovering. These efforts, led first by Nathalie Patenaude, and recently by Emma Carroll, both from University of Auckland, have been instrumental in our understanding of the status of tohorā in New Zealand. I was lucky enough to be invited on one of these research expeditions to the Auckland Islands in 2008. What I experienced in Port Ross blew me away (almost literally, given the frequent 50 knot winds!). I had seen right whales before (I worked briefly as an observer on aerial surveys around Cape Cod), but never like this; they were big, fat, boisterous, and abundant. I was delighted to be invited back in the winter of 2009, and was so enamoured with the whole experience that I was convinced I had to keep working with these wonderful animals. Why were they here, how long did they stay, and how is the population doing? I managed to secure funding for a post-doctoral fellowship, and have now been able to visit the Auckland Islands for nine winter seasons over the past 15 years.

The University of Otago team uses R/V Polaris II as a floating base in the Auckland Islands, typically anchored in the sheltered bays of Port Ross. These bays are often studded with female right whales and their calves, so the view from the saloon window as we hurriedly inhale a hot lunch is always memorable. At night, when the lights are out, and the hum of the generator is silenced, it's a delight to lie in your bunk and listen to the grunts and groans of the chatty whales. If you can stay awake, this is also the prime time for making recordings of the vocalisations. Trudi Webster did this for her PhD, resulting in a comprehensive characterisation of their extensive acoustic repertoire. When dawn breaks, we launch small tender vessels from the mother ship to enable us to get among the whales and take photo-IDs. We also use the tenders as launch pads to gather photogrammetry images, thanks to ace drone pilots Steve Dawson and David Johnston. Our distribution surveys have helped us understand why the whales aggregate in Port Ross. The mums clearly prefer the upper reaches of the harbour, and the western and northern shorelines; areas that are sheltered from the prevailing westerly winds and heavy swells. It seems likely that these relatively tranquil waters afford the newborn calves the ability to suckle efficiently and grow quickly. This rapid growth is probably important if they are to survive their first forays into the wild Southern Ocean. Juvenile right whales are weaned at about a year old, after which the mum normally takes a year off to regain condition, before mating again ahead of a one year gestation. This sequence adds up to a typical calving interval of three years for southern right whales; something we have been able to confirm with our photo-ID data from the Auckland Islands. The mums most commonly show up on a three year cycle, and are absent in the intervening years, probably to maximise foraging opportunities. This means that the effective mating most likely occurs somewhere offshore, away from our cameras. The frolicing juvenile whales don't seem to know that though, and we sometimes witness groups of "surface-active" whales, featuring some very energetic mating attempts.

Will Rayment Cont.

Probably the most important outcome of our research has been the ability to characterise what a seemingly healthy population of right whales looks like. It is well known for example that the imperiled North Atlantic right whale suffers catastrophic impacts due to ship-strikes and entanglement in fishing gear, and that a large proportion of the population literally bears the scars of these encounters. In contrast, only two individuals, out of over 1,000 in the Auckland Islands photo-ID catalogue, show signs of propeller scars. The vast majority look very healthy, with shiny, unblemished skin and the rolls of blubber behind the blow-holes indicative of good condition. Their relative health has been quantified by a comparison with other right whale populations from around the world. Our team contributed photogrammetry data to a global collaboration showing that North Atlantic right whales had significantly lower body condition indices than their congeners from the southern hemisphere. Furthermore, the results showed that the Auckland Islands southern right whales were, on average, in better condition than the Australian and Argentinian whales measured during the study. This healthy status is undoubtedly a result of their relative separation from Earth's human population. Their principal calving area is a group of uninhabited islands protected by its inhospitable location, and reinforced by World Heritage Status and an extensive marine reserve. Their foraging areas, as far as we know, are deep in the Southern Ocean, well away from high concentrations of shipping and fishing. So, for the time-being at least, all seems well for southern right whales in the Auckland Islands and the population is continuing its gradual recovery from the brink of extinction.

The big question that remains is whether tohorā will return to the shores of mainland Aotearoa where they once thrived. In the 1990s and early 2000s the signs looked promising. Sightings of right whales were increasing and a few mature females were choosing the mainland coast to have their calves. Photo-ID and genetic matches showed these were the same whales that were being sighted in the sub-Antarctic islands. Perhaps this was a sign that the recovering population was spilling over from the Auckland Islands and recolonising their former habitat. But, whether or not the trend has continued is debateable; after 2010 the sightings hotlines were eerily quiet. Our dream, that sheltered areas of the mainland coast

like Otago Harbour will one day be full of whales, may never come to pass. The environment may just have changed too much in the last 200 years – too much ship traffic, too much fishing gear and too much underwater noise. Or maybe the more pervasive threats, such as climate change and the effects of industrial fishing, are impacting the Southern Ocean ecosystems which drive their food supply. But there is always hope. This winter a female was seen with a brand new calf, hanging around the old haunts on the South Island's east coast for several weeks. And there are still remote regions of the coastline, Fiordland for example, where the footprint of humans is less prominent. If we can manage such areas appropriately, we may yet see southern right whales return to these shores in abundance.

Relevant Literature

Jackson et al. 2016 An integrated approach to historical population assessment of the great whales: case of the New Zealand southern right whale. *Royal Society Open Science* 3: 150669.

Carroll et al. 2013 Accounting for female reproductive cycles in a superpopulation capture-recapture framework. *Ecological Applications* 23: 1677-1690.

Rayment et al. 2015 Breeding status affects fine-scale habitat selection of southern right whales on their wintering grounds. *Journal of Biogeography* 42: 463-474.

Webster et al. 2016 Quantitative analysis of the acoustic repertoire of southern right whales in New Zealand. *The Journal of the Acoustical Society of America* 140: 322-333.

Christiansen et al. 2020 Population comparison of right whale body condition reveals poor state of the North Atlantic right whale. *Marine Ecology Progress Series* 640: 1-16.

Carroll et al. 2014 Reestablishment of former wintering grounds by New Zealand southern right whales. *Marine Mammal Science* 30: 206-220.

Above: Breaching whales are a common sight during winter in Port Ross. *Photo Credit: Dr. Will Rayment.*

Page 64: Laurie Harbour, in the upper reaches of Port Ross; chock full of right whales, with R/V Polaris II in the background. *Photo Credit: Prof. Steve Dawson.*

AUTHOR BIOGRAPHIES

Kyla Bennett

After Kyla Bennett received her Ph.D. in Ecology and Evolutionary Biology from the University of Connecticut, she went on to get a law degree from Lewis and Clark Law School in Portland, Oregon so that she could better protect animals and their habitats. After a decade-long stint at the EPA protecting wetlands, she worked at International Fund for Animal Welfare (IFAW) for two years as the Deputy Director of Habitat, and then moved to Public Employees for Environmental Responsibility (PEER), where she is Science Policy Director and works on endangered species and chemical toxin issues. Kyla also has a Master Herpetologist certificate from The Amphibian Foundation in Atlanta, Georgia.

Sean Brillant

Sean Brillant is a Senior Conservation Biologist with the Canadian Wildlife Federation and an Adjunct at Dalhousie University. As an experimental marine ecologist, Sean collaborates directly with industry and conservation partners to identify and to implement evidence-based conservation actions that will eliminate threats to large whales.

Fredrik Christiansen

Fredrik Christiansen (Department of Biology, Aarhus University, Denmark) received his PhD from the University of Aberdeen in 2013 on the effects of whale watching on minke whales. Fredrik's current research interests include large whale bioenergetics and behavioural ecology. Much of this research focuses on the southern right whale and understanding the relationship between human disturbance, whale behaviour, bioenergetics and population dynamics. Fredrik is also one of the pioneers in developing drone-based photogrammetry methods to study large whale morphometrics and bioenergetics, and has recently started using drones to study whale behaviour. Fredrik is actively involved in several research projects around the world, including Australia, Argentina, Mexico, South Africa and Oman.

AUTHOR BIOGRAPHIES

IMAGE BY: ROBERT BALDWIN, FIVE OCEANS ENVIRONMENTAL SERVICES.

Peter Corkeron

Peter Corkeron now leads the whale research team at the Kraus Marine Mammal Conservation Program of the Anderson Cabot Center for Ocean Life. These days, his work focuses on the status of North Atlantic right whales, understanding the anthropogenic drivers of their decline and the ecological influences on their movements, and ensuring that management efforts are informed by the best science available. Peter's Ph.D. was on the ecology of inshore dolphins in the waters off Brisbane, Queensland, Australia. Awarded by the University of Queensland in 1989, it was the first Australian Ph.D. on the biology of living cetaceans. Peter has studied whales, dolphins, dugongs, and seals, with occasional forays into the behavior of fruit bats and wallabies. His research has taken him from the Ross Sea in Antarctica to within 300 miles of the North Pole, and many places in between. He believes in using science to understand how we impact marine wildlife, and the working to solve the problems we create.

Jessica Crance

Jessica grew up in Phoenix, and developed a love of the ocean at an early age. She went to college at the University of Arizona and graduate school at the University of San Diego where she studied killer whale vocal development. After graduating, she began working at the NOAA Alaska Fisheries Science Center's Marine Mammal Laboratory, where her research centers on long-term passive acoustic monitoring of Alaskan marine mammals. When not trying to find right whales, she spends as much time snowboarding, scuba diving, or paddleboarding as possible.

Kim Davies

Kim Davies is an associate professor at the University of New Brunswick in Saint John, Canada. She is a biological oceanographer who studies how the ocean creates feeding hot spots for right whales. She also works with industry and government to monitor for right whale sounds in real-time from marine robots deployed in shipping lanes and fisheries management areas.

Top Right Image: Kim Davies doing field work in the Gulf of St. Lawrence (2017). *PHOTO CREDIT TO CANADIAN WHALE INSTITUTE/NEW ENGLAND AQUARIUM/UNIVERSITY OF NEW BRUNSWICK.*

AUTHOR BIOGRAPHIES

Julia Dombroski

Julia was born in Brazil and is currently a Ph.D. candidate at Syracuse University, USA. She completed her bachelor's in Biological Sciences, and she has a master's degree in Animal Behavior. Julia is a behavioral ecologist whose work on right whales focuses on acoustic communication, cumulative effects of disturbance, and acoustic density estimation. Julia uses different methods to research right whales including passive acoustic monitoring and biologging devices. For nearly 10 years Julia has been leading projects on the behavioral ecology of southern right whale off Brazil, in partnership with conservation projects and the local community. She has also participated in research about acoustics and behavior of North Atlantic right whale's female-calf pairs off SEUS. Out in the water or coding and writing in front of a computer screen, Julia loves being a scientist. She is grateful to all her mentors and to the scientist who came before her.

Philip Hamilton

Philip Hamilton has been studying North Atlantic right whales since 1986, when he led the right whale photo-identification efforts at the Center for Coastal Studies on Cape Cod. In 1989, he began working for the New England Aquarium, where he now manages the North Atlantic right whale photo-identification catalog (rwcatalog.neaq.org). In 2003, he received a National Science Foundation grant to develop software to manage all aspects of the images and data in the catalog (DIGITS). Philip is interested in right whale behavior (including associations), disease, and genetics. He works closely with colleagues from St. Mary's universities in Canada to link and query the genetic and photo-identification databases.

Amy Knowlton

Amy Knowlton is a Senior Scientist who has worked on the Right Whale Research Program since 1983. She has been involved in all aspects of the program, including fieldwork, curation of the photo-identification catalog, assessment of human impacts, and policy efforts to protect right whales. Amy's main focus has been the detailed documentation of human impacts on right whales, including fishing-gear entanglement and vessel strikes. By evaluating these data in-depth and linking these findings with the operational aspects of the fishing and shipping industries, she has been able to share these findings with industry groups and guide policy changes in order to improve the protection of right whales from these activities.

AUTHOR BIOGRAPHIES

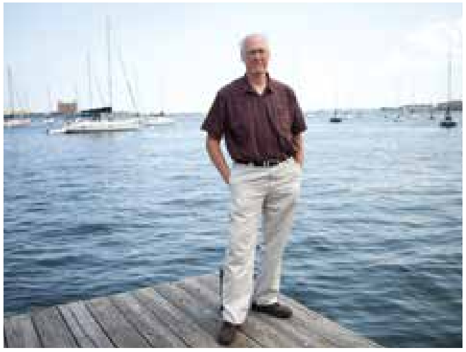


IMAGE BY: KAYANA SZYMCZAK, BOSTON GLOBE.

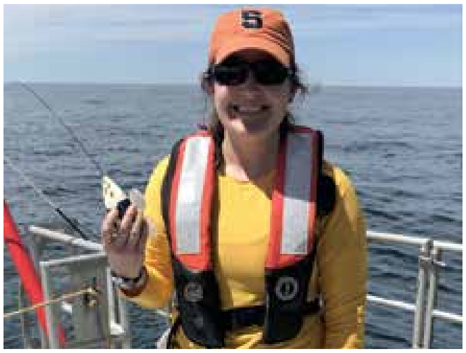
Scott Kraus

Dr. Scott Kraus has more than 40 years of field research on whales and dolphins. He has been a research scientist in the Aquarium's Research Laboratory since 1980, and has published more than 110 papers on marine mammals, bluefin tuna, harbor porpoise, fisheries, and bycatch. Scott has worked on the biology of North Atlantic right whales since 1980, publishing numerous papers on right whale biology and conservation. He is co-editor of "The Urban Whale," a 2007 Harvard University Press book on right whales in the North Atlantic. He was a member of the original U.S. National Right Whale Recovery Team, served on the U.S. Large Whale Take Reduction Team, and was a member of the research faculty at the University of Massachusetts, Boston. His early work included the use of photo-identification of individual animals as a basis for studying the population biology of whales, developing the use of pingers for reducing porpoise bycatch in gillnets, and assessing of marine mammals from aerial surveys. Recent research projects have included studies on marine mammals and sea turtles around proposed wind farm sites, developing methods for reducing incidental bycatch of cetaceans in fishing gear, exploring visual capacities of cetaceans, and investigating the oceanographic underpinnings of marine mammal concentrations in the new Northeast Canyons and Seamounts Marine National Monument. His overarching research interests encompass identifying and testing methods for reducing the impacts of human activities on cetaceans and the marine environment.

William McLellan

William McLellan has been working on marine mammals for over 35 years. He is at the University of North Carolina Wilmington and is the North Carolina Marine Mammal Stranding Coordinator and Master Necropsy Team Leader for NOAA. He has worked on investigating marine mammal mortalities in multiple countries in both the Atlantic and Pacific oceans and has lead necropsies of 35 north Atlantic right whales, over 100 humpback whales and over 2500 odontocete cetaceans.

AUTHOR BIOGRAPHIES



Susan Parks

Susan Parks (*Syracuse University, Syracuse, NY*) is an Associate Professor of Biology and director of the director of the Bioacoustics and Behavioral Ecology Lab at Syracuse University in central New York. She started research on whale acoustics in 1996 as an undergraduate, and received her Ph.D. in 2003 from the MIT/Woods Hole Oceanographic Joint Program under the supervision of Peter Tyack. She's been studying right whale behavior and acoustics since 1998, with most of her research focused on North Atlantic right whale communication. More information is available at: babel.syr.edu.

Heather Pettis

Heather Pettis' primary research interests are using visual health assessments to examine trends in right whale health at both the individual and population levels and to investigate the impact of anthropogenic injuries on right whale health and survival over time. She played an integral role in the development of the visual health assessment technique for right whales and has advised researchers in the development of assessments for other cetacean species. She serves as the executive administrator for the North Atlantic Right Whale Consortium, a collaborative data sharing group committed to long-term research and management efforts to provide management, academic, and conservation groups with the best scientific advice and recommendations on right whale conservation. She is also interested in photo-identification and population monitoring.

Will Rayment

Will Rayment was brought up in Plymouth, in the southwest of England. He studied Biology at Oxford University, before doing an MSc in Conservation at University College London. After moving to New Zealand he completed a PhD at the University of Otago, on the design of marine protected areas for the endemic Hector's dolphin. He is now a Senior Lecturer in the Marine Science Department at Otago, and a trustee of the New Zealand Whale & Dolphin Trust, an NGO dedicated to research and conservation of cetaceans.

You care about whales, dolphins, and porpoises. We're here to protect them, but we can't do it without your help.

The American Cetacean Society is proud to present this special issue of our *Whalewatcher* Journal, highlighting the plight of right whales. We are grateful to our Guest Editor, Peter Corkeron, and all the authors who contributed to this important publication.

Uniquely written by scientists for the lay community, *Whalewatcher* is just one of the many benefits you'll enjoy as an ACS member– from local chapter meetings and action alerts, and issues of *Spyhopper*, our quarterly e-newsletter, your support of ACS puts you at the epicenter of our efforts to protect the future of cetaceans. The best benefit of all, however, is knowing that your investment in the American Cetacean Society is making a meaningful difference in the lives of whales, dolphins, and porpoises everywhere.

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On behalf of whales, dolphins, and porpoises,

President, ACS National Board of Directors

American Cetacean Society

Whale Arrow (#3290) with her first calf, #3990, in the Bay of Fundy in 2009 when she was just seven years old. On average, right whales give birth to their first calf when they are ten years old.
Photo Credit: Anderson Cabot Center/New England Aquarium. Collected under Fisheries and Oceans Canada SARA permit.








AMERICAN CETACEAN SOCIETY

The mission of the American Cetacean Society is to protect whales, dolphins, porpoises, and their habitats through public education, research grants, and conservation actions.

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P.O. BOX 51691
PACIFIC GROVE, CA 93950
acsonline.org