Preliminary estimates of whaling-induced mortality in the 19th century North Pacific right whale (*Eubalaena japonicus*) fishery, adjusting for struck-but-lost whales and non-American whaling

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ABSTRACT

This study develops preliminary estimates of total whaling-induced mortality of northern right whales in the 19th century North Pacific pelagic whale fishery. Best's (1987) study of American whaling returns resulted in estimates of the total American catch of 14,480 and 15,374 northern right whales during the period 1839-1909. The present study offers adjustment factors to estimate total mortality from these catch data. Quantitative data from 14 pelagic expeditions for northern right whales in the North Pacific from 1838-1860 and additional anecdotal information about struck-but-lost animals is reviewed. On 12 voyages, 327 northern right whales were struck with harpoons, but only 133 landed. Adjusted for the subsequent recovery of struck whales, this implies a ratio of 2.43 whales struck for each whale eventually secured and flensed by whaleships. Data from four voyages show that of 148 northern right whales struck with harpoons, 14 sank before they could be processed. From a sample of five voyages, 80 northern right whales were landed and 31 carcasses sank without being secured. During the height of pelagic whaling in the North Pacific, approximately 10% of the fleet was non-American, primarily French. Adjusting recorded catch estimates for struck-but-lost mortality and non-American whaling yields preliminary estimates of total mortality in this fishery in the range of 26,500-37,000 animals during the period 1839-1909. In the single decade of 1840-49, between 21,000-30,000 northern right whales may have been killed in the North Pacific, Sea of Okhotsk and Bering Sea, representing about 80% of the northern right whales killed in this region during the period 1839-1909.

KEYWORDS: WHALING-HISTORICAL; PACIFIC OCEAN; NORTHERN HEMISPHERE; ABUNDANCE ESTIMATE; NORTH PACIFIC RIGHT WHALE

INTRODUCTION

In 1840, the North Pacific right whale (*Eubalaena japonicus*)* was common or abundant during summer in the Gulf of Alaska, North Pacific, southeast Bering Sea, among the Kuril Islands and in the southern Sea of Okhotsk (Scarff, 1991). Ten years later, it was rare; 20 years later it was nearly extinct. The cause for this rapid decline was pelagic whaling. Measurement of the magnitude of the mortality associated with this early pelagic whaling will be an important factor in the estimation of the initial population size of northern right whales in these seas.

Pelagic whaling for northern right whales began in the North Pacific in 1835 when the French whaleship *Gange* killed seven whales (Webb, 1988, p.40). It took about five years for the many whalers operating in the South Pacific to leave those depleted waters and head north to the new whaling grounds in the Gulf of Alaska, in the Sea of Okhotsk and off Kamchatka. Beginning in 1840, and continuing for the next nine years, a tremendous concentration of whaleships, mostly American, searched the North Pacific, Bering Sea and Sea of Okhotsk, hunting northern right whales (Scarff, 1986; Webb, 1988). In 1846 alone, over 290 American whaleships hunted these waters (Starbuck, 1878, p.104). From 1840-1849, American whalers took at least 11,000 northern right whales in the North Pacific, Bering Sea and Sea of Okhotsk, probably more than 75% of the northern right whales that would ever be caught in this region (Scarff, 1986; Best, 1987). In the following decade, 1850-59, American whalers took an additional 2,400 northern right whales, bringing the total catch to 92% of the northern right whales caught prior to 1910. By 1850, the fishery in the Gulf of Alaska was largely over and the whalers moved north to hunt the larger and still abundant bowheads (*Balaena mysticetus*). The fishery persisted for another decade in the more remote Sea of Okhotsk (Henderson, 1983).

Prior to the use of steam-powered whale catchers and explosive harpoons, probably no large population of whales was so severely depleted so quickly. Today, northern right whales remain extremely rare in the Bering Sea and central and eastern North Pacific, with population estimates in the low hundreds. Only in the Sea of Okhotsk does it appear that a remnant population persists, optimistically estimated at less than 1,000 (IWC, 2001).

Initial population size

Published estimates of pre-1840 northern right whale populations in the North Pacific and adjacent seas have been speculative rather than analytical. Berzin and Vladimirov (1981) estimated that the 'pre-exploitation' number of northern right whales in the North Pacific and adjacent seas was about 10,000. They gave no basis for this estimate. Braham and Rice (1984) estimated that the *combined* initial Northern Hemisphere right whale populations were between 30,000-100,000 (one-third of an estimated worldwide population of 100,000-300,000) based 'on recorded catch data' with no further detail provided. Based upon an estimate of American catches in the North Pacific in the 1840s of over

* *Editors' note*: The IWC agreed that the North Pacific right whale (*E. japonicus*) comprised a separate species after this paper was ready for press. In order to avoid extensive changes at a late stage it was decided not to change the common name 'northern right whale' which is used throughout the rest of the paper. That was the common name used for right whales in both the North Pacific and North Atlantic which had been considered a single species, *E. glacialis*.

11,000, the Right Whale Recovery Team (NMFS, 1991) stated that the initial North Pacific population level was 'higher than 11,000'. Neither of the two International Whaling Commission workshops on right whales (IWC, 1986a; 2001) have included estimates of the initial size of any northern right whale stock.

Scarff (1991) argued that the size of the pre-1835 North Pacific population of northern right whales may have been substantially higher than previous minimum estimates of 10,000. He cited the indices of abundance of northern right whales he derived from Maury's (1852) Series F Whale Charts that showed whalers in the 1840s finding northern right whales on 50+% of the days they searched over large areas of the Gulf of Alaska, along the Aleutian Islands, off the coasts of Kamchatka and in the Kuril Islands. He believed that these high sighting frequencies strongly suggested larger initial population(s) of northern right whales in the North Pacific.

Total mortality and struck-but-lost whales

It might be possible to model at least the historic population(s) of northern right whales if the number of whales killed by 19th century whalers can be estimated with sufficient accuracy. Such an analysis was recently presented in IWC (2001) for Southern Hemisphere populations of right whales. Previous studies on North Pacific right whales have analysed only that portion of total mortality reflected in the recorded catch figures where the best data were available. Based on total US import figures for whale oil and baleen and the proportion of species and yield/whale in Townsend's (1935) data, Best (1987) separately estimated the American catch of northern right whales in the North Pacific between 1805-1909 at 15,374 based on oil production up to 1879 and whalebone production thereafter, or 14,480 based on the estimated catch per voyage.[1]

In addition to the northern right whales whose oil or baleen were reflected in the catch data in the 19th century pelagic fishery, many whales were struck with harpoons but lost before they could be secured and processed. Some of these were dead at the time they were lost, while others were suffering from injuries ranging from minor to fatal. The mortality associated with these struck-but-lost whales greatly increased the impact of pelagic whaling on the northern right whale populations but has received relatively little attention in past studies.

Previous studies of 19th century pelagic whaling in the North Pacific have focused on the whaling culture and history (Webb, 1988), the historic distribution of northern right whales (Scarff, 1986; 1991) or the recorded catch by American whalers (Best, 1987). None of these studies discussed total mortality of northern right whales caused by whaling. Scarff (1991, p.479) suggested that the northern right whale's current scarcity in the North Pacific might be the result of a larger kill by 19th century whalers than previously thought, from an initial population size that was also larger. He suggested that the mortality of struck-but-lost whales in the fishery might have been significantly greater than the adjustment factor used in IWC (1986a).

With no new data to review, the IWC Scientific Committee (IWC, 2001) stated that:

> about 14,500 were taken as a total by American pelagic whalers in the North Pacific in 1835-1904, with 90% in 1840-59, but they cannot be allocated to grounds. No allowance can be made in North Pacific catches for hunting loss, nor for catches by other nationalities.

The present study describes a small amount of data that allow preliminary estimates of both struck-but-lost mortality and non-American whaling in the North Pacific.

Prior adjustments for struck-but-lost whales

Best (1987, p.417) explicitly qualified his catch estimates by stating:

> It should also be stressed that the figures produced here are estimates of the landed catch; further work is needed to determine the number of animals that were struck and lost, and the proportion of these that might have died.

The various published catch-to-mortality adjustment factors and struck-but-lost ratios for northern right whales are summarised in Table 1.

IWC (1986a, p.5) noted that to estimate total whaling-induced mortality, the recorded catch figures would have to be adjusted to account for struck-but-lost whales that died. It suggested that:

> an average mortality factor, pertaining to [northern right whale] fisheries in which hand harpoons and lances (non-explosive) were used, would be between 1.2 and 1.5.

The higher estimate assumes that all struck-but-lost whales died from their injuries. In other words, the higher estimate reflects a judgement that on the voyages recorded, of 150 northern right whales struck only 100 whales were secured and the oil or baleen captured. The higher estimate assumes that all of the 50 struck-but-lost whales died. The lower estimate assumes that less than half the struck-but-lost whales died. Both estimates assume implicitly that none of the struck-but-lost whales are ever recovered and used later by another or the same whaleship.

IWC (1986a) also noted significant differences in loss rates by whaling area, time period and technology in use and such differences should be recognised in any reconstruction of the catch history. It noted that losses 'seem to have been higher on the open seas than they were in bay whaling'.

As an indication of how the struck-but-lost ratios may vary between regions and periods, IWC (1986a) described separate high and low bounds for struck-but-lost mortality for seven separate areas/periods. In calculating resulting ratios, it assumed for the high bound that all struck-but-lost whales died; whereas for the lower bound that of those whales lost, 50% of those still alive when lost died later. The first six include: South Atlantic 1783-1794 (1.42-1.61), Bay whaling, South Africa 1804-1837 (1.32-1.50), South Atlantic 1817-1837 (1.21-1.41), New Holland ground

[1] Best (1986) provisionally estimated the total catch of northern right whales in the North Pacific between 1840 and 1909 by the American whaling fleet alone as 15,244. As noted in Scarff (1991, p.479, footnote 4), both Townsend's (1935) and Best's (1986) estimates are cited in Scarff (1986, table 3). Several changes should be made to Scarff's table 3 to make it consistent with Best (1986) and Townsend (1935). First, the citation to Du Pasquier (1986) was to an earlier version of the study finally appearing as appendix 7 in IWC (1986a), but should more precisely be to Best (1986). Second, two typographical errors need to be corrected. The heading of the second column in Scarff (1986) table 3 which reads 'L' should read 'L_t'; this is the summary of Townsend's (1935) data. In addition, the record of whale catches in column 3 for the period 1840-44 which reads '985' should read '2,985', the number reported in Best (1986).

In addition, two related typographical errors should be mentioned. In appendix 7 of the 1983 IWC Right Whale Workshop Report, in the table on North Pacific Whale Catches, 1840-1969 (IWC, 1986a), the reference for the second column, labelled 'Okhotsk Sea', which currently is '(SC/35/RW26)' (Scarff, 1986), should be to Henderson (1983). Also the brackets surrounding these same data indicate that these catches are included in the subtotal data contained in the seventh column labelled 'US Whalers'.

Table 1

Ratio of whales struck to catch, or Catch-to-mortality adjustment factors for pelagic right whaling in the literature.

Ratio of whales struck to processed whales	Comments	Source
1.2-1.5:1	'[A]verage mortality factor, pertaining to [northern right whale] fisheries in which hand harpoons and lances (non-explosive) were used, would be between 1.2 and 1.5'	1983 IWC Workshop on Status of Right Whales (IWC, 1986, p.5)
1:53-1.83:1	Recorded struck-but-lost ratios for the North Pacific, South Atlantic and Indian Ocean (see text)	(IWC, 1986, appendix 8)
1.2:1	Factor for all oceans, may be based on Scammon (1874, p.251)	Starbuck (1878 p.661 table J, footnote)
1.35 and 1.5	Adjustments used by 1998 IWC Right Whale Workshop participants to estimate whaling-induced mortality on right whales in the Southern Hemisphere by pre-modern pelagic whalers	(IWC, 2001)
1.33:1	Estimate for northern right whales in the Sea of Okhotsk	Henderson (pers. comm., 1991)
1.41:1	Data from 48 voyages of French whalers in the South Atlantic 1821-37 (942 right whales processed out of 1,330 struck)	Du Pasquier (1986)
1.5:1	Of 20 whales struck on the Cape Farewell Grounds off the south coast of Greenland 1868-1897, 6 were killed but lost, 1 escaped, 13 were captured but 1 calf secured was discarded	Reeves and Mitchell (1986b, pp.254, 260)
1.93:1	Weighted average 'loss rate factor' (LRF) for three voyages to the Northwest Ground	Reeves and Mitchell (1986b, p.254)
2.46:1	Crude struck-but-lost ratio without adjustment for survivors or subsequent captures based on sample of 327 North Pacific northern right whales	This study, Table 3
1.39:1	Adjustment to reflect only the proportion of northern right whales which sank before escaping or being processed	This study, Table 3

1838-1839 (1.18-1.35), Cintra Bay, northwest Africa 1855-1858 (1.25-1.25) and 60/35 (Cape Farewell, North Atlantic) ground 1868-1898 (1.50-1.54).[2]

For the North Pacific, South Atlantic and Indian Ocean (1834-1864) appendix 8 of the 1983 Workshop Report (IWC, 1986b) shows ratios of total mortality to landed catches of 1.53-1.83:1, based on reports of 170 right whales struck between 1834-64. Although SC/35/RW22 is cited as the source of this information, this is clearly an error.[3] It appears that the reference for the North Pacific, South Atlantic and Indian Ocean data was also intended to be to Reeves and Mitchell (1986a, table 5) which discusses struck-but-lost data for these areas for this period.

However, the data in the IWC (1986) appendix do not quite match the data in Reeves and Mitchell (1986a). The differences are described in Table 2.

The most data on struck-but-lost right whales were reported by Du Pasquier (1986) regarding French pelagic whaling primarily in the South Atlantic. During ten voyages between 1787-1792, 294 right whales were struck. Of these, 181 were processed, 41 sank before being processed and 1 sank while it was being flensed; 70 whales 'escaped'. Du Pasquier (1986) suggested using an adjustment factor of 1.14 to adjust for the whales which sank prior to being flensed. He made no estimate of the number of whales that escaped and later died.

[2] The data regarding the Cape Farewell Ground appears to be derived from Reeves and Mitchell (1986a, p.250). In which case, the total number of whales struck should be 20, not 19 as reported in the table, and the ratios would be 1.50-1.54.

[3] SC/35/RW22 does not discuss struck-but-lost whales. The immediate prior citation in the table to whaling in Cintra Bay is also to SC/35/RW22 and is also an error. The data on Cintra Bay appear to be derived from SC/35/RW23, Reeves and Mitchell (1986a, table 4, pp.252-54).

The recorded ratios for struck-but-lost northern right whales in IWC (1986a) were higher than previously published adjustment factors. In estimating the total number of northern right whales killed, Starbuck (1878, p.661, table J, footnote) assumed that for every 80 right whales caught, secured and processed, another 20 were struck-but-lost and died: Loss Rate Factor (LRF) = 1.25. Best (1987) and Reeves and Mitchell (1986b) described Starbuck as relying on Scammon (1874, p.251), who wrote that 'one-fifth' more whales were killed than estimates of the processed catch (LRF = 1.2). However, Scammon stated this in a chapter on California shore whaling which refers mainly to whaling for gray whales (*Eschrictius robustus*) and humpback whales (*Megaptera novaeangliae*). Northern right whales were exceedingly rare in the catch of California shore stations (Scarff, 1986) and Scammon does not appear to have ever engaged in hunting northern right whales, so his estimate may not be relevant to the pelagic northern right whale fishery.

Reeves and Mitchell (1986b, pp.209-10) reviewed data on struck-but-lost whales in the northern right whale shore fishery off Long Island, New York. They concluded that the LRF in that fishery was probably closer to 1.2-1.6 than to 1.85.

Attempts at categorising the logbook data

IWC (1986a, p.5) listed four different categories of struck whales described in the logbooks:

(1) struck, killed and processed;
(2) struck but escaped (and presumably survived);
(3) struck but escaped, moribund
  (a) lanced and/or spouting blood, or
  (b) with whaling gear attached; and

Table 2

Comparison of struck-but-lost data in IWC (1986b, p.31) and the source data from Reeves and Mitchell (1986a, p.254).

Source	Period	Struck (a)	Struck, killed and not processed (b)	Struck and escaped (c)	Struck, killed and processed (d)	Mortality factor** 'one'	Mortality factor** 'two'
Appendix 8 (IWC, 1986)	1834-64	170	22	55	93	1.83	1.53
Table 5, Reeves and Mitchell (1986a)	1834-80	228	33	71	124*	1.84	1.56

*Includes 'dryskins'. **Mortality factor 'one'=a/d, mortality factor 'two'=(d+0.5c+b)/d.

(4) struck, killed, but not processed; and
  (a) recovered later as a drift whale or stinker, or
  (b) not recovered (due to sinking, rough seas, etc.).

The high estimate assumed that all the 'struck-but-escaped' animals died later and were not recovered, whereas the low estimate assumed that less than half of these died later and were not recovered.

Reeves and Mitchell (1986a, p.254) used a slightly different set of categories in their discussion of struck-but-lost mortality in the North Atlantic northern right whale fishery. They split the data into six groupings:

- *s* whales killed but lost, including those lost spouting blood;
- *u* struck and lost but 'unspecified';
- *d* struck and lost because the iron drew;
- *p* struck and lost carrying whaling gear;
- *c* calves orphaned; and
- *T* whales secured (including carcasses found) and taken alongside, as well as those secured but not tried out because of low oil yield ('dry skins').

From these groupings they derived an LRF to adjust catch records to total mortality according to the following equation:

$$\mathrm{LRF} = [T + s + 0.5(u) + 0.5(d) + p + c] \,/T$$

This assumes that *all* of the whales spouting blood or carrying whaling gear when lost died, and that 50% of the whales that escaped when the harpoon pulled out or for unspecified reasons also died. With these assumptions, their LRF is intermediate between the high and low boundary assumptions given in IWC (1986a).

The LRF for the 15 voyages Reeves and Mitchell (1986b) described ranges from 1.0 (the minimum possible, one whale struck for each one landed) to 3.13 (4 whales landed out of 15 struck). In their data set, no calves were recorded as being orphaned. The three North Pacific voyages they report for the *Mary* (1 June to 8 August 1846) and *Braganza* (30 May to 17 August 1841, and 1 May to 17 July 1842) yield LRFs of 1.79, 2.09 and 1.83 respectively. The weighted average of these three voyages is 1.94.

Whales sinking before processing

It is popularly thought that right whales were the first large whales hunted because, among other factors, they tended to float when killed (e.g. Gilmore, 1978). Although right whales are more likely to float when dead than balaenopterids, they can sink, frequently enough for this loss factor to need explicit consideration when developing an adjustment for struck-but-lost mortality.

Du Pasquier (1986) reported that of 224 southern right whales (*Eubalaena australis*) killed by French whalers primarily in the South Atlantic between 1787-92, 41 (14%) sank before they could be flensed, whilst one sank during flensing. More examples of northern right whales sinking when killed, and the efforts of the shore whalers on Long Island, New York, to keep the carcasses afloat are described in Reeves and Mitchell (1986b, p.209).

Whales found dead

Some whales struck with a harpoon but subsequently lost were later found by the same or another whaleship, retrieved and processed. Best (1987, p.415) found that 103 of the right whales recorded in Townsend's (1935) abstracts (2.9% of the landed catch) were already dead when found by the whaleship. He wrote:

> these figures might be underestimates if (as seems likely) not all whales found dead were recorded as such in the logbooks or logbook extracts. If so, this fact should be borne in mind when corrections are applied to the landed catch to account for whales struck and lost that subsequently died.

Non-American whaling for northern right whales in the North Pacific

Although most of the whaling for northern right whales in the North Pacific was carried out by American whaleships, there were significant numbers of non-American whalers also taking them in these waters. The first northern right whale taken in the North Pacific was probably landed by a French ship, the *Gange* (Webb, 1988).

Immediately prior to the advent of right whaling in the North Pacific, non-American whalers were very active in hunting southern right whales in the South Pacific. French whalers caught *ca*. 4,000 southern right whales in the South Pacific from 1835-39, nearly 30% of a total catch of just under 14,000 southern right whales (IWC, 1986a, p.30). Du Pasquier (1986) noted that in 1839, 20 French whaling ships were whaling near southern Australia, Tasmania and New Zealand; in 1841, 27 French whalers were in these southern waters. The number dropped to eight in 1842 and nine in 1843. Du Pasquier stated that at least these latter whalers went to the North Pacific or the Sea of Okhotsk in subsequent years, presumably following the other French whalers who had departed for these grounds previously.

Webb (1988) reported that of the 161 whaling ships that called at Honolulu in 1845, 21% were of non-American registry: 19 from France, 6 from Bremen, 3 from New Brunswick, 2 from Denmark, and 1 each from Prussia, Hanover, Norway, and Hamburg.

Non-American whaling also occurred near and in the Sea of Okhotsk. Kugler (1984) mentions that in 1845, 11 whaleships, consisting of 8 American, 2 French and 1 Danish whaleship (*Neptun*) called at Petropavlosk, Kamchatka. The French whalers reported catching eight northern right whales in the Sea of Okhotsk that year (Kugler, 1984). In 1847, of the 30 whaleships reported in the Sea of Okhotsk, four were French (Kugler, 1984). Altogether, these 30 whalers took 341 northern right whales that year. Du Pasquier (1986) states that after 1848, French participation in North Pacific whaling declined, and ended in 1868.

Despite its potential significance, the effect of non-American whalers on total northern right whale mortality in the North Pacific has not been quantified in most previous estimates of the catch of northern right whales in the North Pacific (IWC, 1986a; Best, 1987).

Adjustment for 'incomplete' voyages

Not all the vessels that cruised for northern right whales in the 1840s and 1850s returned to port. In 1846 alone, the *Konohasset* of Sag Harbour sank off Kamchatka and the *Baltic* of Fairhaven was lost on Bering's Island (Webb, 1988). Right whales killed during such voyages would not be accounted for in the lists of returns. Nearly 10% of the voyages listed by Starbuck (1878) and Hegarty (1959) were recorded as 'incomplete'. Best (1987) explicitly adjusted his estimates of whale catches arbitrarily assuming that on average incomplete voyages caught half the number of baleen whales as completed voyages. No additional review was made in this study to test the reasonableness of this assumption.

SOURCES

This study incorporates quantitative data from 10 voyages between 1838-52 described in Webb (1988) and additional anecdotal information and impressions from Webb (1988)

not previously considered. In addition, data from North Pacific voyages reported in Reeves and Mitchell (1986b; 1986a) are reviewed in the specific context of North Pacific 19th century whaling. Due to logistical constraints, no attempt was made to examine the actual logbooks themselves for these data, and it is thus possible that substantial additional data are available therein.

RESULTS

North Pacific data on struck-but-lost mortality

Table 3 describes quantified data on the number of northern right whales struck, the number which sank and the number which were landed and processed for 14 voyages of American pelagic whalers in the North Pacific between 1838 and the '1850s'. Webb (1988, p.70) states that his portion of the data 'were an average of the lot'.

In the North Pacific, what little data have been published since IWC (1986a) suggest that the report's estimates of struck-but-lost animals may be too low. Based upon his review of North Pacific logbooks, Webb (1988, p.69) stated:

> The success rate among whaleboat crews on the Northwest Coast during the 1840s was dismal. Even the most experienced men brought back fewer than 50 per cent of the [right] whales they struck with their harpoons; in some ships barely 20 per cent of the whales struck were killed; those crews losing four of five whales…
> …The common ways to lose a whale were these: by the harpoon breaking, or by a line being accidentally cut with a second harpoon; by a harpoon 'drawing' from soft blubber, by a deep dive, necessitating a quick cut to prevent the swamping of the whaleboat; by a fluke or flipper knocking a boat to pieces or capsizing it.

Whalers sometimes had to cut loose from a whale if it was pulling the whaleboat upwind, particularly if the whaleboat was getting out of sight of the whaleship due to fog or other reasons.

Webb suggested that the high percentage of struck-but-lost animals was due in large part to reliance on the double-barbed harpoon in the North Pacific during the 1840s. The much more effective single-barbed toggle harpoon did not reach the North Pacific until the 1850s (Webb, 1988, p.71). Between 75-85% of the total 19th century catch of northern right whales in the North Pacific pelagic fishery occurred in the period 1835-49, prior to the advent of the single-barbed toggle harpoon in the North Pacific (Best, 1987).

In the Sea of Okhotsk, Henderson (pers. comm., 1991) estimated that one northern right whale was killed but lost for every three northern right whales processed (1.33:1 ratio of total mortality:catch). This is lower than the 1.5:1 ratio attributed to Henderson previously in Kugler (1984). Henderson believed loss rates for northern right whales were greater than for bowheads in the Sea of Okhotsk as a result of right whaling occurring offshore whereas bowhead whaling occurred in the bays where many of the struck-but-lost whales could be later recovered.

Gross ratio of struck whales/catch data

As shown in Table 3, on 12 voyages in the North Pacific, 327 northern right whales were struck with harpoons, but only 133 landed. This reflects a crude ratio of total whales struck:whales landed of 2.46:1. This ratio contains no adjustment for struck whales which either survived their injuries, or died from their injuries but were later recovered by whalers as drifting carcasses.

Table 3

Struck-but-lost records for northern right whales in the North Pacific pelagic fishery 1838-1860. n/a = data not available. Sources: A = Webb (1988, pp.65-72), B = Reeves and Mitchell (1986b, table 5), C = Cheever (1850, p.99) cited in Webb (1988, p.72), D = Reeves and Mitchell (1986a, p.209).

			Right whales			
Year	Ship	Lowerings	Struck	Sank	Landed	Source
1838	*Timoleon*	n/a	12	n/a	2	A
1841	*Superior*	n/a	58	5	26	A
1841	*Orozimbo*	n/a	5	n/a	3	A
1841	*Braganza*	44	38	5[1]	17	B,D
1842	*Braganza*	39	25		12	B,D
1842	*Elisa*	n/a	44	n/a	15	A
1842	*Angelina* (French)	n/a	20	n/a	14	A
1844	*Magnet*	n/a	26	n/a	13	A
1845	*Hibernia*	n/a	46	n/a	13	A
1846	*Mary*	37	14[2]	n/a	7	B
1848	*Julian*	n/a	12	n/a	3	A
1840s	unknown	n/a	n/a	6	0	C
1852	*Golconda*	70	27[3]	4	8	A
1850s	*Julian*?	n/a	n/a	11	17	D[4]

[1]Of the 63 whales struck by the *Braganza* in 1841 and 1842, 8 whales in 1841 and 1 whale in 1842 were lost. Of these 9 whales, 5 sank and 4 swam away spouting blood. Reeves (pers. comm.) assumes these latter whales also died.

[2]Of the 7 whales struck-but-lost by the *Mary*, 1 was lost either dead or spouting blood, 1 was lost without explanation, for 2 whales the harpoon drew out and for 3 whales the animals escaped carrying whaling gear on them.

[3]Webb (1988 p.70) summarises from the log of the *Golconda*: 'In the summer of 1852, the crew of the ship *Golconda* remained on the Northwest Coast until 2 September, lowering seventy times for whales and realizing a return of only eight animals. Forty-nine attempts ended in total failure, the oarsmen not able to bring the boatsteerer close enough to the gallied [=frightened] animals. During twenty-one other attempts only twelve whales were killed, and four of these sank irretrievably. The men lost fifteen more to causes beyond their control: three by irons drawing, four by irons breaking, another four escaping when the twisted strands of the whaling line parted. They intentionally cut from two whales, and accidentally separated themselves from a third when a second harpoon severed the fast line. In another case a loose whale stove a boat and forced a cancellation of the hunt.' These numbers suggest that more than one whale was struck on some lowerings otherwise it is difficult to reconcile the 12 whales killed with the 15 whales escaped and the 21 lowerings with some success.

[4]Reeves and Mitchell (1986a, p.209) cite Winegar, S.P. (1860). Cruise of the whaleship *Julian*. *Whalemen's Shipping List, and Merchants' Transcript*, 18(33), 23 October, for this information. They do not specify whether Winegar was referring to the *Julian* or some other ship.

Whales lost because the carcasses sank

The North Pacific data reviewed is consistent with the findings discussed above. The sinking of northern right whale carcasses before 19th century pelagic whalers could flense them occurred frequently. Bowles (1845) stated, apparently in reference to northern right whales:

> Within the deep bight formed by the peninsula of Aliaska [sic.] and near the Island of Kodiak, I have also seen large numbers of whales, but they were of a much smaller size than those we had found more to the Southward, and more than half we captured, sunk when dead. I have known the boats of one ship to kill six whales here in a day, and all of them sunk. Nor can this sinking of whales be at all accounted for. I have known a whale of the largest size, which in cutting him in, was found to be a dry skin (another singular fact in their physiology not to be accounted for, the blubber contained a milky fluid instead of oil) and yet this whale floated as light as a cork. Again, I have killed a whale with a single lance and he sunk like a stone, when another was lanced a hundred times, with the same result. As I said before, the cause of their sinking is unknown, and will be until we are better acquainted with their natural history than at present.

Cheever (1850, p.99, cited in Webb, 1988, p.72) reported:

> The havoc they make of whales is intense…I have heard of one ship that sunk twenty-six whales after she had killed them; of another that killed nine before she saved one; of another that killed six in one day, and all of them sunk.

As shown in Table 3, on the six voyages which data on the number of whales landed and the number which sank was recorded, 31 carcasses sank and 80 northern right whales were landed.[4] This is substantially higher than Du Pasquier's (1986) finding of 41.5 whales sinking out of 182.5 processed in the South Atlantic from 1787-92. Using the sunk/processed ratio from the North Pacific sample suggests that a multiplier of 1.39 should be applied for this factor alone, compared to a multiplier of 1.23 from Du Pasquier's study. The four North Pacific voyages in Table 3, which contain data on both the numbers of whales struck and whales which sank, show that of 148 northern right whales struck with harpoons, 14 sank before they could be recovered.

The analysis is complicated by the fact that whalers were probably able to recover some of the 'sinkers' if they remained attached to the whale. The whaleboat provided some offsetting buoyancy, more if two or more whaleboats were attached to the whale. Mitchell and Reeves (1986b) described the efforts of shore whalers in Long Island to use the buoyancy of the whaleboats to prevent a whale from sinking out of reach. Presumably similar techniques were used by the pelagic whalers in the North Pacific.

Whales found dead

As mentioned earlier, Best (1987) reported that in Townsend's abstracts a minimum of 2.9% of the catch of right whales from all oceans were already dead when found and processed by the whalers. Best (1987) suggested that the actual percentage of the landed catch which represented carcasses found floating might be significantly higher. The small amount of new information from this study supports the idea that the catch of already-dead carcasses may have been greater than 2.9%. Webb (1988, p.71) commented that:

> almost every logbook from the Northwest Coast reports the discovery of a [northern right whale] carcass or two, some bearing in their flesh the identifiable harpoons from the fatal struggle.

[4] *Superior* 1841, *Braganza* 1841-42, unknown 1840s, *Golconda* 1852 and *Julian* 1850s.

He suggested that most of the carcasses found were too decomposed to be rendered into oil and would not be reflected in the lists of returns (oil and baleen) used to estimate catches. As Best (1987) noted, such 'stinkers' may also not have been regularly reported in the logs.

Because 2.9% of the northern right whales reflected in the catch data relied on by Best (1987) were dead when found, it is necessary to adjust the crude struck-but-lost ratio of 2.46:1 described above to avoid double-counting these whales found dead. Accordingly the ratio was adjusted by 2.9% to result in a *net* struck-but-lost ratio of 2.43:1. This is the ratio that is used to calculate total mortality in Tables 4 and 5. If further study shows that more of the right whales eventually flensed were found dead, this would tend to *reduce* the struck-but-lost ratio further.

Adjusting for non-American whaling

These fragmentary data suggest that the non-American registered ships may have constituted as much as 15-20% of the whaleships on the northern right whale grounds. This indicates that more research to quantify their catch is warranted.

Estimates of total mortality

Estimates of total mortality were extrapolated from catch data and are reported in Tables 4 and 5. The catch data used were an average of Best's (1987) two estimates of catches in the American whale fishery developed using production and catch-per-voyage methods. For the period 1840-1909, Best's two methods yield estimates for the catch of northern right whales in the North Pacific (15,374 and 14,480 respectively) that differ by only 6%. Over five-year time periods, the methods differ more due to delays in reporting inherent in the oil production method.

Estimates of mortality from the American fishery were calculated by multiplying the catch data by either the IWC (1986a) struck-but-lost adjustment factors or the adjustment factors recommended in this study. In the first instance, the catch data were adjusted by the adjustments of 1.2 and 1.5 (IWC, 1986a, p.5) for the entire period 1835-1909 to get upper and lower estimates of total mortality.

In the second instance, the catch data were adjusted by struck-but-lost factors derived in this study. A gross struck-but-lost mortality factor of 2.46 was chosen based on Table 3. This was adjusted to reflect the opportunistic recovery of already killed whales, assuming that 2.9% of the total catch fit into this category based on Townsend's (1935) records described in Best (1987), resulting in a net struck-but-lost adjustment factor of 2.43. This factor was applied for 1835-54. Given the change to the much more efficient single toggle harpoon around 1855, a struck-but-lost adjustment factor of 1.4 was chosen for 1855-1909. During both periods, the lower estimates were calculated assuming that 50% of the struck-but-lost whales died; upper estimates were calculated assuming that all the struck-but-lost whales died.

Finally, the impact of non-American whalers was incorporated by assuming that they comprised 10% of the whaling fleet and made 10% of the catch during the period 1835-1859, 0% after 1859, and had struck-but-lost rates similar to the American fleet's. The latter seems reasonable since many officers of these foreign ships were American.

Table 4

Estimates of total mortality of right whales in the 19th century North Pacific pelagic fishery. All the estimates of total mortality reflect adjustments to the average of Best's (1987) two estimates of the catch of the American pelagic fishery.

	Estimated catches by American whalers[1]			Adjusted estimates of total mortality					
				Mortality with only an adjustment for struck-but-lost whales				Including foreign whalers	
Years	Oil production[1]	Catch/ voyage[1]	Average	low bound*[2] (1.2:1)	high bound*[2] (1.5:1)	low bound**[3] (1.69:1)	high bound**[3] (2.43:1)	low bound**[4]	high bound**[4]
1835-39		149	75	89	112	126	181	140	201
1840-44	2,957	5,728	4,343	5,211	6,514	7,339	10,552	8,154	11,725
1845-49	8,001	5,578	6,790	8,147	10,184	11,474	16,498	12,749	18,332
1850-54	1,364	951	1,158	1,389	1,736	1,956	2,813	2,174	3,125
1855-59	1,381	1,221	1,301	1,561	1,952	1,561	1,821	1,735	2,024
1860-64	585	152	369	442	553	442	516	442	516
1865-69	441	434	438	525	656	525	613	525	613
1870-74	58	52	55	66	83	66	77	66	77
1875-79	85	16	51	61	76	61	71	61	71
1880-84	8	48	28	34	42	34	39	34	39
1885-89	356	90	223	268	335	268	312	268	312
1890-94	39	26	33	39	49	39	46	39	46
1895-99	56	16	36	43	54	43	50	43	50
1900-04	38	19	29	34	43	34	40	34	40
1905-09	5		3	3	4	3	4	3	4
Total	15,374	14,480	14,927	17,912	22,391	23,971	33,633	26,466	37,173

* Both high and low bounds apply struck-but-lost factors of 1.5:1 for each whale reported captured 1835-1909. The low bound assumes that 40% of the whales struck-but-lost (SBL) die (1.2:1); the high bound assumes that all the SBL whales die. ** Both high and low bounds apply SBL factors of 2.46 for each whale reported captured 1835-54. The high bound assumes that all of the struck whales die; the low bound assumes that 50% of the struck whales die. Both factors are adjusted to reflect an assumed 3% of the catch being of whales already killed by whalers, yielding net SBL adjustment factors of 1.69 and 2.43 respectively. For the period 1855-1909, it is assumed that the single-toggle harpoon dramatically reduced the number of whales lost, so a SBL estimate of 1.4:1 was used.
[1] Best (1987). [2] Using the SBL factor from the 1983 IWC Workshop Report (IWC, 1986). [3] Using the SBL factors from this study. [4] Assumes 10% foreign participation 1840-59 on SBL factors from this study.

Table 5

Cumulative American catch and estimated total mortality of right whales in the pelagic North Pacific fishery 1835-1909.

	Cumulative American catch		Cumulative mortality				
			Using SBL factors from IWC (1986)		From this study		
Period	No.	%	low	high	low	high	% (high)
1835-39	75	<1%	89	112	140	201	1%
1840-44	4,417	30%	5,300	6,626	8,294	11,926	32%
1845-49	11,207	75%	13,448	16,810	21,043	30,258	81%
1850-54	12,364	83%	14,837	18,546	23,217	33,383	90%
1855-59	13,665	92%	16,398	20,498	24,952	35,407	95%
1860-64	14,034	94%	16,840	21,050	25,394	35,922	97%
1865-69	14,471	97%	17,365	21,707	25,919	36,535	98%
1835-1909	14,927	100%	17,912	22,390	26,466	37,173	100%

Sources: Cumulative American catch is the average of Best's (1987) two estimates. The cumulative mortality is from this study (Table 4, adjusted for foreign whaling). The cumulative percentage is based on the high bound estimate from this study including the adjustment for foreign whaling.

Table 5 presents the same data on a cumulative basis. The total mortality estimates are those (a) from American whaling alone using the IWC (1986a) adjustment factors (1.2, 1.5) giving a range of 17,912-22,391 and (b) those using the adjustment factors recommended in this study giving a range of 26,466-37,173. These estimates illustrate that struck-but-lost mortality combined with non-American whaling may have been as great a factor in overall northern right whale mortality as the recorded catch by American whalers.

Given the rarity of northern right whales in these areas today, the estimated total whaling-induced mortality of 20,000-30,000 northern right whales in a single decade, the 1840s, is particularly striking.

DISCUSSION

How different was pelagic right whaling in the North Pacific from right whaling in other oceans?

IWC (1986a, p.5) stated that there:

> are significant differences in loss rates by whaling area, time period, and technology in use. These should be recognised in any reconstruction of catch history…. Losses seem to have been higher on the open seas than they were in bay whaling.

The North Pacific is not specifically identified as warranting a special adjustment factor; however, combined data for the South Atlantic, North Pacific and Indian Ocean whaling suggest that use of a higher adjustment factor is appropriate (IWC, 1986b, appendix 8). Among those three areas, the particularly bad conditions in the North Pacific and Sea of Okhotsk were well noted by contemporary whalers.

Given the sea conditions frequently found in the Gulf of Alaska, along the Aleutian Islands and along the Kamchatka coast, it is quite plausible that the ratio of the number of animals struck-but-lost to the number of whales reflected in the catch data in the North Pacific was greater than in other regions. Webb (1988, p.65) summarised conditions described in the logbooks he reviewed:

> Accounts of the Northwest Coast voyages are saturated with weather, often 'rugged' with rain, sleet, fog, and snow, punctuated by living gales from the Arctic North and every other point on the compass. 'Thick', they wrote. 'Thick and rain'. 'Thick, wet and disagreeable'.
>
> Coming with the fog, and sometimes apart from it, were the 'strong breezes', gales, and 'near hurricanes' which drove the seas to frothy crests and necessarily inhibited the whaling. The phrase 'Too rugged to lower' pervades the journals; too rugged to chase whales, too rugged to start the tryworks, too rugged to make sail. And if a whale was somehow taken in such dismal conditions…[i]n the deep Pacific swell, the rolling of the whales against the fluke chain and the hull often caused its body to part company with the ship.

The data described in this study represent a very small sample from a very large, albeit brief, fishery. The purpose of the study was to suggest again that the 19th century pelagic whaling on northern right whales in the North Pacific may have depleted an initial population that was substantially larger than may have been previously thought. It seems likely that more data exist in the logbooks that could increase the sample size examined and provide more reliable estimates of struck-but-lost ratios. This study suggests that further examination of those logbooks would be a worthwhile effort.

ACKNOWLEDGEMENTS

I am indebted to Randall Reeves (Okapi Wildlife Associates, Chandler Lane, Hudson, Quebec J0P 1H0, Canada) for review of a preliminary draft of this paper. I am also greatly indebted to Robert Webb (Maine Maritime Museum, Bath, Maine, USA) for his superb book on North Pacific Whaling, *On the Northwest*, and his review of a preliminary draft of this paper. I am also indebted to an anonymous reviewer for thoughtful and helpful comments.

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