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FISHING GEAR INVOLVED IN ENTANGLEMENTS OF RIGHT AND HUMPBACK WHALES

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ABSTRACT

Interactions between marine mammals and fishing gear are an issue of global concern. Entanglements in the western North Atlantic are a major source of injury and mortality for endangered large whales. In this study, entanglements of 31 right whales (*Eubalaena glacialis*) and 30 humpback whales (*Megaptera novaeangliae*) were analyzed to determine the types and parts of gear involved. When gear was identified, 89% ($n = 32$) of the entanglements were attributed to pot and gill net gear; however,

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a wide range of specific gear types were implicated. Despite gear recovery, gear type was not identified in 20% ($n = 9$) of the cases. Although pot gear was recovered from both species equally, gill net gear was less frequently retrieved from right whales ($n = 2$) than humpback whales ($n = 11$). When gear part was identified, 81% ($n = 21$) involved entanglements in buoy line and/or groundline. For right whales, the most common point of gear attachment was the mouth (77.4%); for humpback whales, the tail (53%) and the mouth (43%) were common attachment sites. Four right and three humpback whales in this sample were known to have died subsequent to entanglement. However, when identified, the gear types and parts involved in lethal cases were not substantially different from entanglements with non-lethal outcomes. Large whales can become entangled in a wide variety of fishing gear types and parts, and additional insight will depend on continued efforts to document entanglements and recover associated gear.

Key words: entanglement, entanglement risk, mortality, fisheries, bycatch, gear type, North Atlantic right whale, *Eubalaena glacialis*, humpback whale, *Megaptera novaeangliae*.

Entanglement in fishing gear is a significant cause of injury and mortality to many marine mammal populations throughout the world. Large whale populations along the U.S. east coast remain susceptible to entanglement, despite management efforts to reduce overfishing of lobster and groundfish species.

Mortality from entanglements in fishing gear, in particular fixed gear, is a factor inhibiting the recovery of the critically endangered North Atlantic right whale (*Eubalaena glacialis*) (IWC 1999). Despite nearly 70 yr of protection from commercial whaling, this population of approximately 300 individuals has shown little sign of recovery (IWC 2001). Recent statistical data suggest that this population is declining, and reducing human-caused mortality is necessary to prevent extinction (Caswell *et al.* 1999). Right whale scarification studies conducted by the New England Aquarium indicate that 71.9% of the population has been entangled at least once, and there appears to be an increasing trend in the annual rate of entanglement (Knowlton *et al.* 2003[2], see also Knowlton and Kraus 2001). These findings indicate that documented entanglements are only a fraction of the animals that actually become entangled, and identifying recovered gear is important for developing mitigation strategies.

Entanglements are also a significant problem for North Atlantic humpback whales (*Megaptera novaeangliae*) under U.S. jurisdiction (Waring *et al.* 2003). This endangered species was also subject to historic commercial exploitation. Although its recovery status is not known, the Gulf of Maine stock of humpback whales is believed to number in the high hundreds, and is experiencing positive population growth (Barlow and Clapham 1997, Clapham *et al.* 2003). However, a scar-based study of Gulf of Maine humpback whale entanglement rates indicated that more than half of the population had experienced a previous entanglement, and 8%–25% received new injuries each year (Robbins and Mattila 2004).[3]

[2] Knowlton, A. R., M. K. Marx, H. M. Pettis, P. K. Hamilton and S. D. Kraus. 2003. Analysis of scarring on North Atlantic right whales (*Eubalaena glacialis*): Monitoring rates of entanglement interaction. Final report to the US National Marine Fisheries Service (unpublished). Available from the New England Aquarium, Central Wharf, Boston, MA 02110. 18 pp.

[3] Robbins, J., and D. K. Mattila. 2004. Estimating humpback whale (*Megaptera novaeangliae*) entanglement rates on the basis of scar evidence. Final report to the US National Marine Fisheries Service (unpublished). Available from the Center for Coastal Studies, Box 1036, Provincetown, MA 02657. 22 pp.

As awareness of marine mammal entanglement increases, mitigation efforts focus on disentanglement, gear modification, and deterrent devices such as pingers. However, for large whales, successful development of strategies to reduce or eliminate entanglement is contingent upon a better understanding of what type and part of the gear creates the greatest entanglement risk, and of how whales become entangled.

Here we examine entanglements of right and humpback whales to determine the types and parts of gear involved and where they tend to attach on the body. We also evaluate whether gear type or part affects the persistence of an entanglement, as well as the ultimate fate of the entangled animal.

Methods

We examined records of North Atlantic right and humpback whale entanglements on file with the National Marine Fisheries Service (NMFS). For right whales, reported entanglements ranged from the Magdalen Islands, Canada (Gulf of St. Lawrence) to Amelia Island, Florida, and for humpback whales, Grand Manan Island, Canada (Bay of Fundy) to Cape Lookout, North Carolina. Entanglement cases of right whales date back to 1993, including eight whales reported as entangled in 2002. We began with two humpback whale entanglements in 1997, and examined all other incidents up to and including eight of the eleven animals reported as entangled in 2002. Data availability has been greatly facilitated by a large whale entanglement reporting and response network for the east coast of the United States, implemented by the Provincetown Center for Coastal Studies (PCCS) under the authority of NMFS. The network has produced detailed information on entanglements in the region, including the recovery of part or all of the entangling gear in many cases.

Analyses focused on entanglements from which gear was recovered and examined by gear specialists or other sources considered reliable, as well as cases from which gear type and/or part was identified (*e.g.*, by fishermen or biologists) but not recovered. In some instances, gear removed during a necropsy was included. When documentation was at least sufficient to examine points of attachment of entangling gear, we included cases in which gear was not recovered or identified. We also evaluated whether photographs alone could be of any value in assessing gear type or part. Photographs of entangled animals were obtained from the North Atlantic Right Whale Catalog, which is curated by the New England Aquarium (NEA), and from the PCCS Gulf of Maine humpback whale catalog; all were digitally scanned for analysis. These long-term photographic catalogs were also the source of sighting information about all entangled animals and individual characteristics, such as age and sex. For each incident, we examined types of gear, parts of gear, line type, points of gear attachment on the body, and what is known about the eventual outcome for the entangled animal.

We examined five entanglement variables, as defined below.

Entanglement outcome (at last sighting)—Alive and gear-free (life-threatening gear was shed or removed, includes animals with non-life-threatening entanglements); alive and entangled (life-threatening entanglement retained); dead (recovery of a carcass); potentially dead (right whales only, see below); and status unknown (could not determine whether or not the entanglement was life-threatening). Some right whales have been categorized as "potentially dead" based largely on a NEA visual health assessment (Pettis *et al.* 2004). A comparable health assessment technique does not exist for humpback whales; therefore, the potentially dead category was not used for this species.

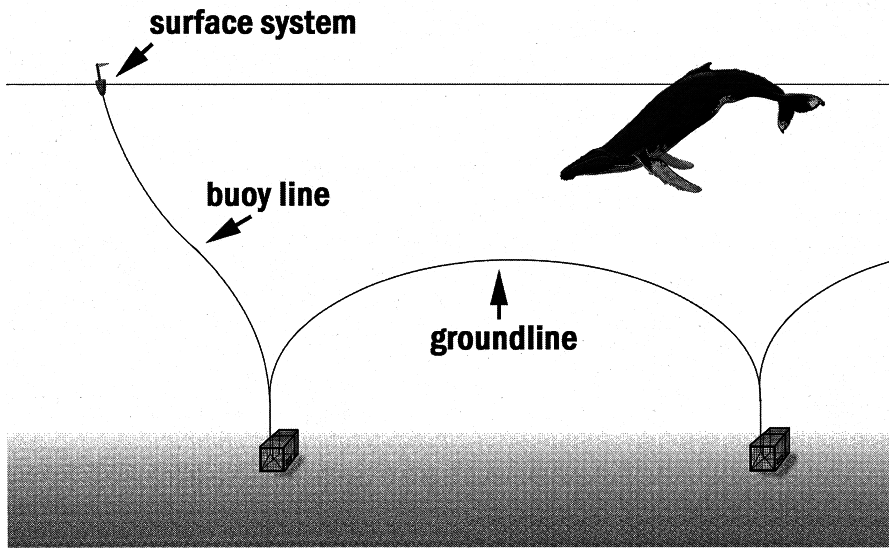

Figure 1. Generalized configuration of pot gear and associated parts, not drawn to scale (source: Provincetown Center for Coastal Studies).

Gear type—Pot: inshore lobster pot, offshore lobster pot, lobster pot unknown location, unknown pot, crab pot, conch/whelk, and slime eel; gill net: sink gill net and gill net unknown type; other: tuna handline, Danish seine, aquaculture, and vessel anchoring system.

Part of gear—Fixed fishing gear can be broken down into four or five components or parts: buoy line, end line, groundline, float line, and lines involved with the surface system (Fig. 1, 2).[4] Buoy and end lines connect bottom gear to the surface and terminate in a surface system, which is sometimes regarded as a separate portion of the gear. We combined buoy line and end line (termed "buoy line"), since both lines connect the bottom gear to the surface system and can be used interchangeably. Groundlines connect traps to each other, forming strings or trawls, and are also used in gill nets to connect a string of net panels to anchors. Floating groundline, used in both pot and gill net gear, forms an arc of line that can float 15–20 ft (approximately 4.6–6.1 m) into the water column. Float lines run across the top of gill nets, holding net panels upright. The surface system includes buoys and high flyers, as well as the lines that connect these components to the buoy line. The fact that many of these lines rise into the water column presents an entanglement risk to large whales. In addition, these lines are made with durable synthetic materials, such as polypropylene and polyester, with characteristics that are meant to withstand extremely harsh fishing conditions.

[4] Fixed fishing gear is defined in the Code of Massachusetts Regulations (322 CMR 12.00) as any bottom or sink gill nets or pots that are set on the ocean bottom or in the water column and are usually connected to lines that extend to the water's surface.

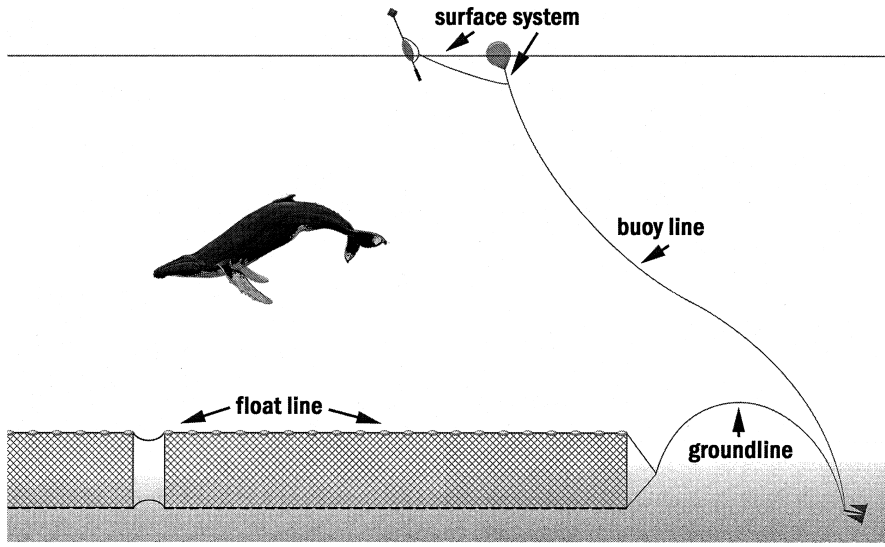

Figure 2. Generalized configuration of gill net gear and associated parts, not drawn to scale (source: Provincetown Center for Coastal Studies).

Line type—Characterized as either floating or sinking. Also included were buoy and surface system lines that had both floating and sinking line spliced together.

Point of attachment of entangling gear—Mouth, flipper(s), body, tail, and unknown/uncertain. For example, a whale with line originating at its mouth and draping over its back was considered to have a mouth entanglement only. PCCS or NEA generally made this assessment, either during a disentanglement event or after examination of photographic documentation. These assessments should be considered conservative because the full extent of the entanglement may not have been visible to observers. For example, observation of the flippers and mouth was not possible in all cases and the configuration of an entanglement may have changed over time. However, secondary evidence of the attachment site, such as scarring and chafing of the skin, was not used when determining points of attachment.

We recorded sex, age (in years), age class (calf, juvenile, adult), and the location of the entangled whale at the first observation (not to be understood as the location of encounter with the gear) for individual right and humpback whales who could be identified. For right whales, "juveniles" included animals from 1 to <9 yr old, and for humpback whales, animals from 1 to <5 yr old. When reported, the straight length of dead animals was collected by members of the Northeast or Southeast Region Stranding Networks, and provided by NMFS.

Results

A total of 61 entanglements (31 right whales and 30 humpback whales) were examined. Four right and three humpback whales had died, five right whales were deemed potentially dead, 12 right and 20 humpback whales were alive and gear-free, six right and five humpback whales were alive and entangled, and four whales (two

Table 1. Entangling gear type for 20 right and 25 humpback whales where gear was either recovered or otherwise reliably identified. UN = unknown/unidentified gear; LI = inshore lobster pot; LO = offshore lobster pot; LU = lobster pot unknown location; Pot = unknown pot; CR = crab pot; CW = conch/whelk; SE = slime eel; SG = sink gill net; GU = gill net unknown type; TU = tuna handline; Seine = Danish seine; Anchor = vessel anchoring system; AQ = aquaculture.

	UN	LI	LO	LU	Pot	CR	CW	SE	SG	GU	TU	Seine	Anchor	AQ
Right whales	6	3	3	2	1	1	0	0	1	1	0	1	0	1
Humpback whales	3	5	0	0	1	1	1	1	11	0	1	0	1	0

of each species) had unknown outcomes.[5] Gear type was determined in 45% ($n = 14$) of right and 73% ($n = 22$) of humpback whale cases. Scanned photographs (representing nine right and seven humpback whales) yielded no useful information about gear type or part because only line was visible on most of these animals. Photographs of five of these whales (three right and two humpback) allowed for their inclusion in the points of gear attachment analysis.

Types and Parts of Gear Involved in Entanglements

Of the 61 entanglements, we examined 20 right whale and 25 humpback whale entanglements where gear was recovered or where gear was identified but not recovered (Table 1). One right whale (#2212, a juvenile male) was entangled three times, and all recovered gear was analyzed. For analysis, gear types were divided into four categories: pot (*e.g.*, inshore and offshore lobster, crab), gill net (all gill net types), other (*e.g.*, tuna handline, Danish seine), and unknown. Eighty percent (36 of 45) of the entangling gear that was identified could be attributed to particular fisheries. Eighty-nine percent of identified gear was attributed to pot and gill net fisheries (Table 1). Pot gear was identified on 10 right and nine humpback whales, gill net gear on two right and 11 humpback whales, and other gear on four whales (two of each species). All but one of the humpback whale entanglements reported in the mid-Atlantic ($n = 6$) involved gill net gear, while entanglements reported in the Northeast involved a wide variety of gear types.

Of 14 juvenile right whale entanglements (involving 12 individuals) where gear was recovered, eight events involved pot gear (three inshore lobster pot, two offshore lobster pot, two unknown lobster pot, and one unknown pot), one involved other gear (aquaculture), and five involved unknown gear types. Five adult right whale entanglement events were analyzed, where one involved offshore lobster pot gear, two involved gill net gear, one involved other gear (Danish seine), and one involved unknown gear. Also, a whale of unknown age class was entangled in crab pot gear. Life history data are presently insufficient to compare humpback whale entanglements on the basis of age class.

Despite gear recovery from 45 entanglements, the parts of the gear were identified in only 25 of those cases (12 right and 13 humpback whales). Buoy line and groundline were recovered in 49% of these cases, whereas float line and surface system lines were recovered in 11% (Table 2). Two whales were entangled in more than one part of the gear. A right whale was reported entangled in two parts of the same gear,

[5] The total number of outcomes described do not equal 61 because right whale #2212, entangled three separate times, was assigned to one final outcome of potentially dead.

Table 2. Entangling gear types and associated parts of the gear. This table contains one right and one humpback whale that were entangled in both buoy line and groundline associated with pot gear. The numbers in parentheses indicate the percent occurrence of that gear part relative to the total number of gear parts that were identified for that gear type. "Other" types of gear were not included, as the parts of the gear discussed here are only associated with fixed fishing gear. RW = right whales; HW = humpback whales.

	Pot		Gill net		Unknown		Total
	RW	HW	RW	HW	RW	HW	Both species
Buoy line	6 (55%)	6 (60%)	0	1 (9%)	1 (17%)	0	14 (33%)
Groundline	3 (27%)	3 (30%)	1 (50%)	0	0	0	7 (16%)
Float line	—	—	0	4 (36%)	0	0	4 (9%)
Surface system line	1 (9%)	0	0	0	0	0	1 (2%)
Unknown	1 (9%)	1 (10%)	1 (50%)	6 (55%)	5 (83%)	3 (100%)	17 (40%)

both buoy line and groundline associated with crab pot gear, and a humpback whale was entangled in buoy line and groundline associated with pot gear.

Buoy line associated with pot gear was recovered from 85.7% (12 of 14) of the right and humpback whales entangled in buoy line, and groundline associated with pot gear was recovered from 85.7% (six of seven) of entanglements in groundline (Table 2). Gill net gear was recovered from more humpback whales than right whales, but in approximately half of the cases, the part of the entangling gear could not be identified.

For both species combined, 64.3% (nine of 14) of buoy line entanglements involved floating and sinking line spliced together, 28.6% (four of 14) involved only sinking line, and one was unknown. Also, 85.7% (six of seven) of groundline entanglements involved floating line, and one was unknown. One surface system entanglement involved floating and sinking line, and one was unknown. Gill net float line, by nature, consists of floating line or line that is made buoyant by floats.

For right whales the most common point of attachment was the mouth (77.4%), with 51.6% involving only this body part. For humpback whales, the most common points of attachment were the tail (53%) and the mouth (43%). Thirty percent involved the tail only and 20% involved the mouth only.

Buoy line entanglements involved the mouth on three right whales and one humpback whale; the mouth, flipper, and tail on one right whale; the mouth and tail on two humpback whales; the flipper on one right whale; the tail on one right and three humpback whales; and an unknown location on one humpback whale. One right whale entanglement in the surface system line involved the mouth, and the other involved the mouth, flipper, and body. Groundline entanglements involved the mouth on two whales (one of each species); the mouth and body on one right whale; the flipper and body of one right whale; and an unknown location on one humpback whale. Float line involved the mouth and/or tail of all four humpback whale entanglements in this part of the gear. For the two whales entangled in multiple parts of the gear (buoy line and groundline), the right whale entanglement involved the tail and the humpback whale entanglement involved the mouth. In summary, buoy line entanglements involved the mouth in a total of eight cases (four of each species), the tail in eight cases (three right and five humpback), and the flippers in two cases (both right whales).

Influence of Gear Type on Entanglement Outcome

Overall, entanglement outcomes were considered positive (*i.e.*, the animal was alive and gear-free, either by successful disentanglement or shedding the gear itself) in 71% ($n = 12$) of pot and 62% ($n = 8$) of gill net cases. Right whale #2212 was not included in these gear analyses. Entanglement outcome was considered positive in 75% ($n = 3$) of cases involving the four other gear types. It was not possible to draw firm conclusions about disentanglement success with regard to the parts of the gear involved because reliable gear part identification depended on successful gear retrieval. However, pot, gill net, and Danish seine gear were all involved in known or suspected lethal entanglements. Out of 17 entanglements of both species in pot gear (not including right whale #2212), 18% ($n = 3$) were known or suspected to have resulted in death, and out of 13 gill net entanglements, a similar number, 23% ($n = 3$), had a comparable outcome. When age class was known, lobster pot gear was involved in the known or suspected lethal entanglement of two juvenile right whales, and gill net gear was involved in the known lethal entanglement of one adult right whale. In addition, one dead adult right whale was entangled in Danish seine gear. Based on their reported lengths (8.6–9.85 m), the three humpback whales known to have died were likely juveniles (Clapham *et al.* 1999).

A wide range of fixed gear parts were involved in entanglements known to have been lethal. Float line was documented on a dead humpback whale. Buoy line was documented on a dead right whale (sinking line) and a dead humpback whale (floating and sinking spliced), and floating groundline was documented on one dead right whale. Right whale #2212, considered potentially dead, was entangled two separate times where gear part could be identified; one event involved buoy line (floating and sinking spliced) and the other involved floating groundline. Similarly, any part of a whale's body can be involved in lethal and non-lethal entanglements. However, five out of the nine (55.6%) dead or potentially dead right whales had entanglements that involved the mouth; similarly, all three humpback whale deaths involved the mouth. The tail was involved in entanglements of one humpback and four right whales that are dead or potentially dead.

Discussion

The 1994 amendments to the U.S. Marine Mammal Protection Act (MMPA) were designed to address bycatch of marine mammals in U.S. commercial fisheries. A study by Read and Wade (2000) concluded that in general, the MMPA and Endangered Species Act (ESA) have been successful in aiding the recovery of many species, but some, such as the North Atlantic right whale, continue to face conservation problems despite protective measures. Cetaceans continue to be taken in fisheries such as the Japanese North Pacific drift net fishery for salmon, Italian and Spanish drift net fisheries for swordfish in the Mediterranean Sea, and coastal gill net fisheries in Europe (Reeves *et al.* 2003). Growing international concern about the effects of entanglements on marine mammal and sea turtle populations has led to research and management measures to mitigate entanglements.

On the east coast of the U.S. and Canada, both right and humpback whales were entangled in all major types of fixed fishing gear, and any part of that gear. Out of the combined 36 entanglement cases where gear was examined and identified, pot and gill net fisheries were implicated in 32 (89%). Both pot (18%) and gill net (23%)

gear were involved in known or suspected lethal entanglements. Conservatively, all fixed gear types should be considered potentially dangerous to these species.

For pot gear, 80% and 56% of right and humpback whale entanglements, respectively, occurred in lobster pot gear, despite management measures to reduce effort in this fishery, such as setting a cap on the number of traps allowed per fisherman and limiting entry into the fishery. When gear type was identified, right whales were found to be entangled in pot gear 71% of the time and gill net gear 14% of the time as compared to other gear types, while humpback whales were entangled in pot gear 41% of the time and sink gill nets 50% of the time. Although humpback whales appear to encounter gill net gear more often than right whales, without a measure of whale encounter rates with gear, we are unable to generalize this finding to the population. Although the location of the reported entanglement is not necessarily the location where the whale encountered the gear, 55% ($n = 6$) of humpback whale gill net entanglements were reported in the mid-Atlantic, where gill nets made up 86% ($n = 6$) of identified gear from humpback whales reported entangled in this region.

The entanglement outcomes of many whales were considered positive; 71% of whales entangled in pot gear and 62% entangled in gill net gear were alive and gear-free, primarily due to successful disentanglement. The determination of both gear types and gear parts involved in these entanglements depended in large part on the successful recovery of gear.

Fifty-six percent of the entanglements for both species involved buoy line, providing evidence that buoy lines present entanglement risk regardless of line type. Sinking (all or part) buoy line was found on more entangled animals than floating buoy line, which may indicate that sinking buoy line creates more entanglement risk than floating buoy line. However, it is possible that the gear observed on or removed from an animal may not accurately reflect the entire history of an entanglement, since some or all gear can be shed by the whale, lost during disentanglement, or change position over time. NMFS gear specialists report that some fishermen do use purely floating buoy line, but most lobster pot and gill net fishermen use buoy line consisting of both floating and sinking line, with floating line near the bottom end to prevent it from chafing on the seafloor. Therefore, sinking buoy line that was removed from an animal may have once been spliced to floating line. However, a relatively large number of entangling gear types and gear parts were unidentifiable, especially when gear was not recovered.

Whether buoy and surface system lines represent more of an entanglement risk than groundline is currently difficult to determine due to unknown biases associated with entanglement reporting effort, as well as lack of information about the types and amounts of gear being used. For example, buoy and surface system lines may be identified at sea more frequently than groundline, since buoy and surface system lines are easier to identify when an attached buoy or high flyer is present. In contrast, groundline does not have any distinguishing characteristics that indicate that it is in fact groundline. Out of 14 entanglement events involving buoy line, nine (64.3%) involved the presence of buoys and/or high flyers. Thus, buoy line may appear to represent a greater entanglement risk than groundline, which is usually identified only when gear is removed from an entangled animal. Interestingly, only two whales (both right whales) were documented with surface system entanglements, which may indicate that entanglements commonly occur below the surface.

This analysis highlighted an apparent difference between floating and sinking groundline in terms of potential entanglement risk. The use of sinking groundline (line in contact with the ocean floor) could be taken as providing some measure of

entanglement risk reduction, since no entanglements of either species involved this type of line. However, we have no knowledge of the relative frequency with which lines of different types are employed throughout the fishing regions concerned and this information would be extremely difficult to obtain; consequently, any comparison of entanglement rates by line type without knowledge of effort may be misleading.

Several body parts were involved in entanglements, both lethal and non-lethal. Right whale entanglements frequently involved the mouth, indicating that many of these entanglements probably occurred during foraging, since open mouth behavior is generally associated with feeding only. Most right whales (78%) that died or were considered potentially dead were commonly entangled by the mouth and/or the tail. Mouth entanglements were also common among humpback whales, although the incidence may be underestimated given that the mouth is somewhat more difficult to observe in this species. However, all three humpback whale deaths involved at least a portion of the entangling gear in the mouth, indicating that humpback whale entanglements also occur during foraging. Humpback whale entanglements were more likely to involve the tail than right whale entanglements, but the reason for this interspecific difference is unclear.

In both species, the mouth and/or tail regions were involved in nearly all buoy line entanglements and all four float line entanglements. Groundline and surface system lines were documented on all body parts. However, without knowledge of the whale's behavior leading up to and following an entanglement, it is difficult to draw conclusions about how different parts of the gear are linked to points of gear attachment on an animal's body.

This analysis did not highlight any trends in gear types and parts that are commonly involved in lethal and non-lethal entanglements of juvenile versus adult right whales. Overall, more juvenile right whale entanglements were analyzed than those of adults, making it difficult to compare age classes. Fifty-five percent of the right whales that died or were deemed potentially dead were juveniles. Right whale #2212 was a special case in that three separate entanglements were documented. Although this whale is considered potentially dead, this outcome cannot be attributed to any one particular entanglement event; rather, the debilitating effects of multiple entanglements, combined with the ingestion of line from an unknown type of gear, most likely lead to this determination.

This analysis confirms that any line rising into the water column poses a significant entanglement risk for these two species. Consequently, reducing the occurrence of line in the water column—for example, by using sinking or neutrally buoyant groundline—could reduce entanglement risk (although it should be noted that the occurrence of benthic foraging by these species is still poorly understood).

The risk presented by buoy and surface system lines might be mitigated by the correct placement of weak links with sufficiently low breaking strengths. However, the efficacy of weak links remains to be demonstrated, and may be countered by the behavior or strength of the whale in conjunction with the entanglement configuration. More information on the specifics of entanglements is required and may be aided by the application of standardized marking of lines used in fixed fishing gear.

Currently, gear removal provides the only reliable information about the nature of large whale entanglements. Gear experts more readily identify buoy line due to the presence of a buoy or high flyer, while groundline is usually identifiable only if it is removed from a whale. Color-coding gear would allow for identification of gear parts both at sea and through photographic documentation.

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