

ESTIMATES OF THE LANDED CATCH OF RIGHT (AND OTHER WHALEBONE) WHALES IN THE AMERICAN FISHERY, 1805-1909

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ABSTRACT

Using a combination of the numbers of bowhead, right, humpback, and gray whales listed for particular voyages by C. H. Townsend, and the declared returns of whale oil and whalebone from the same voyages as listed by A. Starbuck and R. B. Hegarty, mean oil and whalebone yields per whale are calculated and temporal trends in these yields investigated for each species. These are then used to obtain an estimate of the total landed catch for each 5-year period from 1805 to 1909, using the species composition from Townsend's lists and adjusting it upwards from the ratio of oil or bone production for Townsend's sample to the total known importation of these products to the United States for the same period. An alternative estimate is based on the catch per voyage in Townsend's sample, stratified by voyage-type (sperm, whalebone, or mixed), and prorated up by the number of whaling voyages of the same type as listed by Starbuck and Hegarty. The two methods produced estimates of the landed catch by American-registered vessels between 1805 and 1909 of 29,748-30,313 bowhead, 70,325-74,693 right, 14,164-18,212 humpback, and 2,665-3,013 gray whales.

Between 1715 and 1928, whaling vessels from American ports are estimated to have made 13,927 voyages, mostly under sail, in their worldwide pursuit of oil and whalebone (Sherman 1965). In 1846, at the peak of the fishery, the American whaling fleet comprised over 735 vessels displacing 233,189 tons (Hohman 1928). Because of the essentially unregulated and competitive nature of the enterprise, no systematic recording or collection of catch statistics was ever initiated for this very extensive fishery.

In 1875, Alexander Starbuck began to compile a list of the returns of whaling vessels from American ports from 1715, a task continued to the end of the fishery in 1928 by Hegarty (1959). These publications list for each voyage the vessel's name, class, tonnage, captain, managing owner or agent, destination, dates of sailing and arrival, and the results of the voyage in barrels of sperm or whale oil and pounds of whalebone. Numbers of whales taken are not given, but this did not prevent Starbuck (1878) from making his own calculations. In a footnote to his table J, which listed quantities of oil and whalebone imported into the United States from 1804 to 1876, Starbuck stated that

Scammon estimates that sperm whales will average

25 and right whales 60 barrels of oil, and of the former 10 and of the latter 20 per cent of those killed are lost. Upon that basis the above amounts of oil would represent the slaughter of 225,521 sperm, and 193,522 right whales.

The latter figure has frequently been quoted as representing the size of the historical take of right whales (sometimes incorrectly for the period 1804 to 1817, an error apparently originally perpetrated by Harmer [1928], who also inferred that the entire take was of southern right whales). It is clear however that the landings of oil not only included production from both northern and southern right whales, but also from bowhead, humpback, and gray whales, species for which Starbuck (1878) made no allowance in his original calculation.

In this paper, an attempt has been made to revise Starbuck's calculations to account for the species composition of the catch, to extend his analysis forward in time using importation figures provided by Hegarty (1959), and to use whalebone as well as oil production. An independent method of estimating the landed catch using the catch per voyage has also been developed.

The motivation for this paper arose from the International Whaling Commission meeting on the past and present status of right whales, held in Boston in 1983, where the need for an improved estimate of the size of the American catch of right whales became apparent (Brownell et al. 1986).

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MATERIAL AND METHODS

From logbook extractions, Townsend (1935) tabulated the numbers of sperm, bowhead, right, humpback, and gray whales taken per voyage by 744 whaleships (mostly American) between 1751 and 1925. These figures include not only the whales processed but also those killed and brought alongside but subsequently lost before processing; these statistics have thus been termed the "landed catch" in this paper. The numbers of right whales are listed by ocean (i.e., North and South Pacific, North and South Atlantic, and Indian Oceans). In all, 53,877 whales are listed from 1,665 voyages. Excluding non-U.S. vessels, 16,837 baleen whales were taken in a total of 1,651 voyages, of which 636 were only sperm whaling voyages. The species composition of the baleen whale catch as extracted by Townsend has formed the basis of all the analyses performed in this paper, and is henceforward referred to as the "Townsend sample".

Some of the original work sheets used by Townsend in his 1935 paper were discovered in 1978 in the library of the Osborne Laboratory of the New York Aquarium. These comprise voyage abstracts giving the date, ocean, geographical position, number, and species of each whale landed, together with remarks such as "found dead", "cow and calf", etc.; about half of the work sheets are in the original handwriting of the compiler(s), while the remainder consist of typewritten copies. The abstracts cover voyages by most vessels whose names started with letters A through J (bark *A. Houghton* to brig *Juno*). Because some errors apparently occurred between the original abstracts and the final printed version (Schevill and Moore 1983), the catch data for the 438 voyages on which baleen whales were landed and for which abstracts were available has been checked against the figures tabulated by Townsend (1935). Errors were found in 32 voyages (or about 7% of the total) and corrected. The abstracts examined represent a landed catch of 6,982 baleen whales, or roughly 41% of the total Townsend sample.

Mean oil and whalebone yields per whale have been obtained by comparing the numbers of whales caught on a voyage (as listed by Townsend) with the amount of whale oil or whalebone landed for the same voyage (as listed by Starbuck (1878) or Hegarty (1959)). To avoid complications created when more than one baleen whale species was taken, only voyages where a single baleen whale species was taken have been

analyzed. Because of suspected differences in size (and so presumably in yields of products) between North Pacific right whales and those from other seas (Omura 1958), they have been considered as a separate "species" for the purposes of this section. In order to reduce the amount of variation in yield and to avoid situations where Townsend seems to have had access to only a partial log of the voyage, only voyages on which 10 or more animals of that species were taken have been used (or roughly 20% of Townsend's sample of voyages on which whalebone whales were taken). Oil or bone sent home or sold abroad has been included where it is known; as Starbuck (1878) has pointed out, that sold abroad was not always accounted for.

Figures for the total annual importation of oil and whalebone into the United States have been taken from Starbuck (1878) and Hegarty (1959).

For the catch per voyage analysis, the voyages in the Townsend sample have been stratified according to type, either sperm (when only that species was landed), whalebone (when no sperm whales were included in the catch), or mixed (when both sperm and whalebone whales were taken). The numbers of such cruises have then been adjusted upwards by the numbers of such voyages found in the Starbuck/Hegarty compilation, where vessels were identified as sperm whalers if they were reported as returning with or sending home only sperm oil, as whalebone whalers if they only reported whale oil and/or bone, and as mixed whalers if they returned with or sent home both whale oil/bone and sperm oil. Two additional classes were recognized in the Starbuck/Hegarty compilation: "clean" voyages and "incomplete" voyages. Clean voyages were those entered as such by Starbuck (1878), but as Hegarty (1959) did not continue this practice, any of the voyages he listed that were completed but for which no production was reported were scored as "clean". Both authors listed several voyages that were not completed owing to fire, shipwreck, the vessel being condemned, etc., and for which no production was reported. These voyages were scored as "incomplete", and half their number was allocated on a prorata basis as either sperm, whalebone, mixed, or clean whalers, based on the proportions of these categories in the sample of completed voyages. The other half of the incomplete voyages was discarded, the assumption being that such voyages were on average probably half as successful as those completed and that Townsend (1935) was unlikely to have had access

to the logbooks of many of them. Incomplete voyages comprised 9.6% of those listed by Starbuck (1878) and Hegarty (1959).

A "plus minus" figure following any estimate refers to one standard error.

Values given for the coefficient of variation (CV) have been obtained using variances calculated by the jackknife method (using one voyage as the sampling unit). No attempt has been made to calculate coefficients of variation for the final estimates because 1) certain independent components of the variance could not realistically be assessed (e.g., variation in the proportion of a particular species in the total catch to that in the Townsend sample from one 5-yr period to the next) and 2) any biases in the data are likely to be of greater magnitude than statistical errors resulting from sampling variation.

ESTIMATES BASED ON PRODUCTION

The number of baleen whales landed by American whalers as extracted by Townsend (1935) is listed by five yearly period in Table 1. If Townsend's data for a particular voyage covered more than one calendar year, the catch would be entered against the later date, as this was more likely to correspond to the importation figures used as a basis for reconstruction of the catch. A total landed catch of 4,963 bowhead, 8,293 right,

2,879 humpback, and 569 gray whales was recorded for the period 1805-1914.

Average Oil Yield Per Whale

Right Whales

There were 147 right whale cruises producing oil yields ranging from 22.5 to 219 barrels (Fig. 1). As expected, the 17 voyages that took North Pacific right whales had higher yields (83 to 219 barrels) than the 130 taking right whales elsewhere (22.5 to 150 barrels), and so have been considered separately.

There was no significant trend in oil yield per whale during the period in which North Pacific right whales were taken ($b = -1.15 \pm 0.91$, $t = 1.27$, $P > 0.20$), so the overall average oil yield per whale of 41,645/341 or 122 barrels (CV = 0.063) has been used. This compares with published averages of 125 barrels, males making 60 to 100 and females 100 to 250 barrels (Clark 1887a), and 130 barrels (Scammon 1874).

There appeared to be a distinct decline in the oil yield of right whales on other grounds after 1882 ($b = -1.09 \pm 0.30$, $t = 3.60$, $P < 0.02$). Oil yields after this date have therefore been calculated from the least squares estimating equation fitted to the data:

$$y = 64.78 - 1.090(x - 1882)$$

TABLE 1.—Five-year compilation of whalebone whale catches from Townsend (1935).

Period (arrival)	Northern right			Southern right			Humpback	Gray	Total
	Bowhead	Atl.	Pac.	Atl.	Pac.	Ind.			
1805-1809	—	—	—	43	—	—	—	—	43
1810-1814	—	—	—	—	—	—	—	—	—
1815-1819	5	—	—	3	22	—	2	—	32
1820-1824	—	—	—	81	—	—	—	—	81
1825-1829	—	—	—	269	—	—	1	—	270
1830-1834	—	—	—	940	71	72	5	—	1,088
1835-1839	—	—	—	761	356	477	96	—	1,690
1840-1844	—	—	324	53	516	505	66	—	1,464
1845-1849	91	—	1,088	55	349	129	89	—	1,801
1850-1854	1,101	—	165	88	34	48	84	6	1,526
1855-1859	1,238	1	235	53	72	83	242	65	1,989
1860-1864	650	9	117	109	104	48	193	205	1,435
1865-1869	717	2	107	108	25	43	124	215	1,341
1870-1874	471	—	15	45	18	46	774	70	1,439
1875-1879	104	6	13	54	1	13	380	8	579
1880-1884	119	4	1	77	26	—	619	—	846
1885-1889	76	5	38	53	72	3	171	—	418
1890-1894	86	—	3	38	13	—	22	—	162
1895-1899	183	1	12	7	—	6	10	—	219
1900-1904	74	—	6	11	—	2	1	—	94
1905-1909	33	—	1	10	6	71	—	—	121
1910-1914	15	—	—	26	—	25	—	—	66
Total	4,963	28	2,125	2,884	1,685	1,571	2,879	569	16,704

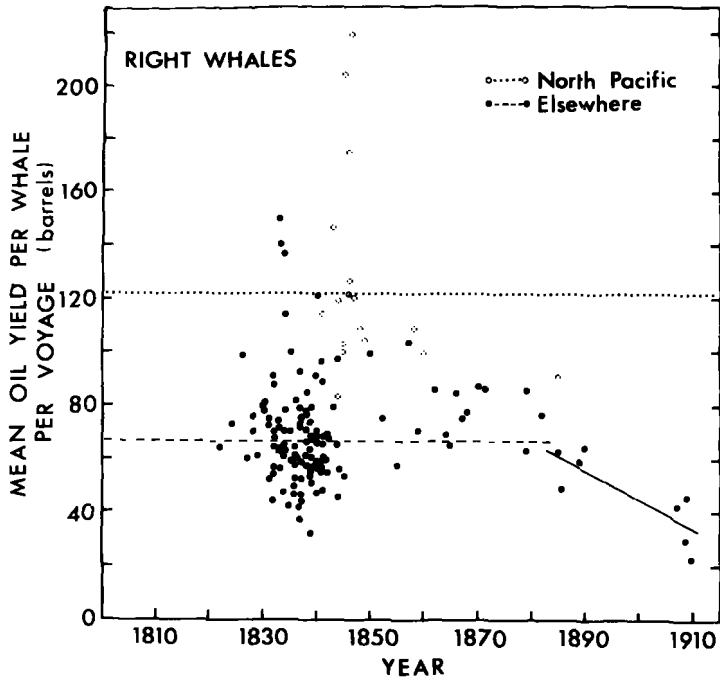


FIGURE 1.—Mean oil yield per whale for right whales landed on U.S. voyages from 1822 to 1910.

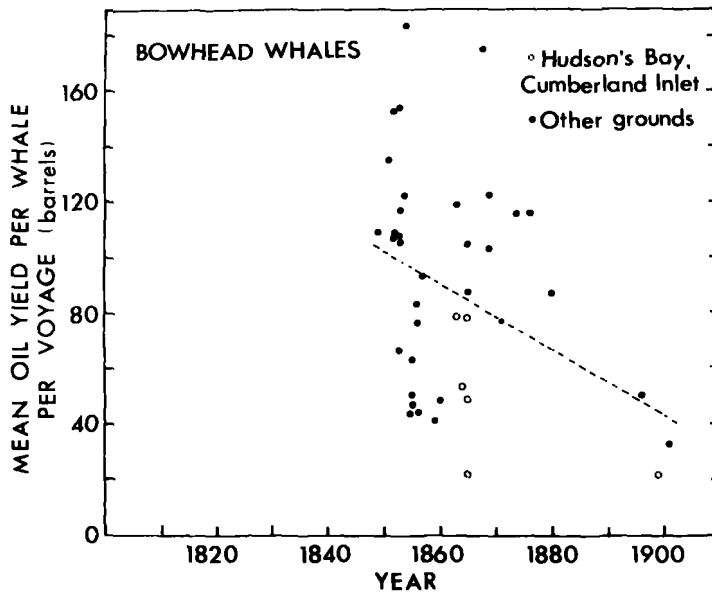


FIGURE 2.—Mean oil yield per whale for bowhead whales landed on U.S. voyages from 1849 to 1901.

where x = year of arrival (>1882) and
 y = average oil yield (barrels).

This produces a decline from 63.7 barrels in 1883 to 34.2 barrels in 1910.

Prior to 1883 there was no significant trend with time ($b = 0.16 \pm 0.16$, $t = 1.01$, $P > 0.2$), so the average overall oil yield of 206,328/3,080 or 67 barrels (CV = 0.024) per whale has been used. Right whales in the South Atlantic were said to yield (when full grown) from 40 to 60 barrels of oil if male and 60 to 80 barrels if female, or about 60 barrels on average. Those in the South Pacific and Indian Oceans were said to be smaller, averaging 40 barrels if male and 60 barrels if female (Clark 1887a). Eleven right whales taken in the Indian Ocean averaged 59 barrels, with a maximum of 80 barrels (Wray and Martin 1983). In a sample of 29 right whales taken in the North Atlantic, Reeves and Mitchell (1986) found a range of oil yields from 6.5 to about 100 barrels with a mean of 58 to 59 barrels. These figures all agree fairly well with the calculated values used here: the decline in yield after 1883 may reflect market considerations and the relative value of oil and whalebone (see below).

Bowhead Whales

Oil yield data were available for 39 voyages on which 987 bowhead whales were taken; six voyages were to "Hudson's Bay" or "Cumberland Inlet" (Fig. 2). The latter voyages had generally lower oil yields (22 to 79 barrels) than the other grounds (32 to 184 barrels), possibly reflecting differences in distribution of size groups, or the effects of greater depletion. However, as no distinction was made in Townsend's (1935) tabulations between bowhead whales caught on different grounds, the data set has not been subdivided. Oil yields seemed to decline throughout the period of the fishery ($b = -1.19 \pm 0.48$, $t = 2.46$, $P < 0.02$), so for any particular year the mean oil yield has been calculated from the estimating equation:

$$y = 105.11 - 1.1892(x - 1848)$$

where x = year of arrival (>1848) and
 y = average oil yield (barrels).

The slope of this regression is very sensitive to the three data points after 1890: their exclusion results in a much slower, nonsignificant rate of de-

cline ($b = -0.58 \pm 0.73$, $t = 0.79$, $P > 0.20$). However, in view of the decreasing oil yields with time found by other workers and the economic incentives after 1880 that favored the collection of whalebone rather than whale oil (see below), the regression coefficient shown in Figure 2 has been retained.

This produces a decline from 103.9 barrels in 1849 to 31.4 barrels in 1910; yields before 1849 (for which no data exist) are taken as 103.9 barrels per whale.

According to Scammon (1874), bowhead whales could be classified into three types, yielding on average 200 barrels, 100 barrels, and 75 barrels of oil. Bowhead whales in the Davis Strait were said to average about 120 barrels (males 100, females 140), but had decreased in size "of late years". In the Okhotsk Sea, cows averaged about 130 barrels and the bulls about 90 barrels, but once again the whales had been much smaller "during recent years" (Clark 1887a). Oil yields for 333 whales from the Western Arctic stock listed by Bockstoce and Botkin (1983) averaged 112.4 barrels. These averages are all somewhat higher than the yield calculated here, but (with the exception of the last) they referred principally to the commencement of the fishery. Bockstoce and Botkin (1983) have also documented a decline in the size of bowhead whales taken over time, but the regression of barrels per whale per year has a somewhat smaller slope (-0.61 barrels per year) than in the present case: the mean yield declined from about 119 barrels in 1850 to about 70 barrels in 1900 (cf 43 in the present data). This difference may simply reflect a different measurement—Bockstoce and Botkin apparently only considered the yield of animals for which a barrel-estimate was made by the whaling vessel so that animals may have been excluded if no oil was rendered from them. The present analysis however considers all whales taken on a voyage (whether processed into oil and whalebone or not), so that it is not surprising that its figures are somewhat lower than for previous estimates. An oil yield as low as 49 barrels per whale was calculated for bowhead whales in Hudson Bay between 1860 and 1890 (Ross 1974).

Humpback Whales

Oil yield data were available for 29 cruises on which 1,137 humpback whales were taken (Fig. 3). There was no significant trend with time ($b = 0.31 \pm 0.19$, $t = 1.58$, $P > 0.10$), so the aver-

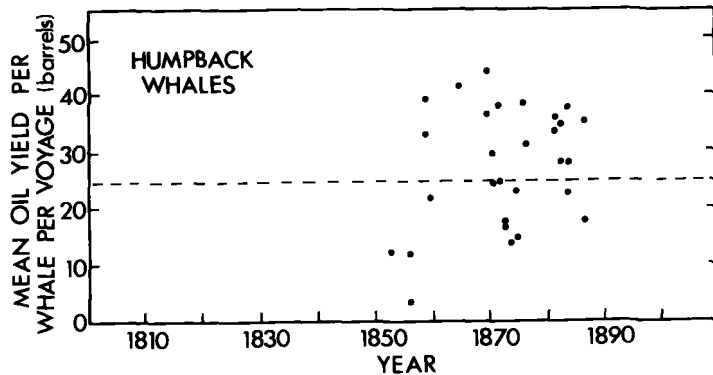


FIGURE 3.—Mean oil yield per whale for humpback whales landed on U.S. voyages from 1853 to 1887.

age overall oil yield of 27,797/1,137 or 24.4 barrels ($CV = 0.110$) per whale has been used throughout. According to Scammon (1874), humpback whales varied more in their production of oil than all other rorquals. Some individuals yielded only 8 or 10 barrels, whereas others gave up to 75 barrels; large females yielded on average 40 barrels. Mitchell and Reeves (1983) used an average of 25 barrels per whale, although individual whales yielded from 5 to 85 barrels each. The value calculated here is thus in reasonable agreement with previous estimates.

Gray Whales

There were no cruises in Townsend (1935) on which gray whales were the only baleen whale species taken, on which at least 10 animals were landed, and for which production figures were available in Starbuck (1878). Consequently the average production figure of 35 barrels per whale estimated by Henderson (1972) has been used throughout.

Average Yield of Whalebone Per Whale

Average yields of whalebone have been calculated essentially the same way as for oil. However, as Starbuck (1878) pointed out, in the earlier years (before about 1844/45), reports of the amount of bone taken were only occasional:

Most of that commodity was imported prior to 1840 in New London and Sag Harbor ships, its value being so low that captains of vessels from many of the other ports

did not care to be encumbered with it. For this reason a large amount of bone was brought home which it is impossible to properly accredit.

Figures for whalebone landings were listed for 94 to 95% of the voyages on which bowhead or North Pacific right whales were taken, but for only 30 and 24% of the voyages taking other right and humpback whales respectively. Two alternative (and probably extreme) assumptions can therefore be made: A) that only those vessels listed as landing whalebone actually did so, or B) that all vessels taking baleen whales retained the whalebone to the same extent as those for which whalebone production was reported. Average whalebone yields per whale (and trends therein) have been calculated here under both assumptions A and B (Figs. 4-7).

Right Whales

Of the 17 voyages on which 10 or more right whales were taken in the North Pacific, whalebone production was reported for 16 (Fig. 4). There was no significant trend in bone yield per whale in all 17 voyages ($b = -6.36 \pm 13.98$, $t = 0.46$, $P > 0.6$) or in the 16 for which bone production was declared ($b = -12.84 \pm 12.14$, $t = 1.06$, $P > 0.3$). Consequently overall mean yields of 384,134/341 or 1,126 lb ($CV = 0.098$) whalebone (assumption A) and 384,134/323 or 1,189 lb ($CV = 0.082$) whalebone (assumption B) have been used. According to Clark (1887a), whalebone yield in North Pacific right whales averaged about 1,000 lb per 100 barrels (equivalent to a yield of 1,250 lb for an average whale), while Scammon (1874) gave a range of 1,000 to 1,500 lb.

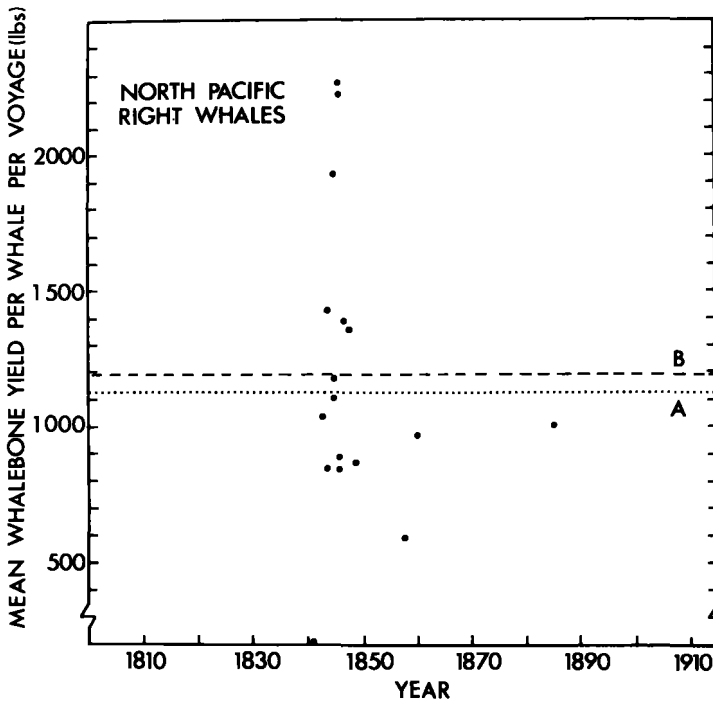


FIGURE 4.—Mean whalebone yield per whale for North Pacific right whales landed on U.S. voyages from 1841 to 1885 (A = assuming only those vessels listed as landing whalebone actually did so. B = assuming all vessels taking whalebone whales retained the whalebone to the same extent as those for which whalebone production was reported).

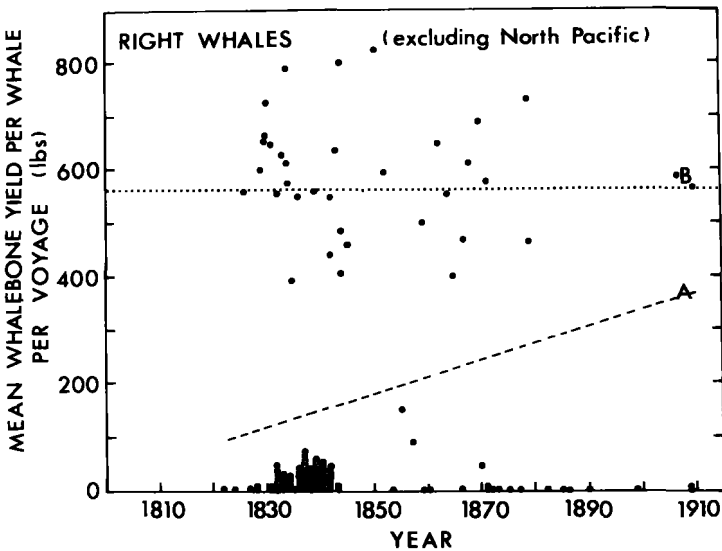


FIGURE 5.—Mean whalebone yield per whale for right whales landed on U.S. voyages (other than in the North Pacific) from 1822 to 1910 (A = assumption A. B = assumption B).

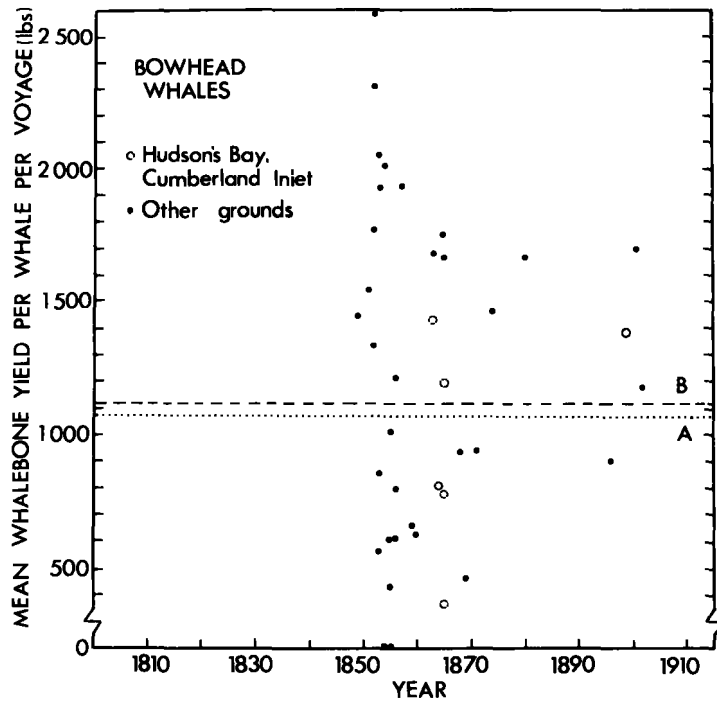


FIGURE 6.—Mean whalebone yield per whale for bowhead whales landed on U.S. voyages from 1849 to 1902 (A = assumption A, B = assumption B).

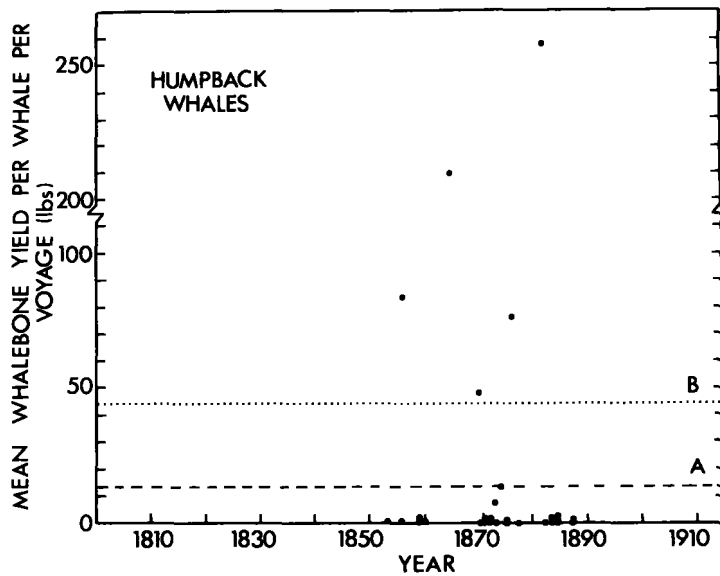


FIGURE 7.—Mean whalebone yield per whale for humpback whales landed on U.S. voyages from 1853 to 1887 (A = assumption A, B = assumption B).

Present calculations are therefore close to these estimates.

Of the 127 voyages taking right whales on grounds other than the North Pacific, bone yields were available for only 37 (Fig. 5). For all 127 cruises there was a significant trend in mean yield with time ($t = 2.40$, $P < 0.02$), so annual values under assumption A were calculated from the least squares estimating equation:

$$y = 92.51 + 3.11 (x - 1821)$$

where x = year of arrival (>1821) and
 y = average whalebone yield (lbs).

This equation produces a yield of 96 lb per whale in 1822 and a yield of 370 lb per whale in 1910; yields before 1822 (for which no data exist) are taken as 96 lb per whale.

For the 37 cruises where bone production was declared, there was no significant trend in average yields with time ($b = -0.67 \pm 1.26$, $t = 0.53$, $P > 0.6$), so the overall mean yield of 497,840/884 or 563 lb (CV = 0.043) of bone per whale has been used under assumption B. This agrees well with a calculated mean of 629 lb and adult range of 250 to 330 kg (550 to 726 lb) for right whales from South Africa (Best 1970) and the North Atlantic (Collett 1909), respectively. Clark (1887a) stated that right whales in the South Atlantic yielded on average about 300 lb of bone per 100 barrels of oil in the male and 400 to 600 lb per 100 barrels in the female (equivalent to an actual yield of about 180 lb per whale in the male and 240 to 360 lb in the female). Although he claimed that right whales in the Indian Ocean were smaller than those in the South Atlantic, average whalebone yields are given as 240 lb for males and 360 lb for females. It is not clear why Clark's figures are somewhat lower than the others quoted here.

Bowhead Whales

Of the 39 voyages taking bowhead whales that were analyzed, 37 included reference to landings of whalebone (Fig. 6). There was no significant trend in the mean yield of whalebone per whale, either under assumption A ($b = 0.03 \pm 7.19$, $t = 0.005$, $P > 0.9$) or B ($b = -2.87 \pm 6.66$, $t = 0.4305$, $P > 0.6$). Overall mean yields can therefore be calculated as 1,060,911/993 = 1.068 lb (CV = 0.098) per whale (assumption A) or 1,060,911/949 = 1.118 lb (CV = 0.095) per whale

(assumption B). According to Clark (1887a), the yield of bone in bowhead whales from the Atlantic-Arctic grounds averaged about 1,300 lb to 100 barrels of oil (or about 1,560 lb per whale), whereas in the Okhotsk Sea the yield was about 1,500 lb to 100 barrels of oil (or about 1,650 lb per whale). In both areas, however, Clark commented that whales found there "during recent years" were much smaller than those taken at the beginning of the fishery; the values given above referred essentially to the start of the fishery. Ross (1974) calculated the average yield for a bowhead whale from the Hudson Bay stock as 1,065 lb, later revised to 916 lb (Ross 1979). For whales from the Davis Strait stock, the average yield was calculated as 1,392 lb (Ross 1979). Present estimates are therefore within the range of those given previously.

Humpback Whales

Of the 29 voyages taking humpback whales that were analyzed, only 7 had associated whalebone production (Fig. 7). There was no significant trend in the mean yield of whalebone per whale, either under assumption A ($b = -0.21 \pm 1.20$, $t = 0.17$, $P > 0.8$) or B ($b = 1.95 \pm 5.12$, $t = 0.38$, $P > 0.7$), so the relevant overall means have been used, i.e., 15,116/1,137 = 13 lb (CV = 0.416) under assumption A and 15,116/345 = 44 lb (CV = 0.652) under assumption B. Scammon (1874) stated that humpback baleen was of inferior quality, but could be collected at a rate of about 400 lb per 100 barrels of oil; this would be equivalent in current calculations to a yield of 98 lb whalebone per whale. Mitchell and Reeves (1983) confirmed that baleen from humpback whales was generally considered of poor quality, but pointed out that it was occasionally marketed.

Gray Whales

There were no voyages available on which 10 or more gray whales were taken and for which whalebone production was declared. According to Henderson (1972:84):

Unlike the valuable baleen of the right and bowhead whales, whalebone from the gray never became an important part of the catch . . . little bone was recorded in the cargos of the gray whaling vessels. The few recorded cargos of gray whalebone to arrive in San Francisco and

San Diego did not appear until gray whaling was in decline and the price of right and bowhead whalebone had risen considerably after the mid 1860s.

Rather than adopting an arbitrary value for the average whalebone yield of gray whales, it has been taken as zero. This means that estimates of the size of the catch of other species using whalebone production may be correspondingly overestimated by an unknown but probably small amount. However, as whalebone production is used only to estimate the landed catch from 1880 onwards (see below), and there are no gray whales in the logbook sample after this date, the practical effect of this assumption is minimal.

Estimates of Total Landed Catch of Whalebone Whales

Figures for the importation of whale products into the United States have been based on table J of Starbuck (1878), supplemented by data in Hegarty (1959). As pointed out by Starbuck, it would appear from a comparison of imports and exports from 1804 to 1817 that much oil and bone must have been imported which was not credited to any port, and thus did not appear in table J. After 1817 exports as listed by Starbuck totalled 0.373 of imports for whale oil and 0.697 for whalebone. It was presumably these figures that led Starbuck (1878) to propose that exportation of whale oil and bone for 1804 to 1817 represented one-third and two-thirds respectively of the importation, and I have followed his proposal in adjusting the figures for 1804 to 1817 upwards on a prorata basis. The validity of this assumption is of course unknown.

Inspection of table K in Starbuck (1878) also shows that importation figures for whalebone from 1838 to 1842 were "estimated" or "assumed", apparently at a rate of 10 lb of whalebone per barrel of oil, and may not therefore be very reliable. The data, summed by five yearly periods, are shown in Table 2.

In order to estimate the total landed catch for any 5-yr period, the catch of each species given in Table 1 has been multiplied by its mean yield of oil or whalebone (corrected for the relevant year of catch, if necessary, using the median year in any 5-yr period) and the resulting production figures summed. Comparison of this total with that in Table 2 for the same period then provides a scaling factor by which the catches in Table 1 have to be multiplied to obtain the total landed

catch for that period. These scaling factors are shown in Table 2.

In two of the three data sets (those for oil and whalebone factor A), there was a tendency for the scaling factors to be particularly high at the beginning of the time series, indicating that logbook coverage (and hence the reliability of extrapolations) was poor in the earlier years. The great differences between the two scaling factors for whalebone before about 1845 suggests either that a lot of whalebone was not being collected from the whales taken, or that it was not possible to allocate imports of it to a particular port or vessel (Starbuck 1878). The low ratio of whalebone to whale oil imported from 1805 to 1834 (Table 2) would indicate that the former was the more likely. Given the unreliability of import figures for whalebone from 1804 to 1817 and between 1838 and 1842, this suggests that oil production figures would be a more appropriate measure of the landed catch before about 1845.

All three factors converge closely from 1855 to 1879, presumably indicating that full utilization was being made of both whalebone and whale oil. During this period the ratio of whalebone to whale oil imported ranged from 7.7 to 11.0, with a mean of 9.1 lb to a barrel of oil (Table 2).

After 1880 the factors tend to diverge again, but this time the divergence is mainly between

TABLE 2.—Five-year compilation of imports of whalebone and whale oil into the United States (from Starbuck 1878 and Hegarty 1959).

Period	Total U.S. imports		Ratio: Bone/ oil	Scaling factors ¹		
	Whale oil (barrels)	Whalebone (lb)		Oil	Bone A	Bone B
1805-09	285,969	360,981	1.3	99.3	87.7	14.9
1810-14	96,759	151,921	1.6	—	—	—
1815-19	130,666	179,793	1.4	58.2	23.2	9.1
1820-24	246,793	429,447	1.7	45.5	55.4	9.4
1825-29	245,777	1,039,134	4.2	13.6	34.7	6.9
1830-34	680,729	1,846,907	2.7	9.4	13.4	3.0
1835-39	917,064	7,947,069	8.7	8.4	34.8	8.8
1840-44	1,032,080	10,159,715	9.8	9.1	19.0	10.2
1845-49	1,324,305	14,073,773	10.6	7.4	9.9	8.3
1850-54	1,193,253	17,143,100	14.4	8.3	12.3	11.2
1855-59	985,480	10,854,100	11.0	5.9	6.6	6.0
1860-64	509,037	4,388,800	8.6	5.0	4.9	4.3
1865-69	390,415	4,045,575	10.4	4.1	4.4	3.9
1870-74	256,714	2,054,769	8.0	3.9	3.8	3.3
1875-79	152,907	1,176,690	7.7	6.5	7.8	6.2
1880-84	138,654	1,785,354	12.9	4.6	10.7	8.1
1885-89	134,438	1,989,176	14.8	5.9	10.7	9.4
1890-94	62,614	1,667,478	26.6	7.6	15.0	12.9
1895-99	21,531	1,067,130	49.6	2.0	5.0	4.7
1900-04	17,175	614,830	35.8	4.0	6.8	6.3
1905-09	15,710	460,100	29.3	3.5	6.8	5.3

¹Rounded to one decimal place.

the oil factor and both whalebone factors. This is accompanied by a marked increase in the ratio of whalebone to whale oil imported, to a peak of 49.6 lb to a barrel of oil from 1895 to 1899 (Table 2). It is assumed that over this period whalebone was collected in preference to whale oil, as described by Ross (1974) for bowhead whales:

... with a dramatic rise in the price of whalebone the oil diminished to less than 20% of the value of a whale after 1890 As a result whaling masters intensified the search for bone: . . . the crews simply stripped away the baleen, which was readily transportable, and left the rest of the carcass, including the bulky blubber, to rot. Oil returns, therefore, do not accurately reflect the number of whales killed in the late decades of whaling.

It is apparent that after 1880, whalebone production would be a more accurate measure of the total landed catch.

The economic basis for these shifts in interest is clearly shown by the average prices of whale oil and whalebone imported into the United States each year from 1804 to 1909 (Starbuck 1878; Hegarty 1959). These have been used to calculate the relative contribution of whalebone to the total value of a right whale, assuming a ratio at maximum utilization of 10 lb of bone to a barrel (= 31.5 gal) of oil per whale (Table 3). Whalebone made a relatively minor contribution to the value of a whale (<20%) up to 1839, ranged from 20

34% between 1840 and 1874, but increased rapidly in value thereafter to a peak of 80.8% in 1905-09.

To conclude, oil production is considered the more accurate measure of the landed catch from 1804 to 1879, but whalebone production thereafter. With the high value of whalebone after 1879 (comprising more than half the total value of the whale), it is likely that it would be utilized whenever possible. Hence scaling factor B would be the more appropriate to use.

Using these factors, the total landed catch from the data tabulated by Townsend (1935) for American vessels only between 1804 and 1909 is estimated as 125,883 whales, comprising 30,313 bowhead, 74,693 right, 18,212 humpback, and 2,665 gray whales (Table 4). Of the right whales caught, 182 (0.2%) were taken in the North Atlantic, 15,374 (20.6%) in the North Pacific, 32,191 (43.1%) in the South Atlantic, 14,699 (19.7%) in the South Pacific, and 12,247 (16.4%) in the Indian Ocean.

ESTIMATES BASED ON CATCH PER VOYAGE

The use of production figures to estimate catches masks certain fundamental problems. According to R. C. Kugler (in litt. 6 March 1985), neither Starbuck nor Hegarty apparently made much effort to report a vessel's total take of oil. They relied primarily on newspapers, especially the Whalemens' Shipping List after it began publication in 1843. These reports, however, seldom gave more than the amount of oil on board at the time of the vessel's arrival. Only sporadically and inconsistently was shipped oil added in. This factor would mean that the mean oil yields per whale calculated here would be underestimated, and the total number of whales landed correspondingly overestimated. Nevertheless, the mean oil yields derived in this paper agreed reasonably well with contemporary opinion on how much a particular species should yield.

A further problem with the use of whale oil production is that the term "whale oil" was used to designate not only that from right and other species of whalebone whale, but also elephant seal and walrus oil. At certain periods the amounts landed of the latter were not negligible (Bockstoce and Botkin 1982; Busch 1985; Kugler in litt. 6 March 1985). However, it is not clear how much and in which direction this factor would affect the present analysis, depending on whether

TABLE 3.—Prices paid for whale products imported into the United States and the relative value of whalebone from a right whale.

Period	Average price (US\$)		% Contribution whalebone in total value of adult right whale
	Whale oil (per gal)	Whalebone (per lb)	
1805-1809	0.48	0.08	5.0
1810-1814	0.64	0.09	4.2
1815-1819	0.59	0.11	5.6
1820-1824	0.32	0.12	10.6
1825-1829	0.29	0.20	18.0
1830-1834	0.29	0.17	15.7
1835-1839	0.37	0.21	15.3
1840-1844	0.33	0.28	21.2
1845-1849	0.35	0.29	20.8
1850-1854	0.44	0.38	21.5
1855-1859	0.65	0.76	27.1
1860-1864	0.75	1.14	32.5
1865-1869	1.05	1.30	28.2
1870-1874	0.64	1.02	33.6
1875-1879	0.50	2.09	57.0
1880-1884	0.53	2.35	58.5
1885-1889	0.37	2.96	71.7
1890-1894	0.41	4.20	76.5
1895-1899	0.34	3.10	74.3
1900-1904	0.37	3.88	76.9
1905-1909	0.33	4.38	80.8
1910-1914	0.37	0.63	35.1

TABLE 4.—Numbers of baleen whales landed by U.S. whalers, 1805–1909, based on oil production up to 1879 and whalebone production thereafter.

Period (arrival)	Northern right			Southern right			Humpback	Gray	Total
	Bowhead	Atl.	Pac.	Atl.	Pac.	Ind.			
1805–09	—	—	—	4,268	—	—	—	—	4,268
1810–14	—	—	—	—	—	—	—	—	—
1815–19	291	—	—	175	1,281	—	116	—	1,863
1820–24	—	—	—	3,683	—	—	—	—	3,683
1825–29	—	—	—	3,663	—	—	14	—	3,677
1830–34	—	—	—	8,804	665	674	47	—	10,190
1835–39	—	—	—	6,394	2,991	4,008	807	—	14,200
1840–44	—	—	2,957	484	4,709	4,608	602	—	13,360
1845–49	669	—	8,001	404	2,567	949	654	—	13,244
1850–54	9,103	—	1,364	728	281	397	694	50	12,617
1855–59	7,273	6	1,381	311	423	488	1,422	382	11,686
1860–64	3,250	45	585	545	520	240	965	1,025	7,175
1865–69	2,956	8	441	445	103	177	511	886	5,527
1870–74	1,815	—	58	173	69	177	2,983	270	5,545
1875–79	677	39	85	352	7	85	2,475	52	3,772
1880–84	958	32	8	620	209	—	4,985	—	6,812
1885–89	711	47	356	496	674	28	1,600	—	3,912
1890–94	1,108	—	39	490	168	—	284	—	2,089
1895–99	860	5	56	33	—	28	47	—	1,029
1900–04	468	—	38	70	—	13	6	—	595
1905–09	174	—	5	53	32	375	—	—	639
Total	30,313	182	15,374	32,191	14,699	12,247	18,212	2,665	125,883

the whale oil production of the voyages listed by Townsend was diluted to a greater or lesser extent with seal and other oil than the total production.

The catch-per-voyage analysis attempts to avoid the problems created by the incomplete reporting of the products of a voyage, and (at least partially) those arising from the dilution of whale oil with seal, walrus, and other oils.

In order to make some further correction for voyages that were entirely devoted to sealing, all voyages recorded as returning only elephant oil, or as "skinning voyages", or voyages labelled as sealing by Starbuck (1878) and Hegarty (1959) have been excluded. In addition, all voyages from the Connecticut ports of New London, Stonington, or Mystic that were recorded as being bound for S. Shetlands, Desolation, Falklands, Hurds Island, or Crozettes and that returned with whale oil but no whalebone have been omitted on the grounds that these were probably sealing voyages. This has resulted in a total omission of 141 voyages between 1804 and 1921.

Obviously this figure does not include all voyages on which seal oil was taken, as many seals were taken on combination sealing/whaling voyages. Between 1840 and 1890, an average 25% of "whaling" vessels leaving New London are said to have visited Desolation or Heard Island for elephant seals (Busch 1985), but of 110 voyages departing to these islands from New London during

this period, 45 were reported as bringing back sperm oil and/or whalebone as well as "whale" oil (Starbuck 1878; Hegarty 1959).

Starbuck (1878) and Hegarty (1959) also listed a number of mixed voyages from other ports in which small amounts of whale oil were landed but no whalebone. While some of these might represent voyages on which whales with inferior whalebone (such as humpback or gray whales) were taken, other such small consignments of whale oil might have originated from seals or from "blackfish" (pilot whales *Globicephala* spp.). Pilot whales were sometimes taken by whalers to supplement their cargoes, the oil being rated as common whale oil. Clark (1887b) listed 36 voyages on which from 2 to 200 barrels of blackfish oil was brought home, 33 (91.7%) of them bringing back 100 barrels or less. To investigate this further, mixed voyages on which 100 barrels or less of whale oil but no whalebone were landed (from Starbuck and Hegarty) were compared with the catch composition of the same voyages as given by Townsend (1935). Of 153 such voyages, baleen whales were reported as being taken on 55 (35.9%) voyages, with the proportion approaching 100% as the amount of whale oil approached 100 barrels (Table 5). Consequently for each 5-yr time period the number of mixed voyages reporting 100 barrels or less of whale oil but no whalebone was adjusted by the proportion of such voyages in Townsend's sample that were reported as taking

TABLE 5.—Proportion of mixed voyages by U.S. whalers landing small consignments of whale oil (but no whalebone) on which whalebone whales were taken.

Amount of whale oil reported (barrels)	Number of mixed voyages examined	Proportion of mixed voyages on which whalebone whales taken
1-10	53	0.113
11-20	19	0.263
21-30	18	0.444
31-40	14	0.500
41-50	11	0.364
51-60	10	0.300
61-70	12	0.750
71-80	8	0.750
81-90	2	1.000
91-100	6	0.833

baleen whales during the same period. This resulted in an effective conversion of 812 mixed voyages between 1805 and 1910 to sperm whaling voyages.

Because Starbuck (1878) and Hegarty (1959) listed voyages by the year of departure, the data in the catch-per-voyage analysis has been compiled against year of departure rather than (as was done for the production-based analysis) by year of arrival. The numbers of sperm, mixed, and whalebone voyages in Townsend's sample for each 5-yr period are given in Table 6, together with the scaling factors A1 and A2 for mixed and whalebone whalers respectively. The latter represent the ratio of the number of voyages of each type in the Townsend sample to the number of similar voyages in Starbuck/Hegarty for that period, after correction (as described above) for voyages believed to be sealing rather than whaling. These scaling factors are then applied to the total numbers of whales landed in the Townsend sample for that period and voyage-type, and the results for each voyage-type added to give the total number of each species for that period.

This analysis provides an estimate of the landed catch of whalebone whales from American vessels between 1805 and 1914 as 117,308, comprised of 29,788 bowhead, 70,343 right, 14,164 humpback, and 3,013 gray whales (Table 7). Of the right whales, 186 (0.3%) were taken in the North Atlantic, 14,480 (20.6%) in the North Pacific, 28,532 (40.6%) in the South Atlantic, 14,652 (20.8%) in the South Pacific, and 12,493 (17.8%) in the Indian Ocean.

DISCUSSION

The two methods used give somewhat similar

Table 6.—Breakdown of Townsend's (1935) sample into voyage-type, with scaling factors (A1, A2) derived from numbers of such voyages in Starbuck (1878) and Hegarty (1959).

Period (departure)	Type of voyage					Total	
	Sperm		Mixed		Whalebone		
	n	n	A1	n	A2		
1805-09	2	1	8.00	1	51.00	4	
1810-14	1	0	—	0	—	1	
1815-19	3	1	89.00	2	49.50	6	
1820-24	6	3	23.67	1	117.00	10	
1825-29	10	12	8.92	8	13.38	30	
1830-34	29	47	6.00	11	18.09	87	
1835-39	54	75	8.28	9	12.33	138	
1840-44	56	88	8.64	4	28.75	148	
1845-49	53	93	6.25	8	9.88	154	
1850-54	51	102	5.74	9	16.56	162	
1855-59	52	101	5.29	11	11.82	164	
1860-64	49	54	4.76	16	3.06	119	
1865-69	55	83	4.02	13	5.46	151	
1870-74	30	31	4.77	4	6.75	65	
1875-79	44	48	3.67	7	6.14	99	
1880-84	29	28	4.32	11	11.91	68	
1885-89	17	22	2.91	14	13.79	53	
1890-94	18	16	2.56	8	18.50	42	
1895-99	7	11	3.27	10	5.90	28	
1900-04	22	9	2.67	10	4.70	41	
1905-09	19	10	1.60	5	5.80	34	
1910-14	11	2	2.50	3	2.67	16	
Total	618	837		165		1,620	

results, estimates of the landed catch differing by <10% in all cases except for South Atlantic right whales and humpback whales (where the production-based estimates exceeded the catch per voyage estimates by 13 and 29% respectively) and gray whales (where the catch per voyage estimate exceeded the production estimate by 13%).

Nevertheless, both sets of estimates are essentially derived from the same basic data (Townsend's sample), and a more fundamental problem with both analyses is how representative this sample was of the contemporary Yankee fishery. The 1,651 voyages examined by Townsend are equivalent to only 12% of the estimated total number of voyages made by American pelagic whalers (Sherman 1965), but the scaling factors in Tables 2 and 6 indicate that the coverage of voyages in some periods (particularly prior to 1830) was much less than this. Unless the log-book sample is truly random with respect to the species and numbers of whales taken, any simple reconstruction of the total catch therefrom is likely to be inaccurate.

The catch per voyage analysis included some stratification of the Townsend sample, so that extrapolations to the total fleet might be more representative. To this extent, therefore, the catch per voyage method might seem the more reliable,

TABLE 7.—Numbers of whalebone whales landed by U.S. whalers, 1805–1914, as calculated from the catch per voyage.

Period (departure)	Northern right			Southern right			Humpback	Gray	Total
	Bowhead	Atl.	Pac.	Atl.	Pac.	Ind.			
1805–09	—	—	—	1,849	—	—	—	—	1,849
1810–14	—	—	—	—	—	—	—	—	—
1815–19	248	—	—	149	1,958	—	178	—	2,533
1820–24	—	—	—	4,468	—	—	—	—	4,468
1825–29	—	—	—	3,617	535	—	63	—	4,215
1830–34	—	—	—	8,902	390	600	384	—	10,276
1835–39	—	—	149	5,662	5,190	5,561	285	—	16,847
1840–44	—	—	5,728	598	3,542	3,939	657	—	14,464
1845–49	2,148	—	5,578	515	1,485	421	669	—	10,816
1850–54	10,260	6	951	511	161	775	565	281	13,510
1855–59	5,454	48	1,221	429	579	501	2,317	1,279	11,828
1860–64	2,583	—	152	516	280	96	447	665	4,739
1865–69	3,215	11	434	354	105	342	2,153	755	7,369
1870–74	744	—	52	81	14	29	2,561	33	3,514
1875–79	417	40	16	400	95	40	1,801	—	2,809
1880–84	604	9	48	216	186	—	1,881	—	2,944
1885–89	729	69	90	113	122	9	134	—	1,266
1890–94	2,098	—	26	44	—	—	59	—	2,227
1895–99	715	3	16	23	—	26	10	—	793
1900–04	353	—	19	27	—	—	—	—	399
1905–09	180	—	—	40	10	154	—	—	384
1910–14	40	—	—	18	—	—	—	—	58
Total	29,788	186	14,480	28,532	14,652	12,493	14,164	3,013	117,308

but other problems (allowance for sealing voyages, correct allocation of incomplete voyages) may not have been adequately solved. Furthermore, even the stratification by voyage-type may have been insufficient to correctly portray the species composition of the total fleet; an alternative procedure might be to stratify by home port, but this would probably involve too fine a stratification for the size of the sample available.

A further problem identified with the Townsend sample is that there may be occasional misidentification or omission of catches (see Bockstoce and Botkin 1983). There is no indication of the extent of this problem (which would require checking Townsend's tabulations against the original journals), but it means that the accuracy of the extrapolations made in this paper may be adversely affected to an unknown degree.

Some independent estimates of the landed catch of various stocks have been made. Henderson (1972) estimated that 4,958–5,058 Californian gray whales were taken by pelagic whalers between 1846 and 1874, whereas calculations from the Townsend sample are that 2,665 to 3,013 gray whales were taken over the period 1850 to 1879. Henderson's estimate, however, includes the catches of non-U.S. vessels. From data in Henderson's table II it can be calculated that 64.9% of the 21,135 barrels of oil from Scammon's Lagoon between 1858 and 1873 were taken by U.S.-

registered vessels. If this proportion is applied to the total catch, it means that U.S. pelagic whalers may have accounted for a landed catch of 3,218 to 3,283 gray whales. On this basis, calculations from the Townsend sample may be about 6 to 19% too low.

Bockstoce and Botkin (1983) calculated that 16,600 bowhead whales were taken from the Western Arctic population by the pelagic whaling industry between 1849 and 1914; this apparently included catches by non-U.S. vessels. Henderson has also estimated that the total catch of bowhead whales from the Okhotsk Sea stock between 1847 and 1867 was about 15,200 animals, with another 92 known to have been taken between 1867 and 1896 (Kugler 1984). About 90% of the voyages to the Okhotsk Sea between 1847 and 1867 were made by American whalerships, which if considered applicable to the catch would mean that they took about 13,760 bowhead whales from 1847 to 1896. Ross (1979) has estimated the catch of bowhead whales by American whalers in the Davis Strait from 1847 to 1891 as 413, and that in Hudson Bay from 1860 to 1912 as 532 animals; his figure for the Beaufort Sea of 794 bowhead whales between 1889 and 1908 is assumed to be included in Bockstoce and Botkin's calculations for the entire Western Arctic. Combining the data from Ross (1979), Bockstoce and Botkin (1983), and Kugler (1984) indicates a total bowhead

catch of 31,305 animals (some of which may have been taken by non-U.S. vessels). This is 3 to 5% higher than the total estimate of 29,788 to 30,313 bowhead whales from the Townsend sample.

Reeves and Mitchell (1986) have attempted to reconstruct the American pelagic catch of right whales in the North Atlantic during the nineteenth century. They document at least 116 right whales that were killed and processed by pelagic whales between 1855 and 1897. The present analysis indicates a total landed catch by U.S. whalers of 182 to 186 right whales over the same period.

These comparisons suggest that, apart from gray whales, the estimates of landed catch obtained in this paper are not unduly biased. They are, however, clearly only first approximations. A much more detailed approach, including examination of primary source material, is required before a more reliable assessment of the American catch of right whales can be made. In particular, there needs to be more adequate sampling of logbooks prior to 1830.

It should also be stressed that the figures produced here are estimates of the landed catch; further work is needed to determine the numbers of animals that were struck and lost, and the proportion of these that might have died, before an estimate of the total kill made by the American fishery can be made. Such research, requiring consultation of primary sources, is outside the scope of this paper. Nevertheless, a significant proportion of the landed catch of some species apparently consisted of whales found dead. In the Townsend abstracts examined here, there were records of 246 baleen whales processed that were found dead: 127 bowheads (6.3% of the landed catch), 103 right whales (2.9% of the landed catch), 5 humpback whales (0.4% of the landed catch), and 11 gray whales (or 4.4% of the landed catch). These figures might be underestimates if (as seems likely) not all the whales found dead were recorded as such in the logbooks or logbook abstracts. Most of these whales probably died as a result of whaling-related injuries. 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.

With no correction for animals dying after being struck and lost, the estimated number of right whales taken between 1805 and 1874 as calculated in this paper, 68,484 to 70,250 (of which 79% were southern right whales), is about one third of Starbuck's original estimate for the

same period. This compares with an estimated total catch by French pelagic whalers between 1817 and 1868 of 11,000 right and bowhead whales (Du Pasquier 1986). Comparable figures for the British take are not yet available.

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