Preliminary Report of the
Dynamics of Large Whale Entanglements in Fishing Gear Workshop

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Overview

From February 9-11, 2011 fishermen, whale scientists, fishing gear engineers, rope manufacturers, and marine wildlife disentanglement experts participated in a workshop to review and examine the dynamics of large whale entanglements in fishing gear. The *Consortium for Wildlife Bycatch Reduction* organized this workshop to increase understanding about baleen whale entanglements and ultimately improve the evaluation of methods for reducing their bycatch.

The Problem

Large whales are frequently injured and often killed as a direct result of entanglement in fishing ropes, especially from pot and gillnet gear. The consequences of these fishing gear conflicts are particularly severe for species such as the North Atlantic right whale, a critically endangered species with an estimated population of only 450 individuals and a geographic range largely restricted to the continental shelf waters of the Northwest Atlantic. Over 80% of individuals observed between 1980-2008 were either entangled or showed entanglement scarring (Knowlton et al., 2011), and documented mortalities as a consequence of entanglement in fishing gear occur regularly (four in just the past nine months). Since the early 1990s, it appears the severity of entanglements is increasing , and there is no evidence yet that regulated modifications to fishing gear—"weak links" in northeast US pot and gillnet gear (as of 2008) or the expanded use of sinking groundline in lobster trawls—have reduced either the number or severity of these entanglements.

Fisheries managers mandate gear modifications with presumed but questionable benefits to large whales because the relative rarity of entanglement events denies them the ability to test their efficacy. Mitigating bycatch in large baleen whales differs from approaches with many other marine animals owing to the inability to evaluate potential new gear modifications through at-sea trials. These trials typically compare catch rates of non-target species between existing fishing techniques and new fishing devices or methods. In the case of the North Atlantic right whale, the species is so endangered, and entanglement events are so rarely observed, that it is not possible to obtain statistically valid measures of the efficacy of new fishing gear using comparative trials. Put simply, we cannot compare entanglement rates of baleen whales between two different gear types using the typical and preferred method.

The Process

> *…the removal of gear from entangled right whales has been a primary source of information for the identification of gear types and fisheries that pose a risk to right whales; this information is critical to the development of appropriate mitigation measures.* (Reeves et al., 2007)

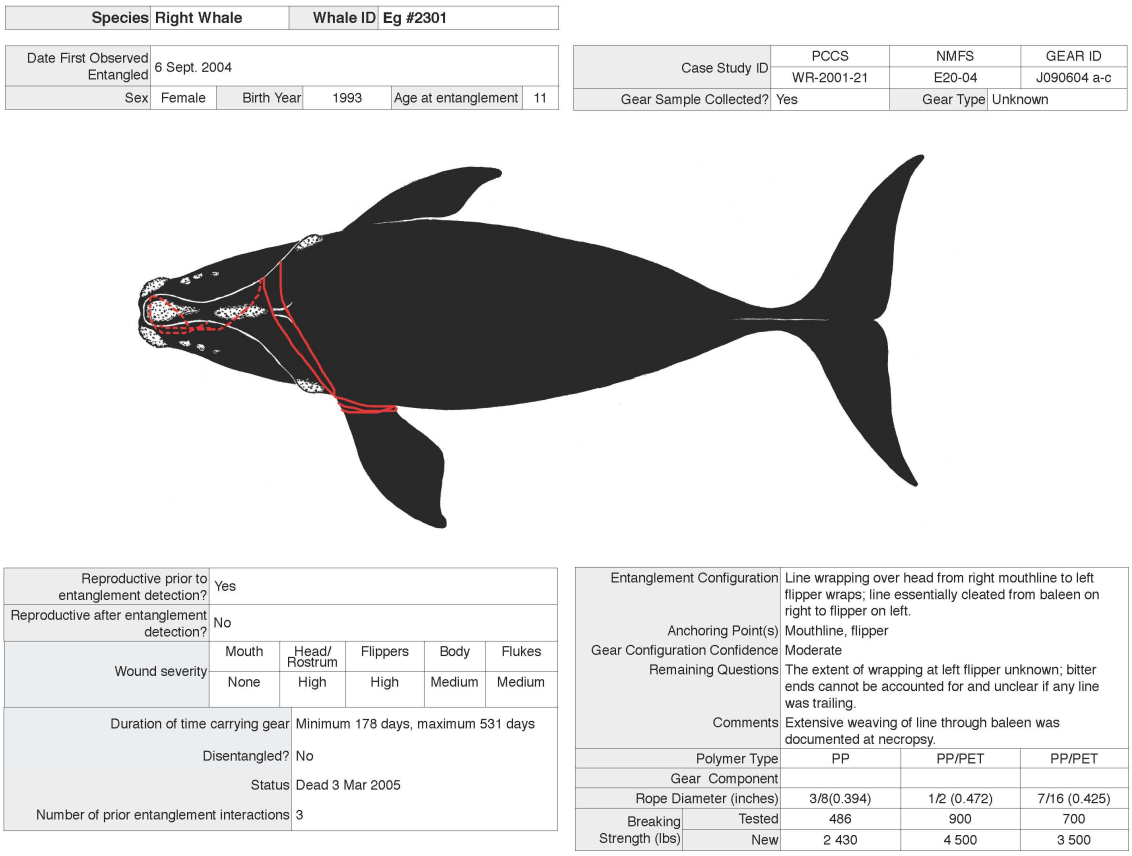
In the absence of carrying out at-sea trials of gear modifications, the *Consortium for Wildlife Bycatch Reduction* decided to see what could be learned by mining other sources of data. The initial outputs of this sponsored research was presented during the workshop and included:

- Analysis of scarring severity of whales carrying gear using photographic survey records (through the *New England Aquarium* and the *Provincetown Center for Coastal Studies*)
- Upgraded illustrations of how ropes were wrapped around the bodies of entangled whales (through the *Provincetown Center for Coastal Studies*)
- Measurements of the diameter, construction, linear density, specific gravity, and breaking strength of ropes retrieved from entangled whales (through rope engineer *Hank McKenna*)
- Simulations of whale flipper-rope encounters (through the *University of New Hampshire*), and
- Development of a computer model for simulating whale entanglements using engineering principles and information on whale swimming behavior (through *Duke University/Bellequant Engineering*).

Outputs from the above first three research projects were assembled into a booklet distributed in advance of the workshop, which contained case studies of whale entanglements for which gear had been retrieved from the animals (Figure 1). The case studies were of 18 right whale and 22 humpback whale events that occurred from 1995-2006, and were intended to provide a comprehensive picture about the entangling gear and its impacts on individual animals. Other whales become entangled in fishing ropes but only right whales and humpbacks had cases of individuals with complete scarring records, illustrated wraps, and retrieved gear. Dr. Michael Moore of *Woods Hole Oceanographic Institution* (WHOI) contributed information from pathology reports for those cases that resulted in death and a necropsy had been performed on available carcasses.

Finally, NMFS brought the fishing gear retrieved in ten of these entanglements (five humpbacks and five right whales) to the workshop, and multi-disciplinary groups carried out detailed examinations of the gear, reviewed the body of evidence for these ten cases, and reported to the entire group on their overall assessments. Part of their assignment was to imagine whale-gear conflict scenarios that could have led to the entanglement observed ("reverse engineering"), and to consider what gear modifications might have prevented the entanglement or reduced its severity.

The majority of the workshop participants (20/50) consisted of fishermen from Canada and the northeastern US who fish primarily with pot, gillnet, and drag gear. The other major groups represented were from academia, non-profit marine science groups, government (the US and Canada, including disentanglement experts), and the rope manufacturing industry.



Species	Right Whale	Whale ID	Eg #2301

Date First Observed Entangled	6 Sept. 2004				
Sex	Female	Birth Year	1993	Age at entanglement	11

Case Study ID	PCCS	NMFS	GEAR ID
	WR-2001-21	E20-04	J090604 a-c
Gear Sample Collected?	Yes	Gear Type	Unknown

Reproductive prior to entanglement detection?	Yes
Reproductive after entanglement detection?	No

Wound severity	Mouth	Head/ Rostrum	Flippers	Body	Flukes
	None	High	High	Medium	Medium

Duration of time carrying gear	Minimum 178 days, maximum 531 days
Disentangled?	No
Status	Dead 3 Mar 2005
Number of prior entanglement interactions	3

Entanglement Configuration	Line wrapping over head from right mouthline to left flipper wraps; line essentially cleated from baleen on right to flipper on left.
Anchoring Point(s)	Mouthline, flipper
Gear Configuration Confidence	Moderate
Remaining Questions	The extent of wrapping at left flipper unknown; bitter ends cannot be accounted for and unclear if any line was trailing.
Comments	Extensive weaving of line through baleen was documented at necropsy.

Polymer Type		PP	PP/PET	PP/PET
Gear Component				
Rope Diameter (inches)		3/8(0.394)	1/2 (0.472)	7/16 (0.425)
Breaking Strength (lbs)	Tested	486	900	700
	New	2 430	4 500	3 500

Figure 1. A sample page from the whale entanglement case study booklet with information on a particular whale entanglement. A second page contained photo documentation of scarring, the gear involved, and the dead animal if the animal perished and there was a beached carcass.

Preliminary Results

Summarized here are some preliminary results and recommendations that will be subject to revision in preparing the final report.

For the fishermen, this was the first time they had been invited expressly to provide their expertise in analyzing whale entanglement events, and given the complete set of available information on the whales and gear involved. Generally, all participants recognized that useful insights into whale entanglements can be acquired by having

a group of fishermen and whale scientists collaboratively review entanglement events including the gear involved. It seems intuitive that the most accurate characterization of whale-gear entanglements would be achieved by engaging the fishermen who best understand the gear, and whale biologists who have studied whales the most. Yet prior to this workshop there has not been a forum in which this exchange could occur purposefully and using the best available information on entanglement events. During the workshop, whale disentanglement experts remarked that they became convinced their initial reports could have been improved by the kinds of insights that fishermen articulated during the examination of case studies and retrieved gear.

Separate breakout groups reviewing the same case studies arrived at the same conclusions and similar insights about particular cases. For example, two groups reported that rope knotting was a factor contributing to a higher likelihood that ropes would become lodged in a whale's baleen. Many also recognized the utility of combing multiple sources of data from individual entanglement events. One breakout group surmised that a particular entanglement originated in the whale's mouth but could only find corroborating evidence from a necropsy report that showed a furrowed scar in the jaw of the whale, the kind that would be produced by a rope.

Some breakout groups independently wondered if many of the entanglements characterized by wraps on the peduncle, flippers, or trunk of the body could be best explained as the result of an initial encounter of gear with the whale's mouth area. Computer modeling that incorporates the physical properties of ropes with whale behavior and biology can help test this hypothesis. Dr. Laurens Howle presented a first version of a computer model developed with a sophisticated custom software system to mathematically model the interaction between whales and fishing trap gear. The model presently allows an anatomically accurate whale model to move through a virtual environment with six degrees of freedom (three translations and three rotations). In addition, it includes a rope model to describe the rope mechanics in response to external forces such as axial current, cross current, weight, and tension. With further development and refinement, this model can provide a platform for studying whale-gear interactions and evaluating potential gear modifications, such as ropes fished under higher tension. Considering the inability to statistically validate gear modifications for whale entanglements, this tool could serve as a useful alternative.

Taking all 40 case studies into account, commercial fishing ropes of all diameters and breaking strengths led to severe injury. Younger right whales were observed entangled in ropes of lower breaking strengths whereas the ropes involved in entangled adults were of higher breaking strengths. This trend applies only to the observed cases, and also excludes entangled whales for which no gear was retrieved. This data suggested that rope breaking strength would need to be reduced to $\leq$ 1000 lbs if it were to result in less severe entanglements in juvenile whales, a strength that is not very practical at least in some fishing locations.

Recommendations

The group suggested a number of recommendations on the final day of the workshop.

1. Many recommendations focused on improving the process by which gear is retrieved and documented from entangled whales. These included a request to thoroughly identify as much as possible the portion of the gear that was cut off during the disentanglement and/or as part of its examination by NMFS (the US National Marine Fisheries Service). Video documentation of gear above and below the water is helpful in characterizing entanglements, and whenever it is safe to do so (for the whales as well as for disentanglement teams) it should be part of standard disentanglement procedure. Illustrations and photography should attempt to accurately capture the true color of the various ropes involved in the entanglement for aiding subsequent physical inspection of the gear. When gear is cut off from the whale, the location's GPS coordinates should be recorded, and every effort made to return to the site and retrieve gear removed at sea. This would help answer questions such as: Was there an additional gear component or another gear type involved in the entanglement? What drag force measurements might be estimated by knowing how much gear was trailing from the animal? Seeing as some entanglements appeared to involve multiple gear types (i.e., different sets), it would be helpful to document how these different types became overlaid on the animal. This would help determine which gear was involved in the initial contact and which may have been picked up subsequently.
2. This workshop demonstrated that important and useful gear diagnoses can be carried out post-disentanglement through collaborative exchanges among fishermen, gear experts, and whale scientists who are given complete information on entanglement events. Participants concluded these examinations of whale entanglements should be carried out on a regular basis by a small team of fishermen from different locations along the east coast of North America who have commitment and expertise in this subject, working alongside whale biologists familiar with fishing gear entanglements.
3. Considering the absence of data to indicate what impact regulated gear modifications are having on whale entanglements and the benefits of carrying out this kind of analysis, it seemed surprising that reports from examination of retrieved gear were only available through 2007. Many fishermen would like to see if retrieved gear can be used to create an historical benchmark and more real-time tracking of how entanglement dynamics may be changing as a result of regulatory changes to fishing gear and methods. Specifically, is there any way to use this process to evaluate the impact of weak links or sinking groundline?
4. Just as the study of individual entanglement cases and their associated gear can be insightful, examination of the body of evidence from all cases assists in identifying patterns that can help inform effective mitigation methods.

5. Workshop participants stressed the need for better gear marking so that entanglement events can be clearly attributed to the exact kind and components of fishing gear involved, which would include information on how and where it was fished.
6. Ghost gear is occasionally involved in entanglements, so any proposed gear modifications should consider how much they might add to ghost gear.
7. A website should give fishermen and other interested parties access to the complete set of photographic and other information on whale entanglement events, including retrieved gear, but excluding personal information of any fisherman.
8. Among the gear modification ideas worth evaluating is the use of fishing ropes that have higher tension while deployed underwater. These ropes might be less prone to wrapping around flippers and the peduncle region.
9. Including rope manufacturers at the workshop was useful given their knowledge of rope and expertise for evaluating the potential of innovative fishing ropes.
10. Necropsy data is extremely useful in understanding whale entanglement dynamics and needs to be better incorporated into the body of evidence assembled for relevant case studies.
11. A computer model with precise rendering of whale anatomy, behavior, rope characteristics, ocean current, and other critical factors that bear on whale entanglement dynamics would be a useful tool for studying various entanglement scenarios and evaluating gear modifications.

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About the Consortium for Wildlife Bycatch Reduction

The *Consortium for Wildlife Bycatch Reduction* consists of *Blue Water Fishermen's Association*, *Duke University*, *Maine Lobstermen's Association*, *New England Aquarium*, and *University of New Hampshire*. Administered out of the *New England Aquarium*, the *Consortium* supports collaborative research between science and the fishing industry to identify practical bycatch reduction solutions for endangered species.