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9 Product Markets

Of the various factors commonly implicated in the decline of the American whaling industry, a failure of demand is widely regarded as most important. The evidence favoring this interpretation is strong, but detailed information on the markets for whale products is not nearly so abundant as are data on whaling vessels and whaling voyages. The voluminous literature on the industry treats the whaling venture from the recruitment of vessel and crew, through the vicissitudes of the voyage, to the return to home port (for those vessels and crews that did return) and the distribution of the proceeds of the voyage among crewmen, agents, and owners. At that stage the river of books, essays, and archival records shrinks to a rivulet. Very little has been written about what happened once the oil, bone, and ambergris were unloaded on the docks. The bits and pieces that have come to hand are assembled in this chapter, which describes the changing market for whale products in the nineteenth century.[1]

"Whale oil enters, as a raw material, into several branches of manufacture, as of wool, leather, soap: it is used also in painting, architecture and navigation. But its great consumption is in lighting houses and cities." So said Thomas Jefferson in 1788 (1990, 53). His account was correct for that day, but times change: the process of industrialization, which Jefferson abhorred, altered the market demands on the whaling fleet. Whale oils were used in a widening array of industries, as softening and cleansing agents, and as constituents of cosmetics, of medicines, and of various other chemicals. The most important new use was the lubrication of industrial machinery. In the years down to 1850, this component of demand grew faster than any other. Thereafter, the markets for all whale products probably shrank, but the demand for baleen, unmentioned by Jefferson because it was of so little importance in 1788, held up

1. "It is much more difficult to trace the development of trade in whale products than it is to trace any other phase in the history of whaling activities" (Tower 1907, 98).

better than the rest. In Jefferson's day baleen was rarely saved; at the end of the nineteenth century, it was the leading product of the fishery.[2]

Whalemen took five materials from the sperm whale: case oil, the junk, white horse, blubber, and, if they were lucky, ambergris (for ambergris, see chapter 2). Three came from the head, which accounted for about one-third of the length of the whale. West describes it well: "A sperm whale's head is divided into three sections, horizontally. The uppermost is the case which holds twenty or thirty barrels of purest oil. Beneath this is the junk, a somewhat fibrous, oily matter, below which are ligaments about a foot thick called 'white horse.' "[3] The case oil could be bailed directly from the head into barrels. It was virtually pure spermaceti, and, for that reason, once it was in the open air, it began to congeal. Case, or head, oil supplied about one-third of the oil taken from a typical sperm whale, and sometimes as much as one-half.

Oil was extracted in try-pots from the junk, the white horse, and the blubber. This oil also contained spermaceti. The degree of concentration varied, depending upon the part of the body from which the oil was taken, but nowhere was it as high as in the head oil. The head and blubber oils were kept separate aboard ship, but combined ashore before refining began.

Virtually all sperm oil was refined. There were several steps to the process, and they produced five forms of output. First, the blubber oil and the head oil were combined in large tanks. Pipes lined the tanks, and steam was introduced to heat the oil to a temperature of about 212 degrees Fahrenheit—a temperature maintained for six to ten hours. The heat boiled off any remaining water and melted any as yet unmelted blubber; it probably also changed the character of the product. In any case the oil that went into the tank was typically light yellow, with a mild odor and taste; the oil that came out was perfectly colorless, odorless, and flavorless. When the steam was turned off, the tank was allowed to cool, and the oil was pumped out into fifty-gallon containers. Soap was made from the trash at the bottom of the tank.

The oil containers were next taken outside and allowed to cool to about 32 degrees.[4] If the outdoor temperature was not low enough, the containers were placed in a pit, covered with ice and salt, and left for ten or twelve days.

Regardless of how the temperature was brought down, the frozen oil was now in granulated form. It was placed in large sacks and entered into a press

2. "The average price . . . for the year 1887 . . . was . . . $3.12 [per pound]. . . . It is within the remembrance of many an old whaleman when this bone, now so precious, was dumped over the ship's side as waste or only saved by the sailors for "scrimshaw work.' . . . When first saved, the bone had a market value of only a few cents a pound. In 1823 it was worth about 12 cents" (Pease and Hough 1889, 32).

3. Stevenson 1904, 189, 190. The material in the next several paragraphs dealing with types of output and oil refining was taken chiefly from this source, 183, 184, 189–91, 199–203, 204, 245. See also Pease and Hough 1889, 181–93; they give a slightly different account and include details of the development of oil refining in New Bedford. The quotation in the text is from West 1965, 13.

4. According to Stevenson the original standard was 32 degrees, but by the turn of the century it had been raised to 38 degrees.

that exerted two thousand pounds of pressure per square inch. The press squeezed out a pure oil—called *winter oil*—that would remain liquid at 32 degrees, a desirable trait. About two-thirds of the volume of the oil and spermaceti taken from the whale was converted to winter oil. (Later in the century, when the test standard changed from 32 to 38 degrees, winter oil extracted by the cooling and pressing process came to about three-quarters of this volume.) Winter oil was either sold as is (about one-half), or bleached to precipitate out the solids before sale. Bleaching precipitated out more solids that could be used in soap making.

After the first pressing the material left in the bags—a brownish solid—was heated to 50–60 degrees and pressed again. The resulting oil, called *spring oil,* amounted to about 9 percent of the total output. Spring oil congealed at temperatures lower than 50–60 degrees and was therefore less desirable than winter oil.

After the second pressing the residual was chopped up and stored for a week at a temperature of about 80 degrees. It was then pressed a third time, at one hundred thousand pounds per square inch. The oil obtained was called *taut pressed oil,* and came to about 5 percent of the total product.

The remainder was pure spermaceti. Under the pressing standards for oil adhered to in the middle of the century, spermaceti and soap together represented about 19 percent of the total product by volume. The pressing standards adopted later in the century yielded more oil, and therefore left less spermaceti—about 11 percent (including soap) of the whole product. The shift seems to have reflected changes in the structure of demand for sperm-whale products. The demands for all declined, but spermaceti candles were particularly heavy losers. The lubricant market for sperm oil remained somewhat more robust. The refiners therefore shifted the composition of their output, producing more oil and less spermaceti.

The spermaceti that resulted from the series of pressings was not a final product. Before being sent to market it was normally heated and combined with caustic soda. The procedure released the remaining oil and whitened the product. The transformed spermaceti was then cut into bricks and sold. Early in the century a certain amount was used in treating a variety of illnesses. As time passed, medical uses of spermaceti became much more restricted, and virtually all of the output was sold to candlemakers.

Until the 1830s the products of the sperm whale were used chiefly as illuminants. Although the rich could afford spermaceti candles and sperm oil lamps, the largest lighting demand came from the public sector. Sperm oil was used in lighthouses and city streetlights because of the brightness with which it burned. As the American economy industrialized, the oil came to be used mainly as a lubricant. By 1835, according to Timothy Pitkin ([1835] 1967, 45), between one-quarter and one-third of the annual output was consumed in cotton and woolen manufacturing.[5] The superintendent of the census of 1860 re-

5. The data in table 9.1 suggest that Pitkin's estimates are in the right neighborhood, if the demand for lubricants in the woolen textiles industry was about as high as in the cotton textiles industry.

ported (U.S. Census Office 1866, 546), "Cotton and woolen factories consume large quantities of sperm oil, each spindle using about half a gallon." If that estimate is correct, in 1860 the New England cotton textile industry alone consumed more than the nation's total output of winter, spring, and taut sperm oil combined (see table 9.1). In fact, the superintendent's estimate was probably of the demand for high-quality lubricants. Sperm oil was certainly the best of the lot, but it was not the only option. Cotton factories may have purchased other oils in addition to sperm oil—indeed, they must have, if the superintendent was right about the annual quantity of lubricant the industry required. The point is that domestic demand for lubricants expanded rapidly in the nineteenth century. After 1845 the amount of sperm oil flowing into the domestic economy declined, partly because output fell, but also because exports rose sharply (see tables 9.8, 9.9, and 9.10, and the discussion below). From that date onward, very little sperm oil was available domestically for purposes of illumination.[6]

Writing at the turn of the nineteenth and twentieth centuries, Stevenson (1904, 202) said of whale oil, "In a crude state it is used to some extent by screw-cutters, steel temperers, cordage manufacturers, and as an illuminant for miners' lamps, but more than half is refined in a manner similar to the treatment of sperm oil." At the high tide of the whale fishery, the fraction of the oil refined was probably about as Stevenson supposed.[7]

The refining process called for whale oil to be boiled and cooled before pressing, but it was typically cooled to temperatures of 36–40 degrees, instead of the 32 degrees usual for sperm oil. It was bagged and thrown on a wooden straining table to take off some of the oil, and it was then pressed. The straining

6. See *WSL* 20 January 1863, which makes the point very clearly. The editor describes the impact of the Civil War on the sperm-whale fishery: "To those who are in any way interested in this Oil it is almost needless to remark that the past year has been very unfavorable to its consumption in consequence of being deprived of our usual supplies of American cotton, and it is useless to offer any opinion as to the period when the free importation of that most useful and necessary material from the Southern states of America will be resumed, but until it is we fear nothing like animation in our Sperm Oil market can be looked for."

7. For example, assuming that the year saw no major changes in inventories, that the refining of oil called for the consumption of very little—other than oil—in the way of raw materials, and that the costs of transporting oil from the dock to the refineries were negligible, in 1860 about 68 percent of the value of output of the whale fishery was refined. (See table 9.6. Compare the value of output of the whale fishery with the value of materials consumed in the refining of oil.) At the same date about 84 percent of the value of output of the fishery consisted of oil; about 50 percent of the value of output consisted of sperm oil (Tower 1907, 126, 128). All of the sperm oil was refined, leaving 34 percent of the value of output of the fishery consisting of whale oil. The unrefined part of the whale oil amounted to 16 percent of the value of output of the fishery (84 percent minus 68 percent), which leaves 18 percent (34 percent minus 16 percent) refined. Thus about one-half (18 percent divided by 34 percent) of the value of whale oil was refined. None of the assumptions on which the estimates rest is strictly correct. Part—a small part—of the value of output of the fishery consisted of ambergris, and the calculation takes no account of that fact; refineries no doubt used materials other than oil; refiners had to pay for transportation of the oil from the docks to the refineries; inventories certainly did change from year to year. The deviations of the assumptions from fact are probably not large. All of them, except for the one involving inventories, bias the calculations in the direction of slightly exaggerating the fraction of the output of whale oil refined. Inventory changes can work either way.

Table 9.1 **Lubricant Requirements for New England's Cotton Spindles, and Domestic Supplies of Sperm Oil, 1827–60**

	Spindles, Fully Employed Equivalents (1,000s)[a]	Lubricant Required (1,000 gallons)[b]	Sperm Oil Entering U.S. Markets (1,000 gallons)[c]	Lubricant Required/ Sperm Oil Available
1827–30	501	251	2,138	0.117
1831–35	913	457	2,904	0.157
1836–40	1,231	616	3,555	0.173
1841–45	1,587	793	3,505	0.226
1846–50	1,934	967	2,035	0.475
1851–55	2,616	1,308	1,296	1.009
1856–60	2,874	1,437	1,087	1.322

Notes: The figures in the first three columns are averages of annual values.

[a]These figures were computed from data in Davis and Stettler 1966. The figures in the last column of Davis and Stettler's table 4, "Output by Region," were divided by the corresponding figures in the column headed "Yards per Spindle-Year—Raw" in their table 8, "Output . . . per Spindle-Year."

[b]These figures are the first column multiplied by 0.5 gallons, an estimate of the amount of lubricant required per spindle per year, from U.S. Census Office 1866, 546.

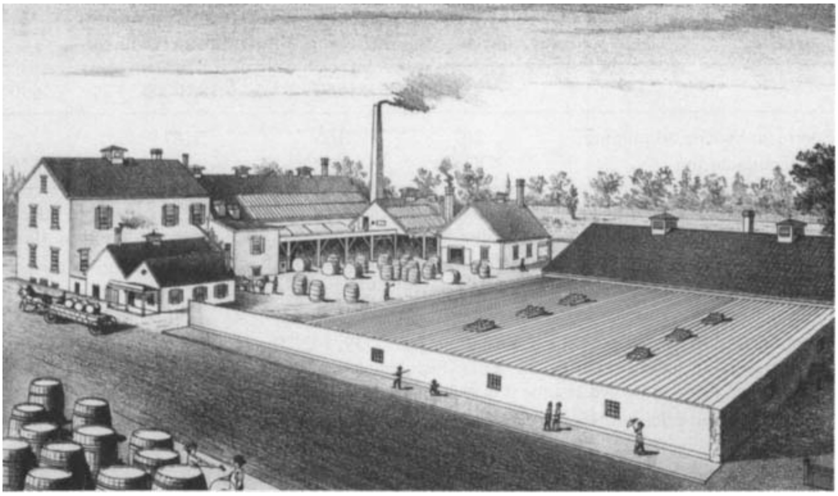
[c]These figures were derived from data in Tower 1907, 126, 127, adjusted in the manner (and for the reasons) described in the notes to table 9.8. Tower's annual sperm oil production figures (summarized in the first column of table 9.8, panel A) were multiplied by 0.81, and from these products his annual sperm oil export figures (summarized in the second column of table 9.8, panel A) were subtracted. The coefficient 0.81 represents the fraction of the refined products of sperm oil that consisted of oil (the rest consisted chiefly of spermaceti). See the text for a description of the refining process.

and pressing yielded *winter whale oil,* which amounted to about 90 percent of the total refined oil product taken from the whale. The residual—called *foots*—could be heated, cooled, and pressed again, to obtain *spring whale oil.* Often the residual was sold as is for sizing textiles.

A small fraction of the whale oil was bleached before sale. The bleaching precipitated a solid that was made into a soap for cleaning furs; a part was also used to produce a protective wash for fruit trees—it drove off the insects.

Like sperm oil, whale oil was employed as an illuminant and lubricant. There were differences, however. On the one hand, the best sperm oil remained liquid at temperatures at which whale oil congealed. Sperm oil of all types gave brighter illumination, and did not have the offensive odor of whale oil.[8] On the other hand, whale oil was cheaper and therefore was for a time a staple in many households. In the United States it was not usually employed in public lighting—it did not burn brightly enough—nor was it found below the ser-

8. Stevenson 1904, 202. Bullen's views ([1898] 1980, 51) are stronger: "But the awful putrid mass discharged from a Greenlander's hold is of very different quality and value, apart from the nature of the substance, to the clear and sweet [sperm] oil, which after three years in a cask is landed from a south-seaman as inoffensive in smell and flavor as the day it was shipped."



The oil and candle factory of George Delano, South Street, New Bedford. In 1884 Stephen and James Delano succeeded their father at the head of this business, and in 1888 their factory (George Delano's Sons) was "the largest grease refinery in the world. The buildings cover nearly two acres of land and in the busy season forty-five men are employed . . . The company manufactures sperm, whale, sea elephant, fish, and cotton seed oils, patent and paraffine wax candles, spermaceti, whale and fish oil pressings, and sperm and whale oil soap. All crude oils are worked out to definite results at the factory and the product is shipped to every part of the world" (Pease and Hough 1889, 181).

Reproduced from the New Bedford atlas of 1881, by courtesy of the Old Dartmouth Historical Society–New Bedford Whaling Museum.

vants' attics in the homes of the rich. Sperm oil lubricated light, fast-moving machinery, whale oil, heavy machinery such as locomotive engines.

The refining processes for both types of oil were simple and called for the consumption of few other resources. The value added by processing came to only 15–20 percent of the value of the raw materials; for manufacturing as a whole, value added was typically about 80 percent (see table 9.2). Furthermore, processing did not significantly reduce the bulk or weight of the product, with the result that refining could be conducted anywhere. Two groups of sites had particular advantages: the whale ports were the first recipients of the oil and had human capital invested in handling it; and large cities and manufacturing centers were the major markets for whale products. In fact, except for New York City, large urban centers did not refine much oil, and it may well be that New York owed its substantial refining facilities as much to the existence of nearby whaling ports as to local demands for lighting and lubricants. New York aside, whaling towns were the principal manufacturers of whale products, although New Bedford accounted for a smaller fraction of the refining industry than of the whaling industry. In 1860, for example, vessels sailing from Bristol

Table 9.2 **Ratios of Value Added to Value of Raw Materials, Sperm and Whale Oil Refining, and All Manufacturing, United States, 1850–90**

	1850[a]	1860[b]	1881–88[c]	1890[d]
Sperm and whale oil refining	.207	.165	.167	
All manufacturing	.836	.828		.816

Note: It would be desirable to include data from the 1880 census in this table, but the value added/raw materials ratio in 1880 is not comparable to the ratio in the years represented. See Gallman 1960.

[a]Computed from figures in U.S. Department of the Interior 1858, 87. The ratio for sperm and whale oil refining rests on figures reported for "oil, whale." Since sperm oil is nowhere dealt with in the census report, we assume it is included in "oil, whale."

[b]Computed from figures in U.S. Census Office 1865, 739, 742. The ratio for sperm and whale oil refining rests on figures reported for "Oil—Fish, whale and other." Since sperm oil is nowhere dealt with in the volume, we assume it is included in "Oil—Fish, whale and other."

[c]Computed from prices in Bezanson 1954, 224–25, as follows: the price of winter-grade (that is, refined) whale oil (specifically baleen oil) minus the price of crude whale (baleen) oil divided by the price of crude whale (baleen) oil. Since the calculation ignores raw materials other than whale oil, the ratio obtained should be a little larger than the true value added/raw materials ratio; but, since materials other than whale oil did not figure in an important way in the production of winter-grade oil, the bias should be slight.

[d]Computed from figures in U.S. Department of the Interior 1895, 95.

County—in which New Bedford was the largest town—produced eight-tenths (by value) of the output of the U.S. whale fishery, while the county manufactured only a little more than one-half (by value) of the refined oil produced in the United States (see table 9.3).

The domestic oil market expanded extraordinarily rapidly in the nineteenth century. Real GNP increased at a rate of almost 4 percent per year across the entire century, and in the three decades before the Civil War, when whaling grew to its peak, the rate was 4.5 percent. In 1860 the American economy was ten times as large as it had been in 1800 (see table 9.4).

The expansion of the economy alone would have led to increased demand for illuminants, even if the standard of living had not changed. After all, on the eve of the Civil War the American population was almost six times as large as it had been in 1800. Even if consumption per head or per family (the number of families increased faster than the number of people) had held steady, demand for lighting materials would have gone up strongly. In fact, the standard of living did not remain static. Real per capita national product rose by over 70 percent between 1800 and 1860, and the rate of increase was especially high—almost 1.5 percent per year—between 1830 and 1860. The demand for illuminants was almost certainly income elastic. Elasticity must have been particularly high for products of good quality, such as spermaceti candles and sperm oil. Until late in the antebellum period, even whale oil was a better lamp fluid than were most of its competitors.

The demand for lubricants grew even faster. The volume of sperm oil needed to ease the movements of the cotton spindles of New England increased six-

Table 9.3 **Production and Refining of Sperm Oil and Whale Oil in the United States, in Massachusetts, and in Bristol County (Massachusetts), 1860**

	A. Whale Fishery, Absolute Numbers		
	U.S.	MA	Bristol County
Value of product ($)	7,749,305	6,734,955	6,225,285
Cost of materials ($)	2,789,195	2,282,000	2,075,000
Number of establishments	422	384	358
Capital invested ($)	13,292,060	12,468,660	11,534,500
Hands employed	12,301	11,296	10,458
Annual cost of labor ($)	3,509,080	3,188,848	3,064,944

	B. Whale Fishery, Relative Numbers		
	Bristol/MA	Bristol/U.S.	MA/U.S.
Value of product	.924	.803	.869
Cost of materials	.909	.744	.818
Number of establishments	.932	.848	.910
Capital invested	.925	.868	.938
Hands employed	.926	.850	.918
Annual cost of labor	.961	.873	.909

	C. Refining of Sperm Oil and Whale Oil, Absolute Numbers		
	U.S.	MA	Bristol County
Value of product ($)	6,099,377	4,087,650	3,062,484
Cost of materials ($)	5,236,495	3,639,121	2,720,600
Number of establishments	48	23	12[a]
Capital invested ($)	1,968,201	1,113,401	723,000
Hands employed	337	166	117
Annual cost of labor ($)	138,276	65,040	45,660

	D. Refining of Sperm Oil and Whale Oil, Relative Numbers		
	Bristol/MA	Bristol/U.S.	MA/U.S.
Value of product	.749	.502	.670
Cost of materials	.748	.520	.695
Number of establishments	.522	.250	.479
Capital invested	.650	.367	.566
Hands employed	.705	.347	.493
Annual cost of labor	.702	.330	.470

	E. Ratios of the Cost of Materials in Panel C to the Value of Output in Panel A		
	U.S.	MA	Bristol County
	.676	.540	.437

(continued)

Table 9.3 (continued)

Sources: For panels A and B, U.S. Census Office 1866, 550. For panels C and D, U.S. Census Office 1865, 233 (Bristol County), 255 (Massachusetts), 739 (United States). Census figures for Massachusetts and Bristol County appear under the heading "oil, whale," those for the United States under the heading "Oil—Fish, whale and other." In both sets of figures we have assumed that sperm oil and spermaceti are included (see table 9.2 notes). Since the U.S. total is more comprehensive than the totals for Massachusetts and for Bristol County, the ratios in the last two columns of panel D are too low.

Note: Panels A and B include all products of the whale fishery; panels C and D include only oil.

[a]The New Bedford City Directories list twenty-one candle houses and oil factories in 1841 and 1856, nine more firms than the census of 1860 records. Since the census enumerated only firms with at least $500 of gross output, there may be no true discrepancy between the two sources.

Table 9.4 **The Growth of American Real GNP and Real GNP per Capita, 1800 to 1899–1908 (1860 dollars)**

	Real GNP	Real GNP per Capita
Indexes (1800 = 100)		
1800	100	100
1810	140	103
1820	191	105
1830	275	113
1840	402	125
1850	603	137
1860	1,017	171
1869–78	1,588	191
1874–83	2,084	225
1884–93	3,151	271
1894–1903	4,293	304
1899–1908	5,409	349
Average annual rates of growth (%)		
1800–1830	3.4	0.4
1830–60	4.5	1.4
1860 to 1884–93	3.8	1.5
1869–78 to 1899–1908	4.2	2.0
1800 to 1899–1908	3.9	1.2

Sources: Population figures come from U.S. Department of Commerce 1975, series A-7. GNP figures for 1800–1830 are obtained by extrapolating the per capita figures for 1840 on Thomas Weiss's real GDP per capita series (1992, 27), variant A (1840 prices). (The quantitative difference between per capita GNP and per capita GDP is slight.) The per capita estimates thus obtained are multiplied by population to get estimates of real GNP. GNP figures for the period 1840 to 1899–1908 are taken from Gallman 1966, 26.

Notes: From 1800 to 1860 GNP dates refer to census years; for example, 1860 refers to the twelve-month period 1 June 1859 through 31 May 1860. In the same period, population dates refer to 1 July; for example, 1860 refers to 1 July 1860.

In the periods 1869–78 to 1899–1908, the reported GNP is the annual average for the specified decade. The years refer to calendar years. Population is as of 1 July and refers to a date six months following the midpoint of the decade. Thus, the midpoint of the decade 1869–78 falls at 31 December 1873 and 1 January 1874. The population figure used to compute the per capita GNP for 1869–78 refers to 1 July 1874.

and-one-half–fold between 1827 and the Civil War (see table 9.1). In 1859 there was eighteen times as much railroad equipment in the United States as there had been two decades earlier; rolling stock was a heavy user of whale oil lubricants, and locomotive headlights were whale oil lamps (see table 9.5). More generally, the structure of the American capital stock was changing. Animals and inventories represented ever smaller fractions of the capital stock, while equipment and machinery became ever more important, especially after 1840. In the first four decades of the century this component of the capital stock increased more than fourfold, and did so again in the next twenty years; in 1860 the real value of equipment and machinery was sixteen times what it had been in 1800. Clearly, the domestic market for lubricants was extraordinarily buoyant. So was the foreign market (see below).

If the whale fishery had had the domestic illuminant and lubricant markets to itself, it would have done very well indeed. In all likelihood the rest of the economy would not have done so well; it is highly improbable that the whale fishery alone could have met the lighting and lubricating requirements of an economy expanding at the rate of the American. In the absence of other lubricants, growth would simply have been slower. As it happened, however, there were competitors from the beginning, and as time passed their number and their advantages grew. This was fortunate for the American economy at large, and initially not harmful to whaling, although by the 1850s there were clear indications that whaling's competitors would eventually drive the fleet to extinction, even if the economy continued to expand.

Prior to 1830 candles and oil lamps dominated the American illuminants market. The chief competitors of the whale fishery were the slaughterhouses, turning out lard (which was made into lamp oil) and tallow (which was made into candles and lubricants). Supplies of lard and tallow were abundant; American per capita meat consumption was extraordinarily high, by virtually any standard one can think of.

The lard oil production process was similar to that of sperm and whale oil. The basic material—pork lard in this case—was chilled and pressed. The resulting oil was of a poorer quality than its rivals. It burned only at a higher temperature, and, since it congealed easily, it did not flow well in the lamp. Tallow candles, made from the fat of cattle and sheep, did not emit as bright a light as sperm candles, burned unevenly, and collapsed in hot weather. Quality differences can be offset by differences in price, however, a point not lost on Thomas Jefferson (1990, 53). Writing about the competition between whale oil and vegetable oils toward the end of the 1780s, he said:

> For this last purpose [illumination] however it [whale oil] has a powerful competitor in the vegetable oils. These do well in warm, still weather, but they fix with cold, they extinguish easily with the wind, their crop is precarious, depending on the seasons, and to yield the same light, a larger wick must be used, and greater quantity of oil consumed. Estimating all of these articles of difference together, those employed in lighting cities find their

Table 9.5 **Stocks of American Machinery and Equipment, Index Numbers on the Base 1840, 1799–1900**

	Railroad Equipment[a]	All Machinery and Equipment
1799		23
1815		32
1840	100	100
1850	350	176
1860	1,800	436
1870	3,350	620
1880	8,650	1,140
1890	18,300	3,608
1900	22,600	6,300

Sources: For railroad figures Fishlow 1966, 626. For all machinery and equipment Gallman 1986, 204; worksheets underlying Gallman 1992.

[a]The dates for the first three years in the railroad series are 1839, 1849, and 1859.

> account in giving about 25 per cent. more for whale than for vegetable oils. But higher than this the whale oil, in its present form, cannot rise; because it then becomes more advantageous to the city-lighters to use others.

The price gap was even greater between tallow and sperm candles: between 1784 and 1800 a pound of the latter cost three times a pound of the former (Cole 1938, 23, 29). Nonetheless, since the quality advantage was great, there were plenty of sperm-candle takers.

The whale fishery and the slaughterhouses were the principal suppliers of the illuminating and lubricating markets in the early nineteenth century. Given the booming long-term advance in demand—especially after the War of 1812—the prospects of firms in both industries were good. As late as 1850, however, the whale fishery had a much larger share of these markets than did the slaughterhouses (see tables 9.6 and 9.9). If home production of tallow candles and other illuminants and lubricants were factored in, the relative importance of whaling would be somewhat diminished, but the fleet would continue to be the chief supplier of lighting and lubrication.

The first important change in the illumination market was the introduction of manufactured gas. The gas was hydrogen, and efforts were made to extract it from a variety of substances. In the late eighteenth century the English succeeded with coal and began to distribute coal gas. The Americans borrowed the process, but it was not until 1802 that the first burner was produced. Given the small sizes of American cities—there were substantial economies of scale in gas distribution—and the initial abundance of whale products, tallow, and lard, it is not surprising that the innovation and diffusion of the extraction process in the United States took a long time. Only in 1816—thirty-four years after the formation of the first English firm—did the first American firm, the Gas Light Company of Baltimore, receive a charter. Even then progress was

Table 9.6 **Value of Output, Whale Oils and Their Chief Economic Competitors, 1850–1900 (thousands of dollars)**

	1850	1860	1870	1880	1890	1900
1. Candles, adamantine	—	1,145	—	—	—	—
2. Candles, wax	—	2	—	—	—	—
3. Candles, not specified	—	—	89	—	—	—
4. Soap and candles	10,200[a]	18,465	22,535	26,553	43,600	53,231
5. Total, soap and candles	10,200	19,612	22,624	26,553	43,600	53,231
6. Oil, neatsfoot	—	16	—	259	—[b]	—
7. Oil, lard	1,618	2,553	—	4,721	1,182	1,222
8. Oil, animal	—	—	9,729[c]	—	—	—
9. Total, animal oils[d]	1,618	2,569	9,729	4,721	1,182	1,222
10. Oil, coal	—	4,255	26,942	—	—	—
11. Oil, kerosene[e]	—	2,143	—	—	—	—
12. Oil, petroleum, refined	—	—	19,304	43,705	85,001	123,929
13. Total, mineral oils	0	6,398	46,246	43,705	85,001	123,929
14. Oil, essential	—	124	631	249	255	850
15. Oil, castor	—	320	758	654	573	395
16. Oil, linseed	1,949	5,982	8,882	15,394	23,534	27,184
17. Oil, cottonseed	—	741	2,206	7,691[f]	19,336[f]	58,727[f]
18. Camphene and burning fluid	—	2,611	—	—	—	—
19. Oil, rosin	—	—	—	238	739	—[b]
20. Turpentine	2,856	6,423[g]	3,585[h]	5,877[h]	8,077[h]	20,345[i]
21. Oil, vegetable, not specified	—	—	773	—	—	—
22. Total, vegetable oils	4,805	16,201	16,835	30,103	52,514	107,501
23. Oil, illuminating, not petroleum	—	—	—	510	600	17,184[j] (lines 23–24)
24. Oil, lubricating	—	—	88	2,926	8,657	
25. Oil, chemical	—	200	—	—	—	—
26. Total, oils not specified	0	200	88	3,436	9,257	17,184
27. Gas, illuminating	1,922	12,016	32,049	—	56,987	75,717
28. Whale fishery[k]	10,056[l]	7,749	—	2,324	1,673[m]	—
29. Refined oil, fish, whale, and other	7,840	6,099	3,993	—	—	—
Whale oils and their competitors, broadly defined						
30. Total of lines 5, 9, 13, 22, 26, 27, 28	28,601	64,745	—	—	250,214	—
31. Total of lines 5, 9, 13, 22, 26, 27, 29	26,385	63,095	131,564	—	—	—
Whale oils and their competitors, narrowly defined						
32. Total of lines 9, 13, 26, 27, 28	13,596	28,931	—	—	154,100	—
33. Total of lines 9, 13, 26, 27, 29	11,380	27,281	92,105	—	—	—

(continued)

Table 9.6 (continued)

	1850	1860	1870	1880	1890	1900
34. Line 28/line 30	.352	.120	—	—	.006	—
35. Line 28/line 32	.740	.268	—	—	.011	—
36. Line 29/line 31	.297	.097	.030	—	—	—
37. Line 29/line 33	.689	.224	.043	—	—	—

Sources: For 1850 U.S. Department of the Interior 1858; for 1860 U.S. Census Office 1865; for 1870 U.S. Department of the Interior 1872; for 1880 U.S. Department of the Interior 1883; for 1890 U.S. Department of the Interior 1895; for 1900 U.S. Census Office 1902.

Notes: The census returned the value of output of natural gas only in 1890; returns for electrical power were made in 1880 and 1890, but they appear to have been fragmentary. Natural gas and electrical power are therefore not represented in this table.

[a]The census term is *chandlers*.

[b]Included elsewhere, according to the census.

[c]Probably includes refined sperm and whale oils.

[d]Except for sperm and whale oils, which are excluded from all entries except probably 1870.

[e]Almost certainly coal oil kerosene.

[f]Includes oil cake.

[g]Distilled turpentine.

[h]Includes rosin and tar.

[i]Includes rosin.

[j]Includes neatsfoot oil.

[k]Includes baleen and ambergris.

[l]All fisheries. The total is presumably dominated by the whale fishery.

[m]Ambergris, $23,200; sperm oil, $472,667; whale oil, $181,953; whalebone, $994,896.

snail-like: after twenty years of operation, the company had laid two miles of pipe (Brown 1936, 11).

Four cities chartered gas companies in the 1820s and 1830s—New York (1823), Boston (1828), New Orleans (1832), Philadelphia (1836)—and seven had some gas lighting by 1840. In the next two decades the list increased by thirty-four. Included in this group was New Bedford, where a plant was opened in 1853.[9] By 1850 the value of output of manufactured gas was about one-quarter of the value of output of refined whale, sperm, and fish oils. The relative situation then changed dramatically. By 1860 the value of gas production was twice the value of refined oils from the fisheries (see table 9.6). The whale industry had encountered its first serious new competitor.

The rapid expansion of the gas industry after 1830 took place in the context of growing urban demand and a series of technical, organizational, and

9. Pease and Hough 1889, 287. A group of Philadelphia entrepreneurs joined with two New Bedford citizens—James B. Congdon and Abraham Howland—in 1850 and got a state charter. Locals bought them out quickly. The first president was William C. Taber, from a distinguished whaling family; the second was Gilbert Allen, from an even more distinguished whaling family; one of the two original local organizers—Abraham Howland—came from a still more distinguished whaling family. Whaling agents knew a good thing when they saw it.

political-economic changes. At the technical level, despite the success of the English with the gasification of coal, the Americans experimented with a series of other fuels. The New York Gas Company tried whale oil for a year, but gave it up because operating expenses equalled "the entire cost of the plant, including the land on which it stood and all their equipment." The firm quickly converted to rosin oil (Stotz and Jamison 1938, 16). Rosin oil had its shortcomings, too: when the gas was pumped any distance, the flammable elements were lost (*Scientific American* 10 November 1860, 313).

Coal was cheaper than whale oil, and coal gas—unlike rosin gas—could be pumped through the distribution system without serious loss of flammable constituents. There were other problems, however. Coal gas had impurities. They could be filtered out, but the equipment was expensive. Engineers set to work and produced an improved process of gasification that automatically removed impurities. The expensive purification equipment was no longer necessary. But there was a catch: the procedure worked only on cannel coal (a type of bituminous coal), and, although cannel coal could be imported from England, it carried a substantial duty.

Political changes eventually solved that problem. In 1846 the schedule of tariffs was reduced. For British cannel coal the duty fell from $1.75 to $0.40 a ton. The change was enough to bring mass conversions from whale and rosin oil to coal in the production of gas, and the price of gas fell. After converting from rosin oil to cannel coal in 1849, the New York Gas Company dropped its rate from $0.70 to $0.60 and eventually to $0.40 per hundred cubic feet. The discovery of domestic supplies of cannel coal settled matters (Collins 1934, 81; Stotz and Jamison 1938, 45; Williamson and Daum 1959, 39). Coal was now the fuel of choice.

These changes meant twofold losses for whalemen. First, gas companies had been buying whale oil to use in their gasification processes. That market was now gone. Second, with cheap coal, gas rates fell sharply. The decline induced urban consumers to shift from whale oil lamps to gas lighting.

The gas companies also developed an important marketing innovation. Before 1830 gas consumers contracted for a certain number of hours of service after sunset. The system had two serious flaws: customers paid for a full evening's service every day, even when they spent the evening away from home; and the gas company had to make sure that customers turned off the gas at the agreed-upon hour. It dispatched monitors to walk the city streets to see that customers adhered to their contracts. The solution to the problem was demonstrated in 1833, when metering was introduced by the New York Gas Company.

Improvements were also made in the quality of animal and vegetable oils in the three decades before the Civil War. Redistilled turpentine—given the name *camphene* or *burning fluid,* and sometimes mixed with alcohol—entered the illuminant market in the 1830s. It was lighter than whale or lard oil, flowed easily in the lamp, gave a bright light, and produced no odor while burning. It also had a serious disadvantage: it was highly volatile and was known to explode. Nonetheless, camphene became an important lamp fuel. By 1860 it accounted for almost 10 percent of the value of output produced by the main illuminant and lubricant industries (see table 9.6). Arnold Daum (1957, 8) attributes the success of camphene to the "growing demands of lubrication on animal oil[s]," which raised their relative prices.[10]

In this judgment he may be correct. A price series for camphene is not available, but price data exist for spirits of turpentine, from which camphene was made. Before 1850 spirits of turpentine cost more than whale oil; in the 1850s spirits of turpentine cost less than whale oil. It is presumably no coincidence that in 1860 camphene is mentioned for the first time in the industrial volume of the census (see table 9.6).

Late in the 1830s Cincinnati soap makers discovered that by heating lard with soda alkali they could create a product with a lower melting point. The new oil flowed more easily than the old, and it was far superior as a lamp fluid. In 1843 the Solar lamp, designed expressly for lard oil, was invented. Lard oil was now competitive—in quality—at least with whale oil; Daum (1957, 11) claims that it was on a par with sperm oil: "Stripped of stearic acid and glycerine, lard oil for the first time became a lubricant and illuminant capable of challenging sperm oil." The census is somewhat less exuberant. In 1860 the value of output of lard oil was less than 10 percent of the value of output of the chief lubricants and illuminants (see table 9.6). It is also true, however, that according to the census the value of lard oil produced in that year had almost caught up with the value of sperm oil. Furthermore, in 1862 lard oil replaced sperm oil in U.S. lighthouses (it was soon replaced by petroleum oil), a clear indication of the high quality of the improved product.[11]

The stearic acid removed from lard oil was a new material for candlemakers, who used it to make *stearin* or *adamantine* candles. The new candles were both harder and more easily lit than sperm or tallow candles. By the 1850s they cost one-third less than sperm candles, and their price advantage continued to increase; in the 1890s they were only one-fourth as expensive (see table 9.7). In 1860 the adamantine candle industry was for the first time important enough to appear in the reports of the census of manufactures. The sum of the value of output of lard oil and adamantine candles in 1860 was substantially greater than the value of output of refined sperm oil and spermaceti.

In 1851 the *WSL* (7 January) analyzed developments in the illuminant and lubricant markets in the following way: "This discrepancy as regards Whale Oil [unsold barrels of oil sitting on the New Bedford docks], is undoubtedly owing to diminished consumption, arising from the very high figure at which

10. Daum (1957, 8) calls camphene "the dominant lamp illuminant during the forties." The product is not listed in the census of 1850, however, and although it is listed in 1860 it seems not to have been dominant at that time. It is possible that some camphene was made by turpentine producers and that the census did not distinguish the redistilled product from turpentine, in which case Daum could be right.

11. Stevenson 1904, 184. Lard oil still cost more than whale oil (see table 9.7), but presumably it was now also of a higher quality than whale oil. For example, it did not have whale oil's unpleasant odor.

Table 9.7 **Wholesale Prices of Lighting and Lubricating Materials, Philadelphia, January Averages, Nominal Prices, 1852–96**

	1850s	1860s	1870s	1880s	1890s
Candles ($ per pound)					
Adamantine	0.229	0.226	0.169	0.114	0.086
Tallow	0.133				
Sperm	0.364	0.397	0.343	0.281	0.345
Sperm/adamantine	1.59	1.76	2.03	2.46	4.01
Sperm/tallow	2.74				
Oil ($ per gallon)					
Lard, winter	0.937	1.263	0.882	0.675	0.438
Petroleum, refined		0.554	0.190	0.081	0.065
Sperm, winter	1.626	2.646	1.628	1.016	0.515
Whale, winter	0.795	1.061	0.750	0.581	0.505
Sperm/lard	1.74	2.10	1.85	1.51	1.18
Whale/lard	0.85	0.84	0.85	0.86	1.15
Sperm/petroleum		4.78	8.57	12.54	7.92
Whale/petroleum		1.92	3.95	7.17	7.77

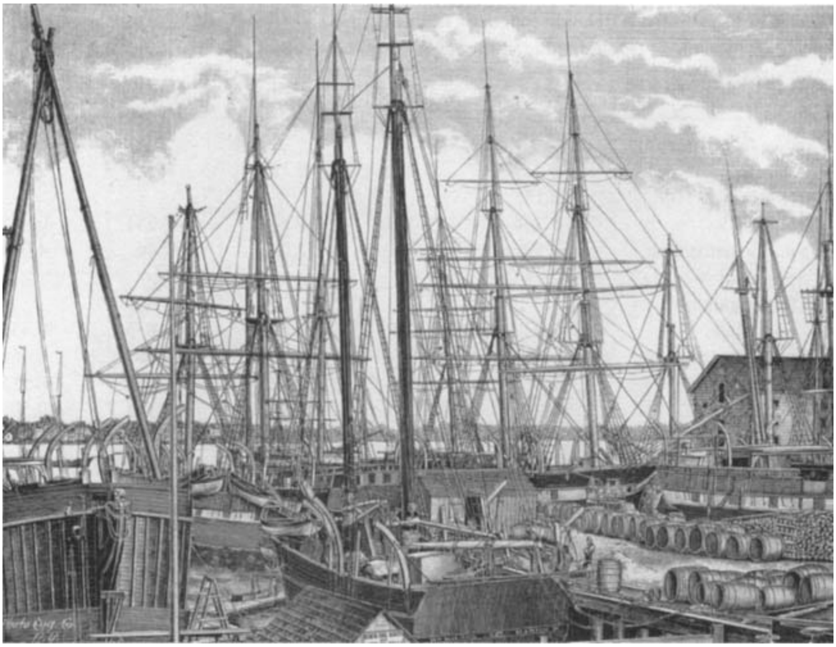
Sources: The figure for tallow candles is the mean of January prices in 1850 through 1859 for the commodity "Candles, Tallow mould, Phila." from Cole 1938, 317, 321, 325, 329, 333, 337, 340, 344, 348, 352. All other prices are computed from Bezanson 1954, 42, 43, 218, 223, 225, 237.

Note: The data for each decade are unweighted averages of average January prices.

oil has been held; which has forced many substitutes into the market and seriously impaired sales." Although the *WSL* does not develop the argument fully, it is suggesting that, in the first instance, the rapidly growing demand for illuminants and, particularly, lubricants drove up prices for these products. Innovative activity was encouraged, and it succeeded. New products were brought into the market, and old products were markedly improved. When account is taken of quality improvements, the long-run costs of both were probably brought down relative to the long-run costs of whaling. The supply of the goods competing with the products of the whale fishery sharply rose.[12]

The evidence does not suggest quite so bleak a prospect. During the 1850s the prices of whale products held up (table 9.7), the number of New Bedford whaling voyages actually increased (table 3.4), and the average profit rate of these voyages was higher than rates in the 1840s (see chapter 11). It is true, however, that, for the New Bedford fleet at least, productivity fell (see chapter

12. Although it was not a major competitor, linseed oil did cater to some needs also supplied by whale oils, and in the 1850s domestic supplies of linseed oil were augmented through international trade. In fiscal year 1849/50 about 30 percent of the value of linseed oil entering the American market was imported. In 1860 the figure had dropped to about 6 percent, still not a negligible figure. See table 9.6. See also U.S. Department of the Treasury 1850–51, 223; 1860–61, 37. Imports did not otherwise figure importantly in the domestic markets for illuminants and lubricants. Since all of these products were subject to tariffs—very high tariffs during and after the Civil War—economic policy helped to retain American markets for American products.



This drawing of whaling vessels at New Bedford wharves was made from a photograph by T. W. Smillie for *The Fisheries and Fishery Industries of the United States,* compiled by George Brown Goode and published by the U.S. Commission of Fish and Fisheries in 1887.

8), that total American output also declined (see table 9.8), and that the fraction of the domestic market held by whale products contained to shrink (table 9.9). Invention and innovation involving competitive products continued well after the 1850s, and the importance of whaling grew ever smaller.

The most important innovations involved coal. According to Daum (1957, 22) the U.S. Chemical Manufacturing Company attempted to extract a lubricating oil from coal, "to exploit the growing shortage of animal and vegetable lubricants," and "fate seemed to smile on the project at its very beginning when simultaneous failures in the hog crop and the whaling catch created abnormal shortages in lard and sperm oils in 1852." That a single year's shortage spurred inventors on to success is doubtful, but that inventors were concentrating on producing new lubricants is entirely reasonable, in view of the condition of the market. The result of their efforts was *coal oil,* also known as *kerosene.* It is listed under both names in the 1860 census, and already at that early date the combined value of output of the two industries exceeded the value of refined whale and sperm oil and of spermaceti (see table 9.6). Developed as a lubricant, it became the leading lamp oil—cheaper than whale oil, and much safer than camphene. The *WSL* (2 July 1861) again had an explanation: "It is known

Table 9.8 **Sperm Oil, Whale Oil, and Whalebone Produced by American Firms, Exported, and Entering American Markets, 1805–9 through 1900–1904**

	Produced	Exported	Entering American Markets[a]	% Exported[b]
	A. Sperm Oil (1,000 gallons)			
1805–9	391	42	349	10.7
1810–14	413	53	360	12.8
1815–19	515	60	455	11.7
1820–24	1,966	13	1,953	0.1
1825–29	2,126	116	2,010	5.5
1830–34	3,320	59	3,261	1.8
1835–39	4,673	122	4,551	2.6
1840–44	4,973	400	4,573	8.0
1845–49	3,672	672	3,000	18.3
1850–54	2,843	857	1,986	30.1
1855–59	2,553	811	1,742	31.8
1860–64	2,065	1,209	856	58.5
1865–69	1,307	587	720	45.0
1870–74	1,362	657	705	48.2
1875–79	1,312	687	625	52.4
1880–84	912	378	534	41.4
1885–89	639	144	495	22.5
1890–94	454	62	392	13.7
1895–99	417	27	390	6.5
1900–1904	571	10	561	1.8
	B. Whale Oil (1,000 gallons)			
1805–9	689	477	212	69.2
1810–14	233	169	64	72.5
1815–19	539	497	42	92.2
1820–24	1,555	1,205	350	77.5
1825–29	1,548	787	761	50.8
1830–34	4,289	2,598	1,691	60.6
1835–39	5,804	2,908	2,896	50.1
1840–44	6,583	3,822	2,761	58.1
1845–49	8,332	2,948	5,384	35.4
1850–54	7,517	1,082	6,435	14.4
1855–59	6,208	721	5,487	11.6
1860–64	3,207	1,699	1,508	53.0
1865–69	2,460	216	2,244	8.8
1870–74	1,618	221	1,397	23.1
1875–79	957	277	680	28.9
1880–84	878	139	739	15.8
1885–89	847	258	589	30.5
1890–94	394	42	352	10.7
1895–99	136	15	121	11.0
1900–1904	115	6	109	5.2

(continued)

Table 9.8 (continued)

	Produced	Exported	Entering American Markets[a]	% Exported[b]
	C. Whalebone (1,000 pounds)			
1805–9	48	39	9	81.3
1810–14	20	16	4	80.0
1815–19	17	4	13	23.5
1820–24	86	38	48	44.2
1825–29	95	245	−150[c]	257.9
1830–34	369	818	−449[c]	221.6
1835–39	1,589	1,042	547	65.6
1840–44	2,027	1,226	801	60.5
1845–49	2,614	1,613	1,001	61.7
1850–54	3,427	2,482	945	72.4
1855–59	2,165	1,691	474	78.1
1860–64	878	796	82	90.7
1865–69	809	492	317	60.8
1870–74	411	240	171	58.4
1875–79	235	114	121	48.5
1880–84	357	148	209	41.5
1885–89	398	185	213	46.5
1890–94	334	119	215	36.1
1895–99	213	175	38	82.2
1900–1904	123	132	−9[c]	107.3

Source: The figures in the first and second columns are the averages of annual amounts reported by Tower 1907, 126, 127.

Notes: Tower's table on production (which he calls "imports") expresses oil output in gallons from 1805 through 1837, and in barrels thereafter. We converted the data expressed in barrels to gallon equivalents, by multiplying them by 31.5. Although Tower does not mention the fact, it is clear that his oil export data for 1864 through 1902 (the last year in his table for which exports are reported) are also expressed in barrels. We converted them to gallons, in the same way that we adjusted the production data. (Tower reports no exports of any kind for 1903 or 1904. We have assumed that his dotted line indicates a zero rather than a missing value.)

[a]Column 1 minus column 2.

[b]Column 2 divided by column 1 multiplied by one hundred.

[c]According to Tower (1907, 127) negative values represent a drawing down of inventories. While that could easily be the case for 1900–1904 and could conceivably be the case for 1825–29, it couldn't be the case for 1830–34. One of the two series is incorrect.

that the discovery and extensive manufacture of coal oil has had a most ruinous effect upon the whaling interest. At New Bedford the business has declined about one-third during the past three years, and it is believed will decline fully a third more within the present year [1861] . . . . Oil, which costs 60 cents to produce, will now bring but 40 cents."

The midcentury lubricant market can be divided into four sectors; derivatives of coal oil were marketed in each. The first such derivative, *kerosene binnacle oil,* like its competitors whale oil and lard oil, served both the illuminant and lubricant markets. It was used in ordinary lamps, such as those on the

Table 9.9 **Values of Illuminants and Lubricants Entering the American Domestic Market, 1850–90 (thousands of dollars)**

	1850	1860	1870	1880	1890
Whale fishery					
1. Value of output	10,056	7,749	—	2,324	1,673
2. Value of exports	2,109	3,223	—	1,092	1,272
3. Line 1 minus line 2	7,947	4,526	—	1,232	401
Refined whale and fish oil					
4. Value of output	7,840	6,099	3,993	—	—
5. Value of exports	673	538	228	—	—
6. Line 4 minus line 5	7,167	5,561	3,765	—	—
Other animal oils					
7. Value of output	1,618	2,569	9,729	4,721	1,182
8. Value of exports	0	56	126	840	1,121
9. Line 7 minus line 8	1,618	2,513	9,603	3,881	61
Mineral oils					
10. Value of output	0	6,398	46,246	43,705	85,001
11. Value of exports	0	0	32,955	36,162	51,609
12. Line 10 minus line 11	0	6,398	13,291	7,543	33,392
Illuminating gas					
13. Value of output	1,922	12,016	32,049	—	56,987
14. Value of exports	0	0	0	—	0
15. Line 13 minus line 14	1,922	12,016	32,049	—	56,987
Grand totals					
16. Lines 1, 7, 10, 13	13,596	28,732	—	50,750[a]	144,843
17. Lines 2, 8, 11, 14	2,109	3,279	—	38,094	54,002
18. Lines 3, 9, 12, 15	11,487	25,453	—	12,656	90,841
19. Lines 4, 7, 10, 13	11,380	27,082	92,017	—	—
20. Lines 5, 8, 11, 14	673	594	33,309	—	—
21. Lines 6, 9, 12, 15	10,707	26,488	58,708	—	—
% shares in line 18					
22. Whale fishery	69.2	17.8	—	9.7	0.4
23. All other	30.8	82.2	—	90.3	99.6
% shares in line 21					
24. Refined whale and fish oils	66.9	21.0	6.4	—	—
25. All other	33.1	79.0	93.6	—	—

Sources: Tables 9.6 and 9.10.

Notes: Estimates of flows of goods into the domestic economy can be approximated by adding imports to domestic production and subtracting exports and reexports. Since imports and reexports of the products listed in the table were negligible in all years, they have been ignored; the desired estimates have been approximated by subtracting exports from production.

[a]The grand totals for 1880 differ from those for other years in that they do not include the value of output of illuminating gas. Therefore, the 1880 percentage in line 22 is not comparable with the values in line 22 for the other years; it is biased in an upward direction.

binnacles of ships, and as a heavy-bodied lubricating oil. *Spindle oil,* the second derivative, was marketed in competition with sperm oil for use on spindles and fine machinery. The third and fourth products were made from the heavier fractions of coal oil and were different grades of *kerosene machinery oil,* used to lubricate steam engines and railroad cars (Daum 1957, 305). Coal oil, however, did not displace whale and sperm oil from the lubricant markets. It was soon discovered that kerosene alone was an inadequate lubricant. Combined with whale or sperm oil, it produced a mix that was superior to either of its constituents—more fluid than the sperm and whale oils, but with more body than coal oil.

On the eve of the discovery of petroleum at Drake's well, then, the whaling industry was already in a kind of retreat. At the beginning of the 1850s, refined oil products of the whale fishery dominated the domestic illuminant and lubricant markets. At the end of the decade the whaling industry's share (by value) of American production of illuminants and lubricants had fallen by two-thirds (see table 9.6).[13] Furthermore, since a substantial part of whale and sperm oil output was exported, while the production of their competitors was chiefly sold domestically, the presence of the whale fishery in the American market was even more tenuous than these figures suggest (see table 9.9).

Tower (1907, 77) says, "The date of opening the first oil well in Pennsylvania may be regarded as the day when the fate of the whale fishery was decided." In view of the developments of the 1850s, it seems reasonable to conclude that the fate of American whaling was settled earlier than that. Tower argues that, even if the illuminant market had been completely absorbed by competitors, the whale oil industries might have persisted for many decades on sales to the lubricant market—had petroleum not appeared on the scene. This may or may not be true; innovation surely would eventually have solved the problems of producing good lubricants from coal oil alone, or from combinations of coal and vegetable oils. It certainly is true, however, that the birth of a large-scale

13. Lines 34 through 37 of table 9.6 give four versions of the share of the whaling industry in the illuminant and lubricant markets. Lines 34 and 36 compare the value of whaling output with the value of output of competitive products, broadly defined. Several of these so-called competitive products, however, sold chiefly in markets that were not entered by whaling products. Therefore, the ratios in these lines understate the importance of the whaling industry. In lines 35 and 37 the comparison is with a narrower group of products, which were more completely in competition with whale products. The ratios in these lines may overstate the importance of whaling, but they are closer to the desired values than are the ratios in lines 34 and 36. In any case, lines 34 and 36, on the one hand, and 35 and 37, on the other, establish ranges within which the correct ratios must lie. As between the figures in lines 35 and 37, those in line 37 are more nearly what is required, since they relate refined oil products to the market for illuminants and lubricants. The data underlying line 35 cover products other than oil (e.g., whalebone) and they relate to unrefined products, so that they are less useful bases for comparison. But beggars can't be choosers: the condition of the data obliged us to use each of these variants, in order to obtain some notion of the range within which the correct ratios lie and in order to draw comparisons across the full period, 1850–90. Notice that each line in the table tells a similar story. The relative importance of whaling dropped very sharply between 1850 and 1860, and continued to fall until by 1890 the industry was of negligible significance.

petroleum industry signalled the eventual death of the American whaling industry.

The *WSL* quickly recognized the importance of the new competitor, and the awesome productive capacity of the petroleum industry. For example, during the heyday of whaling at most four thousand barrels of oil were returned by any one voyage, even after three or four years. In one day three thousand barrels of oil were pumped from just one Pennsylvania well (Folger 1895, 207). In its most productive year the whale fishery produced something over thirteen million gallons of whale and sperm oil. The petroleum industry surpassed that figure in its second year; in its first six years the production of crude exceeded all of the output of sperm and whale oil in the ninety years from 1816 through 1905 (211). The market for oil was flooded, prices plummeted (see table 9.7), and petroleum producers sought ways of restricting output in order to maintain prices. So far as the illuminant market is concerned, petroleum administered the coup de grace to whale oil in the early 1860s. By 1890 even the output of the by-product of the oil fields—natural gas—was almost five times as valuable as the output of the whale fishery (U.S. Department of the Interior 1895).

The lubricant market was another matter. Like coal oil, petroleum had serious disadvantages as a lubricant and was usable initially only when mixed with other oils. The best mixtures were combinations of petroleum products and sperm or whale oil. For a time the fisheries could limp along supplying products for these mixes, which probably explains the relative success of the sperm-whale industry: output of sperm oil contracted somewhat more slowly than output of whale oil, presumably because sperm oil was a superior lubricant. The relief was short-lived, however. Petroleum oils could also be improved by being mixed with vegetable oils. Vegetable-oil production expanded, and improvements were made to enhance the performance of these oils in combination with petroleum.

Although the great burst of petroleum production in the United States awaited the Pennsylvania discoveries, the product was already well known both in the United States and abroad. Like sperm oil, petroleum was used in medicines, but its potential uses as illuminant and lubricant were also obvious. Work on refining processes was going forward well before the Drake well came in; and knowledge gained from the production of coal oil was in some measure transferable to the petroleum industry. Consequently, within six years of the date of Drake's well the cracking process—known also as *destructive distillation*—had been applied to petroleum and widely diffused. The initial purpose of cracking was to maximize the yield of kerosene from a gallon of crude, but it was not long before other possibilities of the process became clear. With controlled cracking a wide range of products could be produced, ranging from gasoline, to naphtha, to kerosene, to paraffin, to a variety of lubricating oils.

By the mid-1880s both high-quality petroleum lubricants and lubricants combining petroleum products and other mineral oils could be produced (Williamson and Daum 1959, 480–82, 489). Among the array of these products listed in the census of 1880, only one is a mixture of petroleum and whale oil, and this one—containing sperm oil—is 95 percent petroleum.

The preceding pages deal almost exclusively with the domestic market.[14] As far as sperm oil is concerned, until the 1840s the domestic market is virtually the whole story. Then, suddenly, sperm oil exports began to rise—in absolute terms and relative to total sperm oil output (see table 9.8). The share of output exported increased from a few percent in the 1830s, to almost one-fifth in the late 1840s, to almost one-third in the 1850s, to almost six-tenths in the early 1860s. It remained high until the very end of the nineteenth century, although the absolute amounts fell rapidly after the 1870s.

The explanations for both the rise and the fall of exports are very simple. For a number of reasons the British whaling trade began to decline after the 1820s, and it virtually disappeared after the 1840s.[15] The British demand for sperm oil was now met almost exclusively by American and Australian whalemen (Jackson 1978, chap. 7). This was the source of the redirection of American output. Sperm whalemen, however, could not long escape petroleum's competition in the lubricant markets. A large fraction of the output of American petroleum was exported (tables 9.9 and 9.10), and England was among the leading buyers (table 9.10, panel B). The opportunities for the sperm-whaling industry were gradually restricted, and the fleet declined, until by the turn of the century it was virtually nonexistent.

The export histories of the products of baleen and sperm whales are quite different. From the beginning other countries took substantial fractions of the American output of whale oil and of whalebone (see table 9.8). The international market continued to be a dominant influence until the mid-1840s for whale oil and until the mid-1870s for whalebone, and it was an important influence thereafter. In contrast to the history of sperm oil, after the mid-1840s the importance of exports relative to total whale oil output actually fell.

In one important respect, however, the impacts of foreign markets on the two products were similar. In both cases English demand, which had not figured importantly in the history of American sales of either oil, suddenly exerted a significant influence in the 1840s. The Scotch also made their presence known (see table 9.10, panel B). At the same time the Continent, the chief destination of American exports of whale oil for many decades, gradually reduced its dependence on American oil. Toward the end of the century, England and Scotland were the chief American whale oil markets. This situation was bound to end soon. Petroleum displaced whale oil as well as sperm oil. Furthermore, as

14. But not exclusively. American petroleum products, for example, entered international markets at an early date. See table 9.8.

15. See chapter 12. British whaling reappeared late in the century, but in quite a new form. English financiers and entrepreneurs organized and financed ventures that were staffed almost exclusively by Norwegian whalemen, and employed Norwegian technology—early examples of multinational firms. See chapter 13.

Table 9.10 Values and Destinations of Exports of American Whale Products and Other Illuminating and Lubricating Products, 1820–90

	A. Values ($1,000)						
	1820	1835	1850	1860	1870	1880	1890
1. Sperm oil	7	53	789	1,789	794	487	125
2. Spermaceti candles	107	284	260	52	0[a]	0[a]	0[a]
3. Spermaceti and spermaceti wax	0	0	0	0	27	45	117
4. Total	114	337	1,049	1,841	821	532	242
5. Whale and other fish oils	631	774	673	538	228	349	441
6. Whalebone	5	0	647	896	344	256	706
7. Total	636	774	1,320	1,434	572	605	1,147
8. Candles	191	0[b]	0[b]	709	375	238	143
9. Animal oils	0	0	0	56	126	840	1,121
10. Mineral oils	0	0	0	0	32,955	36,162	51,609
11. Total, whale products (lines 4, 7)	750	1,111	2,369	3,275	1,393	1,137	1,389
12. Total, other oils and candles (lines 6–9)	191	0	0	765	33,456	37,240	52,873
13. Grand total (lines 11, 12)	941	0	0	4,040	34,849	38,377	54,262
14. % whale products (line 11/line 13 × 100)	80	0	0	81	4	3	3
15. % other oils and candles (line 12/line 13 × 100)	20	0	0	19	96	97	97

B. Destinations[c]

	Sperm Oil	Spermaceti Candles	Whale and Other Fish Oils
1820	Western Hemisphere, England	Western Hemisphere	Hanse Towns, rest of Western Europe, Western Hemisphere
1835	Western Hemisphere (especially Cuba)	Western Hemisphere (especially Cuba)	Holland, Belgium, Hanse Towns
1850	England (9/10)	Western Hemisphere	Holland, England, Hanse Towns, Cuba (together 3/4)
1860	England (9/10)	England	England, Scotland, Bremen, Cuba, France
1870	England (8/10)	—	France, Russia, Western Hemisphere
1880	England, Scotland (virtually all)	—	England, Scotland, France (together 9/10)
1890	England, Scotland	—	Scotland, England

	Whalebone	Tallow Candles
1820	—	Western Hemisphere (virtually all)
1835	France, Hanse Towns, Belgium	—

(continued)

Table 9.10 (continued)

	B. Destinations[c]	
	Whalebone	Tallow Candles
1850	Hanse Towns, France, England (together 9/10)	—
1860	England, France, Bremen, Hamburg (together virtually all)	Western Hemisphere
1870	France, Bremen, Hamburg, England	Western Hemisphere
1880	Germany, France, England (together virtually all)	Western Hemisphere
1890	Germany, France, Netherlands (together virtually all)	Western Hemisphere
	Animal Oils	Mineral Oils
1820	—	—
1835	—	—
1850	—	—
1860	Mainly Western Hemisphere, some to England	—
1870	—	All over, but especially Europe
1880	England, Scotland (together over 1/2); France	France, England, Germany, Belgium, Netherlands, Japan, Scandinavia
1890	—	England, Scotland, Germany, Netherlands, France

Source: Various volumes of the annual *Report on Commerce and Navigation,* U.S. Department of the Treasury.

[a]Included with candles, unspecified.

[b]Included with soap.

[c]Listed in order of importance. The parenthetical statements refer to the part of the total value of exports of the specified products that went to the listed destinations.

the Norwegian pursuit of the rorquals met with success, the Scotch jute industry had a good substitute for the whale oil it had been buying from the Americans. The real prices of both whale oil and sperm oil declined, as the markets for the products of the whalers shrank. (See table 9.11 and appendix 9A.)

The market for whale oil seems to have been crucial to the baleen whalemen and to have settled their fate. As the fishery contracted, prices of whalebone rose sharply and earnings from whalebone kept the industry going a little longer. It seems clear, however, that the chief cause of the increase in whalebone prices was the contraction of the whaling fleet, and the contraction of the fleet resulted from shrinking markets for oil.

Whalebone was sold almost exclusively in northwestern Europe: France, Germany, the Low Countries, and sometimes England. The structure of the market seems not to have changed importantly (see table 9.10, panel B). These

Table 9.11 **Real Prices of Sperm Oil, Whale Oil, and Whalebone in the New Bedford Market, Five-Year Averages, 1816–20 through 1896–1900**

	Sperm Oil ($ per barrel)	Whale Oil ($ per barrel)	Whalebone ($ per pound)
1816–20	21.30	11.20	0.08
1821–25	17.90	9.78	0.13
1826–30	22.06	9.93	0.22
1831–35	26.40	9.68	0.18
1836–40	26.62	10.11	0.19
1841–45	31.42	13.15	0.38
1846–50	38.81	14.37	0.37
1851–55	45.45	19.66	0.43
1856–60	43.82	19.16	0.84
1861–65	39.04	20.35	0.91
1866–70	39.33	17.88	0.72
1871–75	36.79	15.39	0.86
1876–80	33.25	15.57	2.32
1881–85	29.45	16.55	2.59
1886–90	25.25	13.65	3.94
1891–95	26.13	15.98	5.15
1896–1900	20.71	15.39	4.38

Source: The figures are derived from annual data in tables 9A.1, 9A.2, and 9A.3.

were all countries that had active industrial sectors, and baleen was a useful raw material, possessing properties of strength and flexibility that were valuable in a wide array of uses. The fashions of the late nineteenth century used whalebone, and that may explain why France was typically among the leading importers of the product. Changes in fashion may actually have increased the demand for whalebone in the last decades of the century, but the chief explanation for the dramatic increases in price no doubt lies in the contraction of baleen whaling, which in turn was due to changes in the whale oil market.

The demand side of the story of American nineteenth-century whaling can be readily assembled from the elements set out above. Once the Napoleonic wars were over and the process of modern growth diffused and accelerated, the nineteenth-century markets for illuminants and lubricants in North America and northwestern Europe were buoyant. The growth of population and aggregate product was rapid, the fraction of the population living in cities increased, the share of economic activity accounted for by industry and transportation rose, machinery and equipment formed growing fractions of the capital stock, and per capita incomes increased. All of these factors led to a dramatic expansion in demand for illuminants and for lubricants.

The American whaling industries responded: from 1820, when recovery from the War of 1812 was complete, until the years of peak output, whale oil production increased 7.3-fold, and sperm oil production, 4.9-fold (appendix 9B). The real prices of whale products rose, with pronounced increases during the 1850s.[16] Opportunities for firms supplying the illuminant and lubricant markets were excellent. Innovative activity increased, old products were improved, and new products were invented. An eighteenth-century invention, the manufacture of gas, was widely innovated in Europe in the early nineteenth century and in the United States after 1820. In the two decades before the Civil War, innovative activity was particularly intense, and major competitors to the products of the whale fishery were introduced. By 1860 the whale fishery, which had been far and away the most important supplier of illuminants and lubricants in 1850, retained only tiny fractions of those markets, both at home and abroad. The fishery was almost as large as it had ever been, but the overall market was very much larger than it had ever been. Furthermore, the use of coal to produce gas and oil presaged the extinction of the whale fishery, given the American reserves of cheap coal.

Whether these products would indeed have driven the whaling fleets off the seas cannot be known with certainty, because before this could occur the discovery of enormous reserves of petroleum in Pennsylvania settled the future of both coal and whale oils. Real oil prices fell. Petroleum replaced both coal and whale oils in the field of illumination within a decade of the drilling of the first petroleum well. Whale and sperm oils continued to sell as lubricants, alone or mixed with petroleum oils, but their future was limited. Once the techniques for producing good lubricants from mineral oils developed, the markets for whale oil lubricants shrank even further—sperm oil, for example, continued to be used to lubricate watches and other delicate mechanisms, but not much else. Whale oil was used in the textiles and jute industries, but the growth of the Norwegian rorqual fishery meant that cheap substitutes for the oil of right and bowhead whales were now available. The market for whalebone kept a few right whalers afloat into the twentieth century, but not for long. New materials had replaced the products of the old whale fishery. Opportunities continued to exist in the rorqual fishery but not, as it turned out, for American whalers.

Appendix 9A

Prices of Sperm Oil, Whale Oil, and Whalebone in the New Bedford Market

We consulted three sources for the prices of sperm oil, whale oil, and whalebone: table V ("Average Annual Prices of Oil [per gallon] and Bone [per

16. The whale fishery was a competitive industry (see chapter 11). The long-term movements of the prices of whale and sperm oil—first an extended rise, followed by an extended fall—therefore reflect changes in average cost. Costs rose as the industry expanded chiefly because of constraints in the labor market, and they fell as the industry contracted partly because the pressure of

pound], 1804–1905") in Tower 1907, 128; table J ("Recorded summary of importation of oil and bone . . .") in Starbuck 1878, 660–61; the review of the whale fishery published in January of each year (1843–1914, but retrospective to 1838) by the *Whalemen's Shipping List.* Tables 9A.1, 9A.2, and 9A.3 report the prices we found; the prices we chose to use are in the columns headed "CATCHVAL."

The *WSL* reports "average prices" for each year. In addition it reports varying kinds of prices on a monthly basis. In some years (e.g., 1838) these are "prices . . . on the first of each month"; in some years (e.g., 1848) they are "prices . . . on the first and fifteenth of each month"; in some years (e.g., 1873) they are "average prices"; in some years (e.g., 1858) they are "average prices . . . on the first, eighth, fifteenth, and twenty-fifth of each month."

How the *WSL* transformed its first-of-the-month prices, or monthly average prices, or whatever, into its yearly averages is not always clear. Often the yearly prices are the unweighted means of whatever monthly prices are given. In some years they are not, but lie within a few cents of the unweighted means. In a few years the differences between the *WSL*'s "average prices" and the unweighted means are very small and seem to arise out of the *WSL*'s rounding rules, which call for the use of certain fractions (e.g., 1/4, 1/3, 1/2, 2/3, 3/4, 9/10) but not all possible fractions.

In regard to whalebone the *WSL* often reports prices (both monthly and annual) for bone in general, but in some years it reports different monthly prices for different kinds of bone. When different kinds of bone are distinguished, the annual prices are sometimes the unweighted means of the monthly prices of the different types. For example, in 1858 the annual price is the mean of the monthly prices of bone from the Arctic and the Northwest Coast; in 1862 and 1863 the annual price is the mean of the monthly prices of northern and southern bone. On the other hand, the annual price reported for 1860 is in fact the annual average price of northern bone; monthly prices of South Sea bone are also given but were not used in striking the annual average.

In 1871 and 1875 Tower and the *WSL* report gold prices for whalebone. Starbuck's prices in these years are 10 percent and 6.95 percent higher, respectively. They may represent Starbuck's attempts to translate gold prices into currency prices. Nonetheless, we chose to convert the gold prices in these two years to currency prices by means of the ratios reported by James Kindahl (1971, 472): 1871, 1.127; 1875, 1.127. (The *WSL* [4 February 1873] reports that during June 1872 the currency price ran 20 percent above the gold price.)

In order to compute the value of a vessel's catch (CATCHVAL), we used the Tower-Starbuck prices, 1804–37, and the *WSL*'s prices thereafter. There are two exceptions. For 1871 and 1875 we converted the *WSL*'s gold prices of bone

the industry against these constraints was eased, and partly because of the effects of the introduction of new techniques of production (see chapter 8). The innovation of these new techniques was concentrated in—virtually confined to—the second half of the nineteenth century.

Table 9A.1 **Nominal and Real Prices of Unrefined Sperm Oil, New Bedford Market, 1804–1914 (dollars per gallon)**

	Tower	Starbuck	*WSL*	CATCHVAL	Real
1804	1.40	1.40[a]	—	1.40	1.11
1805	0.96	0.96[a]	—	0.96	0.68
1806	0.80	0.80	—	0.80	0.58
1807	1.00	1.00	—	1.00	0.77
1808	0.80	0.80	—	0.80	0.70
1809	0.60	0.60	—	0.60	0.46
1810	0.75	0.75	—	0.75	0.57
1811	1.25	1.25	—	1.25	0.99
1812	1.00	1.00	—	1.00	0.76
1813	1.25	1.25[a]	—	1.25	0.77
1814	1.25	1.25[a]	—	1.25	0.69
1815	1.00	1.00	—	1.00	0.59
1816	1.125	1.125	—	1.125	0.75
1817	0.72	0.72	—	0.72	0.48
1818	0.90	0.90	—	0.90	0.61
1819	0.83	0.83	—	0.83	0.66
1820	0.935	0.935	—	0.935	0.88
1821	0.675	0.675	—	0.675	0.66
1822	0.65	0.65	—	0.65	0.61
1823	0.43	0.43	—	0.43	0.42
1824	0.455	0.455	—	0.455	0.46
1825	0.705	0.705	—	0.705	0.68
1826	0.75	0.75	—	0.75	0.76
1827	0.725	0.725	—	0.725	0.74
1828	0.625	0.625	—	0.625	0.64
1829	0.615	0.615	—	0.615	0.64
1830	0.655	0.655	—	0.655	0.72
1831	0.71	0.71	—	0.71	0.76
1832	0.85	0.85	—	0.85	0.89
1833	0.85	0.85	—	0.85	0.89
1834	0.725	0.725	—	0.725	0.81
1835	0.84	0.84	—	0.84	0.84
1836	0.89	0.89	—	0.89	0.78
1837	0.825	0.825	—	0.825	0.72
1838	0.86	0.86	0.83	0.83	0.75
1839	1.05	1.05	1.03	1.03	0.92
1840	1.00	1.00	1.00	1.00	1.05
1841	0.94	0.94	0.94	0.94	1.02
1842	0.73	0.73	0.73	0.73	0.89
1843	0.63	0.63	0.63	0.63	0.84
1844	0.90625	0.90625	0.905	0.905	1.18
1845	0.88	0.88	0.88	0.88	1.06
1846	0.87875	0.87875	0.87875	0.87875	1.06
1847	1.0075	1.0075	1.0025	1.002548	1.11
1848	1.00	1.00	1.0033	1.0033	1.22
1849	1.08875	1.08875	1.089	1.089	1.33
1850	1.207	1.207	1.207	1.207	1.44
1851	1.2725	1.2725	1.2725	1.2725	1.53

Table 9A.1 (continued)

	Tower	Starbuck	*WSL*	CATCHVAL	Real
1852	1.2375	1.2375	1.2375	1.2375	1.41
1853	1.2475	1.2475	1.2475	1.2475	1.29
1854	1.4875	1.4875	1.4875	1.4875	1.38
1855	1.772	1.772	1.772	1.772	1.61
1856	1.62	1.62	1.62	1.62	1.54
1857	1.2833	1.2833	1.2833	1.2833	1.16
1858	1.21	1.21	1.21	1.21	1.30
1859	1.3625	1.3625	1.3625	1.3625	1.43
1860	1.415	1.415	1.415	1.415	1.52
1861	1.315	1.315	1.315	1.315	1.48
1862	1.425	1.425	1.425	1.425	1.37
1863	1.61	1.61	1.61	1.61	1.21
1864	1.78	1.895	1.78	1.78	0.92
1865	2.25	2.255	2.25	2.25	1.22
1866	2.55	2.55	2.55	2.55	1.47
1867	2.235	2.27	2.235	2.235	1.38
1868	1.92	1.92	1.92	1.92	1.22
1869	1.78	1.8133	1.78	1.78	1.18
1870	1.355	1.3667	1.355	1.355	1.00
1871	1.35	1.31	1.35	1.35	1.04
1872	1.4525	1.4525	1.4525	1.4525	1.07
1873	1.48	1.435	1.48	1.48	1.11
1874	1.59	1.59	1.59	1.59	1.26
1875	1.6033	1.605	1.6033	1.6033	1.36
1876	1.405	1.405	1.405	1.405	1.28
1877	1.13	—	1.13	1.13	1.07
1878	0.915	—	0.915	0.915	1.01
1879	0.845	—	0.845	0.845	0.94
1880	0.99	—	0.99	0.99	0.99
1881	0.88	—	0.88	0.88	0.85
1882	1.06	—	1.06	1.06	0.98
1883	0.97	—	0.97	0.97	0.96
1884	0.85	—	0.85	0.85	0.91
1885	0.82	—	0.82	0.82	0.96
1886	0.745	—	0.745	0.745	0.91
1887	0.66	—	0.66	0.66	0.78
1888	0.62	—	0.62	0.62	0.72
1889	0.656	—	0.656	0.656	0.81
1890	0.65	—	0.65	0.65	0.79
1891	0.69	—	0.69	0.69	0.84
1892	0.675	—	0.675	0.675	0.89
1893	0.735	—	0.735	0.735	0.94
1894	0.56	—	0.56	0.56	0.80
1895	0.48	—	0.48	0.48	0.68
1896	0.40	—	0.40	0.40	0.59
1897	0.46	—	0.46	0.46	0.68
1898	0.53	—	0.53	0.53	0.75
1899	0.49	—	0.49	0.49	0.64
1900	0.525	—	0.525	0.525	0.64

(continued)

Table 9A.1 (continued)

	Tower	Starbuck	*WSL*	CATCHVAL	Real
1901	0.56	—	0.56	0.56	0.69
1902	0.66	—	0.66	0.66	0.77
1903	0.56	—	0.56	0.56	0.64
1904	0.52	—	0.52	0.52	0.60
1905	0.46	—	0.46	0.46	0.52
1906	—	—	0.51	0.51	0.57
1907	—	—	0.59	0.59	0.62
1908	—	—	0.57	0.57	0.62
1909	—	—	0.59	0.59	0.60
1910	—	—	0.63	0.63	0.61
1911	—	—	0.51	0.51	0.54
1912	—	—	0.53	0.53	0.52
1913	—	—	0.48	0.48	0.47
1914	—	—	0.47	0.47	0.47

Sources: See text.
[a]Labelled "assumed" by Starbuck.

to currency prices, in the manner described above. For 1859 we used the Tower-Starbuck price of bone, since the *WSL* provided no price. We were unable to produce CATCHVAL figures for 1814, 1815, or 1910–14, since we have no bone prices for these years.

Ideally the output of each voyage would be valued with the prices in force when the output was sold. We do not have the information necessary to do this, and we therefore settled for the prices relevant to the year in which the vessel returned to New Bedford. As indicated above, these prices are probably mainly unweighted averages of monthly average prices. Given our ignorance of the precise dates on which output was sold, it did not seem reasonable to develop more sophisticated measures.

Monthly prices *and* monthly imports are available, however, for part of the period in which we are interested, and we used these data to run a check to determine how nearly alike weighted and unweighted average prices were. The necessary data begin to appear in the *WSL* in the late 1850s and run to the early twentieth century for sperm oil, the early 1890s for whalebone, and the late 1880s for whale oil. We ran checks for 1857 and 1858, and at five-year intervals to 1888 for whale oil, to 1893 for whalebone, and to 1903 for sperm oil.

In the case of sperm oil the weighted average ran from 10.1 percent below the unweighted average to 2.7 percent above; on average, the weighted averages were 97.8 percent of the unweighted. For whale oil the range ran from −3.5 percent to 3.3 percent, and the average was 99.8 percent. For whalebone the relevant figures were −15.8 percent and 14.7 percent, with an average of 96.9 percent. Clearly, the two sets of averages (weighted and unweighted) differ, but on the whole the differences are not large. Given the roughness of the

Table 9A.2 **Nominal and Real Prices of Unrefined Whale Oil, New Bedford Market, 1804–1914 (dollars per gallon)**

	Tower	Starbuck	*WSL*	CATCHVAL	Real
1804	0.50	0.50[a]	—	0.50	0.40
1805	0.50	0.50[a]	—	0.50	0.35
1806	0.50	0.50	—	0.50	0.37
1807	0.50	0.50	—	0.50	0.38
1808	0.44	0.44	—	0.44	0.38
1809	0.44	0.44	—	0.44	0.34
1810	0.40	0.40	—	0.40	0.31
1811	0.40	0.40	—	0.40	0.32
1812	0.50	0.50	—	0.50	0.38
1813	0.50	0.50	—	0.50	0.31
1814	1.40	1.40	—	1.40	0.77
1815	0.83	0.83	—	0.83	0.49
1816	0.65	0.65	—	0.65	0.43
1817	0.60	0.60[a]	—	0.60	0.40
1818	0.50	0.50	—	0.50	0.34
1819	0.35	0.35	—	0.35	0.28
1820	0.35	0.35[a]	—	0.35	0.33
1821	0.33	0.33[a]	—	0.33	0.32
1822	0.32	0.32	—	0.32	0.30
1823	0.32	0.32[a]	—	0.32	0.31
1824	0.30	0.30[a]	—	0.30	0.31
1825	0.32	0.32[a]	—	0.32	0.31
1826	0.30	0.30[a]	—	0.30	0.30
1827	0.30	0.30[a]	—	0.30	0.31
1828	0.26	0.26	—	0.26	0.27
1829	0.26	0.26	—	0.26	0.27
1830	0.39	0.39	—	0.39	0.43
1831	0.30	0.30	—	0.30	0.32
1832	0.235	0.235	—	0.235	0.25
1833	0.26	0.26	—	0.26	0.27
1834	0.275	0.275	—	0.275	0.31
1835	0.39	0.39	—	0.39	0.39
1836	0.44	0.44	—	0.44	0.39
1837	0.35	0.35	—	0.35	0.30
1838	0.32	0.32	0.32	0.32	0.29
1839	0.36	0.36	0.345	0.345	0.31
1840	0.30	0.30	0.30	0.30	0.32
1841	0.32	0.32	0.3175	0.3175	0.35
1842	0.34	0.34	0.3375	0.3375	0.41
1843	0.34	0.34	0.345	0.345	0.46
1844	0.36583	0.36	0.365	0.365	0.47
1845	0.33	0.33	0.32875	0.32875	0.40
1846	0.3375	0.33	0.3375	0.3375	0.41
1847	0.36	0.36	0.36	0.36	0.40
1848	0.33	0.33	0.33	0.33	0.40
1849	0.39083	0.39	0.399	0.399	0.49
1850	0.491	0.49	0.491	0.491	0.58
1851	0.453125	0.45	0.453125	0.453125	0.55

(continued)

Table 9A.2 (continued)

	Tower	Starbuck	*WSL*	CATCHVAL	Real
1852	0.6825	0.68	0.68167	0.68167	0.77
1853	0.58167	0.58	0.58125	0.58125	0.60
1854	0.59625	0.59	0.59625	0.59625	0.55
1855	0.713	0.71	0.713	0.713	0.65
1856	0.795	0.79	0.795	0.795	0.76
1857	0.7325	0.73	0.7325	0.7325	0.66
1858	0.54	0.54	0.54	0.54	0.58
1859	0.485	0.48	0.485	0.485	0.51
1860	0.495	0.49	0.495	0.495	0.53
1861	0.44125	0.44	0.4425	0.4425	0.50
1862	0.5933	0.59	0.5933	0.5933	0.57
1863	0.9525	0.95	0.9525	0.9525	0.72
1864	1.28	1.28	1.28	1.28	0.66
1865	1.45	1.45	1.45	1.45	0.78
1866	1.21	1.21	1.21	1.21	0.70
1867	0.7325	0.73	0.7325	0.7325	0.45
1868	0.82	0.82	0.82	0.82	0.52
1869	1.0175	1.01	1.0175	1.0175	0.67
1870	0.6725	0.67	0.6725	0.6725	0.50
1871	0.60	0.64	0.60	0.60	0.46
1872	0.655	0.65	0.655	0.655	0.48
1873	0.62	0.62	0.62	0.62	0.47
1874	0.605	0.60	0.605	0.605	0.48
1875	0.6525	0.65	0.6525	0.6525	0.55
1876	0.61	0.56	0.61	0.61	0.55
1877	0.52	—	0.52	0.52	0.49
1878	0.44	—	0.44	0.44	0.48
1879	0.39	—	0.39	0.39	0.43
1880	0.51	—	0.51	0.51	0.51
1881	0.48	—	0.48	0.48	0.47
1882	0.535	—	0.535	0.535	0.50
1883	0.54	—	0.54	0.54	0.53
1884	0.56	—	0.56	0.56	0.60
1885	0.45	—	0.45	0.45	0.53
1886	0.33	—	0.33	0.33	0.40
1887	0.32	—	0.32	0.32	0.38
1888	0.35	—	0.35	0.35	0.41
1889	0.38	—	0.38	0.38	0.47
1890	0.42	—	0.42	0.42	0.51
1891	0.47	—	0.47	0.47	0.57
1892	0.425	—	0.425	0.425	0.56
1893	0.425	—	0.425	0.425	0.54
1894	0.335	—	0.325	0.325	0.46
1895	0.28	—	0.28	0.28	0.39
1896	0.35	—	0.35	0.35	0.51
1897	0.37	—	0.37	0.37	0.54
1898	0.34	—	0.34	0.34	0.48
1899	0.35	—	0.35	0.35	0.45

Table 9A.2 (continued)

	Tower	Starbuck	*WSL*	CATCHVAL	Real
1900	0.37	—	0.37	0.37	0.45
1901	0.38	—	0.38	0.38	0.47
1902	0.37	—	0.37	0.37	0.43
1903	0.38	—	0.38	0.38	0.44
1904	0.36	—	0.36	0.36	0.41
1905	0.31	—	0.31	0.31	0.35
1906	—	—	0.335	0.335	0.37
1907	—	—	0.37	0.37	0.39
1908	—	—	0.32	0.32	0.35
1909	—	—	0.31	0.31	0.31
1910	—	—	0.38	0.38	0.37
1911	—	—	0.38	0.38	0.40
1912	—	—	0.36	0.36	0.36
1913	—	—	0.35	0.35	0.34
1914	—	—	no imports	—	—

Sources: See text.
[a]Labelled "assumed" by Starbuck.

data in general, the use of weighted mean prices would represent excessive scrupulousness. In any case, prices are applied to individual voyages and there is no reason to suppose that weighted average prices would represent any better the prices at which the outputs of any given voyage were sold than do the unweighted average prices.

From 1838 onward the CATCHVAL series describes New Bedford prices. In the years before 1838 the place with which prices are associated is unclear. In all likelihood prices are some average of those obtained in the whaling ports distributed around Buzzard's Bay—perhaps only Nantucket and New Bedford, the chief whaling ports of that period. Differences among the average annual prices in these ports are unlikely to have been large, since the ports were physically close.

Table 9A.3 Nominal and Real Prices of Unprocessed Whalebone, New Bedford Market, 1804–1914 (dollars per pound)

	Tower	Starbuck[a]	*WSL*	CATCHVAL	Real
1804	0.08	0.08	—	0.08	0.06
1805	0.10	0.10	—	0.10	0.07
1806	0.07	0.07	—	0.07	0.05
1807	0.07	0.07	—	0.07	0.05
1808	0.07	0.07	—	0.07	0.06
1809	0.08	0.08	—	0.08	0.06
1810	0.08	0.08	—	0.08	0.06
1811	0.09	0.09	—	0.09	0.07
1812	0.10	0.10	—	0.10	0.08
1813	0.10	0.10	—	0.10	0.06
1814	—	—	—	—	—
1815	—	—	—	—	—
1816	0.12	0.12	—	0.12	0.08
1817	0.12	0.12	—	0.12	0.08
1818	0.10	0.10	—	0.10	0.07
1819	0.10	0.10	—	0.10	0.08
1820	0.10	0.10	—	0.10	0.09
1821	0.12	0.12	—	0.12	0.12
1822	0.12	0.12	—	0.12	0.11
1823	0.13	0.13	—	0.13	0.13
1824	0.13	0.13	—	0.13	0.13
1825	0.15	0.15	—	0.15	0.15
1826	0.16	0.16	—	0.16	0.16
1827	0.18	0.18	—	0.18	0.18
1828	0.25	0.25	—	0.25	0.26
1829	0.25	0.25	—	0.25	0.26
1830	0.20	0.20	—	0.20	0.22
1831	0.17	0.17	—	0.17	0.18
1832	0.13	0.13	—	0.13	0.14
1833	0.13	0.13	—	0.13	0.14
1834	0.21	0.21	—	0.21	0.23
1835	0.21	0.21	—	0.21	0.21
1836	0.25	0.25	—	0.25	0.22
1837	0.20	0.20	—	0.20	0.17
1838	0.20	0.20	0.195	0.195	0.18
1839	0.18	0.18	0.1825	0.1825	0.16
1840	0.19	0.19	0.19	0.19	0.20
1841	0.20	0.20	0.1967	0.1967	0.21
1842	0.23	0.23	0.24909[b]	0.24909	0.30
1843	0.36	0.36	0.3575	0.3575	0.48
1844	0.40	0.40	0.40	0.40	0.52
1845	0.34	0.34	0.33625	0.33625	0.41
1846	0.34	0.34	0.34	0.34	0.41
1847	0.31	0.31	0.30875	0.30875	0.34
1848	0.25	0.25	0.254	0.254	0.31
1849	0.21875	0.21875	0.318	0.318	0.39
1850	0.324	0.324	0.344	0.344	0.41

Table 9A.3 (continued)

	Tower	Starbuck	*WSL*	CATCHVAL	Real
1851	0.345	0.345	0.345	0.345	0.42
1852	0.50833	0.50833	0.5075	0.5075	0.58
1853	0.345	0.345	0.345	0.345	0.36
1854	0.392	0.392	0.392	0.392	0.36
1855	0.4525	0.4525	0.4525	0.4525	0.41
1856	0.58	0.58	0.58	0.58	0.55
1857	0.9675	0.9675	0.9675	0.9675	0.87
1858	0.9225	0.9225	0.9225	0.9225	0.99
1859	0.88	0.88	—	0.88	0.93
1860	0.802	0.802	0.802	0.802	0.86
1861	0.66	0.66	0.66	0.66	0.74
1862	0.82	0.88	0.82	0.82	0.79
1863	1.53	1.53	1.53	1.53	1.15
1864	1.80	1.8067	1.80	1.80	0.93
1865	1.71	1.7167	1.71	1.71	0.92
1866	1.37	1.37	1.37	1.37	0.79
1867	1.175	1.1775	1.175	1.175	0.73
1868	1.025	1.025	1.025	1.025	0.65
1869	1.24	1.23	1.24	1.24	0.82
1870	0.85	0.85	0.85	0.85	0.63
1871	0.70[c]	0.77	0.70[c]	0.7889	0.61
1872	1.285	1.285	1.285	1.285	0.94
1873	1.08	1.0833	1.08	1.08	0.81
1874	1.10	1.10	1.10	1.10	0.87
1875	1.1275[c]	1.206	1.1275[c]	1.2707	1.08
1876	2.14	1.96	2.14	2.14	1.95
1877	2.50	—	2.50	2.50	2.36
1878	2.46	—	2.46	2.46	2.70
1879	2.34	—	2.34	2.34	2.60
1880	2.00	—	2.00	2.00	2.00
1881	1.63	—	1.63	1.63	1.58
1882	1.71	—	1.71	1.71	1.58
1883	2.87	—	2.87	2.87	2.84
1884	3.55	—	3.55	3.55	3.82
1885	2.68	—	2.68	2.68	3.15
1886	2.73	—	2.73	2.73	3.33
1887	3.12	—	3.12	3.12	3.67
1888	2.78	—	2.78	2.78	3.23
1889	3.50	—	3.50	3.50	4.32
1890	4.22	—	4.22	4.22	5.15
1891	5.38	—	5.38	5.38	6.56
1892	5.35	—	5.35	5.35	7.04
1893	3.08	—	3.08	3.08	3.95
1894	2.95	—	2.95	2.95	4.21
1895	2.83	—	2.83	2.83	3.99
1896	3.95	—	3.95	3.95	5.81
1897	3.50	—	3.50	3.50	5.15
1898	3.10	—	3.10	3.10	4.37

(continued)

Table 9A.3 (continued)

	Tower	Starbuck	*WSL*	CATCHVAL	Real
1899	2.70	—	2.70	2.70	3.51
1900	2.50	—	2.50	2.50	3.05
1901	2.65	—	2.65	2.65	3.27
1902	4.20	—	4.20	4.20	4.88
1903	5.25	—	5.25	5.25	6.03
1904	5.80	—	5.80	5.80	5.52
1905	4.90	—	4.90	4.90	5.57
1906	—	—	4.50	4.50	5.00
1907	—	—	5.00	5.00	5.26
1908	—	—	3.75	3.75	4.08
1909	—	—	3.75	3.75	3.79
1910	—	—	—	—	—
1911	—	—	—	—	—
1912	—	—	—	—	—
1913	—	—	—	—	—
1914	—	—	—	—	—

[a]Prices for 1804–27 are "assumed." The term is Starbuck's.

[b]The *WSL* prints 0.23 as the average of eleven monthly prices (no price is given for September). As it happens, 0.24909 is the correct average; 0.23 results from dividing the sum by twelve.

[c]Gold.

Appendix 9B
Whaling Outputs

Table 9B.1 shows whaling outputs. Those for the U.S. fleet are from Tower 1907, 126, adjusted so that oil amounts are expressed in all years in barrels. The New Bedford data are from our Voyages Data Set.

The Tower output series and ours are not fully comparable. The Voyages Data Set associates all output of a voyage with the year the vessel returned to port. Tower's series associates output with the year the output, not the vessel, arrived in port. That is, the difference between our series and Tower's lies in the dating of output shipped home in advance of the return of the vessel that produced it. The difference tends to wash out in quinquennial and decennial averages. (See the notes to table 1.2.)

Table 9B.1 **Outputs of Sperm Oil, Whale Oil, and Whalebone, U.S. and New Bedford Whaling Fleets, 1816–1905**

	U.S. Fleet			New Bedford Fleet		
	Sperm Oil (barrels)	Whale Oil (barrels)	Whalebone (pounds)	Sperm Oil (barrels)	Whale Oil (barrels)	Whalebone (pounds)
1816	7,539	9,350	796	1,150	0	0
1817	32,650	18,471	19,440	6,007	8,300	0
1818	18,625	19,303	65,446	2,850	9,950	14,000
1819	21,323	38,232	83,843	1,297	15,580	0
1820	34,708	44,757	78,879	12,330	21,130	17,045
1821	43,099	38,524	62,893	14,201	7,724	10,409
1822	42,900	51,427	50,799	4,080	15,105	3,231
1823	93,281	53,887	103,404	28,038	21,787	16,568
1824	98,129	58,198	133,427	24,980	28,872	9,314
1825	61,089	52,902	152,534	16,547	22,873	141,665
1826	29,200	35,182	79,368	5,839	18,172	131,889[a]
1827	93,920	35,525	106,225	40,613	19,192	147,636[a]
1828	78,577	50,533	137,323	24,494	29,058	230,651[a]
1829	74,608	71,635	563,654	32,767	22,957	196,081
1830	110,541	89,883	514,991	37,258	34,261	294,628
1831	115,452	114,596	279,279	42,210	36,959	43,200
1832	73,002	181,076	442,881	27,536	46,629	67,200
1833	104,437	163,592	266,432	35,448	45,590	65,000
1834	123,542	131,582	343,324	55,123	23,950	37,000
1835	164,493	125,406	965,192	66,422	32,453	109,000
1836	133,334	136,568	1,028,773	46,134	37,717	32,000
1837	169,179	202,857	1,753,104	58,625	69,001	269,702
1838	132,356	226,552	2,200,000	62,655	68,001	57,500
1839	142,336	229,783	2,000,000	52,450	61,506	156,094
1840	157,791	207,908	2,000,000	51,258	61,883	31,586
1841	159,304	207,348	2,000,000	54,066	58,063	8,400
1842	165,637	161,041	1,600,000	72,895	53,375	143,314
1843	166,985	206,727	2,000,000	62,098	42,434	393,683
1844	139,594	262,047	2,532,445	58,002	109,263	887,243
1845	157,917	272,730	3,167,142	52,130	87,548	782,318
1846	95,217	207,493	2,276,939	40,138	89,146	580,862
1847	120,753	313,150	3,341,680	57,682	101,338	749,845
1848	107,976	280,656	2,003,000	52,254	116,876	975,686
1849	100,944	248,492	2,281,100	49,205	79,292	583,610
1850	92,892	200,608	2,869,200	43,645	90,370	911,508
1851	99,591	328,483	3,906,500	47,613	153,025	1,940,827
1852	78,872	84,211	1,259,900	41,248	30,177	397,575
1853	103,077	260,114	5,652,300	45,481	89,900	1,228,238
1854	76,696	319,837	3,445,200	40,471	155,760	2,116,773
1855	72,649	184,015	2,707,500	33,502	119,131	1,617,010
1856	80,941	197,890	2,592,700	50,572	91,666	1,161,090
1857	78,440	230,941	2,058,900	53,865	123,639	1,406,865
1858	81,941	182,223	1,540,600	42,013	73,195	789,666
1859	91,408	190,411	1,923,850	54,913	80,288	863,461
1860	73,708	140,005	1,337,650	39,101	101,499	1,159,464
1861	68,932	133,717	1,038,450	44,845	76,450	827,285

(continued)

Table 9B.1 (continued)

	U.S. Fleet			New Bedford Fleet		
	Sperm Oil (barrels)	Whale Oil (barrels)	Whalebone (pounds)	Sperm Oil (barrels)	Whale Oil (barrels)	Whalebone (pounds)
1862	55,641	100,487	763,500	37,361	71,464	729,551
1863	65,055	62,974	488,750	42,567	55,767	573,131[a]
1864	64,372	71,863	760,450	56,877	35,594	427,743
1865	32,242	76,238	619,350	24,363	33,939	368,442
1866	36,663	74,302	920,375	17,249	24,196	304,896
1867	43,433	89,289	1,001,397	21,297	47,991	610,450
1868	47,174	65,575	900,850	29,872	44,374	531,461
1869	47,936	85,011	603,606	29,244	56,093	803,240[a]
1870	55,183	72,691	708,365	40,215	38,577	381,760
1871	41,534	75,152	600,655	38,769	81,907[a]	887,821[a]
1872	45,201	31,075	193,793	25,450	15,671	83,226
1873	42,053	40,014	206,396	28,299	16,175	93,015
1874	32,203	37,782	345,560	27,415	21,355	141,254
1875	42,617	34,594	372,303	30,044	25,412	218,341
1876	39,811	33,010	150,628	28,509	18,417	157,334[a]
1877	41,119	27,191	160,220	22,347	13,960	65,129
1878	43,508	33,778	207,259	42,717	27,223	176,887
1879	41,308	23,334	286,280	28,297	18,989	183,586
1880	37,614	34,776	464,028	35,068	42,726[a]	488,034[a]
1881	30,598	31,677	368,322	36,265[a]	37,094[a]	332,801
1882	29,884	23,371	271,999	23,615	27,328[a]	291,610[a]
1883	24,595	24,170	254,037	14,089	11,941	102,696
1884	22,099	24,670	426,968	19,585	20,610	133,765
1885	24,203	41,586	463,990	18,735	17,343	199,900
1886	23,312	27,249	352,490	25,330[a]	15,360	152,400
1887	18,873	34,171	585,011	15,159	20,113	254,468
1888	16,265	17,185	334,572	8,534	10,815	135,900
1889	18,727	14,247	253,113	12,720	6,529	83,550
1890	14,480	17,565	309,700	20,339[a]	9,049	115,805
1891	13,015	14,837	297,768	9,915	6,365	86,100
1892	12,944	13,382	369,885	7,275	6,150	112,510
1893	15,253	8,110	411,315	5,245	3,405	69,250
1894	16,333	8,720	278,800	10,285	2,310	37,000
1895	16,585	4,009	114,960	10,135	1,585	34,700
1896	15,124	4,800	207,850	11,285	2,290	54,850
1897	10,050	3,600	178,010	19,195[a]	1,690	24,780
1898	12,520	5,295	246,120	5,755	840	11,820
1899	11,903	3,827	320,100	7,515	1,995	45,400
1900	18,525	5,510	207,650	11,395	4,055	18,500
1901	14,910	2,930	99,050	17,325[a]	1,420	11,600
1902	21,970	4,725	109,980	18,860	4,020	17,000
1903	18,109	1,260	74,850	10,815	265	0
1904	17,050	3,750	123,300	14,820	1,420	15,000
1905	12,985	1,755	79,900	6,140	1,340	62,400

[a]Note that the New Bedford amount is greater than Tower's report of the amount for the entire U.S. fleet. This may be due in part to the difference in dates of record, described in the text.