ANALYSIS OF SCARRING ON NORTH ATLANTIC RIGHT WHALES *(EUBALAENA GLACIALIS)*: MONITORING RATES OF ENTANGLEMENT INTERACTION: 1980 - 2002

Final Report to:

National Marine Fisheries Service
166 Water Street
Woods Hole, MA 02543

Submitted by:

Amy R. Knowlton, Marilyn K. Marx, Heather M. Pettis, Philip K. Hamilton, and Scott D. Kraus
New England Aquarium, Central Wharf
Boston, MA

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Introduction

Entanglement of North Atlantic right whales in fixed fishing gear is considered a major source of serious injury and mortality for this critically endangered population (Knowlton and Kraus 2001; Hamilton et al. 1998; Kenney and Kraus 1993; Kraus 1990; Right Whale Consortium unpublished data). Despite increased regulations aimed at mitigating the frequency and seriousness of such interactions (Federal Register 64 (30) - 1999; 65 (246) - 2000; 67 (6), 67(7), 67(63) - 2002), entanglements are still being documented and continue to lead to serious injury and mortality that threatens the recovery of this species. The evidence that entanglements are occurring frequently in this population is not a new finding. The incidence and frequency of entanglement scarring, particularly around the tail stock area, was first documented by Kraus (1990) when 52% of adequately photographed animals documented by 1989 were identified as having been entangled (only the tailstock was reviewed) at some point during their lives. This initial review of the nature and extent of the entanglement problem prompted a more intensive scarring analysis project wherein all photographed sightings of individual animals were reviewed through 1995 and coded for all types of scars, including entanglement scars. All parts of the body were reviewed for scarring. The analyses adopted by Hamilton et al 1998 allowed for an in-depth examination of the level of entanglement interaction by sex and age class, scarring frequency by body part, and probability analyses of the time frame of occurrence of entanglement events. At that time, data analyzed through 1995 indicated that 61.6% of the population had been involved in an entanglement and that there appeared to be an increasing trend (Hamilton *et al.* 1998). Their report presented two different techniques for determining the probability of entanglement scarring for a given year period; the first technique was computer generated and the second was manually generated. While we have chosen not to use these specific techniques for this report, we will compare some of the findings here with those presented in the 1998 report as appropriate.

In this report we provide the results of a third examination of the scarring data and several new analyses aimed at assessing trends in entanglement rates from 1980-2002. We will evaluate if with these analyses, it may be possible to monitor the effectiveness of future gear modifications and other changes in fishing practice. However, it must be noted that entanglement rates may be influenced by many different factors. When the value of these analyses as monitoring tools are evaluated, there will be discussion in light of their limitations. One important aspect of the entanglement issue that cannot be discerned from this, or any other study, is the geographic location where entanglement interaction occurred.

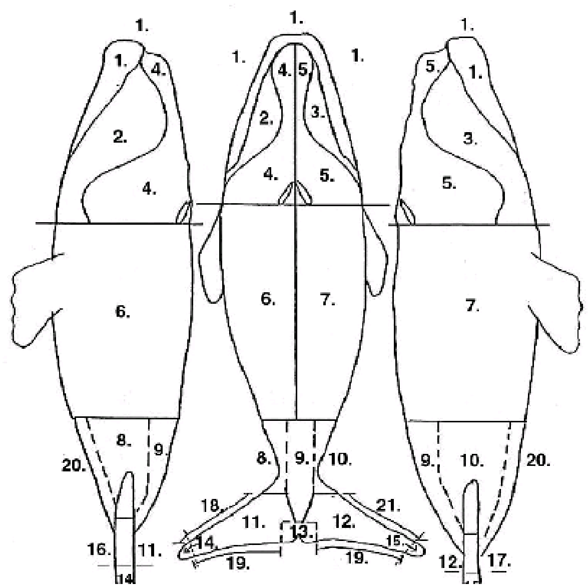
Methods

Background

Right whales have been photographed throughout their known range along the coast from Florida to Nova Scotia (with sporadic sightings further offshore in the western North Atlantic ocean). All photographs and associated data are provided to the New England Aquarium for comparison to, and inclusion in, the Right Whale Consortium catalog. Each sighting event is entered into an Access database with date, time, location, observer, and comments. If a sighting is matched to a cataloged animal, it receives that animals' four-digit catalog number. There have been 459 animals cataloged of which 447 were used in this study.

The scar coding process involved having a researcher review all available photographs of an individual right whale and assess the type and location of all scars. For coding purposes, the body was divided into 21 sections – five sections on the head, two on the dorsal body, and 14 on the dorsal and ventral tail (see Figure 1). Each body section was assessed and coded for each season/habitat area within each year that an individual was sighted. If a particular section of the body was not seen it was labeled as 'X'.

Figure 1. Body sections used for coding.



The types of scars that were coded for include: entanglement, ship strike, circles, dots, skin lesions (of unknown cause), rake marks (scars near the blowholes), blisters, orca teeth marks, scars from implanted satellite/radio tags and scars of unknown origin. The first time that a scar was detected, it was noted with an asterisk in that given habitat/season/year. The scarring data were entered into a Microsoft Access database with a record for each habitat/season/year an animal was sighted. The record included the time frame during which the animal was seen and scar coding for each body part photographed in that habitat/season/year. The database can be queried by animal number, month/year, habitat area, or scar type and linked to existing tables for age and sex. Although scar coding was done for all scar types, the primary focus of the previous report was on entanglement and ship strike scars (Hamilton *et al.* 1998). This report will focus only on entanglement scarring.

For any animal with entanglement scarring, the photographs of the corresponding body parts were reviewed to determine if the new scar was clearly not previously seen and represented a new interaction for that body part or if a slightly different angle or area coverage of the body part showed scarring that may have been from a previous event. If entanglement scars were detected on different body parts in different habitats or years, the reviewer looked at the combined data and determined, based on previous sightings of these given body parts, whether the scars were likely related to one event or multiple events. Once the minimum number of entanglement events were determined, that animals' records were reviewed to determine the minimum time frame within which each entanglement event happened. Unlike Hamilton *et al.* (1998), we included any animal seen carrying gear in this analysis even if scarring was not detected (some whales were seen with gear, but scars were not documented either because they were covered with line or scarred areas were not photographed, or the area was heavily covered with cyamids obscuring the scars). All entanglement events were put into a summary table with a single record for each animal noting its sex, the year(s) the entanglement(s) was/were detected, the year in which it was previously seen without the entanglement, and the age of the animal in the given year the entanglement was detected. This summary table was queried for many of the analyses presented in this report unless otherwise noted.

<u>Analyses</u>

Total number of entanglement events

The summary table was queried to determine the total number of distinct entanglement events documented between 1980 and 2002 for all individuals. These data were further analyzed to determine the number of entanglements per animal and the number of entanglements by sex and age class. The total number of individuals entangled was compared to the total number of animals in the catalog for comparison with previous studies (i.e. Hamilton et al. 1998; Kraus 1990).

Number of entanglement events versus identified individuals

A crude analysis of the number of new entanglement detections versus the number of animals identified in each year was carried out. The resulting proportions were graphed to give a general visual assessment of annual variability in entanglement rates.

Annual Rate of Entanglement

To further refine the annual rate of entanglement, the data were queried to find all animals sighted in both years of specified consecutive two- year periods. The scar coding was examined to determine whether an animal was adequately photographed in both years and assessed as to whether or not it had become entangled by the second year in that time frame. For an animal to be considered adequately photographed, photographs of the dorsal peduncle and/or at least one of the fluke insertion areas must have been taken in both years to allow for comparison between years. This area of the tail was chosen because data in the previous report (Hamilton *et al*. 1998) showed that the peduncle and fluke insertions were body areas where the majority of entanglement scars have been detected. If an entanglement scar detected on another part of the body in the latter year was determined to have not been there in the previous year, these data were also included. Any calf or 1 year old animals with entanglement scars in the later year were also included in the tally. The number of animals entangled in year two that were not entangled in year one was determined and divided by the total number of animals with adequate photographs for both years (or were a calf or 1 year old by the second year with entanglement scars) to obtain a percentage of the adequately photographed animals entangled in the given two year period. This treatment adjusts for biases in differential photographic effort and whale distribution from year to year.

Time Frame of Entanglement Detection

The time frame within which each new entanglement event occurred was determined and tallied. The plot shows, for each year, the total number of entanglements that were first documented in the given year and the breakdown (in percentages) of time frames during which those entanglements occurred. The time frames chosen were from the given year to: 1) within same calendar year; 2) within previous calendar year; 3) within previous two years; 4) within three or more years; and 5) unknown time frame.

Age at Entanglement Detection

Previous studies have shown that juveniles (0-9 years old; Kraus *et al.*, 2001) are more likely to become entangled than adults. To investigate this further, we compared the proportion of entanglements that involved juveniles to the proportion of juveniles in the population annually. The frequency of juvenile entanglements was compared to the percentage of the annual cohort represented by this age class. Although the age at *detection* does not indicate the exact age of entanglement, clearly any detection that occurred while the animal was a juvenile represents an entanglement that happened when that animal was a juvenile.

The number of juveniles vs. adult or unknown age animals carrying gear was also reviewed.

Serious Injuries from Entanglements versus Observed Population

Not all of the right whales that get entangled are actually seen carrying gear. The majority of them apparently get clear of the gear on their own but are left with minor scars. A limited number of animals have been seen carrying fishing gear or with deep wounds from entanglement and have been categorized as serious entanglements. The criteria used to define serious injury from entanglement for right whales include any animal seen carrying line and any animal with a cut deeper than 8 cm caused by an entanglement (Knowlton and Kraus, 2001). Serious injuries from entanglements have been further subdivided into non-fatal, potentially fatal, and fatal injuries. The non-fatal and potentially fatal categories are based on the animals' condition at the initial entangled sighting and any subsequent sightings. An entanglement is considered potentially fatal if the animal appears in poor condition or is wrapped in gear that will impede the animals' movements or feeding behavior. If an animal is subsequently resighted free of gear and with no visible decline in its condition, it is considered a non-fatal entanglement. The definition of "serious injury" as used here is slightly different from that used by the

National Marine Fisheries Service, where serious injury means "any injury that is likely to lead to mortality" (Angliss and DeMaster, 1998).

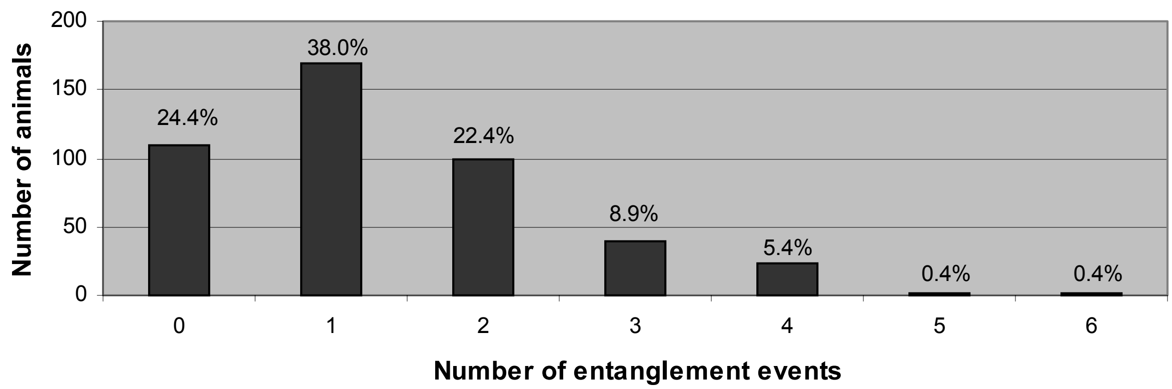
The number of serious injuries, independent of outcome, were tallied by year and those sums were divided by the number of individuals identified each year. The number identified each year was an appropriate measure to correct for effort because serious entanglements, by their definition, are obvious. Unlike entanglement scars, whose documentation requires good photographs, serious entanglements will be visible in almost any photograph that allows you to identify the individual. The resulting annual proportion of seriously entangled animals was graphed to allow for visual comparison over the time period.

Results

Total number of entanglement events

There were a total of 447 individual animals reviewed for this study and 608 separate entanglement interactions were documented between 1980 and 2002. There were 338 of 447 animals (75.6%) entangled at least once. The number of entanglements per individual ranged from 0 to 6 (mean =1.4 entanglements per animal) with 170 animals bearing scars from just one entanglement event and two animals with scars from 6 entanglement events (Figure 2).

Figure 2
Number of entanglement events per individual

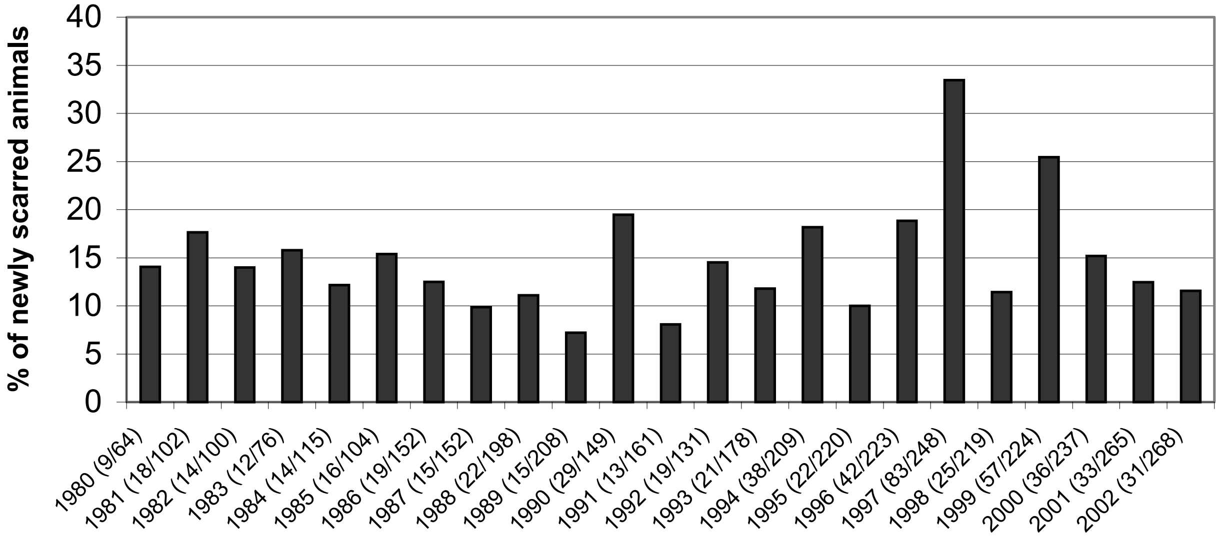


The number of individual females and males entangled versus total individuals of each sex in the population was nearly equal (130/171 females, 76.0%; 159/183 males, 86.9%; 49/93 unknown sex, 52.7%). There was no significant difference in the number of females versus males that carry entanglement scars p =0.705. The breakdown of right whales with entanglement scars by sex of the 608 separate events was also not significant (p = 1.218; 257/608 female, 42.3%; 288/608 male, 47.4%; 63/608 unknown sex, 10.4%).

Number of entanglement events versus identified individuals

Figure 3 displays the annual proportion of new entanglement detections versus the number of animals identified in the given year. The mean percentage over the 23 year time frame is 15% annually. In some years, this percentage increased dramatically as in 1997 when the level was 33% and 1999 when the level reached 25%.

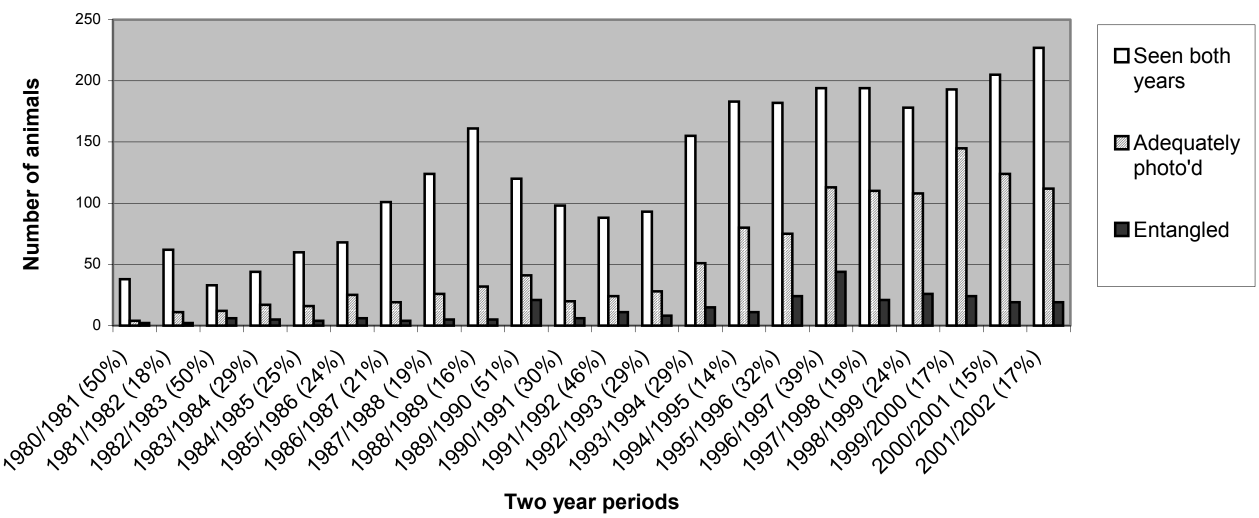
Figure 3
Proportion of sighted animals with new entanglement scars



Annual Rate of Entanglement

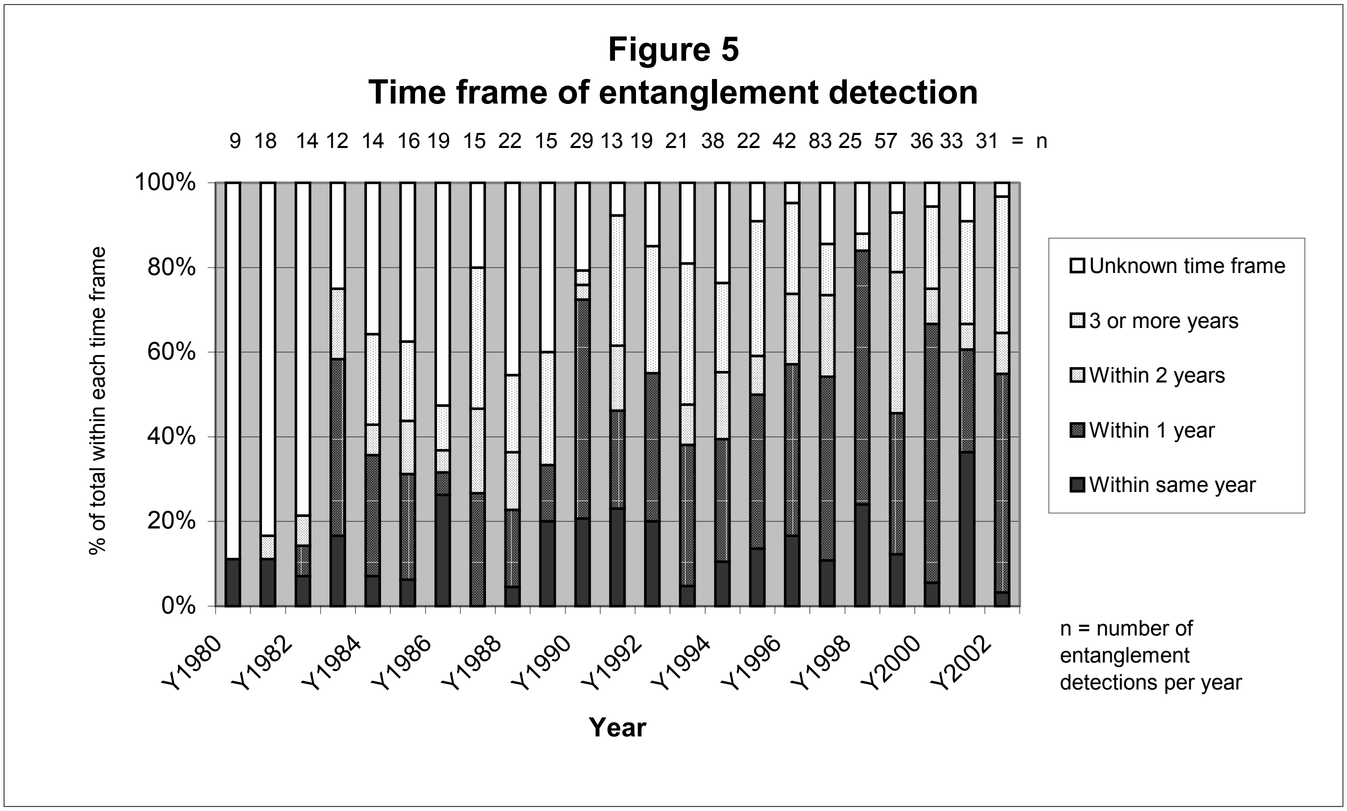
Figure 4 shows by year the total number of animals seen in both years of consecutive two-year intervals, the number of animals adequately photographed in both years, and the number of animals entangled either within the second year or between the first and second year. The percentage given after each year period on the x-axis represents the number of adequately photographed animals that were entangled. This percentage has ranged from a high of 51% in 1989/1990 to a low of 14% in 1994/1995. In all the two-year periods prior to 1993/1994, the number of adequately photographed animals was lower than 25 per year. This number increased dramatically in 1993/1994 when the number of adequately photographed animals exceeded 50. In most years since 1993/1994, the number of adequately photographed animals has exceeded 100. This higher number of adequately photographed animals provides a more robust indication of what the whole population may be experiencing.

Figure 4
Entanglement events compared to adequately photographed and total number of animals seen in each two year period
(percentages after year periods represent number of entangled divided by number of adequately photographed)



Time Frame of Entanglement Detection

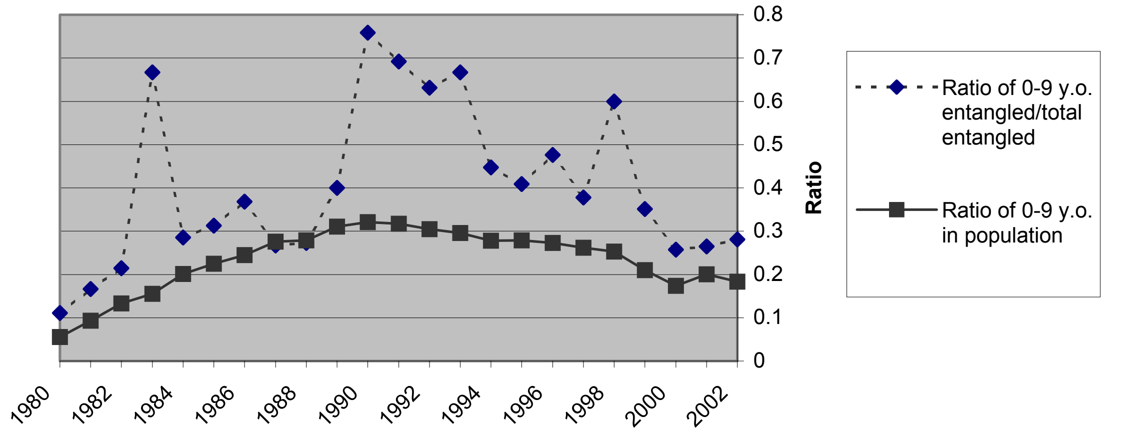
Figure 5 shows the annual tally and timeframe of occurrence (in percentages) of first documented entanglement events for the 447 animals coded. The relatively high number of events categorized as unknown timeframe throughout the 1980's reflects the fact that many individuals were scarred before their first sighting in the early years of this research. These sightings do not allow for a time frame of entanglement to be determined. In the 1990's and the early 2000's, the ability to determine time frame improved with the majority of entanglements detected within 2 years of occurrence.



Age at Entanglement Detection

Figure 6 provides a comparison between the percentage of the known number of juveniles within the living population on an annual basis and the percentage of juveniles entangled annually. This graph shows that for all years but one (1988), the proportion of entangled juveniles exceeded their proportion within the population.

Figure 6. Comparison of entanglement frequency of juveniles vs. total juveniles in population

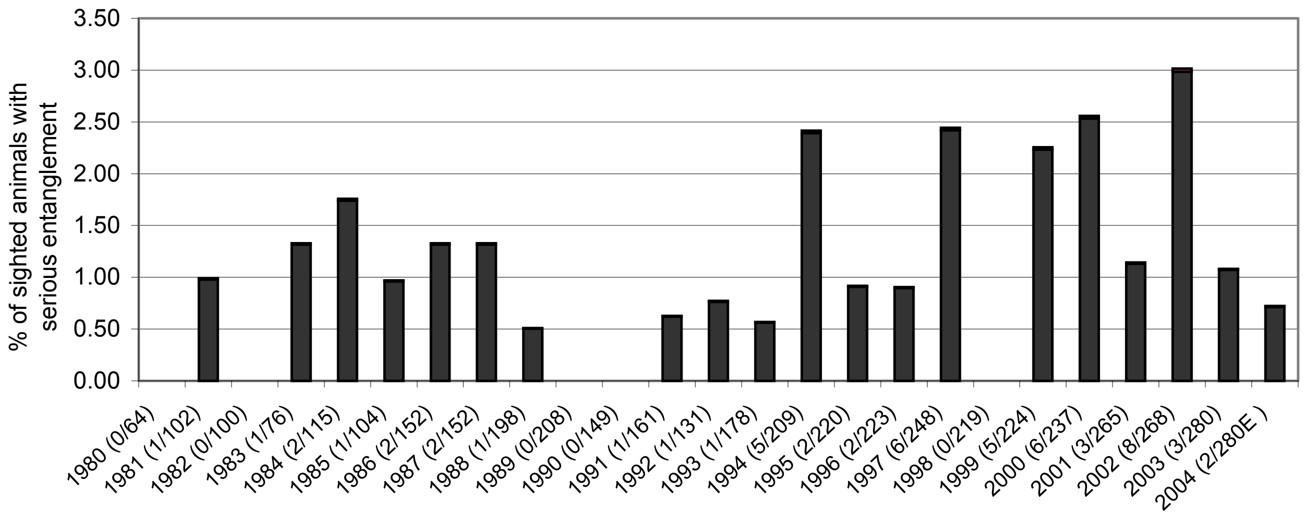


Serious Entanglement Events versus Total Observed

A total of 55 serious entanglement events of identified individuals have been documented since 1981. Figure 7 shows the annual proportion of seriously entangled animals vs. number of animals photographed in that given year.

At least 25 of the 55 serious entanglement events (45%) involved calves or juveniles of 0-9 years old indicating that this age class is more vulnerable to serious injury from entanglement than adults or unknown age animals.

Figure 7. Proportion of sighted animals with serious entanglements
Number after year = # of serious entanglements/# of animals identified



DISCUSSION

Entanglements of right whales in fixed fishing gear are a chronic problem facing this severely endangered species. High levels of entanglement interaction have been noted throughout the 25 year-long study of this population. Further, each time the data are analyzed, the proportion of the population with signs of entanglement scarring has increased, with this analysis finding that 75.6% - over three-quarters of this population, has been entangled at least once. When Kraus (1990) looked at a subset of adequately photographed animals, he determined that 52% had indications of entanglement. Hamilton et al. (1998) found that 61.6% of the animals had entanglement scarring when all photographed body parts were reviewed. The increase to 75.6% by 2002 shows that there are increasingly more right whales becoming scarred by fixed fishing gear over time, a worsening situation through three in depth analyses.

There has clearly been much effort focused by the National Marine Fisheries Service, state agencies, fishing industry representatives, whale biologists, and conservation groups to try to understand the nature of the problem facing the species and to develop regulations aimed at reducing the frequency and severity of these entanglements. As these efforts proceed, it will be critical to monitor whether implemented changes to the fishing industry provide benefit to the animals. This report describes three methods of assessing the level and frequency of entanglement interaction in right whales. Each method has strengths and limitations as described below.

The first method, the number of new entanglement detections versus the number of identified individuals annually is a crude but simple method that provides an annual proportion that can be compared from one year to the next. The method, however, has several limitations and biases. First, it does not account for whether an animal was adequately photographed to detect entanglement scars. Since most entanglement scars are detected around the tail region, animals who were photographed from an aerial platform or whose tail was not photographed during a shipboard sighting may not be tallied as an entanglement detection but would be included in the total tally of individuals for that year. This would lower that year's proportion. The other limitation is that it does not take into account the time frame of the entanglement detection. In years where there is a big influx of individuals into a habitat with intensive shipboard surveys (i.e. Bay of Fundy in the mid 1990's) and some of those animals had not been seen for a couple of years or more, this would increase the number of new entanglement detections thereby increasing the proportion.

The second method of looking at adequately photographed animals eliminates the bias present in the first analysis since it only utilizes animals seen from one year to the next. Thus, the time frame of entanglement is certain which allows for determination of an annual rate. In the early years of this study, there were some biases. The photographic effort in the 1980's was focused on collecting high quality images of the head region for identification purposes. Images of the tail were collected on occasion but at that time, their value for this study was not clearly understood. Observers tended to photograph the tail only if scars were present that would help with the matching process. Therefore, both the number of adequately photographed animals was low and the number of newly entangled animals was biased upward. By the 1990's, this observer bias was eliminated and tail photos were part of standard protocol during shipboard sighting events. The number of adequately photographed animals doubled by 1992/1993, and by the latter 1990's, the number of adequately photographed animals exceeded 100 per year. This happened concurrently with a shift of right whales into the Bay of Fundy where shipboard efforts have occurred throughout the study period. This method is the most effective for monitoring annual rates of entanglement but requires consistent shipboard effort as well as high numbers of right whales from one year to the next to provide a robust annual rate. For both of the above two methods, efforts to remove gear from the water column would ideally show a reduction in the proportions of newly detected entanglements. If efforts are made to modify gear to reduce the severity of entanglements, there may be no reduction in the level of scarring.

The third method of determining the proportion of seriously entangled animals versus the number of individuals observed in a given year is a useful method for assessing whether gear modifications provide a reduction in entanglement severity. If such gear modifications are effective, we would expect a reduction in the number of animals carrying gear or with deep cuts from an entanglement.

The data presented here indicate that the annual rate of entanglement interaction remains at high levels. In Figure 4, from 1993/1994 onwards, when the number of adequately photographed animals has been consistently over 50 animals, the percentage of those animals entangled has ranged from 14% to 39%. If we extend this range to a population size of approximately 350 animals, the annual number of entanglement interactions could range from 49 to 136 animals. Interestingly, these percentages are similar to those found by Robbins and Mattila (2000) for entanglement scarring of humpback whales. Using a similar technique, they found an annual rate of entanglement ranging from 10 to 31% between 1997 and 1999.

The data presented in Figure 6 show the proportion of serious entanglements has often been 2-3% of the observed population during the 1990's and 2000's and lower in the 1980's. The reasons for this apparent increase in serious entanglements could be related to a number of different scenarios – there may have been a substantial increase in the amount of fixed fishing gear in the water; lines with increased breaking strength and improved durability may be in greater use; whales and/or fishing gear distribution may have shifted thereby increasing the overlap.

The data show that right whales of both sexes are equally vulnerable to entanglements but juveniles become entangled at a higher rate than would be expected if all age groups were equally vulnerable. This has important implications for efforts to reduce the severity of entanglements. Because juveniles are still growing, any entanglement where gear remains on the whale is likely to become embedded and eventually infected. Also, calves and juveniles may not have the strength of an adult to break free from line. Therefore, any efforts to model necessary breaking strengths for lines to provide added protection to right whales need to consider the likely reduced strength and mass of juveniles.

Understanding exactly when and where entanglements are occurring cannot be captured with these scarring analyses. Most of the entanglement events are not witnessed or do not result in an animal carrying gear that could potentially be identified. Therefore, this question needs to be addressed by specifically looking at gear that is taken off animals and events witnessed by fishermen and others.

In summary, the situation facing right whales is dire. Entanglements are frequent and the annual rate has remained high and is increasing. Over three quarters of the population have been entangled at least once. Severe entanglements have also become more common with the highest number (n=8) ever recorded in 2002 with an additional three in 2003 and two in 2004. Disentanglement has been conducted on several of the entangled right whales with varying levels of success (Landry *et al.*, 2003). Right whales are notoriously difficult to disentangle and disentanglement attempts are extremely dangerous to carry out. All of the researchers involved in disentanglement see this as a poor long-term option for protecting right whales and strongly advocate for universal and effective gear modifications.

Continued monitoring is critical as actions are taken to minimize the frequency and severity of entanglements of right whales to document the effectiveness of the measures. However, there may be limitations to our ability to detect potential changes in entanglement levels without further understanding of the overlap between fishing effort and right whales and the level of gear modification changes. If there are efforts to remove the amount of line from the water column, there should be a reduction in the number of new entanglement scars detected. If gear modifications are focused on using weak links or weak line in the vertical line, or some other change to the line parameter, but the amount of vertical line in the water column remains static, the number of scars may not change, but there may be a reduction in the number of animals seen carrying gear and/or a reduction in the severity of the entanglement. Monitoring such changes using the scar coding techniques presented here and evaluating the severity of each entanglement where an animal is carrying gear should provide some insight into the effectiveness of future gear modification efforts.

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