<u>Project 1 – Dynamics of Large Whale Entanglements in Fixed Fishing Gear</u> (New England Aquarium [NEAq], Maine Lobstermen's Association [MLA], Provincetown Center for Coastal Studies [PCCS], and Woods Hole Oceanographic Institution [WHOI])

Project 1 Final Report

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The Relationship Between Fishing Gear and Large Whale Entanglement Severity

> *…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)

Project Overview

Mitigating bycatch in large baleen whales represents a continuing challenge to fisheries managers and others interested in reducing the often lethal and sublethal impacts of these entanglements. Many gaps in knowledge exist about when and where these entanglements occur and the relationship between the characteristics of the fishing gear used and the types of injuries observed. Despite over 15 years of dedicated efforts by the Atlantic Large Whale Take Reduction Team to develop and implement gear modifications and/or closures to reduce entanglement levels, a recently published paper analyzing North Atlantic right whale entanglement interactions documented from 1980-2009 indicate there has been no detectable change in the overall entanglement interaction rate, and the rate of severe entanglements has increased over the 30 year timeframe (Knowlton et al. 2012). In addition, entanglements of humpbacks and minkes in the western North Atlantic remain a conservation concern.

This project was undertaken to investigate in more detail the parameters of rope removed from disentangled or dead large whales, the resulting severity of their injuries and whether any linkage was evident involving species, animal age, entanglement complexity and injury severity. A second aspect of the project was to investigate rope manufacturing history and assess whether changes in rope resulted in changes to fishing practices or changes in entanglement complexity and severity.

This project report represents the summation of two years of work undertaken by multiple researchers to analyze and integrate both the whale biological information, rope parameter findings, and rope manufacturing changes. The principal results are provided as two separate deliverables:

- A scientific manuscript attached as Appendix 1 that in January of 2013 will be submitted to a peer-review journal for publication.
- A compendium of case studies of right and humpback whale entanglements (Appendix 2) integrating analyses undertaken for this project (injury severity, and examination of ropes retrieved from disentanglements), illustrations of the entanglements by PCCS, life history

information on the whales, photographs of the entanglement and/or its aftermath, and information from NOAA Fisheries examination of the retrieved gear.

This narrative includes much of what is reported in those deliverables, and also summarizes the activities carried out in producing them, organized into different work phases, described below.

Phase 1 – Development of injury and entanglement severity levels

The presence of scars and/or entangling gear show evidence of each entanglement interaction that a whale experiences. As part of the investigation of rope parameters on injury and entanglement severity, three different injury levels - low, medium, and high, and three different entanglement severity levels – minor, moderate, and severe, were developed and reviewed by veterinarian Dr. Rosalind Rolland. For each right whale[1] with evidence of entanglement interactions based on scars or presence of gear (1,032 events from 1980-2009), these entanglement severity levels were applied to each event. For all humpback whales reviewed for this study (animals with retrieved gear only), these entanglement severity levels were determined.

A description of the categories accompanied by images are provided below.

INJURY SEVERITY

Any wound/scar related to entanglement is reviewed using the criteria below. Injuries were coded at the highest severity level if any one of the criteria in the category was depicted. For a scar to be attributed to entanglement, it had to show evidence of the rope having "wrapped" on a given body part (see *Figure 1* for examples of injury severity).

LOW

- Small, linear wrapping scars or depressions in the skin that do not penetrate into the blubber and are less than ~ 2 cm in width, less than 2 cm in depth (approximate depth of epidermis).

  Note: Extent of depression/scar coverage in any given body area is low; these types of scars may fade altogether over time especially when found on calves or young juveniles.

MEDIUM

- Wrapping wounds or depressions that are bright white when healed and are greater than ~ 2 cm in width, and/or between 2 and 8 cm in depth, and/or penetrate the skin extending into the blubber (hypodermis layer) but not into muscle or bone.

- Broad areas of abrasion on a given body area that have removed a layer of skin but may not penetrate into the blubber.

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[1] Unless otherwise indicated, the term "right whale" in this report refers to the North Atlantic right whale (*Eubalaena glacialis*)

- Wounds or bright white scars on the head, flipper or tail that extend beyond the skin but do not extend beyond blubber (actual depth of wound not measured at these areas as blubber layer is shallow).

  Note: The wounds may be raw (red) looking when fresh but typically heal within weeks leaving no raw areas.

HIGH

- Wrapping wounds on the body more than 8 cm in depth and/or extending into bone or muscle.
- Tail, flipper, or head wounds extending into the bone or muscle.
- Broad areas where skin and blubber tissue has been removed and muscle or bone is exposed. (Note: These wounds may also extend beyond 8 cm however this was often difficult to ascertain – often these wounds will heal but sometimes raw areas may still be evident months or years after the initial event).
- Significant deformity or discoloration of fluke or flipper, for example a twisted fluke caused by torquing by rope/gear, or evidence of a white flipper (indication of circulation impairment) that occurs in conjunction with a known entanglement event even if gear or wounds are not seen on the flipper. (This last criterion [“white flipper”] applies to right whales, only).

  Note: In cases of an animal carrying rope around the rostrum or taught over the blowhole where feeding or breathing is considered to be impeded, these injuries will be coded as severe; and if a juvenile has constricting wraps anywhere on its body and is still growing, these injuries will also be coded as severe.

<u>OVERALL ENTANGLEMENT INJURY SEVERITY</u>

Overall entanglement injury severity, herein referred to as “entanglement severity” refers to the maximum observed injury level across all body regions. Entanglement severity is categorized as minor, moderate, or severe and is determined by evaluating the injury severity determined for different regions of the body (rostrum/head, mouth, flippers, body, tail). For example, if the injury severity for any given body region was categorized as high, the entanglement severity is categorized as severe. If all the injuries seen on multiple body regions from a given entanglement event are determined to be low severity, the entanglement interaction is coded as minor. In some cases, the documentation was not adequate to reliably assess entanglement severity, particularly when the attachment site(s) were not well-documented. When the full extent of the injuries could not be adequately assessed, the case was listed as “Unknown”.

Figure 1-1 (a-c). Entanglement severity level examples.

(a) Minor

(b) Moderate

(c) Severe

Phase 2 – Development of entangling gear complexity levels

Entangling gear complexity levels were developed to investigate how complexity may have changed over time, whether complexity was related to rope parameters, and what role complexity had on the fate of the whale.

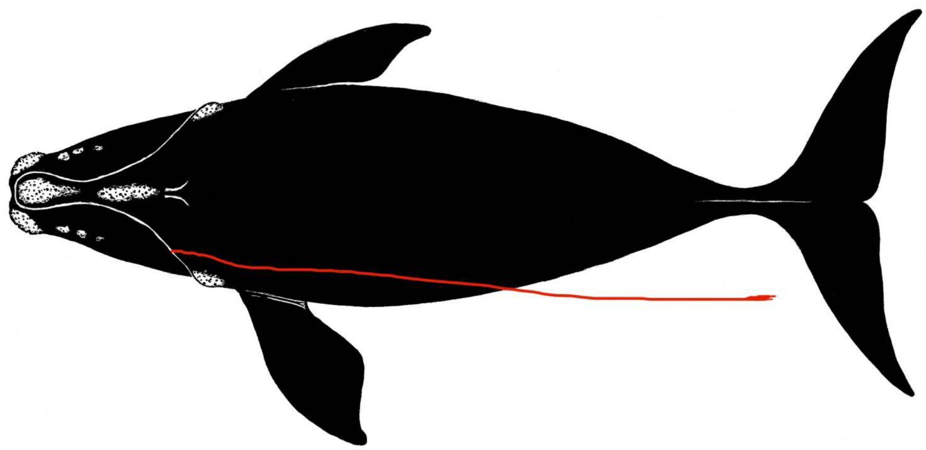
Two levels of entangling gear complexity were developed – high or low. Complexity was categorized as high if any one of the following criteria were met. If the whale experienced none of the following, complexity was categorized as low:

- More than one body area involved (potential attachment or anchoring points: mouth, flipper, body, tail)
- Dragging significant gear (greater than 1 body length trailing)
- Constricting wraps (anywhere on animal)

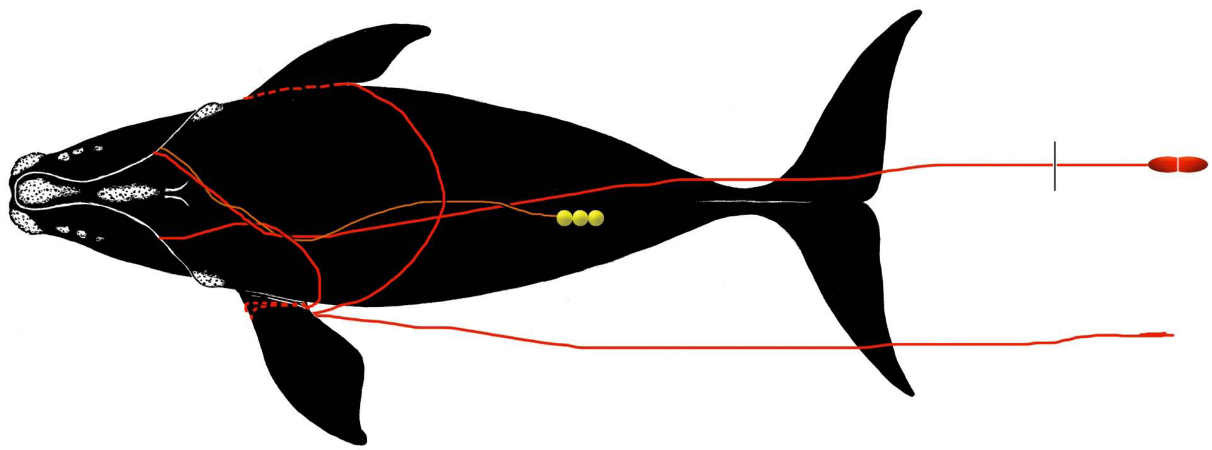
These criteria were developed based on known deaths or disappearances of both species when these types of entanglement configurations were observed.

All right whales with gear attached (including retrieved gear) and all humpback whales with retrieved gear only were categorized as high or low complexity.

Examples of whales with high versus low entangling gear complexity are provided in Figure 1-2.



(a)



(b)

Figure 1-2. Examples of entangling gear complexity for right whales: (a) Low entangling gear complexity; (b) High entangling gear complexity.

Phase 3 – Integration of whale and gear findings

This phase of the project involved the integration of the whale life history and fate data with the analyses on retrieved gear (Appendix 3) carried out by Hank McKenna, an expert in rope engineering, into whale entanglement case studies involving both right and humpback whales. In addition, the results of the combined analyses have been written up into a draft manuscript that we will be submitting for publication in January of 2013 (Appendix 1). A summary of the main findings described in this manuscript are provided below.

A second aspect of this phase was a survey of fishermen involved in the industry for several decades to see what types of changes had occurred in fishing practices between the 1980s and the present, and to also look at present seasonal variation in their fishing activity. An evaluation of rope manufacturing changes and how this might have influenced fishing activities was also explored.

Methods and findings related to this study are touched upon in the draft manuscript (Appendix 1), but more details are provided in this report.

Case studies

To visually display the integration of the whale entanglement information with the gear configuration and rope parameters, case studies were developed for all right whales with gear attached (including cases where gear was not retrieved or analyzed) as well as all right whales with severe injuries from entanglement. Case studies were also created for humpback whales with retrieved and analyzed gear. Each case study is two pages in length – one page includes an entangling gear configuration diagram (created by Scott Landry) when the relative placement of gear on the body could be reliably determined, a description of the entanglement, life history information about the individual when detected with the entanglement, injury and entanglement severity, and details about rope parameters for those cases with retrieved and analyzed ropes. The second page shows images of the entangled whale. Appended to each case study, as available, are the associated gear reports developed by Hank McKenna and the Fishery Interaction Gear Analysis produced by John Kenney of NMFS.

A total of 86 right whale case studies and 22 humpback whale case studies were created. The right whale case studies are divided into three groups: whales with retrieved and analyzed gear (n = 29), whales with gear that was either not retrieved or not able to be analyzed (n = 44), and whales with severe entanglement injuries but no gear attached (n = 13). A total of 22 humpback whale case studies were created for those animals with retrieved and analyzed gear, only. An additional eight humpbacks and one right whale had retrieved gear but not enough information to create a case study, although rope information from these entanglements was included in all the analyses related to ropes.

Of the 73 right whales with gear attached, 47 cases had enough documentation to create gear configuration diagrams. The 22 humpback whale case studies all had entanglement configuration diagrams created.

Findings of rope and whale analyses

Methods summary

The following segments are brief summaries taken from the draft manuscript that should be consulted for clarification or more information (Appendix 1).

132 ropes from 69 individual whales (30 right whales [RW]), 30 humpback whales [HW]. 8 minke whales [MW]) and one fin whale were tested for a variety of parameters in particular estimated breaking strength and rope diameter. Because gear from only one fin whale was tested, this case was not included in any of the analyses below.

The estimated breaking strengths found on these 68 whales were compared between species and within species. Statistical differences in the average breaking strength of gear among different groups of whales were tested with a one sided Student's t-test. A one-sided test was chosen to evaluate the hypotheses that MW, HW, and RW would be found in increasingly stronger ropes because of their differences in size and weight, and whales of the same species with severe injuries, or that are older/bigger, or with higher entangling gear complexity would also be found in stronger ropes. Significance or non-significance findings are reported below and the related t-test results can be found in the draft manuscript.

To compare entangling gear complexity and entanglement severity in RW over time, two additional analyses were carried out: (1) A graph of the number of individuals seen with low or high gear complexity entanglements and visually comparing years and decades; (2) A comparison of the relative proportions of minor, moderate, and severe entanglement for all RW with either gear attached or with scars only as described in Knowlton et al. (2012). Entanglement events were combined for sequential three-year periods beginning in 1980-1982 through 2007-2009. This represented a total of 1,032 entanglement interactions. Visual differences between time periods were evaluated using a Fisher's Exact Test.

Findings

Comparison by species
No significant difference was detected in the rope breaking strengths between RW (mean = 3,292 lbs) and HW (mean = 2,952 lbs). Both HW and RW had significantly higher breaking strengths than MW (mean = 1,682 lbs).

Comparison by age
A significant difference was detected in the breaking strengths found on all juvenile RW (mean = 2,510 lbs) versus adult RW (mean = 6,184 lbs). No significant difference was found between juvenile and adult HW.

Comparison by entanglement severity
For RW, an increasing trend in breaking strengths versus severity was detected but was not significant. For HW, no trend or significant differences were found between breaking strength and severity.

Comparison by entanglement complexity
All RW cases with retrieved gear were coded as high complexity. RW are typically not anchored and few had single attachment points, therefore no comparison was carried out to investigate these parameters. Nearly all (88%) of the HW cases were coded as high complexity. A comparison of multiple attachment points vs. single attachment points was not significant. A comparison between anchored and non-anchored also was not significant.

Comparison by fate
No significant difference in breaking strength was detected for RW or HW in comparison to fate of the whale. However, most or all of the HW and RW cases respectively were considered high complexity. In most cases where the whale survived, it had been disentangled. Therefore, these findings are not surprising.
Boxplot comparison

An evaluation of the 1st quartile breaking strengths for all the different groups compared averaged 1,895 lbs with a range from 968-5,960 lbs. Interestingly for both RW and HW, the severe entanglement 1st quartile averaged 1,328 and 1,224 lbs, respectively.

Entangling gear complexity in right whales over time
The 73 cases of RW with gear attached were plotted by year and entangling gear complexity. During the 1980s and extending into the middle of the 1990s, the majority of detected entanglements had

low entangling gear complexity and they were few in number. This changed from the mid-1990s onward with the majority of entanglements having a high entangling gear complexity and a concurrent, dramatic increase in the number of entanglement events. In addition, there were no detected cases of severe injuries in the 1980's, only three detected in the 1990's, and the remaining 10 documented between 2000 and 2009.

Entanglement severity in right whales over time
A graph of the relative proportions of minor, moderate, and severe entanglements (both with gear attached or with just scars) vs. the total entanglements detected within each three-year time period showed that from 1980-1982 through 1995-1997, the relative proportion of moderate and severe entanglements was below 20% of the total. Beginning in 1998-2000 and for every three-year time period thereafter, the relative proportion of moderate and severe entanglements exceeded 20%. A Fisher's exact test comparison of the tallies from these two different time periods indicated this increase was statistically significant.

Rope Manufacturing and Changes to Fishing Practices
To explore how changes in rope manufacturing may have led to changes in fishing practices, two different avenues of inquiry were followed. First, a web-based survey (Appendix 4) was distributed to fishermen by MLA The survey had a variety of questions focused on understanding where they fish, what gear types were used, the configuration and estimated weight of their gear and rope diameters used presently, seasonal changes to how and where they fish, and what changes in their fishing practices have occurred between the 1980s and the present. Many of the questions had multiple choice options. For example, the bottom depth where they fish was given in 10-fathom increments ranging from <10, 10-20, and on up to >150 fathoms. Similarly lobster configuration options were given as singles, pairs, triples, four, five, 6-10, 11-15, 16-20, 21-25, 26-30, 30-40, and 40 plus pots per trawl.

The second avenue of inquiry was to explore the internet for information related to ropes and fishing. Although we attempted to reach out to rope manufacturers (a list of four companies provided by NMFS), we did not receive enough responses to gain useful information. One responded to say they were in sales and were not manufacturers. The others could not be reached or did not return our calls or emails. Nevertheless, there were salient pieces of information found on the internet that provided some insight into changes in fishing practices. In addition, there was some useful information obtained from dialogues with fishermen and rope manufacturers during the two-day workshop held in Woods Hole in February 2011 (see below).

<u>Web-based Survey</u>

A total of 70 fishermen began the survey and 50 completed the entire survey (71.4%). For those fishermen that provided information on their home ports, most (45) were from Maine, 18 from Massachusetts, and one each from Florida and New York. Individual questions had response rates between 15.7% and 99%. Most of the respondents were lobster fishermen (70%). Others reported fishing gillnets, shrimp and crab traps, and longlines. Some of the questions apparently led to some confusion for the respondents and therefore an in-depth investigation was only carried out for those questions that had adequate information to analyze.

Years Fishing

To understand fishing practices in the past and how they have changed, we wanted to reach older fishermen, fishermen who had been fishing for many decades or fishermen who had knowledge about how fishing practices have changed. Most of the respondents reported that they had been fishing for more than 15 years (n= 52 of 67). This was corroborated by responses that the majority of the fishermen began fishing between the 1970s and 1990s.

Past Fishing Area/Time

Only 15.7% of respondents answered at least some of the questions about past fishing practices related to area and time. The first question was especially confusing about the years previously fished, because it was too similar to previous questions about years fished. The ports fished from were more numerous in the past, including locations from more southern states. Respondents also indicated that they mostly fished in state waters in the past.

Current Fishing Area/Time

The majority of respondents were fishermen working out of ports in Maine and Massachusetts, representing nearly all zones and statistical areas. Most of the fishermen spent the majority of their time fishing in state waters. Fishermen reported fishing in all months of the year, with the highest number reported between May and December.

Bottom substrate

Most lobstermen reported fishing on some type of rocky substrate at depths less than 100 fathoms although this would vary for most fishermen between seasons.

Gear Configuration and Water Depth Versus Season

Lobstermen reported setting a variety of gear configurations, from singles to 30-40 trap trawls. Most reported fishing doubles or 6-10 trap trawls, with 12-20, singles, and triples being in a distant 3rd, 4th, and 5th place, respectively. The range of total weight reported for these gear configurations was less than 50 to as much as 2500 pounds.

When each individual's response on gear configuration was categorized according to season and averaged, the data showed that for those who fish in the winter, during the winter months they shifted to longer trawls and into deeper water. The average trawl length in winter was 7.2 pots where as in spring and fall it was 6.7 pots, and in summer it was down to 6.3 pots. When the median was compared between seasons, winter had 8 pots, fall had 5 pots, and spring and summer both had 3 pots.

The average water depths fished by season was 50 fathoms in winter, 36 fathoms in fall, 34 fathoms in spring, and 25 fathoms in summer.

Current Buoy Line

More respondents answered some of the questions about current buoy lines (73%). Fifteen different answers were given for rope brand, which included multiple spellings and material instead of brand. This suggests that having provided a list of possible brands would have been more effective. The most frequently mentioned brands were Everson, Hyliner, and Manline (Mainline). About half of the respondents reported fishing with 3/8” diameter rope, with 11/32” and 7/16” also being popular.

Past Buoy Line

Fewer responded answered the questions about what buoy lines were used in the past (67%). One brand mentioned much more frequently as being used in the past than any other was Crow(e). Each individual’s response was assessed to determine how rope diameter had changed from the 1980s to the present with the results shown in Figure 1-3. While the majority of respondents stated they used the same diameter presently as they did in the 1980s, seven respondents noted that the diameter they used was lower in the 1980s versus what they use now. None of the respondents said they used higher diameters in the 1980s.

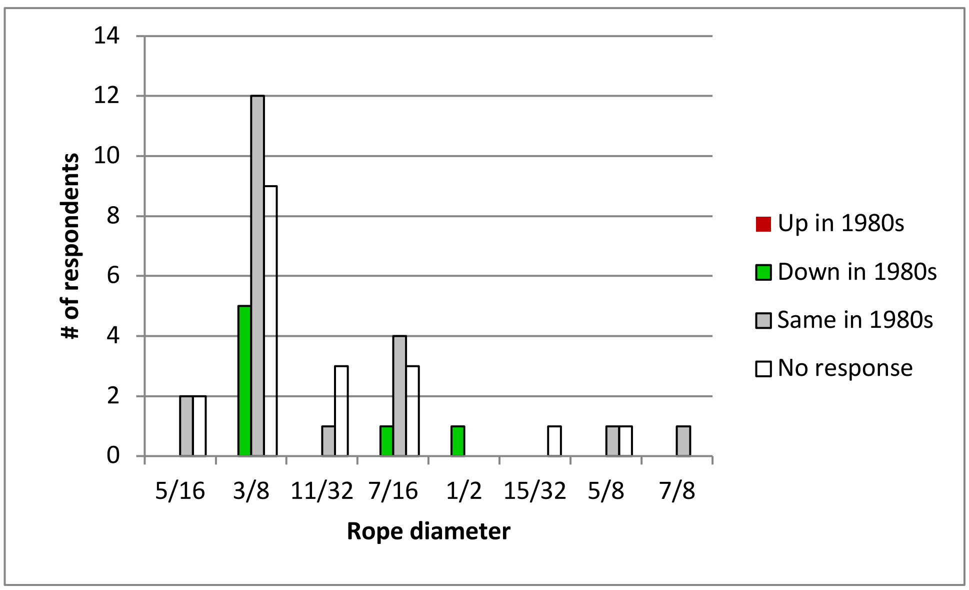


Figure 1-3. Diameters of buoy line used by individual fishermen presently and their response to whether the diameter used in the 1980s was higher or lower, the same, or if they did not respond (n = 47).

Current Groundline

Slightly fewer respondents answered questions about groundlines (67%). Everson remained the most popular brand, with Hy-liner being a close second. Again, most fishermen reported using 3/8” diameter rope, with 7/16” also being used frequently. The question about groundline configuration perhaps was not specific enough, so the responses varied significantly.

Past Groundline

Again, fewer fishermen responded to the question about past use of groundline (59%). Crow(e) was the brand used the most in the past, predominantly of 3/8" diameter.

An assessment of each individual's response comparing the 1980s to the present showed that a majority of those who responded used lower diameter groundline in the 1980s although three said they used higher diameter rope in the 1980s. (Figure 1-4).

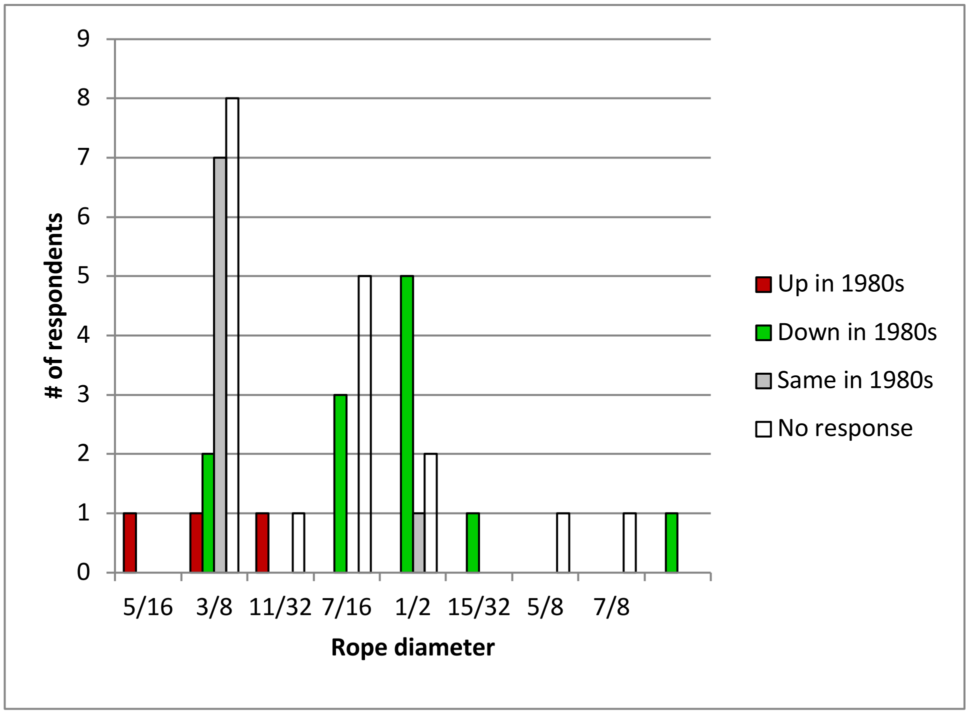


Figure 1-4. Diameters of groundline line used by individual fishermen presently and their response to whether the diameter used in the 1980s was higher or lower, the same, or if they did not respond (n=41).

Rope Characteristics (Question 14)

Most characteristics were deemed to be 'Very Important' for vertical lines (Figure 1-5). Durability was considered very important by nearly all of the respondents followed closely by breaking strength and abrasion resistance. Color was reported to be 'Not important' by most respondents. And noise was either not important or somewhat important by most respondents.

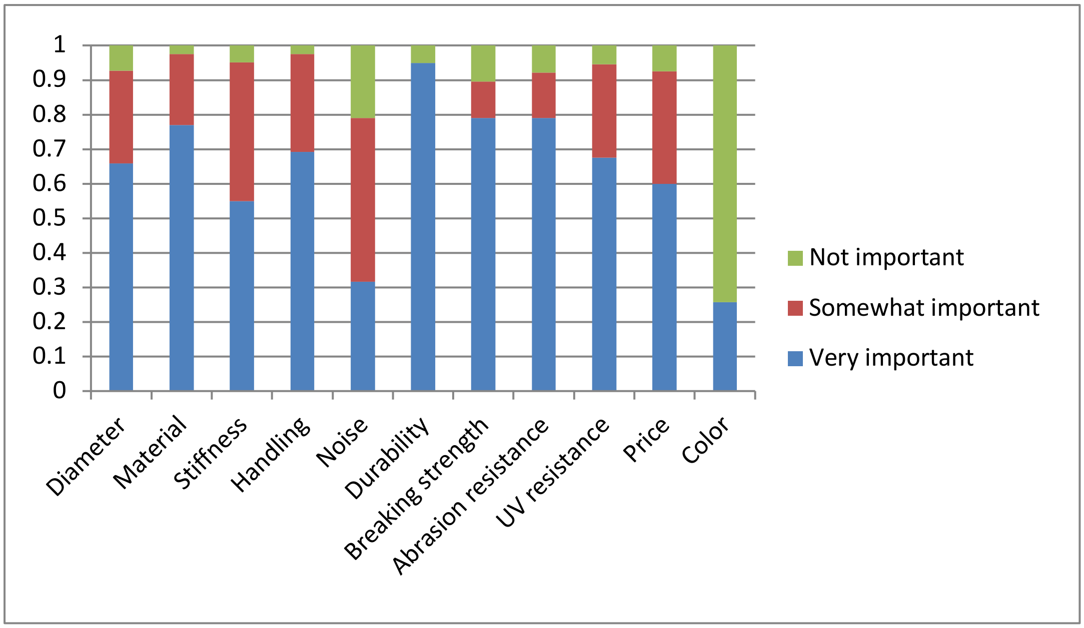


Figure 1-5. Relative ratios of importance for rope attributes.

Changes in fishing and ropes (Questions 15/16)

The last two questions invited unformatted comments how fishing practices have changed due to changes in rope. Many fishermen commented that the change to sinking groundline has been the main change in recent times with the change to synthetic ropes as the biggest change prior to that. Several noted that the sinking groundline chafes more quickly and they need to replace their gear more often. Others noted that because of sinking groundline they have shifted to less rocky bottom to avoid hangdowns. Others noted that they have increased the rope strength and diameter in groundlines to avoid gear loss. Another change noted by a couple of respondents was the shortening of groundline lengths between pots to save in cost. Lastly, several respondents noted that the change to sinking groundline has led to safety concerns. Perhaps the attention of respondents on groundline was related to when the questionnaire was administered, coinciding with the enforcement of a new regulation in which many who had previously used float rope as groundline were required to switch to sinking groundline.

Several commented that ropes are stronger and gear is heavier now than it used to be. Several respondents said that they now fish less on hard bottom and have increased the rope strength and diameter used to fish in response to the sinking groundline rule. Most respondents skipped the question about historical changes in rope use (n = 41). Those that did answer said that gear has gotten stronger and heavier because of the move to synthetic rope. Some said that they use larger diameter rope due to gear getting heavier.

Other interesting findings and recommendations

There have been several other interesting anecdotes learned from internet searches, and from conversations with rope manufacturers and fishermen over the years.

Changes in lobster pots

The vast majority of lobster pots used in the industry presently are wire traps with a plastic coating to prevent rusting. Prior to the 1970s and early 1980s wooden traps were used. As one trap manufacturer noted: "Once they caught on it changed everything, revolutionized the fishery. It allowed fishermen to fish large gangs of gear, in some cases year round, and the wire traps were found to fish better."[2]

Developing ropes at a standardized breaking strength

One rope manufacturer mentioned that a salmon fishery on the west coast that used small boats in a river requested ropes with breaking strengths of 250 lbs in order to reduce the chance of their boats capsizing if they got hung up in gear. This rope manufacturer was able to comply with that request.

Vessel loss due to gear entanglement

Recently, there have been incidents in which humans were killed and vessels lost after becoming entangled in fishing gear. The first event occurred in March 2012 off the coast of Washington state when the fishing vessel Lady Cecilia sank and four crew were lost.[3] Underwater footage has revealed that the vessel had crab pot gear entangled in its rudder and there is speculation that this entangling gear is what led to its demise. The second case occurred off of Cape Cod in November 2012 when a scallop vessel's dredge became entangled in lobster gear and the vessel capsized while the captain was trying to free it from the gear. The captain was lost.[4] These two vessels, probably similar in weight to an adult large whale, were not able to break free from the fishing gear they encountered, indicating that strong rope breaking strengths used in fishing can be deadly for both whales and humans.

Rope diameter reduction with increased breaking strength

One fisherman had mentioned that as rope strength increased, fishermen typically reduced diameter slightly to reduce cost. None of the survey responses however reported this.

Seasonal changes in gear configuration and water depth

The survey responses indicated that fishermen use shorter trawls and fish in shallower water during the summer. As fall progresses to winter, the trawls become longer and the water depth

[2] Mike Wadsworth, manager of Friendship Trap in Friendship, Maine as reported in *Fishermen's Voice* June 2011, Vol. 16(6).

[3] http://m.dailyastorian.com/mobile/free/did-crab-pot-lines-cause-the-lady-cecelia-s-sinking/article_8ab55064-38c6-11e2-9adc-001a4bcf887a.html (accessed on 12-1-12)

[4] http://www.wickedlocal.com/provincetown/news/x1233652477/Underwater-robot-locates-sunken-Provincetown-fishing-vessel#axzz2E6OUYghB (accessed on 12-1-12)

increases. Come spring, this pattern starts to shift back again. Although this question was not investigated for this report, there may be a higher incidence of severe right whale entanglements detected in the fall and winter as opposed to summer. This also could correspond with the opening of the Canadian lobster fishery in the Bay of Fundy in early November. There have been several occasions where retrieved gear has been able to be traced back to both the Bay of Fundy and to coastal Maine and the timing where the fishermen lost the gear has typically been in late fall or winter. A more in-depth exploration of the timing of detection of entangled right and humpback whales (especially anchored humpbacks), and the location of where the gear is traced back to and when the gear was lost may provide insights into whether there are seasonal differences in the severity and complexity of entanglements.

Historical natural fiber ropes

A study of the natural fibers ropes used historically in the sailing industry[5] showed that they used to be made at a higher quality and with better rope fibers than used presently in making natural fiber ropes. Hemp coated in pine tar was the rope of choice. Natural fiber ropes made today are typically made of manila or sisal, are prepared more coarsely, and are infused with chemicals and biocides. They are therefore difficult to handle and do not have as good breaking strength qualities as historical ropes.

Summary

Although the authors of this report are neither fishermen or rope manufacturers, the insights we have gained from surveying fishermen, talking with rope experts, and doing some web searches have helped us to better understand some of the changes that have been observed in the fishing industry and how these might be impacting large whales. The overarching finding is that the ropes used in fishing have become stronger and this fact may have resulted in an overall expansion of the industry into areas where large whales are more frequent. This in turn has led to more frequent serious entanglements and a higher severity of entanglement injuries for right whales and humpback whales. This increased level of takes by entanglement exceeds the levels allowed by Federal law. Based on our findings we believe that reducing the rope breaking strengths used in fishing to levels that a right whale and humpback could break free from without sustaining severe injury or complex entanglement is an important tool that should be examined as a complement other measures being developed by NMFS, i.e. the vertical line strategy, and would allow fisherman and large whales to co-exist.

Dynamics of Large Whale Entanglements in Fishing Gear Workshop

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* organized this workshop to

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[5] http://www.neropes.com/resources/history_of_rope.pdf (accessed on 12-27-12)

increase understanding about baleen whale entanglements and ultimately help improve the evaluation of methods for reducing their bycatch. We wanted to bring together important and varied points of view from individuals who too often in the past have not collaborated neither in studying the problem nor in solving it.

Much of the first day was devoted to reviewing what was known about baleen whale entanglements in the region, and sharing the results of the scarring/entanglement/injury severity results together with the findings of the analysis from ropes retrieved from entanglements. Dr. Laurens Howle of Duke/Bellequant Engineering also presented an early version of a computer model he was developing for simulating whale entanglements using engineering principles and information on whale swimming behavior.

Drafts of the whale entanglement case studies were assembled into a booklet distributed in advance of the workshop; the final versions are attached to this report (Appendix 2). 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.

In advance of the workshop, ten case studies were selected for groups to work up. They were selected to represent both right and humpback whales, a range of different gear and types of entanglement, and ones in which both retrieved gear and adequate scarring data were available. The cases selected were:

<u>Humpback Whales</u>

1. "Hat Trick" – PCCS Case WR-2003-11; NMFS Case E14-03
2. "Inferno" – PCCS Case WR-2003-21; NMFS Case E26-03
3. "Mosquito" – PCCS Case WR-2006-10; NMFS Case E13-06
4. PCCS-0208 – PCCS Case WR-2002-07; NMFS Case E11-02
5. "Tanith" – PCCS Case WR-2003-08; NMFS Case E10-03

<u>Right Whales</u>

1. Eg 1971 – NMFS Case E9-97
2. Eg 2030 – NMFS Case E4-99
3. Eg 3107 – PCCS Case WR-2002-12; NMFS Case E15-02
4. Eg 3120 – PCCS Case WR-2002-04; NMFS Case E07-02
5. Eg 3610 – PCCS Case WR-2006-28; NMFS Case E32-06

NMFS staff brought the fishing gear retrieved from these ten entanglements to the workshop, and were on hand to answer questions based on their understanding about them. 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.

Results

A selection of observations made on individual case studies follows. Items 1-5 involve humpbacks; 6-10 right whales.

<u>Humpback Whales</u>

1*. Hat Trick* – This was a mouth entanglement involving trap gear and trailing buoys. The trailing polyballs were a unique ovoid shape. The fishermen linked this type of buoy to areas with strong currents and high tidal flows, such as downeast Maine, although no consensus was achieved and a range of areas suggested including offshore Maine, Canadian crab pots, and even perhaps Cape Cod offshore. All agreed however that based on the size of the poly balls and line diameter that it was almost certainly offshore gear. An assumption is that most likely the whale encountered vertical line while feeding. There appeared to be an abundance of splices and end knots and some examiners wondered if this wouldn't increase the probability of the line becoming fixed in the baleen.

2. *Inferno* – The whale in this case has never been re-sighted since it had partial disentanglement of very heavy gear (including an anchor) trailing from its peduncle and fluke. There appeared to be multiple gear involved in this entanglement; certainly gillnet was present, but it is conceivable that some of the gear was picked up after the initial entanglement event. During the disentanglement, Scott Landry reported that the team removed a high flyer for safety reasons, and to some examiners this suggested that the endline may have been attached to something well beneath the whale. Separate groups independently suggested that the whale may have become entangled in a vertical line and then picked up gillnet gear afterwards.

3. *Mosquito* – A mouth entanglement in lobster pot gear. One of the groups reviewing this case study recommended that disentanglement teams document on the PCCS illustrations where they cut the ropes. The scarring observed on the leading edge of the fluke is not an uncommon result of trailing gear. One possible entanglement scenario is that the whale picked up the vertical line while feeding on its side, and then the line became stuck in its baleen. Subsequently, the pulling force of the whale resulted in the groundline parting between the first and second traps. Knots were observed in the vertical line, and may have increased the probability of the baleen entanglement. It

was not clear however whether or not knots may have been made by NMFS staff who carried out tests on the retrieved gear. One recommendation is that if this occurs that it be documented and incorporated into the gear analysis and entanglement case study.

4. *PCCS-0208* – NMFS was unable to determine what kind of gear was involved in this entanglement. Rope was wrapped around the flukes on an animal never seen before or since in the Gulf of Maine. The entanglement had severely deformed the whale's flukes, changing their normal orientation to a vertical one. Workshop study groups concluded that the rope was very probably endline given the mix of float and sink line used. One possible scenario put forward was that the whale may have hrolled when the line hit the body aft of the flippers, and the twisting movement could have explained the pattern observed. Reviewers wondered if a line with reduced scope could have helped avert the entanglement. They conjectured that a stiffer rope perhaps would have been more likely to slide off the leading edge of the fluke and avoided this entanglement.

5. *Tanith* – This was a mouth entanglement with trailing gear. At least a portion of the gear (gillnet) was traced back to its owner. The gear attached to the animal consisted of vertical line and a surface system with highflyer and tailer line attached to a bullet buoy. The line consisted of six different types sinking and floating line of various diameters. One explanation offered for why the entanglement occurred was that the whale encountered the vertical line on its side while feeding and the line become lodged in the baleen. The presence of a knot suggested to some reviewers that perhaps the line might have slipped through the baleen and an entanglement avoided had the knot been absent. The gear appeared to have been dragged through other gear that was incorporated into what the whale ended up dragging.

Right Whales

1. *Eg 1971* – This entanglement was assumed to be relatively straightforward, with a single anchoring point of rope within the upper jaw of the whale attached to a trailing vertical line and surface system. The simplest explanation of the entanglement was that the whale was feeding when it became entangled. Abrasions observed at the base of one of the flippers presumably was caused by the trailing gear scraping against it. This gear was previously determined to be offshore lobster gear, although the way the polyball was tied into the surface buoy--with a double spliced bridle– was a technique unfamiliar to all group members. The only alteration of gear suggested for avoiding this entanglement was the complete removal of vertical line from the water column.

2. *Eg 2030* - This whale had been entangled for at least 163 days and perhaps as many as 768. As a result, the gear was in a very degraded state. There were two sets of gillnet gear but it is not clear if they were part of the same gear. One of the reviewers who manufactures gillnet gear concluded it was likely from two different sets. Wrapping was extensive around the body and both flippers, and the whale eventually died from it. Reviewers postulated an entanglement scenario in which the whale encountered the line first with its mouth but then rolling behavior produced the body wrap. Although there was no mouth entanglement observed, further examination uncovered that during the necropsy a small mouth wound was reported. In fact, one group of case study reviewers during the workshop wondered if perhaps most entanglements begin as a gear encounter with the mouth region of the whale.

3. *Eg 3107* – This was a peduncle entanglement that proved fatal to the whale. The gear involved was from an inshore lobster fishery, although fishermen remarked that the buoy present was one used for a large trawl uncharacteristically found in inshore waters. It was conjectured that perhaps a fishermen had lost the usual buoys and replaced them with a trawl buoy as a temporary measure. The reduced flotation with this buoy conceivably could have caused the line to have more of a horizontal profile that may contribute to an increased entanglement risk. The distance between the surface gear and where the line was wrapped around the peduncle was approximately 40', suggesting a possible depth at which the contact initially occurred, assuming the gear was actively fished.

4. *Eg 3120* **-** For this case it was known the location of where the retrieved gear was fished, although it was not clear when the entanglement occurred and therefore whether the gear was actively being fished or had become ghost gear. It did appear that the initial point of contact was between the vertical line and the mouth based on the first observation of the entanglement. Examination of the retrieved gear showed knots in the vertical line, perhaps increasing the risk of line becoming lodged in the baleen. Some reviewers pointed out that once gear becomes lost ("ghost gear") it has altered properties from when it is fished, so that even if fishing gear is designed to be "whale safe," as ghost gear it may no longer act as a bycatch deterrent.

5. *Eg 3610* – Unlike the other cases for which the gear type was identified, this entanglement involved longline gear of light duty, such as from a tub trawl. The location of the entanglement was the mouth. Reviewers struggled to match how the multi-colored lines were wrapped on the whale because the entanglement illustration used only one color to depict the rope.

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, and the gear manufacturers who understand the material property and construction of the ropes involved. Yet prior to this workshop, there had not been a forum in which this exchange could occur purposefully and using the best available information on entanglement events together with the actual gear involved, corresponding information about the whales, and analyses involving both.

Separate breakout groups reviewing the same case studies often arrived at 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.

Apart from contributing expertise on the gear and geographic differences in how gear is rigged, engaging fishermen in this workshop emphasized that hands-on examination of gear and how it entangled the whale can give them a better appreciation for how the range of gear types, as well as particular methods for configuring gear (such as the use of knots), are involved in actual whale entanglements.

Workshop 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 would be 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 and portions of the gear), 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. Finally, any alteration of the gear (such as knot-tying) by NMFS examiners should be documented.
2. This workshop demonstrated that insightful observations 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, it seemed surprising that reports from examination of retrieved gear were only available through 2007 [note: after the workshop, additional right whale samples were able to be made available for rope parameter analysis]. 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 the implications for lost gear, including both how the modifications might increase the probability that gear becomes lost and irretrievable, and any increased entanglement properties once it becomes 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.
12. One recommendation is that if this occurs that it be documented and incorporated into the gear analysis and entanglement case study.

Project 1 Recommendations

The main findings from this project suggest ropes used in fishing are too strong for large whales to successfully escape in all cases, and rope strengths have increased since the mid-1990s resulting in more complex entanglements and severe injuries, especially for RW. If the fishing industry is to coexist with large whales without causing severe injuries to these endangered species, among the strategies that should be examined are reducing the breaking strengths of ropes used in fishing and ideally moving towards rope-less fishing especially in areas where more heavy-duty gear is required.

Based on the findings of this study, we have several specific recommendations as described below:

- The computer modeling effort undertaken by Laurens Howle at Duke University for the Bycatch Consortium should be used to simulate entanglements using the breaking strengths and configurations found on the entangled large whales presented in the case studies as well as age and estimated weight. When a reasonable simulation is created that results in the entanglement configuration observed, use the breaking strengths described below to evaluate how the entanglement configuration would change with the weaker rope.

- This study provides some of the first data on rope breaking strengths in relation to negative entanglement outcomes. For both RW and HW with severe injuries, the lower quartile measurements are just above 1,200 lbs. Although the average for all groups compared is higher at 1,895 lb, the data show that one fourth of the severely injured RW and HW were found in ropes below this 1,200-1,300 lb range, therefore we recommend that an examination be carried out to determine in what fishing areas north of Cape Hatteras a maximum breaking strength standard might be imposed at 1,200 lbs, to ensure that entanglements of all age groups of RW and HW would have a chance of breaking free from fishing gear before a complex entanglement develops. This analysis should include an assessment of how practical this measure would be for fishermen, and a projection of how much it might inadvertently contribute to the volume of ghost gear. Although this may not help MW (as well as leatherback sea turtles that also become entangled) as much as RW and HW, the limited data set does show the median and mean of rope breaking strengths found on MW to be at around 1,700 lbs suggesting they could also benefit to some degree from a reduced breaking strength. Any efforts to reduce rope breaking strengths used in fishing gear should be carried out to complement and strengthen the benefits that will be provided by the vertical line strategy under development by the NMFS and the ALWTRT for implementation by 2014.

- A recent analysis of RW growth rates indicates that calves experience rapid growth in their first year reaching three-fourths of adult size within 12 months (Fortune et al. 2012). Females typically give birth to calves between North Carolina and Florida during the winter months and remain resident there for several months before transiting north to spring feeding grounds. Two dead right whale calves have been found dead from entanglement in this region although there was no entangling gear attached and thus no information about the rope parameters in these cases. Only one RW calf was documented with gear and it had the lowest breaking strength of the 0-2 year old age group at 1,215 lbs. This whale (#2366) acquired the gear sometime between August and December of its calf year during which time it would have been in the feeding grounds north of Cape Hatteras. Because newborn calves are considerably smaller than a calf at six months or more in age, we recommend an examination to determine if there are fishing areas south of Cape Hatteras where it would be feasible to use vertical lines with a maximum rope breaking strength of 600 lbs to give newborn calves a better chance of breaking free from entangling gear.

- For fishing situations where weaker rope cannot be used safely or effectively, develop and implement alternative bycatch-reducing gear alternatives, especially in light of the fact that new fisheries types and effort may change over time and other protected species (such as small toothed whales, pinnipeds and sea turtles) may not be able to endure even the whale-safer breaking strengths.

- Work with the rope manufacturing and fishing industries to develop, test, and implement lower breaking strength ropes that would work well within the industry (i.e., durable, abrasion resistant, easy to handle, safe, etc.). This should include an investigation of historical natural fiber rope-making technology as they were made at a better quality than today's natural fiber ropes.[6]

- Continue to remove and analyze gear from entangled whales to improve understanding of the types and nature of the gear that is involved, and promote multi-disciplinary examination of the gear involving fishermen, whale biologists, fisheries engineers, and gear manufacturers.

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