AQUATIC PRODUCTS IN ARTS AND INDUSTRIES.

FISH OILS, FATS, AND WAXES. FERTILIZERS FROM AQUATIC PRODUCTS.

By CHARLES H. STEVENSON.

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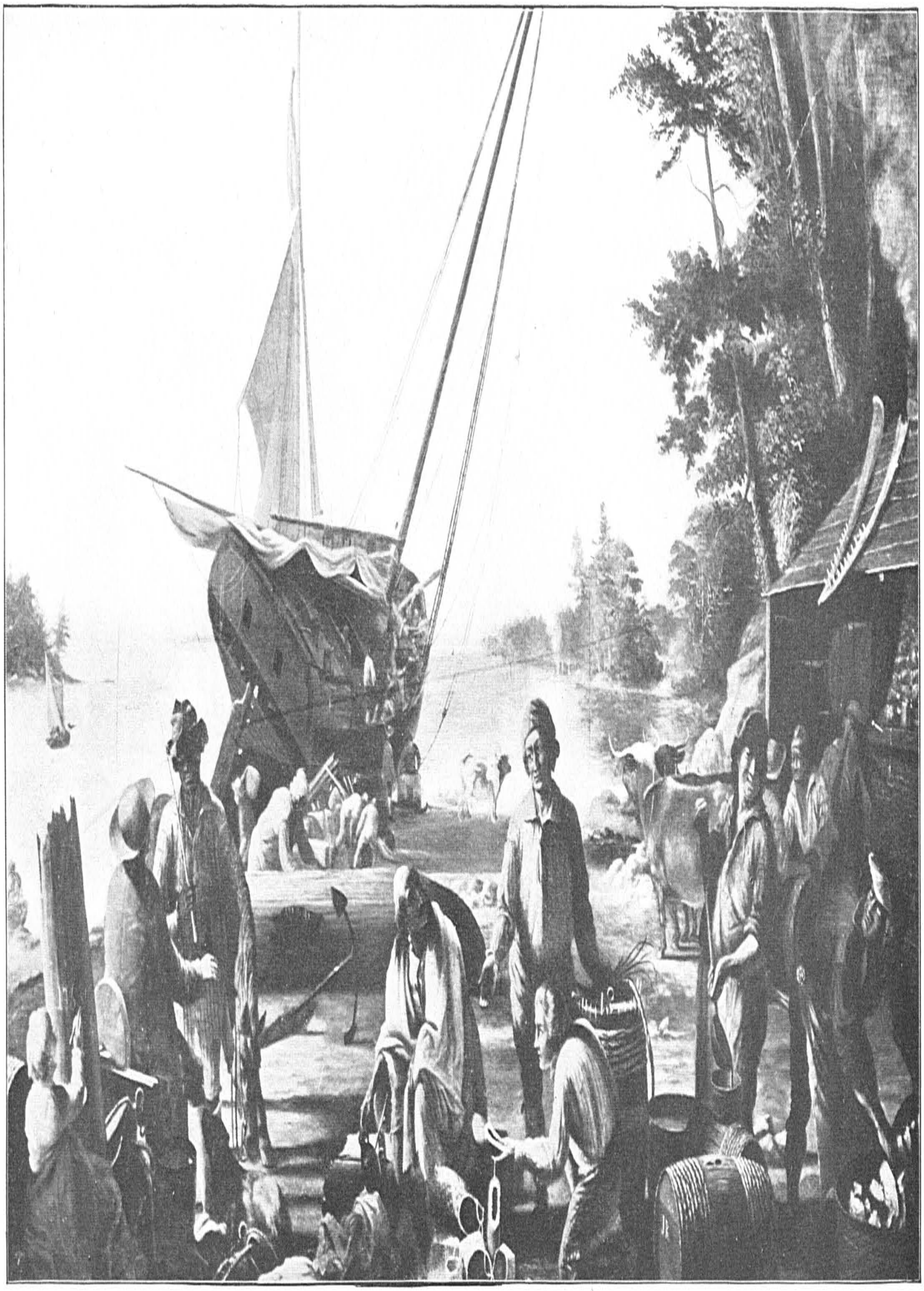

ORIGIN OF THE WHALING INDUSTRIES AT NEW BEDFORD, MASS., 1763.

Copy of painting by Wall.

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By Charles H. Stevenson.

PREFATORY NOTE.

The diversity and magnitude of the industries based on the utilization and manufacture of aquatic products are not fully appreciated. In a previous publication of this Commission[a] the great variety of fishery products used for food and their methods of preparation were discussed. In addition to the numerous items of food articles, the materials employed in the arts and industries compare favorably in variety and interest with similar products of the land. These may be roughly separated into five classes, viz, (1) oils, fats, and waxes; (2) fertilizers from aquatic products; (3) skins of aquatic animals and their products of furs and leathers; (4) the hard substances, as shells, scales, bones, ivories, etc., and (5) miscellaneous articles not properly classed with any of the foregoing, as glue, isinglass, seaweeds, sponges, marine salt, etc. The total value of the annual product of these throughout the world roughly approximates $45,000,000 in the condition in which they are first placed on the market, of which the United States contributes $11,000,000.

Some of the most extensive fisheries of the world have been prosecuted almost wholly for the purpose of supplying the oil markets. Whale oils were the first of all oils—animal or mineral—to achieve commercial importance, and for fully a century the whale fishery ranked as one of the principal industries of America. Indeed it was of far greater relative value in the industrial wealth of the country than the petroleum industries are at the present time. The seal fisheries of Newfoundland, Norway, and other northern countries, which rank among the most daring and venturesome of marine enterprises, are dependent for their prosperity on the oil obtained from the thick blubber underlying the skins of the animals. The taking of menhaden on the Atlantic coast of the United States for conversion into oil and fertilizer gives employment to thousands of men and to several million dollars of capital. And in the various cod fisheries of the world the rendering of the livers into oil for medicinal as well as for technical uses is a source of great profit. In addition to these extensive industries there are numerous minor fisheries supported entirely, or to a large extent, by the oil markets.

[a] The Preservation of Fishery Products for Food, Bulletin U. S. Fish Commission, 1898.

From all varieties of aquatic oils may be separated, at a low temperature, a solid fat or grease known as "foots" or "stearin," somewhat similar to the tallow obtained from sheep and oxen. This is obtained in the process of refining the oils, and the yield ranges from 3 to 20 per cent of the bulk of the crude oil. It is sold at a few cents per pound, and is used as a substitute for tallow from sheep and oxen in sizing yarns, as emollient in leather-dressing, and for various other technical purposes.

Bleaching the various marine oils produces a semi-solid fat known as "sperm soap," "whale soap," "menhaden soap," etc., according to the variety of oil treated. This material is used in smearing sheep, washing fruit trees, soap-manufacture, etc.

In the process of refining sperm oil, instead of the foots, the wax-like spermaceti is obtained, the quantity yielded approximating 11 per cent in weight of the crude sperm oil. Spermaceti is used principally in candle-making, as an ointment for medicinal purposes, for producing a polish on linen in laundering, and for self-lubricating cartridges.

Another wax-like substance peculiar to the sperm whale is ambergris, an extremely valuable substance found at rare intervals, but sometimes in comparatively large quantities within the intestines of that animal, and also afloat on the sea or cast up on the shores. A single whale has yielded $50,000 worth of this material, and several intances are reported in which $20,000 worth has been obtained from one cetacean. Ambergris was formerly used as an incense, in cookery, as a medicine, and as a perfume. Its principal use at present is in the preparation of fine perfumes.

The principal aquatic products used for fertilizer are seaweeds, shells of mollusks and crustaceans, non-edible species of fish, especially the menhaden, and waste parts of edible species. At present the quantity of this fertilizer produced annually in the United States alone approximates 420,000 tons, worth $2,120,000. This is capable of very great increase, especially in the quantity of seaweeds and waste fish employed.

Doubtless 50 per cent of the world's stock of furs is obtained from aquatic animals. Formerly this percentage was greater, but it is reduced by the decrease in product of beaver, fur-seal, otter, and sea-otter, and the large increase in quantity of certain land fur-bearers. Fully 75 per cent of all the furs produced in the United States are yielded by aquatic animals, principally the fur-seal, mink, muskrat, beaver, otter, and sea-otter. The value of the annual output of these in the United States approximates $2,500,000 in the raw or undressed state.

Leather is made from the skins of practically all the aquatic mammals and of most of the species of fish, but these usually rank among novelty or fancy leathers. Seal leather is produced in large quantities, the value of the annual product averaging $1,500,000.

The hide of the beluga, or white whale, is one of the best of all skins for leather purposes, on account of its durability, strength, and pliability. It is sold as porpoise leather, and probably $200,000 worth of tanned hides are marketed annually. Alligator skins are also obtained in large quantities, and owing to the peculiarity of their markings, are used entirely as fancy leather. Tanned walrus hides, especially the thick ones, are in great demand for polishing-wheels and other mechanical purposes, and about $100,000 worth are sold annually. Among the aquatic skins used to a less extent for leather purposes may be mentioned sea-lion, porpoise, sea-elephant, and a very large variety of fish skins, especially those of sharks.

Of the hard substances existing in the form of shells, bones, scales, etc., shells are by far the most important. Nearly, if not quite, 1,000,000 tons are secured annually in the United States, consisting principally of the shells of oysters, clams, river mussels, and a very much smaller quantity of other varieties. A fair valuation of these at the places of consumption would doubtless amount to $1,500,000; to this should be added about $600,000 as the value of pearls secured during the last year in the Mississippi Valley and elsewhere. The value of the shells secured outside of the United States, principally mother-of-pearl shells, amounts to $5,000,000 or $6,000,000 annually, and the pearls secured sell for nearly an equal amount. Pearls are not obtained in the seas in such large quantities as formerly, but their value is greatly increased. The manufacture of mother-of-pearl and sweet-water shell in the form of buttons, buckles, knife-handles, pistol-stocks, etc., gives employment to nearly 10,000 persons in this country and to probably three times that number in Europe and elsewhere.

The yield of whalebone in the United States fisheries is less than 5 per cent as much as it was 50 years ago, but the reduced yield has been largely counterbalanced by the increase in value per pound. The product in the American fisheries now approximates 120,000 pounds each year, worth $500,000, and about $150,000 worth is obtained in all other parts of the world. At the present market price the total value of whalebone secured in the United States fisheries since 1850 is not far from $200,000,000.

Comparatively little tortoise shell is produced in this country, the annual yield approximating $12,000 in value. The West Indies, South America, Africa, East Indies, Pacific islands, etc., supply probably $500,000 worth each year, much of which is manufactured in the United States.

Little economic use is made of fish scales, except in the production of artificial pearls and other ornamental objects. Unique and attractive artificial flowers are made from the scales of sheepshead, tarpon, drum-fish, channel bass, etc.

Cuttlebone and coral are not produced in the United States, but large quantities are imported into this country.

The yield of ivory in the form of walrus tusks, sperm-whale teeth, etc., is small at present, amounting to less than $25,000 annually.

The principal industrial use for bones of aquatic animals is for conversion into fertilizer. Several varieties of curious bones are used for ornamentation, but their aggregate value is inconsiderable.

The sponge output of Florida approximates $500,000 annually, and the value of the product throughout the world is probably not far from $5,000,000.

The uses of seaweeds are numerous. They furnish thousands of tons of fertilizer, many nutritious foods, and a variety of chemicals, especially iodine and bromine. Other uses are in sizing fabrics, as a mordant in dyeing, in refining beer, in making paper, fishing lines, ropes, for stuffing upholstery, packing porcelain, etc. The Japanese have been especially adept in discovering uses for seaweeds.

Glue-manufacture provides an outlet for the profitable use of much waste in dressing dried codfish. This material was formerly discarded as useless, but now tens of thousands dollars' worth of choicest glue for postage stamps, court-plaster, adhesive paper, labels, envelopes, for mechanical purposes, and for sizing of straw goods and textile fabrics, and likewise office and domestic mucilage are manufactured from fish skins. The product is very much stronger and more durable than glue made from the skins of mammals.

Isinglass made from the sounds or swimming bladders of sturgeon, hake, cod, squeteague, etc., is used for clarifying fermented liquors, the cellular construction forming a sort of net which carries down floating particles. However, the use of this material has been much reduced, owing to the numerous substitutes obtained from domestic animals.

Commercial albumen may be made from the eggs of cod and other species, but it has not yet been extensively manufactured.

The preparation of oils and fertilizers, to which the present report is devoted, is intimately associated, especially in the case of the menhaden industry. The tissues remaining after the extraction of oil from herring and other waste fish, from the blubber of seals, porpoise, and the like, from the livers of cod and related species, the livers of sharks, from the waste parts of fish in dressing, etc., are commonly prepared for fertilizing purposes, and the preparation of the two materials is usually carried on in the same factory and in some instances by the same workmen. For this reason it appears desirable to combine in one paper the account of the preparation of oils and fertilizers from aquatic products. This paper, however, is divided into two parts, one relating to the preparation, characteristics, and uses of fish oils, fats, and waxes, and the other to the utilization of aquatic products as fertilizers.

FISH OILS, FATS, AND WAXES.

GENERAL REVIEW.

Previous to 1600 there was comparatively little demand for oil of any kind. Tallow dips, pine knots, and the like afforded the principal means of illumination. The quantity of machinery in use was small and lubricants were in little demand. The leather industries were undeveloped and the greases required in currying were obtained principally from the fat of the animal furnishing the skin, supplemented later by certain vegetable oils.

The value of whale oils for purposes of illumination was not unknown previous to the seventeenth century, but the fishermen were unequal to the task of capturing the cetaceans, in large numbers. A few that drifted ashore were secured, the use of the oil for illuminating purposes developed; and, as the experience and daring of the fishermen increased, their wanderings extended not only offshore, but to distant seas. After the invention of the Argand burner in 1784, whale oil became the principal illuminating agent, and at the beginning of the nineteenth century it was in general use. Not only were residences lighted with it, but also streets and municipal buildings. A large quantity of sperm oil was used in residences of the wealthy and also in lighthouses, that being the principal illuminant in the coastal lights of the United States, England, Scotland, Ireland, France, and other advanced countries up to 1832. The currying trade had in the meantime increased in importance, and grease for softening was secured in the form of oil from seal, walrus, sea-elephant, cod livers, etc. The increasing use of machinery resulted in an enhanced demand for a lubricant, which was generally furnished in the form of sperm oil. This resulted in very high prices; sperm oil, for instance, ranged from $1 to $2 per gallon, although the fishery increased until it was one of the most important organized industries of the world. Other fish oils became important commercial products, including oils from the livers of cod, haddock, sharks, etc., from herring, menhaden, sardine, pilchard, and other species of the *Clupeidæ* family, and a miscellaneous variety of minor importance.

The continued upward tendency in prices, as a result of an increased demand, led to endeavors to find substitutes. Lard oil was successfully introduced as a summer lubricant in the place of sperm oil for ordinary uses. Colza or rape-seed oil likewise entered into competition with it as an illuminant, and the process of refining was improved until it became a fairly satisfactory substitute at about half the price. In 1832 France adopted colza in place of sperm oil as a light-house illuminant, and in 1845 it was adopted in the light-houses and light-ships of Great Britain. The difficulty of obtaining rape-seed oil in the United States and the importance of the whaling industry to the national welfare caused the use of sperm oil in this country for ten years longer, when through the researches and experiments of Professor Henry it was found practicable to use lard oil, and in 1862 that became the illuminant in the light-houses of the United States. A few years later both colza and lard oils were superseded by forms of petroleum.

Not only did the products of petroleum take the place of aquatic-animal oils as illuminants, but they seriously interfered with them in the markets as lubricants. Then came the development of rendering and refining a large number of vegetable oils, which are now used for many purposes formerly served by fish oils. Among these vegetable products are olive oil, cotton-seed oil, linseed oil, and, to a less extent, palm oil, cocoanut oil, corn oil, etc. The employment of these substances and a large decrease in the abundance of whales have resulted in a great reduction in the extent of the whale fishery, the fleet decreasing from 735 vessels in 1846 to 38 in 1902. Those marine enterprises more or less associated with the whale fisheries, as the taking of seals, sea-elephants, walrus, etc., have decreased correspondingly.

Fish oils have therefore, to a large extent, given place to land products, and their diminished sale and reduced price have greatly decreased the prosperity of many fisheries. At present the use of fish oils for illumination as compared with that of mineral oils is very small in those countries where the latter are obtainable, their principal use being in miners' lamps. But among many semicivilized people, especially those of subpolar regions, marine-animal oils are more easily obtained than petroleum, so that the native products continue in use. And notwithstanding the large amount of mineral oils now used for lubrication of heavy machinery, there is yet an extensive demand for fish oils for that purpose, experience having shown that by their judicious blending with hydrocarbon oils a greater uniformity of lubrication is secured, and that less quantity is required than by use of mineral oil alone. The outlook for an increased use of fish oils in leather-dressing is said to be not encouraging, owing to a decrease in "hand-stuffing" and the increasing popularity of chrome tannage, in which only a small quantity of oil is required, and that usually a superior quality of neatsfoot. There is a wide field of technical uses wherein certain fish oils can not readily be dispensed with, especially for lubricating delicate machinery, in steel-tempering and screw-cutting, as a body for paints to be applied to out-of-door surfaces, in the textile trades where only saponifiable oil can be satisfactorily employed, etc.

In addition to their many technical uses, marine-animal oils are also used for nourishment to a considerable extent. The Eskimos and other primitive people depend very largely on the blubber of seals, walrus, and whales, for food supplies. Among more civilized nations fish oils are not used ordinarily as an article of diet; an exception, however, is the well-known and valuable cod-liver oil, of which twenty or thirty thousand barrels are annually consumed in cases of malnutrition. Certain therapeutic qualities are also attributed to various minor oils, as those from the shark, eulachon, manatee, dugong, alligator, terrapin, etc., but the use of these is not general.

The marine-animal oils are divisible into four principal groups, viz: (1) blubber oils; (2) head oils; (3) liver oils, and (4) body oils. The blubber oils are obtained from the layer of fat between the skin and the flesh or muscular tissues of whales, seals, walrus, sea-lion, porpoise, black-fish, etc. Head oils are secured from cavities in the skull and from other head parts of sperm whales, black-fish, porpoise, sword-fish, halibut, etc. Some of these are of superior quality, as those of the black-fish and porpoise, for instance, which sell for $5 to $10 per gallon. The head oil of the sperm whale yields the valuable spermaceti. Those of the third group are obtained principally from the livers of cod and to a less extent from haddock, hake, pollock, cusk, ling, sharks, and skates. The bodies, heads, and viscera of these fish are so slightly oleaginous that they are rarely utilized economically for oil purposes. The body oils, or fish oils,[a] as they are now generally known commercially, are obtained principally from species of the herring family—the menhaden in America, the herring, sardine, and pilchard in Europe, and the iwashi in Japan. In case these fish are used for food in large quantities, the viscera are generally devoted to oil-rendering. Most of the other species of food-fish contain so little oil that it is profitable to use only the intestines or other refuse dressings for this purpose. And in some the yield of oil is so small that not even the waste parts can be profitably utilized in this manner. In addition to the foregoing, there are a number of oils produced in various localities which enter largely into the domestic economy of those procuring them and yet are of little commercial importance, as alligator oil, turtle oil, terrapin oil, etc.

The total annual product of crude oil from marine animals throughout the world is estimated at 18,300,000 gallons, of which 5,500,000 represents the product from the blubber and fat of whales, seals, and the like; 5,300,000 gallons is from the livers of cod, shark, etc., and 7,500,000 gallons from menhaden, herring, sardine, and other species, including waste in dressing fish.

Even a brief survey of the fish-oil industries reveals the fact that they are not by any means so extensive as the natural resources permit. True, the right-whale fishery is prosecuted apparently to an

[a] The term "fish oil" is used by chemists and other technologists as comprising oils from all aquatic animals. Previous to 1800 it generally referred to whale oils. At the present time its commercial use is generally confined to oils obtained from fish alone. In a restricted sense it refers especially to oil obtained from the principal species of the herring family in the locality in which the term is applied. Thus "fish oil" on the Atlantic coast of the United States indicates in a restricted commercial sense the oil of the menhaden; in Norway, the herring; in France, the sardine; in Japan, the iwashi, etc.

extreme limit, and the same is possibly true of the seal fisheries of certain regions. However, there is probably no other oil-yielding fishery of which the same can be said. Sperm whales are more numerous than they were fifty years ago, when the United States employed 300 vessels in their capture, securing 100,000 barrels of oil annually, as compared with the present product of less than 20,000 barrels. Porpoise and other small cetaceans exist in such large numbers that hundreds of thousands if not millions of gallons of oil can be secured from them. Only a very small percentage of the oil-yielding sharks are utilized. Much greater quantities of menhaden might be taken than are secured at present, and comparatively little of the abundant waste fish and dressings or refuse from the markets, canneries, etc., are used in oil-production.

The principal reason for this is that the present economic conditions do not warrant an extension of these industries. The market for fish oils is regulated by that of the mineral and vegetable products which are used as substitutes, and which can be sold at very low prices, making it necessary to exercise very great economy in the production of fish oils. Vessels, factories, etc., already on hand may be used, but in the United States at least it is questionable whether the building of new and costly equipment for oil-production would prove profitable under present market conditions except in specially favorable instances, unless the closest economy be practiced. The vessels composing the present sperm-whaling fleet, for instance, may be kept employed with a fair profit, but with the present prices the fitting out of expensive new vessels can scarcely meet with a large return on capital invested. The present equipment of menhaden steamers and factories was built and paid for during a period of prosperity, when menhaden oil was high in price, and they may be continued in service with profit, but the conditions are not encouraging for a great extension of the industry. If a profitable market could be found for the product, the yield of fish oils throughout the world could probably be increased many times its present extent.

THE WHALE OILS.

BRIEF REVIEW OF THE WHALING INDUSTRIES.

It is scarcely within the province of the present report to enter into a detailed history of the whale fisheries, unquestionably the most picturesque and once the most extensive of all marine industries of the world. In order, however, to present a fair idea of the production and utilization of whale oils, it is desirable to review briefly the history and present conditions of these industries.

Whales are divisible into two groups, (1) toothed whales and (2) bone-bearing or whalebone whales. To the first group belongs the sperm whale or cachalot, which yields sperm oil, spermaceti, ivory, and ambergris. This group also includes the bottle-nose whale, the

WHALING VESSELS AT NEW BEDFORD, MASS., IN OCTOBER, 1901.

pilot whale, the beluga or white whale, and many species which are not popularly known as whales, including the narwhal, grampus, orca or killer, dolphins, porpoises, etc. The bone-bearing whales are divisible into two classes, (*a*) smooth whales and (*b*) furrowed whales, or rorquals. The first embraces the right whales of different species and the bowhead or Arctic whale, all of which are prized for their oil and baleen. Of the rorquals, or those whales possessing longitudinal folds of blubber on throat and stomach, may be mentioned the humpback, finback, sulphur-bottom, and California gray whale. As these are ordinarily difficult of capture and are of minor value, the whalebone being rather short for commercial use, they have not been pursued so extensively as have the sperm, right, and bowhead whales. In the United States markets the standard varieties of oils are "sperm oil" and "whale oil," and sometimes "humpback oil." "Whale oil" is a mixture of the product of all whales except the sperm whale, and sometimes includes that of black-fish and walrus.

The use of whale oil appears to be of ancient origin. Doubtless it was first obtained from whales accidentally stranded on the shores, a more frequent occurrence during the early abundance of the cetaceans than at present, when their numbers have been so greatly reduced by excessive fisheries. As the demand for the oil increased beyond the supply available from stranded whales, individuals sighted from the shore were attacked and beached. Owing to the frailty of the boats and equipment, this was a more daring attempt than might be supposed. It is difficult to trace the origin of the fishery, but certainly it was prosecuted a thousand years ago.

Just prior to the Revolutionary war, according to Starbuck and other authorities, there were 183 American vessels in the right-whale fishery of the North Atlantic waters, and 125 were engaged in cruising for sperm whales from Newfoundland to the coast of Brazil. The Revolutionary war and the war of 1812 interfered with the fisheries; but during the period of peace following 1815 they increased greatly in extent until 1846, when the fleet numbered 678 ships and barks, 35 brigs, and 22 schooners, a total of 735 vessels, with an aggregate tonnage of 233,189 tons, and a value of $21,075,000, exclusive of outfits and supplies. The entire capital invested in the fishery and its associated industries at that time approximated $40,000,000, and 40,000 persons derived from it their chief support. During the same year the whaling fleet of all Europe numbered but 230 vessels. The crude value of the American catch from 1840 to 1860 averaged about $8,000,000 annually. The greatest value was in 1854, when 2,315,924 gallons of sperm oil worth $1.48¾ per gallon, 10,074,866 gallons of whale oil worth 59⅝ cents per gallon, and 3,445,200 pounds of whalebone worth 39⅙ cents per pound were secured, the total value being $10,802,594. In the preceding year, 1853, the total product was 3,246,925 gallons of sperm oil, 8,193,591 gallons of whale oil, and 5,652,300 pounds of whalebone, the whole valued at $10,766,521.

Sperm oil and whale oil then served nearly all the diversified uses for which oil was required, the chief exception being leather-dressing, for which neatsfoot and cod oils were largely employed. The principal uses were as illuminant, lubricator, in cordage-manufacture, screw-cutting, and steel-tempering. The streets of the principal cities were lighted with the oil, and theaters and public buildings were lighted with gas made from the foots. A stock anecdote at the time referred to foreign sailors climbing up the posts of the New York street lamps to drink the whale oil, thus leaving the city in darkness.

The extent of the fisheries soon began to tell on the abundance of the whales, necessitating much longer and more costly voyages, and consequently higher prices for the products. With the increased price came the active search for substitutes, and colza oil and lard oil were largely employed. The competition, however, had little effect on the market for whale products until the adoption of petroleum as an illuminant, and subsequently as a lubricant. Its dangerous qualities at first greatly checked its use, but as improved methods of refining were introduced it was quite generally adopted and proved most influential in decreasing the profits of the whale fishery.

The restricted market and the reduced price resulted in a gradual decrease of the whale fishery. Various agencies accelerated this decrease, while others retarded it. Among the former may be mentioned the destructive influences of the civil war, including the sinking of 36 vessels in blockading Charleston Harbor, and the burning of 46 vessels, with outfit, supplies, and cargoes by privateers; also the loss of 33 ships in the ice of the Arctic Ocean in 1871, and a similar abandonment of 12 vessels in 1876. Among the agencies tending to retard the decrease in the fishery is the greatly enhanced value of whalebone, which increased from 13 cents per pound in 1833 to $7 per pound in 1891. Indeed it is the whalebone market alone which sustains the present right-whale fisheries of the world. The table on page 204, showing the annual product of sperm oil and whale oil from 1860 to 1902, inclusive, presents a fair idea of the gradual reduction in extent of the American whale fisheries. Owing to the decreased extent of the fishery, sperm whales are increasing in numbers and are apparently more abundant at present than at any time since the fifties. The bowhead and right whales, however, are doubtless more scarce than at any time since their capture became an object of commercial pursuit.

In 1901, the 20 sperm-whalers cruising in the Atlantic Ocean met with good success, especially those on the Hatteras and Charleston grounds, securing 12,550 barrels of oil, according to the *Whalemen's Shipping List*, an average of 627 barrels to each vessel. The same season in the Arctic and North Pacific, however, was the poorest for many years. The fleet there consisted of 11 steamers and 6 barks. Three steamers were lost, and the total catch was only 43 bowheads and 13 right whales, as compared with 80 bowheads and 14 right whales in 1900. The yield of oil approximated 2,870 barrels, and of whalebone 105,150 pounds. Five barks were employed in sperm-whaling off the coast of Japan, taking 4,100 barrels of oil. The market for sperm oil in 1901 opened at 55 cents per gallon, but gradually increased and closed the year at about 68 cents per gallon. The price of whale oil at San Francisco was 32 to 38 cents and in the Eastern markets 38 cents per gallon.

In 1902 the whaling fleet of the United States consisted of 8 steamers, 18 barks and brigs, and 12 schooners, aggregating 8,366 tons. Of these, 11 barks and 10 schooners were sperm-whale fishing in the Atlantic Ocean, 8 steamers in the Arctic, 6 barks in Okhotsk Sea and off the coast of Japan, 2 schooners in Hudson Bay, and 1 brig at Desolation Island.

The total whale-oil product of the world at present approximates 3,000,000 gallons yearly; of which 750,000 gallons are produced by the United States fisheries, 900,000 by those of Norway, and the remainder by Scotland, Russia, Japan, Newfoundland, and other countries.

THE BLUBBER AND ITS YIELD OF OIL IN DIFFERENT WHALES.

The blubber is a layer or blanket of fat lying between the skin and the flesh or muscles and encompassing the bodies of all cetaceans and likewise of most of the other aquatic mammals. It varies in thickness from 1 to 22 inches, according to the species, size, and condition of the animals. The blubber of right whales is thicker, on an average, than that of the cachalot or sperm whale, although an individual of the last-named species has afforded fat 22 inches thick. The blubber of most species is tough and elastic, but that of the humpback is soft and yielding, and the ropes and chains encompassing it tear out easily. The blubber of poor whales is hard, compact, and tenacious; but when the animals are fat it is softer and yields oil readily, even when handled. In color it varies from a yellowish or dirty white to a somewhat unusual pinkish or reddish cast. The whitish blubber is usually found on young whales, more especially sucking calves, and is of a milky appearance. That of old whales has a coarse grain, and yields or gives out the oil freely; hence it is not so difficult to boil as is the fat of young whales, from which it is almost impossible at times to extract the oil, the texture being so fine and close.

In case of the baleen whales the blubber from all parts of the animal is commingled and boiled together. With the sperm whale, however, the process of saving the oil is different. The most valuable oil of this species is found in a large cavity or reservoir known as the "case," situated anterior to the cranium, which yields clear oil and spermaceti, in equal quantities. These products are known as "head matter." Lying beneath the case is a wedge-shaped mass of pinkish fat, composed of oil, spermaceti, and "white horse," the last being an extremely tough and sinewy blubber-like substance found about the head and neck, as well as upon other parts of the whale. The lower anterior portion of the junk, known as the "nib end," is similar to the body blubber and devoid of spermaceti. Spermaceti is also found on certain parts of the body, especially in the core of the "hump" and about the "ridge," situated along the back toward the "small," but not in so great abundance as in the case. The yield of the head averages about one-third of the total oil-product of the sperm whale. Instances have been reported, however, in which it has been 50 per cent and even as high as 60 per cent of the total.

The following parts in the sperm whale are utilized as an oil-yielding product: The body blubber, case, junk, hump, ridge, lower jaw, head skin, scalp, small flukes, vertebræ, and fin bones. The bones of all whales are porous or spongy in texture, and the cavities are filled with more or less oil. The small bones, such as the fin bones and the vertebræ, as well as the "pans," or broad posterior extremities of the lower jaw-bone, are chopped up with axes and boiled out. The cranium, or, as it is known to whalemen, the "scalp," is generally thrown overboard, but sometimes it is chopped up and boiled. The "head skin," or the great mass of fat covering the scalp, may be rendered if whales are scarce, but when they are plentiful its utilization is not profitable. Some of it is exceedingly tough, and the small quantity of oil it contains is difficult of extraction.

Whales are generally rated by the amount of oil which they yield rather than by the size or length. The yield is expressed in barrels, and an animal may be a "40-barreler" or a "100-barreler." In appearance they are often deceptive, the largest ones not always yielding the greatest amount of oil. Usually the whalemen approximate the product with remarkable accuracy, but sometimes their guesses miss the mark widely. Blubber yields about 75 per cent of its weight in oil, 4 tons of blubber producing about 3 tons of oil, each containing 252 gallons wine-measure. Sperm whales yield from 5 to 145 barrels of oil, averaging about 25 or 30 for the cows and 75 to 90 for the bulls.

The oil-producing parts of the right whales are the body blubber; the tongue; the head gear, comprising the head, scalp, throat, lips, and head skin; and the blubber on the fins. The right whales yield a larger quantity of oil than the cachalot, and the bowhead or Arctic whale yields a larger quantity than the right whale of temperate waters. In 1861 the *General Pike*, of New Bedford, took a right whale on the Kadiak ground which stowed down 274 barrels of oil. The schooner *Lizzie P. Simmons*, New London, killed a bowhead whale on October 28, 1882, in Cumberland Inlet, which yielded 2,550 pounds of whalebone and 6,000 gallons of oil, the value of the former being $7,687 and of the latter $3,500, a total of $11,187 from a single animal. According to whalemen, the right whales now captured are not so large as formerly, but the sperm whales seem to average about the same.

The humpback whales and the finback whales of all oceans are frequently captured by deep-sea whalemen and often by shore whalemen, especially in the Finmarken fishery. Since both of these varieties usually sink when killed, they are rarely hunted except "on soundings." The oil-yielding portions of the humpback are the body blubber; head skin; lips, which are small; tongue; entrail fat, the source of a large percentage of the oil, and the striated folds of fat on the breast and abdomen. The entrail fat resembles very closely in appearance the corresponding fatty substance of the ox; its oil is of the same grade as that of the blubber of this species, which is equal in grade to the oil of right whales.

Not only are the oil and whalebone yielded by finback whales much less in quantity, but they are also inferior in quality to those obtained from the right whales. For this reason, and also on account of their great activity and the difficulty of capturing them by harpooning, they were formerly neglected by whalers; but since the employment of steam vessels with bomb guns and explosive lances an extensive fishery for them has been established on the Norwegian and Newfoundland coasts and minor fisheries on the coasts of Russia and Japan.

The California gray whale is occasionally taken in the lagoons of Japan and on the west coast of the United States. The oil-bearing parts of this species which are utilized are the body blubber, head skin, throat, lips, flukes, and entrail fat. According to Capt. George O. Baker, of New Bedford, during several years following 1866 a brig from New Bedford, Mass., made quite a business of catching California gray whales for the food markets of Japan.

The bottle-nose whale, so called from the peculiar shape of its head, yields on an average about 12 barrels of oil. The principal places where this species is caught are along the edges of the ice fields of northern Europe, between Bear Island and Iceland, the fishery being prosecuted principally by Norwegians hailing from Tönsberg and Sandefjord. Like the sperm whale, the bottle-nose possesses a quantity of oil in the cavity of the head, which yields spermaceti in the process of refinement. The blubber oil of the bottle-nose comes next to sperm oil in quality. It gives no residuum, and is therefore employed for lubricating small machines, spindles in mills, etc.

Besides the above, a number of minor cetaceans are occasionally utilized for their oil; among them the orca or killer whale, the narwhal, the beluga or white whale, the black-fish, and the porpoise. These have a coating of blubber ranging from one-half to 4 inches in thickness, and, although not extensively sought after, many are taken in various parts of the world.

The beluga is plentiful in the Arctic seas and in the North Pacific and comparatively numerous on the Labrador coast and in the St.

Lawrence River, where it forms the object of a small but profitable fishery. The steam-whalers sometimes pursue and capture it in great numbers in the Arctic, but only when the Greenland whale can not be found, for the yield of oil is small and the animal is so swift and active that it is not readily captured. The adult is from 10 to 15 feet in length, and of a creamy white color. The blubber is about 2 inches thick, and each animal yields from 20 to 100 gallons of oil excellent in lubricating qualities.

The orca affords a good variety of oil, but owing to its aggressiveness it is not often attacked by the whalers. It has occasionally been captured on the New England coast, and has also been taken on the west coast of Africa, especially off Walfisch Bay. The blubber is 2 or 3 inches thick, and similar in color and texture to that of the sperm whale.

The narwhal yields a small quantity of oil, which is used considerably by the Eskimos and Greenlanders. It is ordinarily very pale in color, in fact almost colorless. The narwhal is not usually an object of pursuit by our whalemen, as its capture is surrounded with many difficulties, owing to its retreats in the ice floes. The valuable black-fish and porpoise oils are discussed in a separate chapter.

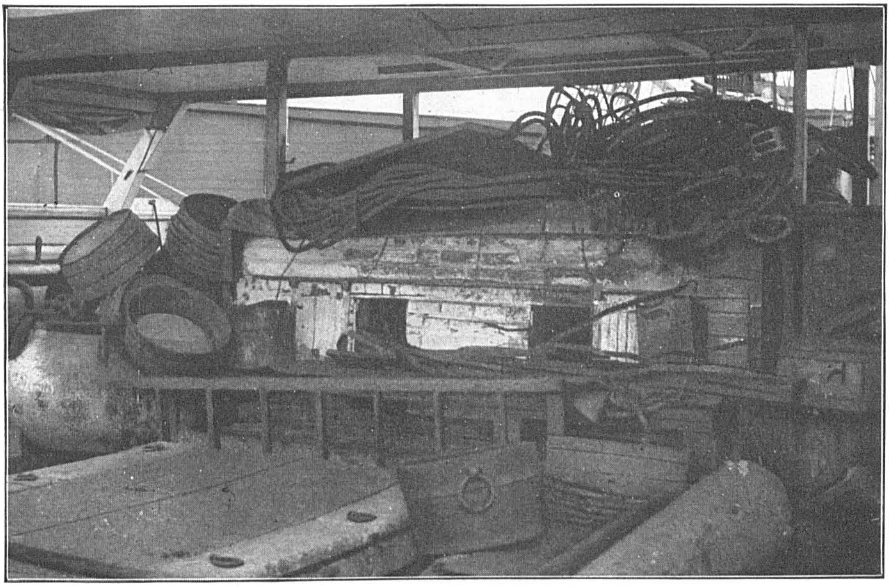
The following tabulated statement of the yield of oil from the several species of cetaceans has been prepared with much care after consultation with the most experienced whalemen of various ports:

Species.	Yield of oil in barrels of 31½ gallons.	
	Variations.	Average.
Right whale, Pacific	25 to 250	90
Right whale, Atlantic	25 150	75
Bowhead	30 250	100
Sperm whale	5 145	45
Humpback, Pacific	10 110	42
Humpback, Atlantic	10 100	40
Finback, Pacific	10 70	35
Finback, Atlantic	20 60	38
California gray whale	15 60	30
Bottle-nose whale	4 25	12
Orca or killer whale	1 6	2½
Beluga or white whale	¾ 3	1¼
Black-fish	⅛ 4	1⅛

The methods of cutting-in and removing the blubber have already been described by numerous writers, and especially by James Temple Brown,[a] rendering unnecessary any extended description in this paper. Suffice it to state that the whale is attached to the side of the vessel, and by cutting in a spiral line and at the same time rolling the cetacean, the blubber is removed in a helical strip 5 or 6 feet wide, and this is boarded in lengths of 12 or 15 feet, called "blanket-pieces." The manner of doing this and of boarding the head gear is germane to nautical engineering rather than to the subject of oil-rendering.

[a] Fishery Industries of the United States, Vol 2, Sec. 5, p. 278.

REMOVING BLUBBER FROM WHALE BEACHED ON CALIFORNIA COAST.



TRY-WORKS ON MODERN WHALER, LOOKING AFT.

CONVERSION OF THE BLUBBER INTO OIL.

The following notes on the present methods of converting whale blubber into oil are the results of inquiries and investigations made by the writer during the last four years, and especially in October, 1901, when many practical whalemen were interviewed. Especially are we indebted to Capt. George O. Baker, Capt. Charles H. Robbins, Capt. James Avery, and Mr. W. R. Wing, of New Bedford, Mass.

The reduction of oil from the solid mass of blubber, though tedious in detail, is an operation of simple character, requiring merely that the substance shall be exposed to heat. The blanket-pieces, 12 or 15 feet long and 5 or 6 feet wide, are first "leaned," consisting in removing the pieces of muscles which cling to the fat during the process of cutting-in. By means of spades they are cut into smaller sections, called "horse-pieces," about 2 feet long and 6 inches wide. These are passed to the mincers. If the blubber is too thick, say over 12 inches, it is sometimes split before it is minced.

Two methods of mincing the blubber are employed, viz: by hand and by machinery. The former was the first adopted and is generally used at the present time. It is extremely laborious, but most whalemen prefer it, since the pieces are minced more uniformly and consequently the oil boils out more freely. The horse-pieces are laid lengthwise and with the flesh side downward upon a bench called the "mincing-horse," and are scored or cut into slices varying from one-fourth to three-fourths inch thick, called "minced horse-pieces." The knife cuts through the skin, but is stopped within about an inch of the base, so that the slices are held together like the leaves of a book, and in this condition they are pitched into the try-pots.

The try-works are built of brick athwartships between the foremast and the mainmast. The usual dimensions are 8 or 10 feet long, 7 or 8 feet wide, and about 4½ feet high. The first course of bricks, or the base, is laid in openwork, forming channels through which the water may freely circulate. The fireplaces, or "arches," as they are known aboard a whale ship, are strengthened by pieces of iron and are furnished with sliding doors. Two large metallic try-pots are placed within the try-works, with their bottoms resting upon the arches or furnaces. These are shaped like the old-fashioned 3-legged pots so intimately associated with the domestic hearths of our forefathers. They range in capacity from 120 to 200 gallons each.

While boiling the blubber, the fires are kept up day and night. Naturally, the fuel supply is an item of no small consideration to the whalemen. A quantity of cord-wood, each stick sawed into two pieces, and all kinds of refuse wood are included in the vessel's outfit and relied upon for starting the fires. But when fairly under way the highly combustible residue of the fat, known as "scrap," is mainly depended upon. Once in awhile a whale is secured so fat that the scrap is not sufficient to keep the fires going and the "fat lean" and similar materials are burned, and sometimes even a part of the rich blubber is consumed as fuel in order to save the remainder.

It is well known that the boiling point of oil far exceeds that of water. So intense is the heat at times that the solder upon the implements used about the pots is melted. It is important that all water should be expelled in order that the oil may not become rancid when barreled. It is equally important that every precaution should be taken to prevent water from getting into the pots during the process of boiling, the action of the oil under such circumstances depending upon the quantity of the extraneous fluid which is suddenly brought in contact with it. If the pots are not sheltered heavy rain may cause the oil to foam up, and when the vessel ships a heavy sea or when a very heavy rainstorm occurs, the contents of the pots are apt to throw up an immense cloud of steam and scatter the seething oil. Communicating with the fire, the oil is ignited with a flash, and the streams of burning liquid pour out upon the deck, sometimes with disastrous effect. As soon as the contents of the pots show a tendency to boil over, pieces of fresh blubber are pitched in, and if this is not sufficient the fire is immediately banked.

To prevent the vagrant pieces of lean which have accompanied the blubber from clinging and burning to the side and bottom of the pot and thus darkening the oil, the boiling mass is vigorously stirred. This is one of the most important duties in the process of oil-rendering.

Instruments are never used on a whale ship for testing the heat or culinary condition of the oil; the men rely mainly on their experience as to the best time for removing it, judging either by the color of the scrap or by spitting into the boiling mass, this producing a peculiar crepitating noise when the blubber has been sufficiently cooked.

As fast as the pieces of blubber are resolved into oil, the residuary fragments are transferred to a rough box called the "scrap-hopper" or "strainer-cooler." Its size depends upon the dimensions of the try-works, but usually it holds from 1 to 1½ pots of scrap. It consists of two compartments, the upper portion, or hopper, for the scrap and the lower part for the oil, the two separated by a wooden partition containing numerous holes, so that the oil may readily drain from the material.

The best and most economical way of utilizing the scrap has always been an important problem to the whalemen. The body of the sperm whale usually boils out freely, and consequently the scrap is dry, contains little oil, and is valuable only as fuel. The refuse of the right whale, however, retains considerable oil, and the whalemen are averse to burning it until after they have extracted the oil by compression. The scrap from both the sperm and the right whales is regarded as an important fuel supply and is economically saved at each fare during the voyage and used for boiling the blubber of whales taken subsequently.

Although the oil may be thoroughly cooked when the first scrap is removed, it is not bailed off, the usual plan being to fill the pot with fresh blubber and again boil it down until the pot is full. In this manner the hot oil melts the cold blubber and the latter reduces the temperature of the oil already rendered.

The bones of cetacea contain more or less oil, but they are utilized in oil-rendering only when whales are scarce. On a good voyage the endoskeletons are thrown overboard as fast as the coating of fat is removed, provided they are not required for fuel.

The blubber of the "small" and the lobes of the flukes are cut into horse-pieces and boiled out with the body blubber, being of the same nature. The entrail fat of the humpback whale may be boiled by itself or with the blubber, whichever is more convenient, the oil of the fat and that of the blubber being of the same grade. The fins of the sperm whale are cut up with spades; the fatty covering is boiled with the body blubber, and the bones with the fat-lean. The oleaginous covering of the fins of the right whale is cut into horse-pieces and boiled with the body blubber; the fin bones of this species are rejected. The head skin, or the fatty covering of the crown of both the right and bowhead whales, and, indeed, the "headgear" of both, are cut into horse-pieces and run through the pots with the body blubber.

The tongue of the bowhead as well as of right whales is also reduced to horse-pieces and boiled out. The tongue blubber is close-grained, or of much finer texture than that of the ordinary blubber, and is usually boiled out last. When "green" its oil is extracted with great difficulty, if, indeed, this can be accomplished at all when cooked by itself, unless very finely minced; hence it is sometimes laid aside and run through the pots in easy stages with the body blubber of the next cut. A muscular, fibrous substance known as "plum pudding" permeates the blubber of the tongues of these two species of whales, extending longitudinally through the central part and in greater abundance near the roots. Most of it is utterly worthless and is thrown overboard when detached from the fat of the tongue. At times, however, when the fat predominates, the "plum pudding" is saved and boiled out with the tongue or the refuse of the whale. It is almost impossible to render it when cooked alone.

The "ginger rolls," or plaited folds on the throat and breast of the humpback, are cut into horse-pieces and rendered with the body blubber; but the intermediate substance, resembling "white-horse" in some respects, is extremely tough and elastic, and is absolutely worthless as an oil-yielding substance.

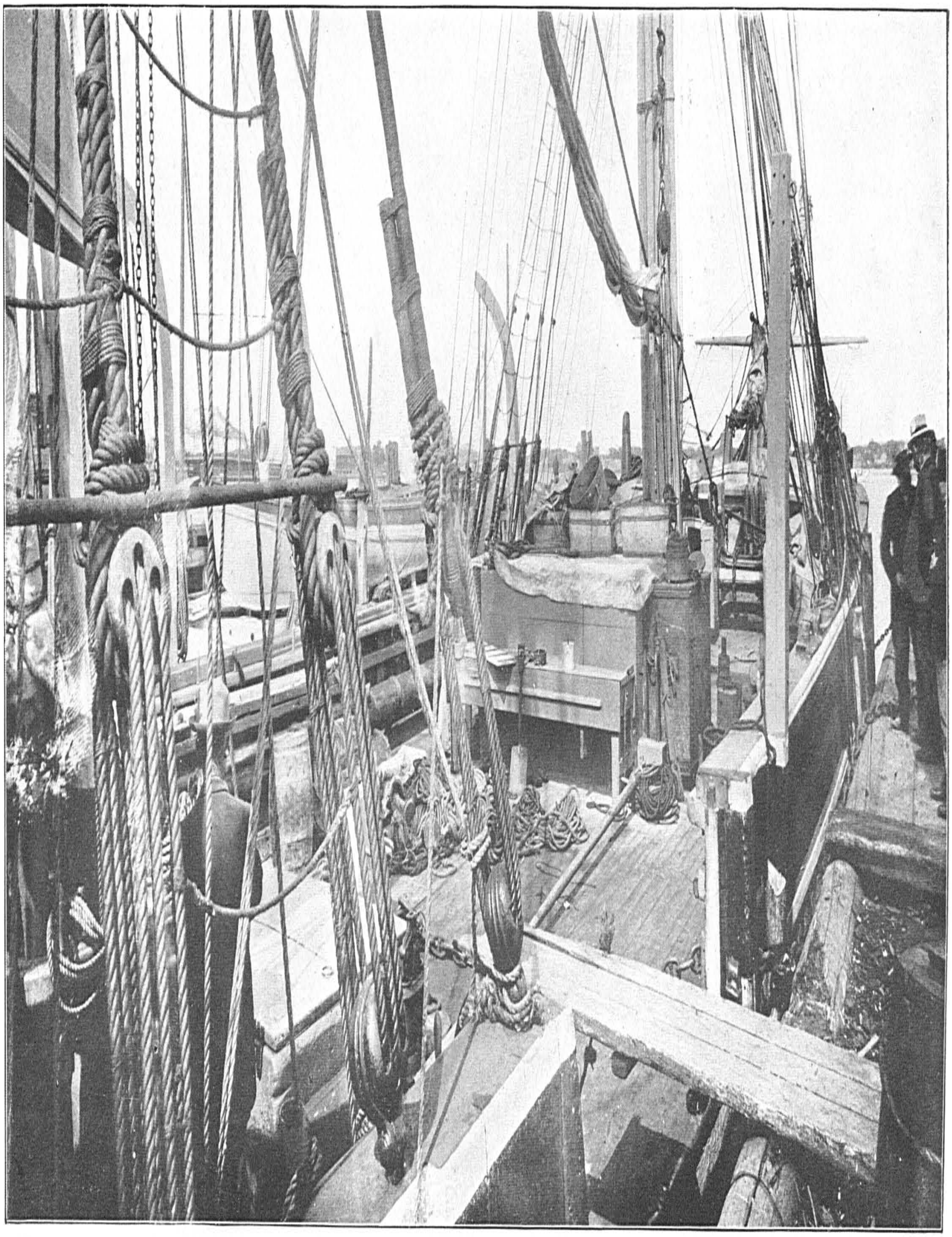
In trying out a sperm whale, either the body blubber or the head matter, including the junk and case, may be boiled out first; but they are never cooked together, since it is not policy to mix the oils, the head oil being worth a cent or two per gallon more than the body oil. The manner of preparing the case and junk for the pots being different, they will be described separately.

If the body blubber is tried out first, the head matter is deposited in junk casks as fast as it is whipped or bailed from the case. The junk is reduced to horse-pieces, placed in similar receptacles, and held in reserve with the head matter until the body blubber has been disposed of. The junk casks are ordinary oil casks with one head removed, and vary in capacity from 100 to 300 gallons each. They are also used to hold the scrap which is saved as fuel. Instead of the casks some of the larger vessels have one or two tanks between decks, which are used as temporary receptacles for the head matter and also for storing the oil.

When ready to boil out the head, the try-pots are well scrubbed, greater care being taken than when boiling the body blubber. They are next about half filled with some of the head matter as soon as it is bailed from the case, the remainder being stowed away as just mentioned. With legs and feet bare, men get into the pots and, standing in this odorous compound, squeeze out the soft pieces of fat. The oil flows freely between their fingers into the pots, while the refuse, called "twitter," is thrown into another receptacle, called the deck-pot, or perhaps into scrap-tubs. Notwithstanding the many improvements that have been made in the oil industries, no process of eliminating this membranous texture from the crude sperm oil has yet been discovered except the one just referred to—that of squeezing by hand. It is necessary to remove these fibers to prevent them from charring and darkening the oil. The case being carefully squeezed, the fires are started and the cooking then commences. The pots are spaded constantly to prevent the small but sometimes numerous particles of twitter, which have not been removed, from burning against the sides and bottoms. Meantime other men are squeezing out the remainder of the head matter deposited in the junk cases, and this is kept in scrap-tubs and poured into the pots as soon as the first installment has been properly cooked and bailed off, this operation continuing until all the head matter has been boiled out.

While the case is boiling, some of the crew cut the junk into horse-pieces somewhat larger than the body-blubber horse-pieces, and these sections, after mincing, are pitched into a pot of thoroughly cooked head matter. The hot oil of the case soon dissolves the junk, the two mingling most intimately, being of a kindred nature. Sometimes the case and the junk are boiled separately.

White-horse in considerable quantity ranges through the junk in streaks. It is tougher and whiter in large whales than in small ones. The fatty substance found between these layers, or strata, is soft—about the consistency of butter—and is of a pinkish cast, resembling somewhat in color the meat of a watermelon. The white-horse of large whales, especially of an aged male, is remarkably tough and is detached by means of sharp cutting-spades and thrown overboard. There is little oil in it, and its extreme toughness prevents it from being minced. If attempts are made to boil it out with the junk, it usually soaks up more oil than it yields. But the junk of small whales, more



DECK OF MODERN WHALER, SHOWING TRY-WORKS, SCRAP-HOPPER, AND UTENSILS EMPLOYED IN TRYING-OUT OIL.

particularly the cows, including both the white-horse and the fat, may be cut into horse-pieces, minced, and boiled out together. The process of mincing the pieces of junk and pitching them into the try-pots is identical with that previously described in connection with the body blubber. While some of the men are cutting out the white-horse and preparing the junk for the pots, others are scraping up the oil, which flows out profusely during the operations.

The hump and ridge of the sperm whale are cut into horse-pieces and boiled out with the head and with the fat secured from the jaws.

The term "twitter," which has been previously referred to as applied to the thread-like or membranous substance ranging through the contents of the case, is also applied to the lining of that reservoir. This is from 2 to 3 inches thick, glutinous, and extremely tough. In decapitating the sperm whale, especially in severing near the bunch of the neck, a very sharp spade is required to cut through this tough and elastic formation. Although it is very difficult to manipulate, an economical whaleman never throws this substance away. Since it can not be boiled out with the case, for the reason above given, it is saved and run through the pots with the fat-lean after the case and junk have been cooked.

There are two kinds of "lean," the "clear-lean" and the "fat-lean." The clear-lean, as the term signifies, is composed almost entirely of muscles, and is rejected as utterly worthless to the uses of whalemen. The fat-lean is composed of fat and lean so intermixed that separation by means of knives is impracticable. It is obtained principally about the jaw, as well as from other external parts of the whale. A large portion of it is cut from the blanket pieces during the process of leaning. When whales were abundant, the fat-lean was thrown away, but at present many, if not all, of the whalemen convert it into oil after the oil from the head and body blubber has been boiled out and bailed off. The fires are then drawn, the try-works cooled down, and the fat-lean is pitched in. This is a delicate operation, and if not performed in the proper manner there is danger of cracking the pots. Water is usually placed in the pots first and the fat-lean is pitched in until the pots are about two-thirds full, and then the twitter and lipperings are added. The fires are started, the admixture brought to the boiling point, and the works are again cooled down. When cold the oil floats upon the surface, and the water and cracklings remain at the bottom. If the process has been skillfully conducted, the oil may be almost as light and clear as any obtained from the better and purer parts of the whale. As a rule not more than two pots of this substance are boiled down, for the oil obtained from it is generally more or less sour—a result probably from either mixing it with water when boiling, or because it had become tainted through decomposition, or it may be due perhaps to both causes. This oil is usually barreled separately.

The oil obtained from the fat-lean of one whale is sometimes mixed with that obtained from the blubber of the next capture, this being effected by putting a few gallons of it into the cooling tank every time a pot of the subsequent fare is bailed off. Notwithstanding the importance of keeping the different grades of oil separate, some whalemen adulterate the blubber oil to a greater or less degree by the addition of fat-lean oil, yet they are prudent enough to save several casks of the latter grade to show on their return that the fat-lean has not only been economically saved, but also that its product has not been mixed with oils of higher grades.

The slivers, or small pieces that have been cut and hacked from the blubber while reducing it to horse-pieces and mincing it, are also saved and boiled with the blubber. The "slumgullion" and "lipperings" or "dreenings" of the blubber—consisting of a mixture of the blood which issues from the fat-lean and the salt water and oil which flows from the blubber while the men are handling it as they hoist it aboard ship, stow it away, and prepare it for the try-pots—though discarded in the palmy days of whaling, are now carefully husbanded and amalgamated. Like the sweepings of the floors of mints, this liquid refuse of the catch is refined in the whaleman's crucible in order that nothing may be lost. After the solid matter has been disposed of, both the deck lipperings and the blubber-room lipperings are usually deposited in barrels or tubs and there scalded with hot oil. The oil thus obtained is raked off and transferred to the cooling tank. In case the lipperings are not clean they are cooked with the fat-lean.

"Slush" is the skimmings from the tops of the pots, and is usually saved by the cook, who is commonly entitled to one-half of it. On arrival home it is sold to manufacturers of soap, and it is even clarified and mixed with lard. At sea the whalemen sometimes eat the slush as a dressing in the form of gravy on sweet potatoes, etc., but it is doubtful if they could be induced to eat it ashore, although it is quite clean and nutritious.

The different varieties of oils are barreled separately. A cask that has contained whale or humpback oil should be thoroughly cleansed before putting sperm oil into it, but a cask that has been used for sperm oil need not be cleansed should it be necessary to use it for whale oil; the small quantity of whale oil that might be left in the cask would perhaps make the sperm oil somewhat heavy, but a little sperm oil would not injure the whale oil. The casks of a ship engaged solely in right-whaling are not marked at all; should the vessel incidentally catch sperm whales, the casks containing oil from this species are marked S O, and the other casks are supposed to contain whale oil. Casks containing right-whale oil taken by a sperm-whaler are marked W or W O. The head oil of the sperm whale, unless the quantity be very small, is always kept in separate packages, which are marked H; those containing the body oil of this species are marked S O or Sp O. The packages of fat-lean oil bear the initials F L O, and black-fish oil B F O. Except when large catches are made, black-fish oil may be kept in meat barrels. The lettering is done in white paint, on the heads of the casks. When the oil is shipped home by another vessel the name of the ship is also branded on the cask, the impression being made with an implement called the "ship's marking iron," and the casks are numbered consecutively.

REFINING SPERM OIL AND WHALE OIL.

The rendering and care of the oil on shipboard having been described, there remains to be discussed its further treatment for commercial purposes, especially extraction of the foots and bleaching. The headquarters of the refiners of whale oils in the United States are at New Bedford, Mass., and San Francisco, Cal. Twenty years ago New Bedford monopolized the business, but large refineries have been erected at San Francisco, and at present about 20 per cent of the sperm oil and 60 per cent of the whale oil are refined at that port. The subjoined description is prepared almost wholly from information furnished by the principal refiners of New Bedford in 1901. The writer wishes especially to acknowledge, in this connection, the courtesies of Messrs. William A. Robinson & Co., and of Messrs. Frank L. Young & Kimball.

As received at the refineries, the casks of oil have been inspected and gaged by customs officers. They may have been kept in storage for months, and in some cases years, before reaching the refiner. Formerly, on the wharves at New Bedford might be seen thousands of casks filled with oil awaiting sale, being preserved from great leakage in the meantime by a covering of seaweeds; but in recent years the quantity has been much reduced, and on the occasion of the writer's last visit to New Bedford (October, 1901) not a single barrel of oil was on the wharves.

The oil is of two principal kinds, viz, sperm oil and whale oil, the former being obtained from sperm whales and the latter from all other varieties of whales and also from walrus, black-fish, sea-elephant, etc. It ranges in color from clear amber to very dark brown, depending on the variety of animal, the condition of the blubber, and the success of the rendering. The quality is determined by appearance, odor, and flavor. There is some difference in the value of crude oil of the same species of whale from Northern and from Southern seas, the former selling for a few cents more per gallon. Crude sperm oil was formerly worth about double the value of whale oil, but in recent years the difference has been much less. Little use is made of unrefined sperm oil, but considerable of the product of whale oil is sold in a crude state to steel-workers, miners, and cordage-manufacturers.

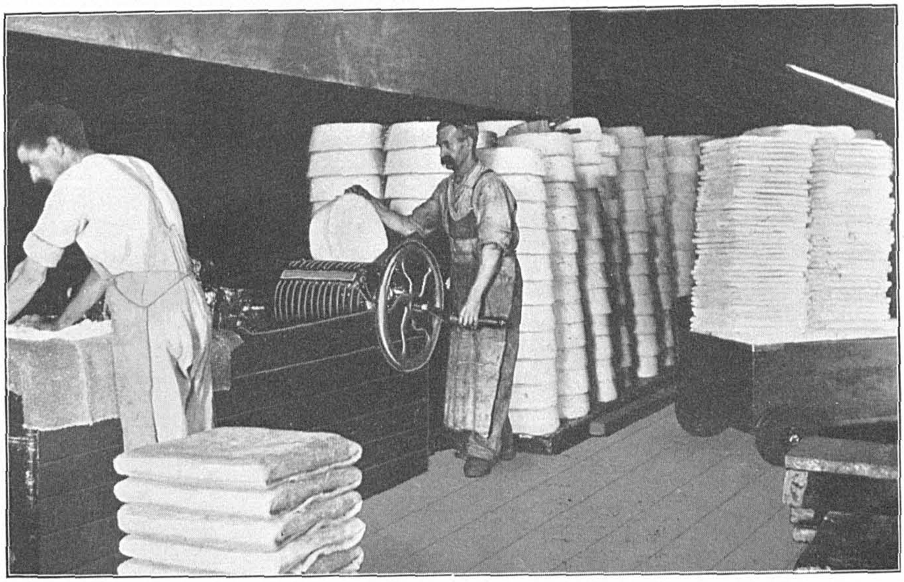
The products from refining sperm oil are the "winter sperm," which is the first running from the crude oil after it has been granulated by refrigeration; the "spring sperm"; the "taut-pressed," and spermaceti. The refined sperm oils are not generally sold in their natural color, however, but are usually bleached by a process which leaves "sperm-oil soap" as a product. The products of whale oil, including that of walrus, black-fish, sea-elephant, etc., are the winter, spring, and summer pressings, a tallow-like substance known as whale foots, and "oil soap."

Sperm oil.—The two varieties of oil obtained from sperm whales, viz, body oil and head matter, differ greatly in appearance. The former is of a light straw color, while the latter when first taken from the head of the whale is as clear and limpid as water, but after a short time thickens and hardens into a white mass. Each animal is supposed to yield about two-thirds body oil and one-third head matter. These are kept separate on shipboard, but when received at the refineries they are generally mixed in natural proportions and together submitted to the processes for separating the oil and spermaceti.

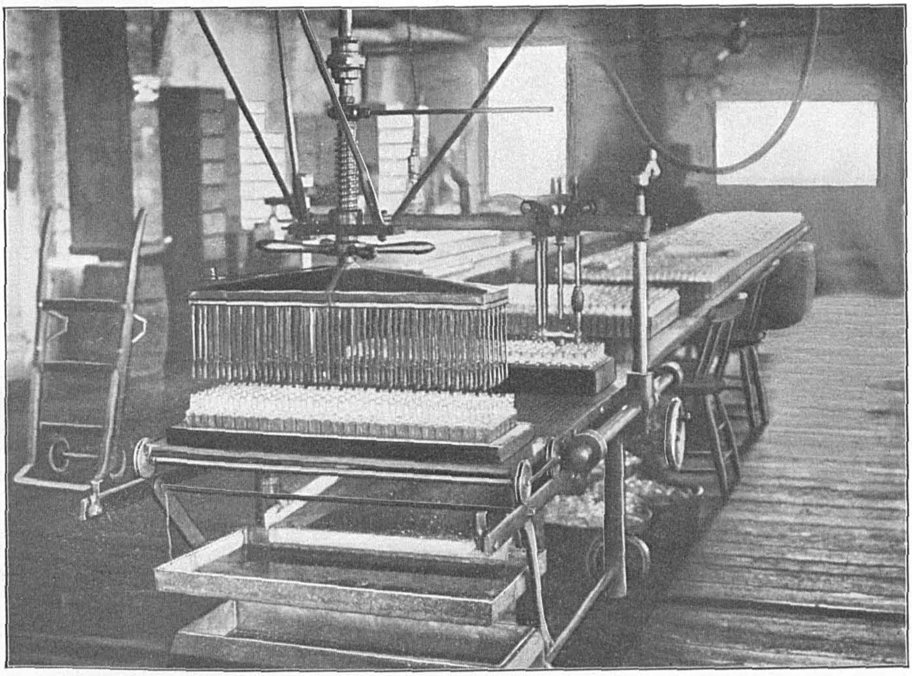
In the process of refining, the crude oil is drawn from the casks and heated for the purpose of driving off all the water. This is conveniently done by running it into large iron tanks of several hundred, or even thousand, gallons capacity, where it is subjected to heat by means of coils of steam-pipes running around the inside of the tanks. When heated in excess of 212° F. all moisture is soon expelled, and the oil resists water; that is, water will refuse to mix with it and will "snap" when dropped into the oil. By continuing the heating from six to ten hours the crude oil is converted into a clear liquid state, all particles of fat and blubber boiling out and the impurities settling at the bottom of the tank. The steam is then shut off and, after the oil has partly cooled, it is drawn off from the top of the tank into barrels or casks with capacity of about 50 gallons each. The sediment which precipitates at the bottom is drawn off and made into soap.

In the barrels the oil is chilled. In cold weather, from December 1 to March 31, this is done by exposing the barrels and their contents to the weather; but during the balance of the year it is necessary to place them in large covered pits, where the oil is frozen by using ice and salt packed among the barrels. To avoid the expense of artificial refrigeration, it is preferable to do the refining during the winter season.

After remaining in the pit from ten to fourteen days, at a temperature of about 32° F., the oil is thoroughly chilled, shrinks, and separates or granulates into little balls or grains. It is then removed from the refrigerator, shoveled from the barrels into canvas or hempen bags holding from 2 to 4 gallons each, and placed in a press, where it is subjected to a pressure of from one to two thousand pounds to the square inch. There is thus pressed out a clear, cold oil known to the refiners as "winter sperm oil," which will stand bright or will not congeal at a low temperature fixed as a standard. Formerly the standard was 32° F., but at present the usual commercial test is 38° F. Oil of 23° F. test has been prepared, but there was no demand for it. Since the lower the temperature at which the congealed oil is pressed the less the quantity yielded, it is not desirable to use any lower temper-



GRINDING AND PRESSING CRUDE SPERMACETI FOR REMOVAL OF TAUT-PRESSED OIL.



INTERIOR VIEW OF OIL REFINERY. FILLING BOTTLES WITH SPERM OIL.

ature than required. When producing oil of 38° F. test, the amount of "winter sperm oil" yielded is about 75 per cent of the original quantity. In former times when a 32° F. test was used, the "winter sperm oil" was about 67 per cent of the original bulk. This may be sold either in its natural state or bleached. It is used principally as a lubricant, and, to a less extent, as an illuminant in mines.

After the "winter sperm oil" has been pressed from the bags there remains in them a solid of a brownish color, which is again submitted to pressure at a warmer temperature, say 50° to 60° F., and there is produced an oil known as "spring sperm oil," which congeals at the test of 50° to 60° F. above noted. The quantity of "spring sperm oil" is about 9 per cent of the original quantity of crude oil.

The solid now remaining in the bags is emptied into receptacles and, after remaining for several days at a summer temperature, is dumped out in the form of solid cheese-like cakes. These are stored where the temperature is kept at about 80° F. and in the course of a week or so are shaved up by revolving knives and again bagged and subjected to a pressure of about 100,000 pounds to the square inch. This yields a third grade of oil called "taut-pressed oil," which will chill at a temperature of 90° to 95° F. The quantity of oil of this grade is about 5 per cent of the original bulk, making a total of 89 per cent of refined oil obtained. The residue in the bags after the extraction of "taut-pressed oil" is crude spermaceti of a brown color, which will melt at a temperature of 110° to 115° F. The methods of refining spermaceti are set forth on page 245.

As refined at the present time, sperm oil, including both body oil and head matter, yields about 11 per cent of crude spermaceti and 89 per cent of refined oils, in the following proportions: 75 per cent of "winter sperm," 9 per cent "spring sperm," and 5 per cent "taut-pressed oil." A barrel of crude sperm oil of 31½ gallons, weighing 231 pounds, yields 25 pounds of refined spermaceti, 23.6 gallons of "winter sperm," 2.8 gallons of "spring sperm," and 1.5 gallons of "taut-pressed oil." The prices of these (January, 1902) are: Spermaceti, 23 to 24 cents per pound; winter sperm, 75 to 77 cents per gallon; spring sperm, 60 to 61 cents; taut-pressed, 50 to 53 cents, and sperm soap 3 cents per pound; a total of about $24.50 resulting from one barrel of crude oil.

Sperm oil is one of the most characteristic and valuable oils in commerce. It is very generally conceded to be the best lubricator in existence for light, rapid machinery, such as the spindles of cotton and woolen mills, its viscousness, tenacity, and high flash-point causing it to work with great uniformity and with a small amount of friction. But there are many cheap substitutes—made from petroleum principally—which, though not so good, answer the purpose nearly as well; consequently the demand for sperm oil is far less than formerly, and even much of that sold as sperm contains a large admixture of hydrocarbon and other oils.

Whale oil.—The color of whale oil depends on the "age" of the blubber, or the time that elapses between the death of the whale and the trying-out of the oil. Usually it is brown, much darker than sperm oil, with a slightly disagreeable odor. 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. The first boiling and freezing processes are the same as with sperm oil. When removed from the refrigerator the congealed mass is usually dumped on woolen strainers, 2 feet wide and from 10 to 20 feet in length, stretched across frames. The process of straining is employed to reduce the bulk, since much oil will pass through the woolen cloth and leave a less quantity to be pressed. The thick part remaining on the strainers is placed in bags, as in case of sperm oil, and subjected to great pressure. The first oil from the press congeals at 36° to 40° F. and is called "winter whale oil." The foots or stearin that remains in the bags, averaging one-tenth of the original bulk, and about the consistency of leaf lard, is usually white and clean. This may be reheated and refrigerated, and upon a second pressing yields "spring whale oil" of a higher degree test; but this is not frequently done.

The oil with the foots removed may be sold in its natural color or it may be bleached. One-eighth of the whale oil and probably half of the sperm oil is bleached by the refiners. In this process it is first placed in the refining tanks and heated. When partially cooled the water and sediment are drawn off from the bottom of the tank, and while the oil is agitated or stirred some soda ash or caustic soda is added. This so acts on the oil as to cut the gum, and the thick part settles to the bottom, leaving the oil clearer and of a lighter color. It is also accomplished by exposing the oil under a glass roof to the sunlight for a few hours, or even days, in large shallow vats or pans from 3 to 12 inches deep, each with capacity for several hundred gallons.

The refuse in the bottom of the tanks is drawn off and boiled down into oil soap, which is worth about 3 cents per pound. The first bleaching will give about 2 per cent in hard soap, the second and third each give about the same. If the oil is clear and sweet the first bleaching is sufficient. Much of the oil soap is shipped to California, Florida, and other fruit-growing sections, where it is employed as a wash for trees to protect them from the ravages of insects. It is also used to some extent in fur-dressing.

In the usual pressings, the oil of the right whale taken in high northern latitudes gives about 8 per cent of foots or stearin; if taken in the vicinity of the equator, or south of it, about 15 per cent of stearin is yielded. Humpback and finback oils yield about 12 per cent of foots; sea-elephant yields 5 or 6 per cent; menhaden from 5 to 10 per cent; and seal oil yields only 3 or 4 per cent in the customary pressings. Of course this varies according to the temperature at which the oil is pressed. Tallow regulates the price, in a measure, as the stearin is substituted to quite an extent for that article. The market price approximates 5 cents per pound. It may be refined in a manner similar to spermaceti, though it is generally sold in the crude shape, packed in barrels. The chemical constituents are mainly glycerides of stearic and palmitic acids, mixed with oil. It is used principally as a sizing for yarns, smaller quantities being used in Europe for smearing sheep after shearing. Other uses are in making soaps and in filling or stuffing leather.

The various whale oils are hard and strong, and range in specific gravity from 0.900 to 0.927 at 59° F.. Oil of the right whale has specific gravity of 0.925 to 0.927 at 59° F. Oil from the humpback and likewise from the sulphur-bottom whale is somewhat lighter in weight, the specific gravity varying between 0.915 and 0.920 at 59° F. According to Brannt, the composition of right whale oil is carbon 76.85 per cent, hydrogen 11.80 per cent, and oxygen 11.35 per cent; while that of humpback and sulphur-bottom whales is carbon 77.05 per cent, hydrogen 12.05 per cent, and oxygen 10.90 per cent. Refined whale oil is extensively used in machine shops to reduce friction, particularly in cutting bolts and screws. It is also used as stuffing in leather-dressing, especially in the manufacture of chamois leather.

The following summary, compiled from the trade journals, shows the range of prices per gallon for crude sperm oil and for whale oil during a series of years ending in 1901:

Statement of the maximum and minimum prices per gallon of sperm and of whale oil each year from 1868 to 1902, inclusive.

Year.	Sperm oil, per gallon.		Whale oil, per gallon.		Year.	Sperm oil, per gallon.		Whale oil, per gallon.	
1868	$1.75 to	$2.00	$0.64 to	$1.13	1886	$0.67 to	$0.85	$0.36 to	$0.48
1869	1.59	1.93	.84	1.13	1887	.57	.65	.35	.36
1870	1.22	1.55	.63	.75	1888	.55	.62	.37	.40
1871	1.22	1.57	.54	.84	1889	.62	.68	.40	.42
1872	1.35	1.63	.62	.73	1890	.58	.65	.42	.50
1873	1.40	1.55	.52	.68	1891	.63	.68	.50	.54
1874	1.50	1.66	.57	.63	1892	.63	.65	.50	.53
1875	1.48	1.84	.62	.70	1893	.62	.90	.40	.48
1876	1.27	1.62	.55	.70	1894	.56	.62	.38	.43
1877	1.03	1.40	.50	.70	1895	.50	.56	.36	.40
1878	.81	1.05	.35	.52	1896	.35	.45	.30	.35
1879	.71	1.00	.35	.57	1897	.36	.49	.32	.38
1880	.80	1.08	.45	.57	1898	.38	.57	.31	.39
1881	.87	1.05	.50	.59	1899	.40	.61	.32	.40
1882	1.05	1.15	.57	.60	1900	.45	.60	.33	.37
1883	1.08	1.15	.56	.60	1901	.55	.68	.34	.38
1884	.87	1.05	.55	.63	1902	.62	.70	.34	.38
1885	.85	1.00	.42	.55					

In the early years of the whale fishery nearly all the sperm oil produced in the United States fisheries was exported in a crude condition, and during the period of greatest prosperity in the fishery about one-half was exported, but at present the exports in a crude state are very small. For the first time in a hundred years none whatever was exported in 1901. Most of it is refined at New Bedford, and some of the refined oil and a large percentage of the spermaceti are exported. Of the whale oil the greater part is consumed in this country.

The annual product of sperm and whale oils, quantities exported, and quantities consumed in this country, are shown in the following:

Table showing, in barrels of 31½ gallons each, the production of sperm and whale oils by the whaling fleet of the United States, the export to foreign countries, and the home consumption from 1860 to 1901.

[Compiled from the Whaleman's Shipping List.]

Year.	Sperm oil.			Whale oil.		
	Production.	Export.	Home consumption.	Production.	Export.	Home consumption.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
1860	73,708	32,792	38,507	140,005	13,007	143,009
1861	68,932	37,547	31,091	133,717	49,969	105,839
1862	55,641	27,970	27,759	100,478	68,583	67,254
1863	65,055	18,396	32,527	62,974	11,297	65,352
1864	64,372	45,000	30,100	71,863	12,000	62,528
1865	33,242	20,158	27,606	76,238	1,600	64,107
1866	36,663	10,630	19,133	74,302	618	69,534
1867	43,433	25,147	22,968	89,289	18,253	58,836
1868	47,174	18,916	23,258	65,575	9,885	72,390
1869	47,936	18,645	17,230	85,011	3,842	56,236
1870	55,183	22,773	28,812	72,691	9,872	68,452
1871	41,534	22,156	33,528	75,152	18,141	63,011
1872	45,201	24,344	24,052	31,075	1,528	42,852
1873	42,053	16,238	24,190	40,014	2,153	33,881
1874	32,203	18,675	21,768	37,782	3,300	44,357
1875	42,617	22,802	18,453	34,594	5,424	31,860
1876	39,811	23,600	14,473	33,010	10,800	22,020
1877	41,119	18,047	31,737	27,191	6,390	20,501
1878	43,508	32,769	11,124	33,778	14,371	12,557
1879	41,308	11,843	23,315	23,334	7,374	24,885
1880	37,614	12,283	17,750	34,776	4,385	23,856
1881	30,600	16,600	25,275	31,650	6,450	32,000
1882	29,844	13,006	13,053	23,371	4,421	21,425
1883	24,595	13,996	17,324	24,170	4,543	19,052
1884	22,080	5,143	15,481	24,070	2,343	23,777
1885	24,203	7,554	18,279	41,586	5,384	50,529
1886	23,312	3,118	15,170	27,249	18,253	9,176
1887	18,873	4,955	14,953	34,171	8,205	34,786
1888	16,265	1,345	21,410	17,185	8,578	7,747
1889	18,727	5,823	13,339	14,247	440	12,667
1890	14,480	2,000	11,015	17,565	4,366	14,549
1891	13,015	3,218	14,412	14,837	608	13,864
1892	12,944	1,787	12,757	13,382	291	12,746
1893	15,253	1,165	11,088	8,110	1,064	6,721
1894	16,333	1,720	7,764	9,720	276	8,379
1895	16,585	1,225	15,949	4,000	825	4,534
1896	15,124	215	20,419	4,800	500	5,050
1897	15,050	280	18,020	3,600	422	3,178
1898	12,520	1,952	11,848	5,205	675	4,450
1899	11,903	550	13,095	3,827	....	3,997
1900	18,525	1,100	17,973	5,510	500	3,410
1901	14,910	....	17,900	2,930	....	4,530
1902	21,970	470	[a] 18,250	4,725	400	[b] 4,325

[a] On hand Jan. 1, 1903, 3,600 barrels sperm oil. [b] There was no whale oil on hand Jan. 1, 1903.

PORPOISE AND BLACK-FISH OILS.

Among the minor oils of technical importance are those of porpoise and black-fish, which are nearly equal in texture and are used for similar purposes. These oils are in two grades of widely different characteristics, viz, blubber oil and head or jaw oil; the former is worth about the same as right-whale oil, or 35 cents per gallon, while the latter sells as high as $10 per gallon. They are generally known as "porpoise oil" and "porpoise-jaw oil," respectively, although the black-fish yields many times as much oil of each grade as the porpoise.

Porpoise have at times been taken in considerable quantities in shore fisheries established primarily for securing the hides for tanning purposes. 6,450 porpoise secured on the North Carolina coast in 1887 yielded 10,460 gallons of body oil; 2,283 porpoise in 1889 yielded 3,897 gallons, and 1,747 in 1890 furnished 2,746 gallons.

This oil is pale yellow to brown in color, and has a slight fishy odor, which disappears on exposure to air. The specific gravity, according to Brannt, is 0.918 at 59° F., and it congeals at about 3° F. When fresh it is indifferent to litmus paper, but absorbs acid properties from the air. It is used for tanning purposes and in compounding with mineral lubricating oils.

The sperm-whalers of the Atlantic occasionally harpoon Hatteras porpoise from the bow of the vessel and lift them aboard for food purposes. In many cases the blubber of these is removed and tried-out for oil. This blubber is of a yellowish white or pearl color, varies in thickness from ½ to 1½ inches, and is of about the same texture as that of the beluga or white whale. It is cut in longitudinal strips 4 or 5 inches wide, minced, and placed in the try-pots with other blubber. The yield of oil is usually less than 2 gallons to each animal, consequently the whalers do not often render it.

From the jaw-pans of porpoise taken more particularly for food, the whalers obtain the highly renowned "porpoise-jaw oil," which is used for fine lubricating purposes. The lower jaw is removed from the head, the pans extracted therefrom with a knife, minced, and placed in a small tin, such as a meat-can, and placed on the stove to simmer or boil gently. The quantity of oil obtained from each jaw is very small, probably about one-half pint, and the total quantity secured by the whaling fleet of New Bedford probably does not exceed 5 or 6 gallons annually, the market price of which is upward of $6 or $8 per gallon.

Some years ago the Passamaquoddy Indians on the Maine coast captured numbers of porpoise. Indeed, at one time that fishery furnished their principal means of support. As the animals were taken mostly during the winter and inshore, where food is abundant, they were very fat. The largest individuals measure about 7 feet in length and 5 feet in girth, weighing 300 pounds or more. The blubber of a large porpoise is from 1 to 2 inches thick and weighs 75 pounds and upward, yielding 5 or 6 gallons of oil, but the average for all taken was only 2 or 3 gallons. In the primitive method employed by the Indians, the blubber is stripped off and cut into small pieces, which are placed in a large pot. Inside a semicircle of large stones a fire is made, and when the stones are hot the fire is scattered and the pot containing the fat suspended over the stones and sufficient fire kept up to insure the melting of the blubber. The oil rising to the surface is skimmed off and placed in suitable receptacles. This oil, when pure, formerly sold for 60 to 80 cents per gallon, but was frequently adulterated with seal oil and sold at less price. It gives an excellent light, and also is good for lubricating machinery, as it is free from sticky characteristics and has quite a low weather-test. The superior oil in the jaw-pans is also extracted by hanging the jaws in the warm sunlight and permitting the oil to drip into cans placed underneath to receive it. About half a pint of this oil may be secured from each porpoise; it is sold at a very high price for lubricating watches, clocks, and the like. Very few of the Passamaquoddy Indians are now left, and these few have almost entirely abandoned "porpusin" for other occupations.

The "black-fish" (*Globiocephalus melas*) occurs in many parts of the Atlantic Ocean. Individuals vary in length from 8 to 22 feet. They are captured by the sperm-whalers, and also at irregular intervals they are secured when stranded on the shore, especially in Cape Cod Bay, where they have gone in pursuit of food, the fishermen getting to the seaward of them and driving them ashore. They are likewise secured on the rocky coast of Scotland and other parts of northern Europe.

According to Capt. James Avery, of New Bedford, the sperm-whalers take them at all seasons of the year and throughout the Atlantic, but probably in greatest abundance on the west coast of Africa in 20° W. longitude, and 6° to 10° N. latitude. The number caught annually has greatly decreased in the last fifteen or twenty years. In 1881 the *Eleanor B. Conwell* caught 196, probably the greatest number taken in any one year by a single vessel. During the last three or four years the entire whaling fleet probably has not captured more than 20 or 25 annually, yielding about 800 gallons of body oil and 50 gallons of head oil, the former worth $280 and the latter $350 at fisherman's prices.

The black-fish are captured in much the same manner as very small sperm whales, and for cutting-in they are hove up on deck by means of lifting tackle. The blubber is nearly white, from 1 to 5 inches thick, and is removed from the carcass in longitudinal strips 8 or 10 inches wide. These strips are cut in horse-pieces and minced in the same manner as already described for whale blubber, the blood being washed off the fat by dashing buckets of water over it. The minced blubber is then placed in the try-pots and cooked, and subsequently treated precisely as that of the right whale. The product of oil ranges from 5 to 120 gallons from each individual, averaging probably about 35 or 40 gallons. This is sometimes mixed with whale oil, although it has a greater value, selling usually for several cents per gallon more than that of the right whale.

The head oil of the black-fish is taken from the melon or junk and the jaw-pans. The melon is a fatty mass on the top of the head, reaching from the spout hole to the end of the nose, and weighs about 25 pounds. This is washed free from blood, minced, and placed in the try-pot. The lower jaw is cut off, the jaw-pans cut out with a knife, minced, washed, and placed with the cleaned jaws and the melon in the try-pot. Some whalers cook the melon and the jaw materials separately, but the above is the usual method.

It is customary to cook the head matter of black-fish in fresh water. About 15 gallons of fresh water is placed in the pot, the fat is then added, and the whole brought to a gentle boil by means of a slight fire. At this point a little overheating will effect great injury. When the cooking is completed the pot is allowed to cool and the following morning the oil is skimmed off. The product of head oil from individual black-fish ranges from three-fourths of a gallon to 3 gallons, averaging probably about 2 gallons. At ordinary temperatures the blubber oil and the head oil of black-fish are much alike in their appearance, thus furnishing great temptation to the fishermen to mix a little of the cheap product with that of greater value, resulting in much vexation and loss to the refiner, as it is only in the process of refinement that the adulteration is revealed.

In addition to the black-fish secured by the sperm-whalers, large numbers have been captured on the shores of Cape Cod, where they are attracted by squid on which they feed. The animals are surrounded by boats and driven like cattle to the beaches, and are there stranded in endeavoring to escape. They are lanced to death and when the tide falls the blubber and the oil-producing head matter are stripped off and conveyed to try-works on the shore, where the oil is extracted in much the same manner as already described for the vessel fishery.

The greatest catch of black-fish on Cape Cod was made in 1884. On November 17 of that year 1,500 were killed at Blackfish Creek, South Wellfleet, where they had been driven ashore. About a month later 500 more were slain in a great round-up in the bay. Since that time very few have been secured in the bay, nor have they been seen at sea in any such numbers as previous to the slaughter above noted.

The oil from the blubber of porpoise and of black-fish is refined in precisely the same manner as whale oil, but the process of treatment applied to the head oils is far more complicated. These are very limpid, of an unusually low weather-test, and have little corrosive effect on metallic surfaces, making them when refined superior for lubricating such delicate mechanisms as watches, chronometers, typewriters, etc. Practically all of these oils secured in the American fisheries are refined at New Bedford and Provincetown, Mass., there being two refiners at the former place and one at the latter. We are indebted principally to Mr. William F. Nye and to Mr. Joseph K. Nye, of New Bedford, for the subjoined notes relative to the methods of refining.

In the preparation of watch and chronometer oils much depends upon the freshness of the fat at the time the oil is rendered and the freedom of the material from adulterants. Fresh substance produces much better oil than that which has partly decomposed, the product being sweeter and less rancid. No choice seems to exist between the porpoise-jaw oil and the black-fish-head oil, both producing refined articles of equal merit; but that of the black-fish seems to be the favorite by a slight margin among the refiners, owing to its having more body, and possibly also to its greater abundance. A peculiarity of these oils is that they improve with age, differing in this particular from blubber oils. This is accounted for by the alternate gathering and emission of moisture upon exposure to changes of temperature, and by this and other treatment they become clear and brilliant, in consequence of which they are seldom used within less than a year or two after they are obtained.

On receipt of the oil at the factory the first step in the process of refining is to gently heat it to complete the process of cooking begun by the fishermen. The oil is then placed in tanks or casks to await the process of grading, and often two years may elapse ere the trained and skillful eye of the refiner can determine to what class it belongs. It is almost impossible to describe the extremely delicate variations in color, texture, odor, and flavor which enter into this grading. The claim is made that there are not half a dozen men in the world who have had the training and experience necessary to separate these delicate oils into their proper classes, and yet a very large part of the reliability of watch and chronometer lubricants lies in the gradation under the almost instinctive skill of the refiner.

According to Mr. Joseph K. Nye:

> After two years or more of rest, the oil has got to a condition where its surplus oxygens have united with whatever animal or loose organic matter may have been floating in microscopic particles within it, and they are easily removed by the ordinary strainers of an oil factory. But something is still left in the oil which is very sensible to the high or low range of temperature, and to remove this requires its subjection, while spread out in thin layers, to a temperature far below zero. No further change in its construction can be made except at this very low temperature, nor must it be cooled too rapidly. When properly done the process is one most interesting to watch. All through its liquid amber little flecks of translucent material appear, joining and rejoining like frost on a window pane into most beautiful forms, resembling a miniature forest whose foliage is white. By means of a certain fine and close-grained fabric these particles at this juncture are filtered out: and strange to say, this residuum, once a portion of a brilliant, almost colorless fluid, never even at normal temperature becomes anything but a slimy mass, resembling poor lard.

In order to get this low temperature, one of the New Bedford refiners has established a chilling plant at St. Albans, Vt., where long-continued cold can be depended upon.

To be thoroughly satisfactory the refined oil must be of uniform quality, entirely devoid of acidulous properties, absolutely gumless, withstand the rigors of the coldest climate without congealing, and maintain its body or stability in a high temperature. This is the most delicate and highly refined lubricant known, and some has been produced for which a temperature of $-50°$ F. has been claimed. While all watch-oil users do not prefer colorless fluid, the average customer demands an oil almost if not absolutely colorless and of crystal clearness. Much of the product is sold for repairers' use in wooden boxes containing 1 dozen half-ounce bottles, each bottle inclosed in a small pasteboard box. The remainder, in tin cans having capacity for 1 pint, 1 quart, or of larger capacity, goes to the manufacturers of watches, clocks, chronometers, typewriters, etc.

SCHOOL OF BLACK-FISH STRANDED ON THE SHORE OF CAPE COD, MASS.

OILS FROM SEALS, WALRUS, ETC.

The blubber or fat lying between the skin and the muscular tissues of the various members of the *Pinnipedia* yields oil of much importance for technical purposes. The principal varieties on the market are from the common seals or hair-seals of the North Atlantic, the walrus, the sea-elephant, and the sea-lions. Each of these will be discussed separately.

SEAL OILS.

Seals are found in various northern waters and especially off the coast of Labrador and Newfoundland, in the waters of Greenland, the Arctic Ocean north of Europe, in Caspian Sea, along the Nova Scotian and New England coasts, in the Northern Pacific, and to a much less extent in the Antarctic seas. The principal fisheries are in the Arctic and North Atlantic oceans, especially off the coasts of Newfoundland, Greenland, and Northern Europe. The Caspian Sea also affords an important seal fishery.

The blubber of seals ranges in thickness from 1 to 3 inches, according to the species, age, and condition of the animals. It is removed from the pelts usually as soon as the latter are landed. If the weather is warm, considerable oil of prime quality flows from the blubber during the process of separating it from the pelt, and provision is made for this free oil to flow into suitable receptacles.

The oil may be at once extracted, or the blubber may be stored for a more convenient season, especially if the weather be cold, as it is much easier to extract the oil during warm weather. If the blubber is stored, it should be in well-ventilated apartments, so arranged that the oil forced out by compression and warmth may run into suitable reservoirs. In the best-arranged storage rooms the reservoirs are oak-wood casks, lined with lead in some instances, with capacity for a thousand or more gallons. These are placed at intervals in the floor, which is so inclined as to cause the oil to flow into the receptacle. The oil which flows under these circumstances is usually clear, sweet, and of prime quality.

There are several methods of extracting the bulk of the oil from the blubber, the one adopted depending to some extent on the proposed use of the product and also on the amount of capital available for equipment and the quantity of blubber to be handled. The methods may be divided into three principal classes, viz, (1) by maceration exposed to solar heat, (2) by cooking in open kettles, and (3) by the application of steam.

The simplest method of extracting the oil is by exposing the minced blubber in a mass to the weather. The blubber is heaped up in large tanks and—when the temperature is suitable—clear, pale oil flows from the mass. As putrefaction advances and the cellular texture is destroyed, the mass yields oil of a reddish yellow and then a dark brown color, with somewhat disagreeable odor and flavor, owing to the decomposition products evolved. When the oil ceases to flow, usually at the end of two or three months, the mass of fat is boiled in water with the fleshy or fat-lean portions. During this boiling the oil rises to the surface and is skimmed off. The residue is evaporated by pressure and drying, and is used for fertilizer. This was formerly the usual method employed in rendering seal oil in Newfoundland, but during the last twenty-five or thirty years the steam process has been generally adopted.

In treating a small quantity of blubber for extraction of the oil it is usually more convenient to mince it finely and cook it in a kettle over a fire. The oil rises to the surface and is skimmed off and placed in casks or other suitable receptacles. This is the method commonly employed by the shore hunters whose catch is small.

At the large sealing ports, as St. Johns, Tönsberg, Dundee, Astrakhan, etc., the oil is usually rendered by means of steam. The minced blubber is exposed to the action of steam in large inclosed tanks. The oil flowing therefrom passes through pipes into large reservoirs, of which there are usually three or more, the overflow from the first passing into the second, and the overflow from the second into the third. This furnishes the first quality of steam-refined oil. By pressing the steamed blubber, a second quality of dark-brown oil is obtained.

The steam process of rendering has the advantage of rapidity in operation, also the oil is free from disagreeable odor and is of superior burning qualities. However, for use in mines the sun-extracted oil is preferred, especially that of young seals, owing to its greater freedom from smoke, the odor being of little consequence to miners. According to Mr. Carrol,[a] oil from old seals is more smoky than that from young ones; it is also of greater specific gravity, and when the blubber of both are rendered together, the young seal oil comes out first.

Although the catch of seals in the Newfoundland fishery in 1901 was almost as large as in 1900, being 345,380 in 1901, as compared with 353,276 in 1900, the yield of oil was about 120,000 gallons less, representing a difference in value of about $50,000. This was principally because the average weight of the seals was small, owing to the fact that in 1901 the seals whelped some days later than in 1900, and furthermore, they were taken two or three days earlier than usual, the absence of pack ice enabling the vessels to reach them promptly after leaving harbor. In 1900 the average weight of the seal pelts was about 46 pounds, whereas in 1901 it was but 38 pounds. The young seals gain daily two or three pounds in weight of blubber, and if the vessels had been three or four days later in reaching the herds, the yield of oil in the Newfoundland fishery in 1901 would probably have been approximately the same as in 1900.

The decadence of the seal-oil industry, especially in the waters north of Europe, has been gradual but certain, owing to the introduc-

[a] The seal and herring fisheries of Newfoundland, by Michael Carrol, Montreal, 1873, p. 30.

tion and adoption of cheaper substitutes for the relatively high-priced seal oil. Every year shows a decrease in the number of vessels employed in the fishery, and when a vessel is lost or sold it is rarely replaced. Comparatively little seal oil is imported into this country, the quantity in some years amounting to less than 1,000 barrels. The price in bond approximates 45 cents per gallon. The Newfoundland oils are marketed principally in St. Johns, Glasgow, London, and Leith; those from the waters north of Europe, at Dundee, Copenhagen, Hamburg, and Archangel, and that from the Caspian seal fisheries at Astrakhan.

Seal oils vary in specific gravity from 0.915 to 0.930 at 59° F. According to Brannt, they are composed principally of glycerides of physetoleic acid, of palmitic, stearic, and a small quantity of oleic acid and traces of butyric acid, valerianic acid, etc. They show a slight acid reaction when fresh, the acidity increasing with age. Instead of the albuminous substances present in vegetable oils, the seal oils contain a small quantity of glue which can be precipitated with tannin and metallic salts. They are very slightly soluble in alcohol, and require almost an equal volume for solution in ether. Mixtures of equal volumes of nitric and sulphuric acids produce a reddish color, quickly changing to brown. The adulteration of seal oils is detected principally by the incomplete saponification if resin oil be the adulterant, and by the degree of solubility in alcohol if other blubber oils are employed.

In addition to the pure oils there are several well-known compound seal oils on the markets, the best known being the "three crowns." Greenland "three crowns" is a mixture of several varieties of blubber oil, chiefly seal oil, or rather seal-oil foots, and small quantities of whale and walrus, combined with oil from shark livers, the fluidity and low specific gravity of the shark oil imparting the special qualities to this compound. Swedish "three crowns" oil is a compound of various seal oils with herring oil.

The principal use for seal oil is for burning in miners' lamps, and it is also employed in currying and to a very small extent for miscellaneous purposes, especially fiber-dressing. About 2,500 barrels are used annually as an illuminant in the light-houses in the British North American provinces. Owing to its sluggish nature it is usually improved by the addition of mineral colza. An excellent miners' lamp oil is said to be composed of seal oil, 40 per cent; whale oil, 25 pér cent; lardine (0.980), 10 per cent, and mineral colza, 25 per cent.

SEA-ELEPHANT OIL.

The sea-elephant or elephant-seal has furnished a large quantity of oil to the American markets during the last eighty years. The whalers operating in the extreme South Atlantic, and also the fur-sealers sailing to Falkland, South Georgia, and the coast of Patagonia, secured odd lots previous to 1803, but the first vessel specially fitted out for securing this article appears to have been the ship *Alliance*, which sailed from New Bedford in 1803 for Patagonia, and returned home in 1804 with a full cargo of oil. This was the pioneer of a large number of vessels sailing to the Patagonian coast for sea-elephant oil. That coast seems to have been abandoned about 1820 for the South Shetland Islands, which for seventeen years furnished many cargoes to the fur-sealers sailing from Stonington. Since 1837 Desolation or Kerguelen Island has furnished the great bulk of the sea-elephant oil. Heard Island has furnished many cargoes since 1857, but on account of the exposed situation of that island vessels do not usually go there when a cargo is obtainable elsewhere. South Georgia, South Shetlands, and the Patagonian coast also have many sea-elephants and are occasionally visited by the hunters, but the great bulk of the catch has been obtained at Desolation Island.

Although the taking of sea-elephant oil originated with the Nantucket whalers, it has been peculiarly a New London industry since 1820, the neighboring ports of Stonington and Mystic furnishing a number of vessels during certain seasons. From 1820 until the present time 94 per cent of all the voyages have been made by vessels from these three ports, and 80 per cent have been made by the New London vessels. The fleet was largest in 1858 and 1859, 18 vessels, with an aggregate tonnage of 4,527 tons, being employed in 1858, and 20 vessels, with 4,461 tons measurement, in 1859.

The last vessel to return with a cargo was the brig *Leonora*, which arrived in 1902 with 2,900 barrels of oil and a quantity of hides. In 1900 the schooner *Robert S. Graham* brought in 2,600 barrels of oil and 70 hides, the oil selling at 38 cents per gallon and the hides at $2 each. In 1898 the bark *Swallow*, of Boston, returned with 2,000 barrels of oil, the product of 4,000 sea-elephants secured during the three months of the summer of 1897–98.

According to Capt. James W. Budington, of Groton, Conn., to whom we are indebted for most of the subjoined data relative to methods of capture and of oil-rendering, sea-elephant blubber is somewhat whiter than whale blubber, and ranges in thickness from 1 to 8 inches, according to the size and condition of the individual. It is thickest on the males, especially the "March bulls," from the neck of which 10-inch blubber has been secured. On the cows the thickness is from 2 to 3 inches and on the pups it is much less.

Much variation exists in the yield of oil from sea-elephants. The quantity secured from the March bulls taken shortly after they land is very large, amounting sometimes to 220 gallons from a single individual. Only a small number of this variety is secured. The November bulls yield from 100 to 120 gallons each early in the season, but after remaining on the shore for months, abstaining from food, they become emaciated, and yield scarcely more than 30 gallons. The product from females and pups is much smaller, some of the pups yielding only 4 or 5 gallons, especially when the season is well advanced, thus greatly reducing the average take, which probably does not exceed 12 or 15 gallons to each individual throughout the season. The cargo of 2,000 barrels secured by the bark *Swallow* in 1898 represented an average yield of 15.75 gallons per individual. Another cargo of 600 barrels, secured late in the season when the animals were in poor condition, represented the capture of 2,000 individuals.

The hunters endeavor to arrive at the islands as soon as the sea-elephants come ashore, usually the early part of November. The animals are found in herds or pods varying in number from 20 to 300 or more each, the favorite resort apparently being the numerous mud puddles. The largest and fattest are selected for killing, females and pups being unmolested if a sufficient number of large bulls is obtainable. The bulls are sometimes of enormous size, frequently 16 feet or more in length and 12 feet in circumference. The females are very much smaller, probably one-third the size of the bulls, but generally they are fatter for their size and their blubber is somewhat more yellowish. A number of seals of various species, especially the leopard-seal, are frequently met with and are driven out and slaughtered when sea-elephants are scarce; otherwise they are not molested, as they are not nearly so fat as the sea-elephants. Rifles and lances are the weapons commonly employed in the slaughter.

After killing a sufficient number the skin is roughly and quickly gotten out of the way and the blubber taken off in horse-pieces of suitable size for handling, say about 18 inches wide and 2 feet long, or less, this varying according to the thickness. The horse-pieces are strung on a pole and carried down to the shore, 15 or 20 making a good load for two men. At the shore the pieces are strung on raft-tails or ropes, 18 or 20 feet long, and towed to the ship. The long immersion in the water soaks off the sand and blood and cleanses the blubber.

The oil is extracted in much the same manner as in the whale fishery. The blubber is lifted on deck, cut into strips about 2 inches wide, and these are minced or partly cut through at intervals of about 1 inch and placed in try-pots, precisely as in the case of whale blubber. The cooking is only slight, much less than applied to the whale blubber, being continued for only about 15 minutes. The fuel consists of the dry scrap, supplemented with wood procured on the islands. After cooking for about 10 or 15 minutes and dipping off all the oil on the surface, the scrap is placed in a receptacle and subjected to considerable pressure, in the manner customary in the right-whale fishery already described. The oil does not run as freely from the blubber as whale oil; especially is this the case with the fat of the pups, which is fine-grained and "milky." Occasionally the oil is tried out on shore in a manner similar to that aboard the vessel, the try-works being erected near a running stream wherein the blubber may be washed free from sand and blood.

The product from all the southern islands from 1803 to 1900, inclusive, amounted to upward of 242,000 barrels, or 7,643,000 gallons, worth $5,420,000, apportioned as follows:

Decade ending June 30—	Barrels.	Decade ending June 30—	Barrels.
1810	2,500	1860	62,754
1820	9,000	1870	48,783
1830	9,500	1880	34,015
1840	23,000	1890	8,150
1850	38,000	1900	6,300

This oil is classed as whale oil and has been included in the product of that article, as shown on page 204, although it is usually sold for 3 or 4 cents per gallon more than the latter. The process of refinement is precisely the same as in case of whale oil, the foots yielded amounting to 5 or 6 per cent of the original bulk. Its principal use has been in the dressing of morocco leather.

WALRUS OIL.

When the whalers entered the North Pacific, walrus were found in great numbers, but were not disturbed, owing to the abundance of cetaceans. At times when whales were not to be found and many walrus were met with, a number of these were killed and the blubber tried-out, and this practice extended with the increasing scarcity of whales. About 1863 the northern whalers began to make a business of taking walrus during the first part of each season, some vessels securing upward of 500 barrels. Mr. A. Howard Clarke estimated that, during the eleven years ending in 1880, 1,996,000 gallons of walrus oil were secured by the whaling fleet in the North Pacific, the value of which was about $1,000,000.[a] The hunt was carried on with much waste. It is stated that on one occasion 1,600 walrus were killed on a sand bar in one day, and the whole number were washed into the sea by an unusually high tide and thus lost. Since 1880 the quantity secured has decreased, and at the present time not more than 100 walrus are obtained annually by the entire North Pacific fleet, representing an oil product of less than 2,000 gallons.

The blubber of walrus averages 2 or 3 inches in thickness, and usually it is is not detached from the skin until after the removal of the latter from the carcass. In case the hide is to be saved for tanning, the pelt is placed on a flensing board or platform, skin-side down, and the blubber is cut off in irregularly shaped horse-pieces of 10 or 15 pounds' weight each. During the height of the Pacific walrus fishery the hides were not used, and then the skin and blubber were removed from the animal in horse-pieces of convenient size, say about 10 by 14 inches, and these were separated aboard the vessel.

The horse-pieces are next prepared for the try-pots. They are placed on the mincing-horse and scored or minced precisely in the manner described in the treatment of whale blubber. The cooking must be

[a] The Fishery Industries of the United States, Sec. V, Vol II, p. 318.

slow, the pot being well spaded during the boiling to prevent the blubber from sticking and burning to the bottom or side.

The individual yield of oil varies considerably, walrus being much fatter in some years than in others. But in general it is small in proportion to the size of the animal, an individual weighing 1,500 pounds yielding only as much blubber as a seal of 600 pounds. An old bull weighing 2,500 pounds might yield 600 pounds of blubber, but it is seldom more than 450 pounds, and the average for the entire catch is probably not in excess of 200 pounds. Nor is the blubber as rich in oil as is that of the seal, 100 pounds of walrus fat yielding an average of 10 gallons of oil, whereas an equal weight of seal blubber yields about 11¼ gallons. In 1869 the ship *Progress* secured 565 barrels of oil from 700 walrus, an average of 25.42 gallons each. This was considered an extra good yield. One thousand walrus secured by the ship *Onward* in 1874 yielded 600 barrels of oil, and 2,000 taken by the *Mercury* in 1877 produced 1,100 barrels of oil.[a]

Walrus oil is usually of a yellowish color, with greater fluidity than seal oil, and has a specific gravity of 0.925 at 59° F. according to Brannt. It is more difficult to refine than the oil of the right whale. Although classed roughly as "whale oil" in the United States, it is usually kept separate from the oil of the right whale and sold for 2 or 3 cents per gallon more than the latter. It is stated that the product in the fisheries north of Europe is generally mixed with and sold as seal oil.

OIL FROM SEA-LIONS AND FUR-SEALS.

The blubber of the sea-lion is from 1 to 4 inches thick, and that on each individual yields from 6 to 20 gallons of oil. Thousands of barrels of this oil were formerly secured along the coast of California, but owing to the decrease in number of these animals, comparatively little is now prepared. It is somewhat inferior to sea-elephant or walrus oils, but much better than fur-seal oil.

A number of years ago when whale and seal oils were quoted above a dollar per gallon, there was some sale in this country for oil prepared from the blubber of the fur-seal; but owing to the small quantity available, the cost of production, and the technical inferiority of the product, there has been no market for it for many years. The blubber may average 1½ inches in thickness, varying according to the time the animal has been on shore. The oil is of a yellowish-brown color, gummy, and possesses an offensive odor. According to the terms of the lease of the fur-sealing rights on the Pribilof Islands to the North American Commercial Company, the United States Government is entitled to receive 50 cents per gallon for all fur-seal oil produced there. This is in excess of the market value of the article, leaving nothing for the cost of production and transportation, and, needless to state, there is no revenue whatever from this item.

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[a] The Fishery Industries of the United States, Sec. V, Vol. II, p. 318.

OIL FROM LIVERS OF COD AND RELATED SPECIES.

SOURCES OF SUPPLY.

Cod oil is obtained from the livers of several species of fish. In its pure state it is obtained from the livers of cod only, but those of haddock, pollock, hake, cusk, ling, and even shark and dog-fish are also used. The last two, however, are not generally recognized as cod-liver oil sources, but are used mainly for purposes of adulteration. In the trade the term "cod-liver oil" is used in a restricted sense, applying to the best quality of oil made from choice fresh cod livers and intended for medicinal purposes; all other oil manufactured from livers of cod and related species, not of quality fitting it for medicinal uses, is designated as "cod oil" or "curriers oil."

Cod oil is of comparatively recent development as an article of commerce, although it was used locally previous to the nineteenth century. On account of the ease with which whale and seal oils could be secured, cod oil was not in great demand for technical purposes until after the beginning of the nineteenth century. There is nothing to indicate that in the early cod fisheries on the American coast the livers were utilized to any great extent for oil-rendering, and the same is true of the early fisheries prosecuted in the seas north of Europe. The small demand for medicinal and for technical purposes was readily supplied by a few fishermen of economical and industrious habits, but their output bore only a small proportion to the total quantity obtainable. Curriers used a small quantity, and some was employed on fruit trees for destroying insects and fungous growth.

Early in the nineteenth century the production of cod oil became quite general on the New England coast. The livers were placed in butts and permitted to decompose, and the oil exuding therefrom was dipped off from time to time. Not only was this done by the fishermen who landed their catch ashore each night, but also by the "bankers" who carried butts and barrels for the purpose. As the tanning industries developed, the output of cod oil increased, and by 1845 practically all the livers secured were rendered into oil. The output, however, did not keep pace with the demand and during the sixties the price went up to $1.25 per gallon. Mr. Eben B. Phillips, of Swampscott, was one of the pioneer dealers in this product and amassed a fortune in the business.

Gradually other substances were introduced as materials for dressing leathers, especially sod oil, degras, and compound greases, the cheapness of which has greatly affected the market for cod oil. The substitution of machine stuffing for hand stuffing in leather-dressing and the introduction of chrome tannage have also reduced the demand. However, the market for medicinal oil has constantly increased up to the present time. As a result of these combined uses, the rendering of the livers into oil is almost coextensive in point of territory with the prosecution of the cod fisheries. The only exception is in certain market fisheries where the men do not have time to handle the livers properly.

The market price of medicinal oil frequently falls so low that it pays the manufacturer better to prepare only low-grade oil for leather-currying, soap-making, and the like. The common oil is, of course, turned out at much less cost than the white, odorless, medicinal variety. The stearin, which is worth comparatively little and forms a considerable portion of the oil, need not be removed from the manufacturing grade. The use of the expensive refining plant required for medicinal oil is also obviated. And, finally, there is a very considerable saving in the cost of packing, as the ordinary oil is shipped in old petroleum barrels, while for the finer grade expensive new casks or metallic drums have to be provided. For several seasons there was a large overproduction of low-grade medicinal oil, and three years ago it sold in New York as low as 50 cents per gallon. Curriers' oil does not often sell for less than 30 cents per gallon, and the demand for it is fairly constant.

The principal sources of cod-liver oil are the coast of North America from Labrador to Cape Cod, Norway, Scotland, Iceland, the Pacific coast of the United States, and, during recent years, Japan. On account of its greater value, efforts are made on all these coasts to produce the light oil for medicinal purposes; but in most sections, on account of unfavorable natural conditions, only dark or low-grade oils are practicable. Medicinal oil is prepared chiefly on the coast of Norway and to a limited extent on the Massachusetts, Maine, Nova Scotia, and Newfoundland coasts.

Owing to the favorable conditions under which the cod fishery is there prosecuted, Norway ranks first among countries producing medicinal oil, the annual product amounting to about half a million gallons. The fishing-grounds are concentrated and situated very near the coast, so that the fish are landed in quantities within a few hours after capture and before decomposition of the livers has set in. Furthermore, the temperature during the fishing season is very low, being close to the freezing point, and this tends to retard putrefaction. In no other part of Europe are the conditions favorable for producing medicinal cod-liver oil. A large quantity of low-grade or curriers' oil is also produced in Norway, amounting probably to as much in bulk as the medicinal oil.

In Newfoundland much attention has been given to the production of medicinal oil, the manufacturers endeavoring to make it as near like the Norwegian product as possible. Freezing machines were introduced and a considerable quantity of white, odorless, and non-congealing oil was made. The general experience, however, was that the difference in market value of the medicinal and the trade oils was not sufficient to warrant the extra care and the additional expense. At present comparatively little medicinal oil is produced in Newfoundland. The livers are mostly all converted into curriers' oil, resulting in an annual output of about 1,100,000 gallons.

The situation in Nova Scotia is pretty much the same as in Newfoundland, although much less oil is produced, the annual output probably amounting to about 20,000 gallons of medicinal oil and 250,000 gallons of curriers' oil.

The bank fisheries of America are situated too far from the land to permit the use of the livers in making medicinal oil; but the shore fisheries during autumn and winter, when the spawning fish visit the coast, furnish good material for that purpose, resulting in the preparation of about 25,000 gallons each year. Much of this is of superior quality, and unsurpassed for color and pleasantness of odor and taste. The livers taken in the bank fisheries are practically all used in preparing curriers' oil, the total annual product of which is about 450,000 gallons.

Considerable cod oil has been exported from Japan for medicinal purposes, but that received in this country has not found favor with the wholesale druggists and has usually been sold for currying. The first shipment of 200 cases, made in 1889, sold at 35 cents per gallon. We have no data bearing on the cod-oil output in Japan, but with an annual catch of 7,000,000 fish it probably does not exceed 100,000 gallons.

The entire product of cod oil is estimated as follows: Norway, 1,200,000 gallons; Newfoundland, 1,100,000 gallons; Dominion of Canada, 300,000 gallons; United States, 475,000 gallons; Japan and all other countries, 450,000 gallons, making a total of 3,525,000 gallons of all varieties of oil produced from the livers of cod and related species. Of this quantity about 650,000 gallons represent the output of medicinal oil, and the remaining 2,875,000 gallons is curriers' oil.

DESCRIPTION OF LIVERS AND THE RESULTING OILS.

The following description of livers and the account of rendering them into oil are the results principally of an inquiry made by the writer on the New England coast in October and November of 1901. Most of the oil factories were visited and many of the principal fishermen were interviewed. The writer is especially indebted in this connection to Mr. A. W. Dodd and Messrs. George J. Tarr & Sons, of Gloucester, and to Messrs. Geo. H. Leonard & Co., Mr. John B. Baum, and Mr. F. F. Dimick, of Boston.

Normal cod livers in good condition are of a cream color, uniform texture, and very soft, so that the finger may be readily pushed quite through them. Lean livers are frequently found. These are tough and dark in color, the toughness and darkness increasing with the degree of leanness, the color finally reaching a dark brown hue. Lean livers furnish very inferior oil, as well as only a small quantity. A certain percentage of the livers are diseased. This condition is usually evidenced by a greenish color or by the presence of colored spots, which increase in size and number as the disease advances until the entire organ is affected. Diseased livers are never used in the preparation of medicinal oil, but are freely utilized in making curriers' oil. The size of the livers varies considerably, but averages about 12 inches in length and 2½ inches in thickness in the center, the weight being somewhat over half a pound. Some livers weigh only 1½ ounces each, and an instance is recorded by Dr. F. P. Moller of one taken in the Lofoden fishery which weighed 11 pounds, its length being 43 inches and its greatest thickness 6½ inches.

Considerable difference exists in the size, shape, and general appearance of livers of the cod family. Cod livers are elongated, with the large end near the dorsal fins and the small end toward the tail. Haddock livers are much shorter than those of cod, and have little frills or scallops on the edges, whereas those of cod are smooth. Haddock and pollock livers are of a cream color, similar to those of cod, while cusk and hake livers are of a light straw color. The livers of all *Gadidæ* are usually mixed together by the fishermen, but in the season when any particular species is abundant the livers of that variety are kept separate. On the New England coast of the United States cod livers predominate during the coldest months and pollock are taken mostly in October and November.

In the United States fisheries livers represent about 3½ per cent of the weight of the fish, and they yield about 40 per cent of their weight in oil; consequently 100,000 pounds of fish yield about 180 gallons of oil. On an average, from January to June, 1,000 pounds, dressed weight, of cod yield about 1 bucket, or 2½ gallons, of livers, and during the latter half of the year the yield increases to 4 gallons per 1,000 pounds of dressed fish. A bucket of these livers yields 5 or 6 quarts of oil on an average throughout the year, except that in the spring the product is sometimes reduced to about 3 quarts to the bucket of livers. The yield of hake livers per 1,000 pounds of fish is somewhat larger than in case of cod, but the quantity of oil secured from a bucket of livers is about the same. Haddock yield best from October to December, and during the spring and summer the result is small, sometimes not over 1½ quarts to the bucket. On account of the small yield and the conditions surrounding the haddock fishery, only about 15 per cent of the livers of that species are saved in the New England fisheries. At present pollock do not yield so much as cod, averaging about 5 quarts to the bucket of livers throughout the year; but previous to ten years ago on the New England coast they usually yielded 7 quarts of oil in the fall.

In the Lofoden fishery, according to the official returns, ordinarily 20 to 30 livers are required to produce 1 gallon of medicinal oil. During some seasons the livers are quite fat, and 8 to 12 are sufficient;

but when they are very lean, as was the case in 1896, for instance, from 36 to 56 are required for 1 gallon of oil. In that fishery the livers are fatter at the beginning than at the end of the season. They average about 55 pounds to the 100 fish; but during the years when they are unusually lean it is much less, as in 1883, when the average weight of 100 livers was only 12½ pounds. Usually at the Lofoden Islands 250 to 1,100 cod give 1 barrel of livers, and 2 barrels of livers yield 1 barrel of oil; but in 1883 from 700 to 1,100 fish were required for 1 barrel of livers, and 4 or 5 barrels of those were necessary for 1 barrel of oil. Aside from the benefits accruing from the fatness of the livers, anything gained in quantity is always lost in quality in the preparation of medicinal oil.

While it is somewhat difficult to distinguish among the oils made from the livers of the various members of the cod family, yet ordinarily there are certain distinctive characteristics apparent to the skilled oil-refiner. Cod oil is of a greenish yellow color and usually has less pressings or foots than any of the others. Hake oil is almost white, but that made from hake taken on certain grounds has a pinkish color, which may be removed by filtration through a mineral earth. Pollock oil is distinguished by a slightly bitter taste and has a faint reddish cast. Its weather-test is rather lower than that of cod oil, especially when it has been slightly overcooked in the rendering.

Oil extracted from perfectly fresh cod livers is light and odorless, and, owing to its extensive use in medicine, is known as medicinal cod oil or "cod-liver oil." According to the extent of decomposition of the material before the extraction of the oil, the color ranges through all shades of yellow and brown to very dark brown, this color being attributed to the decomposition of the hepatic tissues and fluids. These dark oils are of two general grades; one, the brown, which is inferior to the light-brown or medicinal oil, but is frequently used for such; and the other, the dark-brown or curriers' oil, is the poorest grade prepared, and is exclusively used for technical purposes. Probably it would be better to say that there are two principal varieties of oil, the medicinal and the curriers', and that unusual market conditions may result sometimes in the employment of the poorest of the medicinal oil for technical uses or the best of the curriers' oil for officinal purposes.

The medicinal value of cod-liver oil was known centuries ago among the Laplanders in northern Europe, the descendants of the Norsemen in Iceland, and the Eskimos in Alaska. The use of the oil gradually extended in Europe during the eighteenth century, being a popular home remedy among many seacoast communities and used empirically by physicians. Percival and Bardsley in 1782 recommended its use in cases of gout and chronic rheumatism. In 1841, J. Hughes Bennett, of Edinburgh, published a pamphlet on its medicinal qualities, strongly recommending it in many cases, and this had much to do with the general introduction of the oil as a medicine in England and America. From that time to the present it has held a prominent place in the confidence of physicians, and is regarded as a remedy of the highest value in diseases which are marked by malnutrition, pulmonary tuberculosis furnishing the most frequent occasion for its employment.

Few subjects connected with materia medica have provoked so much discussion as the comparative merits of the light and the dark grades of cod-liver oil. Formerly, the brown oil was considered superior in efficiency to the paler sorts, and was generally favored for medicinal purposes. In recent years, however, chemists have claimed that analysis does not reveal any substance in the dark oil which would account for greater beneficial activity than the paler grades are supposed to possess. While many physicians yet recommend the brown oil, the drift of public opinion seems to favor the pale oil, and certainly it is more popular with the patients. A discussion of these rival claims is beyond the scope of this paper. For information on the subject reference is made to A. Gautier and L. Morgues' *Les Alcaloides de l'Huile de Foie de Morue*, Paris, 1890, and to F. P. Moller's Cod-Liver Oil and Chemistry, London, 1895.

PREPARATION OF MEDICINAL OIL.

On account of its greater value, it is generally desirable to convert the livers into medicinal rather than curriers' oil. For this grade the livers must be perfectly healthy and fresh, all diseased, lean, or slightly decomposed ones being rejected. On account of the necessity for having the material perfectly fresh, it is impracticable to manufacture good medicinal oil during the warm months, and even in cold weather the sooner the extraction of the oil is begun the better the grade secured. Furthermore, it is desirable that the livers should be from cod only, those from other species being excluded. This, however, is not the uniform practice, and the livers of haddock, hake, cusk, etc., are sometimes thrown in with those of cod. It does not appear that American manufacturers are any more prone to this adulteration than those of other countries. Possibly oil from other livers may be equally as efficient as cod, yet until that fact is demonstrated beyond a doubt those should be rejected.

On the New England coast of the United States, the best medicinal oil is made from livers collected from the shore fishing boats, which land their catches almost daily, and thus deliver them in fresh condition. From May to October only a small amount of the best oil can be made, because of the scarcity of fish along shore during that season and the danger of the material putrefying before reaching the oil factory. From October to May the shore fishermen carefully save the livers in clean barrels, and if landed within a day or two they are sold for making medicinal oil, but if softened or damaged in any way they are used only for curriers' oil.

Second only to the careful selection of the livers is the observance of perfect cleanliness in the entire process of rendering the oil. The livers are thoroughly cleansed from blood and other impurities by washing in several waters, and the gall sacs and attached membranes are removed. Throughout the entire process of expressing and refining the oil, all tanks, receptacles, and the like are kept free from putrefying texture. Some oil-renderers chop the livers into small pieces for the purpose of securing a greater quantity of oil, but this is by no means the general practice.

There are two general methods of cooking the livers, viz, (1) by wood or coal fire under a water bath, and (2) by the use of steam. The first-named is the oldest in use and is also the most economical where the quantity of material to be rendered is small. Two metallic receptacles or pots are provided, one, in which the livers are placed, fitting loosely in the other, with 2 or 3 inches of space between, and the larger one set into a furnace so that a fire may be built beneath. The space between the two receptacles is filled with water during the process of cooking, and this is renewed as required. A fire is built in the furnace and the water brought to a boiling point, thus imparting a moderate heat to the contents of the pan. In order that the cooking may be expeditious the pan should be small, holding not over 50 or 60 gallons. Furthermore, it should be narrow, for greater ease in stirring and to minimize the oxygenizing of the oil. Owing to the cheapness of this apparatus it is quite popular with those who try-out only a small quantity of oil.

In the second method of cooking, steam-jacket kettles are used, the steam-chest being provided with a self-acting safety valve by which the pressure can be controlled and regulated. Within the kettle there is usually a stirring apparatus operated by steam power. By means of this apparatus the cooking may be performed much more expeditiously than with the former one, as any desired temperature may be secured and uniformly maintained.

In order to prevent, so far as practicable, the formation of hydroxylated compounds, the alleged cause of the unpleasant eructations or gastric disturbance from which many persons suffer after taking the oil, there was introduced in Norway in 1892 an apparatus for its extraction without permitting oxidation to take place. This apparatus is so contrived that the air can be completely excluded from it during the whole operation, the process being conducted in a current of carbonic acid gas from the moment the livers are placed in the apparatus until the oil is sealed up in the market receptacles.

Whatever process of cooking may be adopted, it is desirable that the oil be forced out of the hepatic cells in a short space of time and by a moderate degree of heat only. The length of time usually allowed for cooking is from 2 to 3½ hours, and at no time should the temperature exceed 200° F. The duration of the cooking process is an item of great importance in the preparation of medicinal oil, and on it is dependent in a large measure the quality of the product. In order to get the largest possible amount of oil, some producers cook the material entirely too long, notwithstanding that beyond a certain point anything gained in quantity is at great sacrifice of quality. In producing a choice grade of oil, the livers must not be exposed to heat any longer than absolutely necessary.

The longer the cooking is continued, the greater the quantity of acids and decomposed albumen extracted from the hepatic tissues. These substances render the oil strong and unpalatable, and detract from its appearance. Further, the longer the livers are exposed to heat, the more oxygenized the oil becomes, making it irritative to the stomach and causing disagreeable eructations. For the production of the clearest and lightest medicinal oil, the livers should not be exposed to a greater heat than 160° F., and that only for about 45 minutes. This, however, is not feasible because the quantity of oil produced in that case would be too small to make the business profitable. The time must, therefore, be extended as far as practicable without detracting too much from the quality. But in order to produce a first-class medicinal oil, the length of the cooking should on no account exceed 2½ or 3 hours, provided the capacity of the liver-receptacle does not exceed 50 gallons.

On completion of the cooking process, the mass of livers and oil is allowed to cool. The oil rises to the surface and is drawn off and filtered. The liver magma is subjected to pressure and yields a quantity of dark oil suitable only for curriers' use. The residuary mass of hepatic tissues is dried and used for fertilizing purposes. Its market value in Gloucester and Boston was formerly $6 or $8 per ton, but at present it is only about $3 per ton.

Filtering the medicinal oil is accomplished by running it through a box fitted with several straining frames covered with cloth of successive degrees of fineness and with a tap at the bottom through which the oil can be drawn. Or the filter may consist of one or two light canvas bags fitted inside of a white moleskin bag with the smooth side out. But in filtering the dark oil, it is better to run it through charcoal.

In the process of refining, the medicinal oil is placed in small receptacles, as 5-gallon cans, and refrigerated either naturally in cold weather or by means of ice and salt, as already described in the process of refining sperm oil. When thoroughly chilled and granulated the congealed oil is compressed through cotton or canvas bags holding about 4 gallons each, for the purpose of extracting the foots, white pressings, or stearin. Two or three bags are placed regularly upon a substantial wooden platform or table provided with grooves for conducting the outflowing oil to a receiving tank. On this row of bags there is laid a thin iron plate or slab, then another layer of bags, and so on, layer after layer, until 15 or 20 bags have been piled up. Heavy pressure is then applied and continued 10 or 12 hours, when practically all the oil drains from the bags, leaving behind an unctuous mass of the consistency of tallow or butter, composed of nearly pure stearin, with a small quantity of débris and fibers. The quantity of stearin removed depends on the temperature at which the congealed oil is pressed. At the usual temperature of 28° to 30° F., about 1¼ pounds are removed from each gallon of crude oil, the latter weighing about 7½ pounds. The stearin is sold at 5 or 6 cents per pound and is used by soap- and candle-makers and as a tallow substitute in leather-dressing.

Medicinal cod-liver oil should be exposed to the air as little as possible during the whole process of extraction, filtering, and pressing; and as soon as the last operation is completed, it should be placed in shipping packages and stored in a cool place until marketed. This oil has a greenish tint, is almost tasteless and odorless. For the purpose of making the oil lighter in color, it is sometimes bleached by exposing it in a thin layer to the sun's rays for an hour or more. Bleaching medicinal oil is an objectionable process, resulting in no particular benefit, and, on the contrary, is productive of much harm when long continued.

The style of the package in which medicinal oil is placed is of much importance. Since cod oil readily acquires the flavor of wood and becomes discolored thereby, glass or metal receptacles are preferred. Tin is much the best material when glass is not used. The Norwegians use tin-lined barrels. When wooden barrels are employed, white oak is preferable to other varieties.

During recent years many manufacturing pharmacists have prepared cod-liver oil in such a manner as to overcome the disagreeable flavor and the even more objectionable gastric disturbance which so frequently follows its use. These products are mostly in the form of emulsions, gelatinous capsules, with sirups, creams, jellies, etc.

Furthermore, some pharmacists remove the so-called "active principles" in cod-liver oil, the oil itself being subsequently used for technical purposes. These "active principles" are extracted by means of an alcoholic menstruum, then concentrated by evaporation and dissolved in wine. They are placed on the market under various proprietary names. In some factories the fresh livers, rather than the oil, are used in manufacturing the "active principles," since the latter are alleged to occur in far greater abundance in the liver tissues than in the oil. According to an account given by the proprietor of one of these preparations, the livers are thoroughly minced in a steam-power chopping-machine and macerated for several days in large stirring machines of special design, a menstruum being employed consisting of diluted alcohol containing a small quantity of citric acid. The extract is then drawn off and concentrated in vacuo at a temperature of 40° F. When the liquid is reduced to about the consistency of extract of beef, it is removed from the vacuum pan, assayed for alkaloidal contents, and then dissolved in wine in proper proportion to represent the "active principles" contained in one-fourth its bulk of cod-liver oil.

Only about 10 per cent of the cod-liver oil consumed in this country is produced in the American fisheries, the great bulk of it being imported from Norway. As already shown, the product of medicinal oil in the United States fisheries is only about 25,000 gallons each year, whereas the imports usually exceed 200,000 gallons annually, and in some years exceed 500,000 gallons.

The following summary, showing the total quantity and value of cod-liver oil imported for consumption into the United States during a series of years, is compiled from the United States customs returns:

Statement of the quantity and value of cod-liver oil imported into the United States during a series of years.

Year ending June 30—	Gallons.	Values.	Average value per gallon.	Year ending June 30—	Gallons.	Values.	Average value per gallon.
1880	316,910	$152,441	$0.483	1891	248,894	$98,865	$0.397
1881	516,657	236,763	.459	1892	202,959	115,577	.569
1882	302,137	162,563	.538	1893	190,432	99,709	.524
1883	218,716	159,271	.733	1894	209,865	99,318	.473
1884	412,135	275,078	.667	1895	207,145	131,804	.636
1885	221,030	153,945	.696	1896	179,660	203,588	1.133
1886	115,454	67,652	.586	1897	179,677	170,610	.961
1887	130,296	69,326	.532	1898	201,582	116,913	.582
1888	165,633	78,233	.472	1899	233,176	127,074	.545
1889	287,183	81,589	.284	1900	276,940	136,666	.494
1890	267,555	86,476	.323	1901	235,749	137,715	.584

PREPARATION OF COD OIL FOR TECHNICAL PURPOSES.

The methods of extracting cod oil for currying and other technical purposes does not differ essentially from the extraction of medicinal oil, the principal difference being the use of all livers secured, the absence of extreme cleanliness, and the greater putrefaction or the more extensive cooking of the material. Considerable common oil is also expressed from the livers cooked for medicinal oil after the latter has been dipped or skimmed off.

The original method of extracting cod oil, and the most common one at the present time, is by putrefaction. In the Grand and the Western banks fisheries, during the process of dressing the fish, the livers are collected and placed in liver-butts. These butts are characteristic of vessels engaged in a salt-fish trip; in the market fishery for cod, haddock, etc., their place is taken by upright barrels or gurry kids. There are two liver-butts on each vessel; they consist of large casks, with a capacity for about 150 gallons each, mounted horizontally on skids immediately in front of the house and lashed securely to the deck. On the top, in the bilge of each cask, there is a large square opening, covered with a piece of tarpaulin securely fastened at one end, through which the livers are dropped into the cask. As the oil cells in the livers are broken by decomposition and by their constant churning with the rolling of the vessel, the oil rises to the surface, and is bailed off from time to time to make room for fresh livers. The oil dipped or bailed off, known as "sun-tried oil" or "top dippings," is placed in barrels, while the refuse blubber remains until the vessel reaches port, when it is boiled to extract the remaining oil.

The "sun-tried oil" represents probably 20 to 40 per cent of the total quantity of oil produced. It is superior to that rendered by cooking, being heavier bodied, and does not chill so quickly, the quantity of foots being much less. The oil first obtained from the butts is of a light yellow color, and formerly was used to some extent for medicinal purposes. As putrefaction advances, the color deepens to a brownish shade, and that extracted by cooking the decomposed livers ashore is very dark, with a greenish fluorescence in reflected light. In small quantities it shows a brown color, and therefore is known as brown oil. None of this oil is used for medicinal purposes, owing to its strong odor and flavor and the abundance of decomposed tissue contained in it. The market fishermen, who return to port every two or three weeks, save the livers and sell them to the oil-merchants at 25 or 30 cents per bucket of 2½ gallons each.

Of the several grades of cod oil used for technical purposes, the best is that made from livers taken in the Grand Banks fisheries; this is known as "Newfoundland cod oil" and sells for about 2 cents per gallon more than "domestic cod oil" made from livers taken on Western and Georges Banks. "Straits oil" and "bank oil" were formerly well-known grades of cod oil, but these are now made entirely from menhaden. The low grades of cod oil are strained or filtered in the same way as the medicinal oil, 100 gallons yielding 15 or 20 pounds of foots, worth about 4 cents per pound.

Cod oil is used for currying mostly in New York, Pennsylvania, Ohio, Michigan, Illinois, and Wisconsin, only about 20 per cent being used in New England. Some of the best quality is exported. Small quantities are also used for soap-making and in various compounds.

The following table (based upon the closing quotations each week for prime domestic oil, as contained in the New York trade journals) shows the lowest and highest selling prices for cod oil for technical purposes in the New York market during each year from 1891 to 1902:

Year.	Price per gallon.	Year.	Price per gallon.
1891	$0.32 to $0.43	1897	$0.24 to $0.30
1892	.37 .39	1898	.28 .35
1893	.36 .39	1899	.32 .34
1894	.28 .38	1900	.30 .37
1895	.27 .30	1901	.31 .38
1896	.24 .27	1902	.33 .39

OIL FROM LIVERS OF SHARKS AND RELATED SPECIES.

The livers of various species of sharks and allied fish are suitable for oil-production, giving rise in some localities to important fisheries. The principal species used are the sleeper shark, otherwise known as the nurse, ground, or gurry shark (*Somniosus*), taken in northern waters from the Arctic seas southward to Massachusetts, Oregon, and France; the basking or bone shark (*Cetorhinus*), formerly quite numerous, but now taken to a less extent, north of Europe and on the coast of Peru, Australia, California, etc.; the oil shark (*Galeorhinus*), on the Pacific coast, especially in California, and the dog-fish (*Squalus*), distributed throughout both hemispheres. In addition to these, nearly every species of shark yields livers suitable for oil-rendering.

The sleeper shark appears to be the most important species so far as oil-making is concerned. This is a large fish, individuals ranging in length from 12 to 25 feet. The livers yield from 12 to 50 gallons of oil each when taken in the autumn, but in the spring and summer they are almost worthless for oil purposes. On the New England coast this species is much less numerous than formerly, but it is reported in abundance on the Pacific coast of the United States.

During the autumn the taking of the sleeper shark is a somewhat important branch of the minor Icelandic fisheries, and it is also taken by the Russians off the Kola Peninsula. The most important fishery, however, is off the coast of Norway, and especially between Lofoden Islands and Bear Island, in depths of from 150 to 200 fathoms of water. The Norwegians employ small vessels of 20 to 35 tons, carrying about six men each, the season beginning the first of October and ending in February. The fish are taken by means of large, strong hooks baited with fish or salted seal blubber.

The basking shark, probably the largest of all sea fishes, has been taken very extensively for the oil contained in the livers, but owing to decrease of the species the quantity now secured is much reduced. This fish attains an enormous size, the prevailing length of fully-grown individuals being 30 to 35 feet. The liver is proportionally large, yielding ordinarily from 80 to 200 gallons of oil and occasionally as much as 400 gallons. Indeed, a yield of 600 gallons has been reported from a single individual, but this has not been satisfactorily established. This species differs from other sharks in not being voracious. Therefore it must be taken with harpoons rather than with baited hooks. There is said to have been quite an extensive fishery for it on the Massachusetts coast about the middle of the eighteenth century. According to Captain Atwood, writing in 1880, "Not more than half a dozen have been caught near Provincetown since 1810."

The basking shark is numerous on the coast of Peru and Ecuador, and its capture gives employment to a large number of small vessels, manned by 6 or 8 men each. The American vessels fishing for humpback whales on that coast have occasionally engaged in its capture when whales were not in sight. Capt. George O. Baker, of New Bedford, reports that on one occasion in two days' fishing he secured 125 barrels of shark oil while on the lookout for humpback whales.

The method of taking this fish off the Peruvian coast, according to Captain Baker, is to approach it while it is lying motionless at the surface of the water and to fasten a harpoon in the top of the head forward of the eyes, so as to hold the head up and thus prevent the fish from going down or "sounding," and then the boat approaches and lances it until it is quite dead. It is taken alongside the vessel, a hole is cut in one side of the abdomen, a strap inserted on either side of the incision and the tail hoisted up so as to raise the body somewhat out of the water. A man then enters the abdominal cavity and with a knife cuts out the liver in pieces. These are passed up on deck, minced, as in the case of whale blubber, and placed in the try-pots. After a sufficient length of time the cooked liver-pieces are removed from the pot, placed in a canvas or hempen bag, suspended from aloft, and permitted to drain. Nothing but the oil is saved. A considerable market for it exists in South America, where it is used principally as a body for paints for exterior surfaces. The price is usually 8 or 10 cents per gallon more than that of humpback oil.

The basking shark is taken occasionally on the California coast, the individual yield of oil there averaging about 125 gallons. The same species is also said to be taken in the waters of British India, being harpooned in great numbers by the fishermen of Karachi and other coastal districts.

The common dog-fish (*Squalus*) of the Atlantic coast and a similar species on the Pacific coast are the principal oil-yielding sharks in America. These fish range from 2 to 5 feet in length and from 5 to 15 pounds in weight. They are the great pest of fishermen, destroying nets, robbing fish from the trawls, and committing other depredations.

It does not appear that any important fisheries are organized especially for the capture of these fish, but many are taken incidentally in the shore and Georges cod fisheries, particularly during the spring, and the livers are extracted and thrown in the liver-butts along with those of other fish. The livers are generally of a bluish-gray color, shaped somewhat like those of cod or pollock and are very brittle, breaking readily when lifted.

In Boston and Gloucester dog-fish livers are sold at the same rate as those of cod and related species—viz, 25 to 30 cents per bucket of 2½ gallons. The yield of oil during August, September, and October is about 6 quarts per bucket, but at other seasons it is much smaller.

Because of the small quantity secured, this oil is rarely kept separate from cod oil for currying purposes, and it sells for about the same price per gallon. A distinctive characteristic is its strong odor when warm, resembling that of ammonia; but this may be removed by proper refining. It is estimated that from 10,000 to 15,000 gallons of dog-fish oil are prepared on the New England coast annually, nearly all of which is combined with and sold as cod oil for currying purposes.

Captain Atwood writes:[a]

> When I first began to go fishing, in 1810 to 1820, the dog-fish fishery was considered one of the most valuable fisheries that we had around the shore. They appeared here in the spring and were very plenty, and would last a day or two and then all would be gone. Then you would not see a dog-fish again all summer, but about the 10th or middle of September they came to us again, returning South. They would stay into November, and during that time the fishermen would get—a man and a boy—all the way from 8, 10, to 15 barrels of oil. Twenty-five years ago we would occasionally see dog-fish in the summer. The last fifteen years they have been here all summer. During the war they were plenty all summer, and the livers sold for $1 a bucket, and now they are worth but 20 or 25 cents.

On the coast of Oregon, Washington, and British Columbia, large numbers of dog-fish are taken for conversion of the livers into oil, which finds a ready sale, owing to the high cost of other oils on that coast. These fish are reported especially abundant in the vicinity of Queen Charlotte Island, in British Columbia, where they are captured by the Indians. The livers of 100 dog-fish yield 6 or 8 gallons of oil, and the rest of the carcass is utilized for fertilizer. Not only is there an abundance of this oil produced for local use, but also much for export. As long ago as 1876, about 60,000 gallons were exported from Victoria, at a valuation of 40 cents per gallon.[b] The present annual product is said to exceed 200,000 gallons. New York dealers have received some good samples which indicate a very low weather-test, but owing to the duty and freight rates little has come on the Eastern market.

Dog-fish oil has been used on the Pacific coast in competition with other oils with most favorable results, being "equal, if not superior, to oil supplied to Her Majesty's ships by the service, both for lubricating and lighting purposes."[c]

Similar species of dog-fish are taken on the coasts of Norway, Chile, and elsewhere, the fisheries being confined to the summer months and the catch secured with nets as well as with hooks.

Along the Atlantic coast of the United States but little attention is given to the capture of sharks for economic purposes, notwithstanding the many species which occur there in comparatively large numbers. In several localities on the southern coast small fisheries are prosecuted during the winter months, for then the yield of oil is greatest. Among the species taken, other than those above mentioned, are the sand or yellow shark (*Carcharias littoralis*), which

[a] Fishery Industries of United States, Sec. I, p. 674.
[b] Report of the Commissioner of Fisheries of Canada for 1876, p. 346.
[c] Fourteenth Annual Report of the Department of Marine and Fisheries of Canada for the year 1881, p. 214 of supplement No. 2.

attains a length of 5 feet, and yields from 1 to 2 gallons of oil; the leopard or tiger shark, length from 10 to 25 feet, yielding 10 to 20 gallons of oil; the mackerel shark, also known as porbeagle or blue shark, measuring from 8 to 10 feet in length, and the liver yielding from 2 to 7 gallons of oil; the dusky shark (*Carcharhinus obscurus*), which attains a length of 10 feet; the hammer-headed shark (*Sphyrna zygæna*), of 12 or 15 feet in length; the dog shark (*Mustelus canis*), 2 or 3 feet in length; and the thresher shark (*Alopias vulpes*). Some of the large sand and leopard sharks are difficult to secure and their capture gives considerable trouble. They are taken usually by means of harpoons or stout hooks and lines. When taken from a small boat at sea, immediately after the fish has been secured it is lanced to death, the belly is ripped open with a knife, the boat canted, and the large, slippery liver pulled over the side into the boat, and then the carcass is discarded. Many of the smaller sharks are captured with menhaden, in purse seines, and are utilized at the menhaden factories. Owing to the damage which they do to the twine, the fishermen prefer to not set the seines around sharks, but it is difficult to avoid taking a few of them with the menhaden. It is estimated that from 7,000 to 10,000 sharks are captured annually by the menhaden steamers, all of which are converted into oil and fertilizer.

On the Pacific coast of the United States, especially in California, the oil shark (*Galeorhinus*) is utilized. It is 4 to 6 feet in length and weighs from 40 to 70 pounds, the yield of oil from the livers varying from two-thirds of a gallon to 1 gallon each. The fish are taken by means of hooks and lines when they enter the lagoons for reproductive purposes during the summer. The fins of this species are dried and sold for 12 or 15 cents per pound, the Chinese using them in soup-making. Other species of shark utilized on the Pacific coast are the shovel-nose shark, thresher shark, and the man-eater or white shark. The shovel-nose shark was taken extensively along the coast of Humboldt County, Cal., from 1858 to 1868, from 50 to 60 men being employed at times in the fishery. It is harpooned in deep water and taken by means of hand lines in shallow water. This species measures from 6 to 10 feet in length, and the liver of each individual yields 3 to 7 gallons of oil.

There are several species of skates, rays, etc., occurring on the United States coasts which are utilized to some extent for oil-production. Principal among these are the common skate (*Raja erinacea*), the prickly skate (*R. eglanteria*), the smooth or barn-door skate (*R. lævis*), the sting ray (*Dasyatis centrura*), the cow-nose ray (*Rhinoptera bonasus*), etc. Many thousands of these are captured by the menhaden fishermen and utilized at the factories for conversion into oil and guano. Oil from the liver of the torpedo or cramp-fish (*Tetronarce occidentalis*), a large species, which at times attains a weight of 200 pounds, is said to be valued by the fishermen in the treatment of cramp and rheumatism.

Captain Atwood wrote in regard to the oil from the torpedo:

I used to go and look for them for their livers—for the oil. The oil is one of the best lamp oils that I ever saw. It has been used sometimes beneficially in cases of cramp. I got a gallon of oil from one liver. I do not know but I have seen a cramp-fish big enough to make three gallons of oil.[a]

The liver of the saw-fish (*Pristis*), numerous on the South Atlantic and Gulf coasts of the United States, yields from 6 to 18 gallons of oil. It is said that in British Guiana this oil is used for illumination and also for anointing the bodies of the inhabitants. The liver of the elephant-fish (*Chimæra*), which occurs in abundance on the California coast, is large and yields choice oil. This fish has a maximum length of 2 feet and weighs 6 or 7 pounds.

It appears from the above that the yield of oil from individual shark livers ranges from much less than 1 pint in case of the dog-fish and others to the 400 gallons procured from the basking shark. Other than the livers, the carcasses of sharks are slightly oleaginous, and are rarely ever utilized in oil-rendering, but they are of course useful for conversion into fertilizer. The method of extracting the oil from the livers is much the same in all cases. If they are large, they should first be cut in small pieces or minced, as is done with whale blubber. The pieces are then subjected to heat until the cells are thoroughly broken, when the oil is extracted by pressure or it is permitted to drain therefrom. In case the oil is to be used for medicinal purposes great cleanliness is observed, the livers being washed free from blood and the gall bladder removed. A quantity of water is placed in the kettle with the hepatic tissues and the whole boiled gently for an hour or two. On cooling, the oil floats on the surface and is dipped off and stored. It may be refined in precisely the same manner as cod oil.

According to Brannt, shark oils are distinguished as being the lightest of fixed oils, their specific gravities ranging from 0.870 to 0.880 at 59° F., so that a mixture with blubber or other fish oils can at once be recognized by the higher specific gravity. They are pale yellow and clear, remain fluid at 21° F., and contain very little stearin. They burn with a bright flame without carbonizing the wick. Brannt further states that they contain about the same constituents as cod-liver oil, but are richer in iodine. On account of their percentage of gall constituents the liver oils are readily distinguished from other fish oils.

Shark oils are largely used in tanneries, in steel-tempering, and in various compounds where it is desired to impart a low specific gravity. They are also valuable as a body for paints for out-of-door objects, as walls, fences, etc. In some localities certain kinds are used by medical practitioners, who consider them quite equal to cod-liver oil. In the drug stores of this country shark oil is occasionally found with a label suggestive of an oriental origin and recommending its use as an embrocation in numerous diseases.

[a] Natural History of Aquatic Animals, p. 667.

MENHADEN OIL.

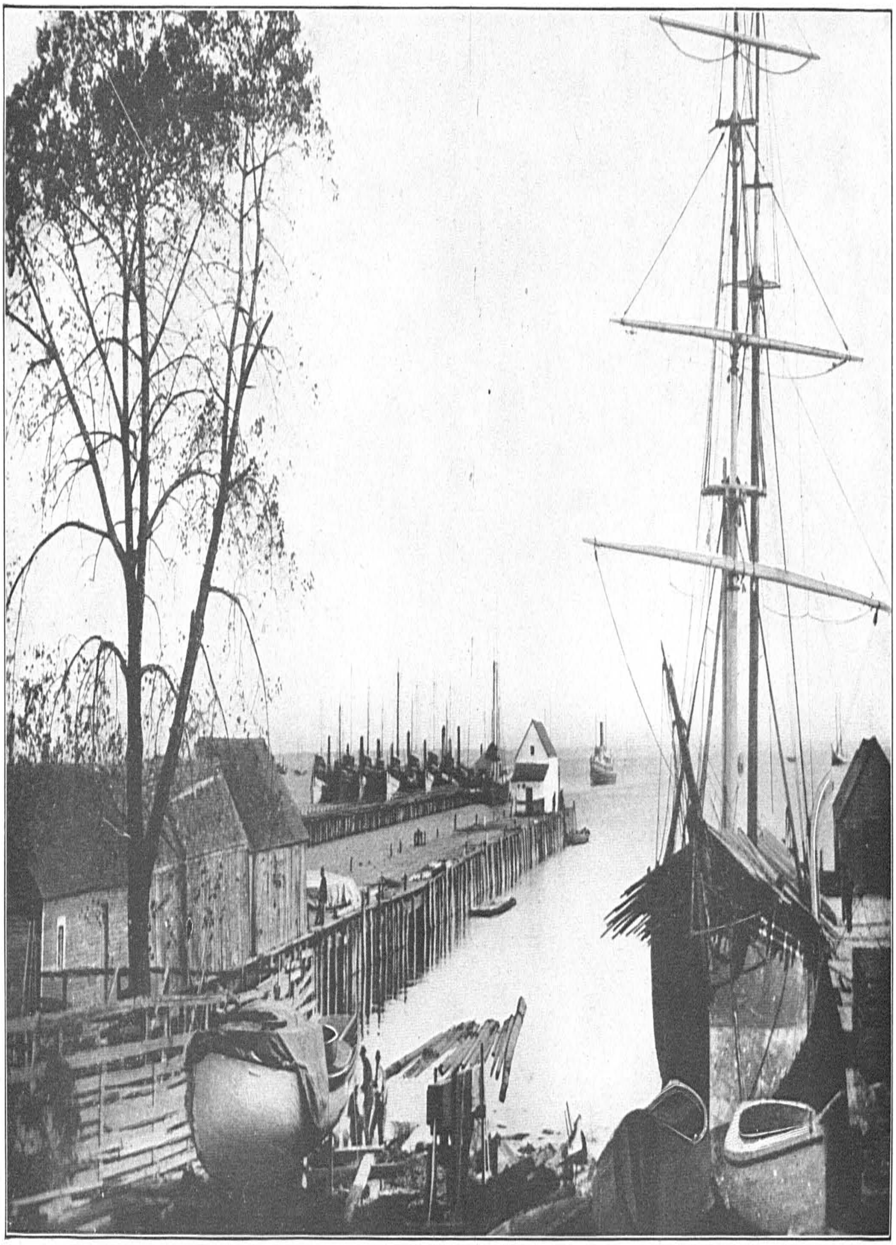
In speaking of fish oil in a restricted sense along the Atlantic coast of the United States, reference is made generally to that yielded by the menhaden (*Brevoortia tyrannus*), a member of the *Clupeidæ* or herring family, known locally by a score or more of names. This species occurs from Maine to Texas, the principal fishing-grounds being the bays and sounds from Maine to North Carolina, with the addition of the Texas coast during the last two years.

The extraction of menhaden oil differs from the preparation of other marine-animal oils in that the scrap or solid tissue remaining after the liquids have been removed is usually greater in value than the oil. Indeed, it was principally as a fertilizer that the menhaden was first utilized, the oil being extracted as an incidental product. Because of the greater value and importance of the scrap, the methods of manipulating the fish, extracting the oil, and the like are described in the second part of this report, relating to the preparation and utilization of fertilizers from fishery products. (See pp. 255–265.)

While small quantities of menhaden oil were prepared for domestic and local use previous to 1860, there was comparatively little marketed previous to the civil war. The first lot on the New York market sold at 75 cents per gallon and, its use giving satisfaction, the market price quickly advanced to $1.40 in 1865, the highest figure ever realized. For ten years the menhaden producers sold their crude oil within a range of 50 cents and $1 per gallon, resulting in great profit. This led to a large increase in the number of factories, the purchase of costly steamers and equipments, and a great overproduction.

The excess of production, a lack of cooperation among the factorymen, and competition with substitutes resulted in a gradual reduction of prices, until in the autumn of 1887 menhaden oil sold at 19 cents per gallon, which was much below the cost of manufacture. The necessity for protecting their invested capital led to concerted action among the producers and an attempt to bring about an agreement on prices and also a limitation of the fishing season. Many factories were closed and the vessels laid up, the owners preferring to keep them idle rather than to engage in unprofitable work.

The diminished extent of the output and a better understanding among the producers resulted in an improvement in prices, which finally reached 40 cents per gallon in the spring of 1893. Then, owing to unfavorable conditions, prices began to decrease until in the fall of 1896 crude northern menhaden oil was sold at 18 cents per gallon, the lowest price ever reached. Since 1896 the business has been conducted with much less competition and with greater economy by reason of improved machinery and increased facilities, and as prices have been somewhat higher a fair profit has been derived from the business by those whose invested capital is not greatly in excess of the value of their respective plants.



VIEW OF MENHADEN FLEET AT PROVINCETOWN, MASS.

During the last thirty years the product of menhaden oil has averaged about 2,000,000 gallons annually. The largest yield was in 1878, when 3,809,233 gallons were produced, and the smallest in 1881, when the reported product was only 1,266,549 gallons. The following summary, compiled from the returns of the United States Menhaden Oil and Guano Association, shows the product for each year from 1873 to 1898, inclusive, and also the number of fish taken. For purposes of comparison, the average quantity of oil to the thousand fish in each year is also given.

Statement of the quantity of menhaden oil manufactured, the number of menhaden utilized, and the average quantity of oil to the thousand fish in each year from 1873 to 1898, inclusive.

Year.	Oil made.	Fish utilized.	Quantity of oil to 1,000 fish.	Year.	Oil made.	Fish utilized.	Quantity of oil to 1,000 fish.
	Gallons.	*Number.*	*Gallons.*		*Gallons.*	*Number.*	*Gallons.*
1873	2,214,800	397,700,000	5.57	1886	1,805,544	283,106,000	6.38
1874	3,372,847	492,878,000	6.84	1887	2,273,566	333,564,800	6.81
1875	2,681,482	563,327,000	4.76	1888	2,051,128	439,388,950	4.67
1876	2,992,000	512,450,000	5.84	1889	3,327,030	555,319,800	5.99
1877	2,426,589	587,642,125	4.13	1890	2,939,217	533,686,156	5.51
1878	3,809,233	767,779,250	4.96	1891	1,946,642	355,138,873	5.48
1879	2,258,901	637,063,750	3.37	1892	1,329,644	223,623,750	5.95
1880	2,034,940	776,875,000	2.62	1893	1,269,002	366,406,625	3.47
1881	1,266,549	454,192,000	2.79	1894	1,999,506	533,361,900	3.75
1882	2,021,316	346,638,555	5.83	1895	1,767,754	461,747,000	3.83
1883	2,180,320	613,461,776	3.55	1896	1,741,530	401,425,800	4.34
1884	3,722,927	858,592,691	4.34	1897	2,147,113	584,302,980	3.68
1885	2,346,319	479,214,415	4.89	1898	2,450,000	542,500,000	4.51

The following shows the lowest and highest prices quoted for crude northern menhaden oil in the New York market each year from 1863 to 1901, inclusive. These figures are based on the closing quotations published in the New York trade journals, especially the *Oil, Paint and Drug Reporter*, each successive week.

Statement of the range of prices for crude northern menhaden oil in the New York market from 1863 to 1902, inclusive.

Year.	Lowest.	Highest.	Year.	Lowest.	Highest.
1863	$0.75	$1.00	1883	$0.35	$0.48
1864	1.10	1.35	1884	.26	.47½
1865	.80	1.40	1885	.21	.30
1866	.70	1.13½	1886	.20	.26
1867	.45	.70	1887	.19	.21
1868	.50	.95	1888	.20	.32
1869	.62½	1.02½	1889	.21	.32
1870	.40	.68	1890	.22	.30
1871	.35	.55	1891	.25½	.30
1872	.36	.65	1892	.30	.38
1873	.32	.60½	1893	.33	.40
1874	.35	.47½	1894	.21	.33
1875	.30½	.48½	1895	.19	.25
1876	.30	.50	1896	.18	.23
1877	.30	.46	1897	.18	.25
1878	.23	.45	1898	.22½	.24
1879	.24	.35	1899	.22½	.27
1880	.29	.43	1900	.25	.27
1881	.30	.39½	1901	.26	.30
1882	.32	.42	1902	.26	.29

Menhaden oil varies in color from clear straw, through amber and the various shades of brown to almost black, depending principally on the condition of the oliferous material when the oil is rendered. If the fish are fresh, the resulting oil is usually clear, bright, and comparatively odorless and tasteless; and according to the extent of the decomposition the oil becomes darker in color until it approaches a very dark brown. However, this is not always the case, for perfectly fresh fish sometimes yield dark oil.

The standard grades recognized for crude oil are A, B, C, and D; these terms being synonymous, respectively, with extra light crude, light crude, brown crude, and dark brown crude. The bulk of the output is of A grade, and little D oil is now prepared except in the Southern factories.

In the process of refining, menhaden oil is first heated and then placed in barrels and chilled in the manner already described for whale oil, either by exposure during cold weather or by refrigeration. This chilling grains the oil, the thick parts collecting together and the limpid oil forming globules. The grained oil is then placed in bags made of coarse material, and these carefully arranged one above another in a press. On applying compression, the thin oil comes out first and the impurities and stearin are left behind. The oil is then placed in shallow vats or tanks, exposed to the rays of the sun and protected by a glass covering, where it remains for a day or two. It may also be clarified by treating it with caustic soda and acids, resulting in a short time in a clear, light-straw color.

The pressing of the oil in connection with its refinement may be done at a summer temperature, but in that case only a portion of the foots are extracted and the oil has a poor weather-test. The usual weather pressing during the summer yields 5 per cent of foots, and the oil stands a temperature of about 50° F. If pressed at a temperature of 32° to 35° F., the foots extracted represent about 10 per cent of the original bulk. The foots are used as a substitute for tallow in leather-currying and also in soap-making, the market price approximating 3 cents per pound.

The products from refining menhaden oil are pressed extra light, pressed light, pressed light brown, pressed dark brown, bleached, extra bleached, oil foots or pressings, bleached oil foots, extra bleached oil foots, and menhaden oil soap. The first four grades of pressed oil are obtained respectively from A, B, C, and D grades of crude oil. A difference of about 1 cent per gallon exists between the prices of each of these consecutive grades of pressed oil. The pressed light is the standard grade, and when that sells at 30 cents per gallon the pressed extra light sells at 31 cents, the pressed light brown at 29 and the pressed dark brown at 28 cents per gallon. On the same basis the bleached sells at 33 cents per gallon, the extra bleached at 35 cents; and the same oils pressed at a low temperature sell for 1 or 2 cents more per gallon. A corresponding price for the unbleached foots is 2½ cents per pound; bleached foots, 3½ cents per pound; extra bleached foots, 4 cents, and menhaden-oil soap, 4 cents.

The names "straits oil" and "bank oil" were formerly applied to certain grades of cod oil, but at present these refer, respectively, to B and C grades of pressed menhaden oil, gradual increase in adulteration having resulted in complete change of material.

The principal uses for menhaden oil are currying or filling leather, illuminating, paint-making, lubricating compounds, tempering, soap-making, screw-cutting, wire-drawing, and cordage-manufacture, the first three consuming about 80 per cent of the total product. The light and extra light oils are generally employed in illuminating, lubricating, painting, and cordage-manufacture; the light brown for currying, and the dark oil for tempering and screw-cutting.

Large quantities of menhaden oil were formerly used by miners in safety lamps, but leather-currying has been the principal consumer during the last thirty years. Its use in steel works is of comparatively recent origin, and the steel industries now require many thousands of barrels annually.

It was as a substitute for linseed oil in painting that menhaden acquired its first popularity prior to 1865. The oil as then prepared was of very indifferent quality, the process of manufacture being comparatively crude, and much of the product would not now be considered marketable. On account of its being too highly recommended and all grades being sold for the purpose, considerable prejudice was soon created against it as a substitute for linseed oil. But with the improved methods of extraction and refining and with a better understanding of its limitations and technical qualities, these objections have been largely overcome. Its odor makes it undesirable for interiors and restricts its use to outside surfaces. According to Mr. A. H. Gill, its value for drying is somewhat less than that of linseed, but greater than that of poppy-seed, corn, cotton-seed, and sesame oils.

Menhaden stands the weather much better than linseed oil, especially when applied to tin roofs and ironwork. Owing to its glutinous nature, it is harder to apply than linseed oil, and consequently workmen do not always favor its adoption. This use of menhaden oil is now increasing and a single paint factory in New York City consumes 4,000 or 5,000 barrels annually.

If the oil is cleared from the foots by straining or pressing, cut with sulphuric acid of 45° strength in proportion of 1 gallon of acid to 50 gallons of oil, well stirred in and permitted to settle, and then washed down by a spray of cold water played on it, the acid and gluten are precipitated. Thus treated, menhaden makes a good substitute for linseed oil in mixing paints; it may also be used for leather-dressing and, mixed in equal proportions with paraffin and plumbago, makes a desirable lubricator.

The use of menhaden oil for illuminating purposes is confined to miners' lamps, especially in the coal mines of Pennsylvania and West Virginia. For this purpose it is generally combined with mineral or vegetable oils, the mixture giving better satisfaction than the use of menhaden oil alone. It is non-explosive and therefore much safer than mineral oil. The luminous effect of refined menhaden oil has been found to be high with a relatively low consumption, as compared with petroleum.

The following treatment of menhaden oil in combination with other substances for painting purposes is recommended by Andes:[a]

Into a wooden barrel are brought 144 liters of good vinegar, 6 kilograms of litharge, and 6 kilograms of zinc sulphate; then the barrel is rolled about for a long time, and the liquid then poured into 100 liters of fish oil. The mixture is well stirred, and then left at rest for twenty-four hours; when the clear oil is drawn off, seven-eighths of the original quantity is obtained. Fifty-four liters of linseed oil and 9 liters of turpentine are at once added. The liquid is left at rest for several days, and then drawn off. The residue is mixed with an equal volume of milk of lime, and used for painting wood and iron which are exposed to the air.

When whale and cod oils are scarce and high in price menhaden oil is extensively used as a substitute. Its chief competitors are degras, petroleum compounds, and herring oil made in the United States and in Japan and Europe, the latter competing with it principally in Europe. For further data in regard to this oil, especially the methods of manufacture, extent of production, and so forth, see pages 255–265.

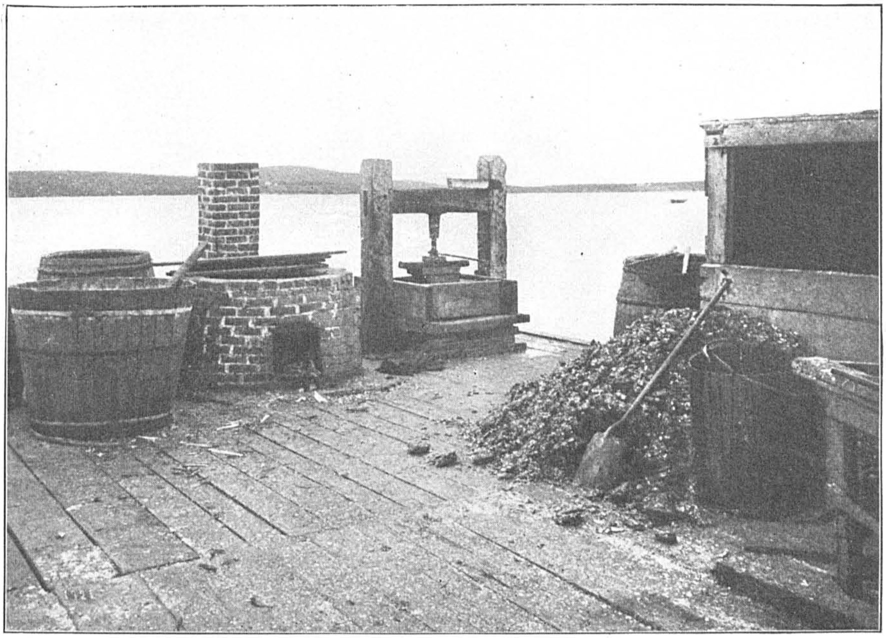
HERRING OIL.

The herring, including its related species—the sardine, pilchard, sprat, anchovy, etc.—is probably the most valuable and important product of the world's fisheries, not so much on account of the choice nutritive qualities, perhaps, as because of the enormous quantities obtained. When the product exceeds the demands of the food markets, including those required for salting, canning, etc., these fish furnish excellent material for oil-production. Their utilization for this purpose is by no means of recent origin, the production of herring oil in the Bohuslan fisheries of Sweden over a century ago ranging between 1,000,000 and 2,000,000 gallons annually. Nor is it of limited geographical distribution, as the oil is produced to a greater or less extent in nearly every maritime country of Europe, in the British North American provinces, on the northern coast of the United States, in Japan, certain parts of the African coast, etc.

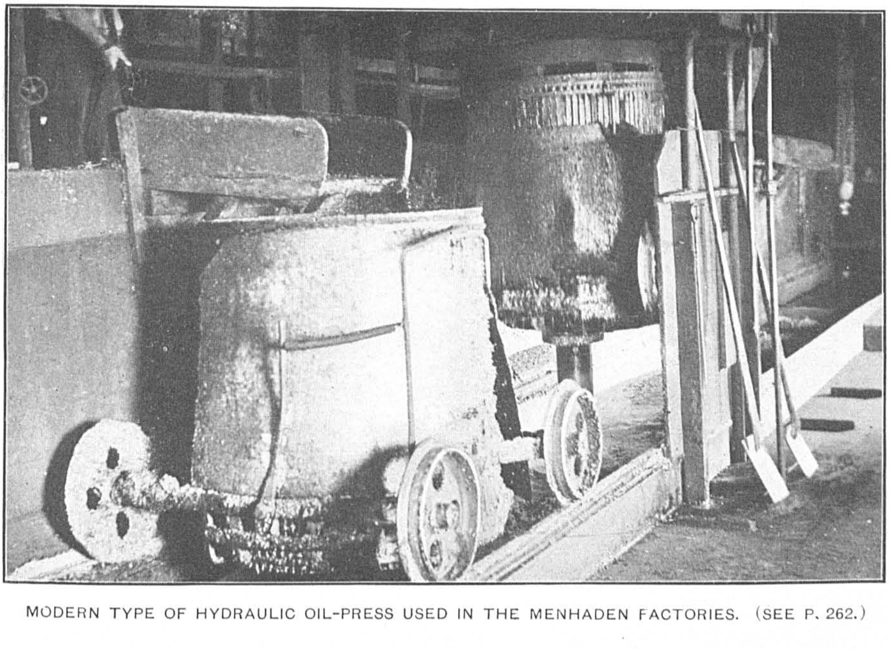
Since only the surplus or waste fish are used in oil-making, and as the catch fluctuates greatly, it follows that much variation occurs from year to year in the quantity produced. The figures showing the output in a certain territory are quite unreliable for any year except the one to which they particularly relate. It is therefore difficult to approximate the product of herring oil throughout the world. It seems probable, however, that a reliable estimate would place the average annual yield at not far from 3,500,000 gallons, of which only a small portion is produced in the United States.

During the fifteen or twenty years preceding 1875, when fish oils

[a] Andes: Drying Oils, p. 280, London, 1901.



PRIMITIVE FORM OF KETTLE AND PRESS FOR RENDERING OIL FROM HERRING ON THE MAINE COAST.



MODERN TYPE OF HYDRAULIC OIL-PRESS USED IN THE MENHADEN FACTORIES. (SEE P. 262.)

were worth about double their present values, there were small plants all along the eastern coast of Maine for utilizing the herring in oil-manufacture. The crude material consisted principally of refuse fish taken in connection with the smoked-herring business, especially the small fish which otherwise were valueless. Sometimes the larger herring—over 6 inches in length—were utilized, but only when the comparative prices of oil and smoked fish warranted. This business did not engage the attention of large establishments, but was conducted by many fishermen in a small way, each man working for himself.

As the refuse herring accumulated they were sprinkled with salt, using about 1 bushel to 3 or 4 barrels of fish. After remaining in the salt about 24 hours, they were boiled in open kettles and then subjected to pressure in a screw press with capacity for about 1½ barrels. The average yield was about 16 gallons of oil to the ton of fish, but at times the fish were so fat that 20 and even 25 gallons were secured to each ton. The chum or scrap was partly dried and then sold as fertilizer at about $12 per ton.

The development of the sardine business furnished more profitable use for small herring, and since 1875 the waste from the sardine canneries has provided most of the material for herring-oil production in Maine. This waste consists of the spoiled fish and of the heads and viscera of fish used in canning, each factory generally using its own refuse. The extent of the business is small. The total output in 1889 amounted to 34,316 gallons of oil, valued at $8,580, and 1,941 tons of scrap, worth $15,528. Owing to the decreased value of the oil, this business has since fallen off considerably, the output in 1898 amounting to only 12,672 gallons of oil, worth $2,116, and 785 tons of scrap, worth $5,910.

The method of manufacture is described by Mr. Ansley Hall on page 479 of Report of U. S. Fish Commission for 1896.

Considerable quantities of oil have been prepared from herring on the Pacific coast of the United States. The industry dates from 1867, but the output was irregular for a number of years. In 1885 the product amounted to upward of 200,000 gallons, much of which is alleged to have been sold as whale oil. In 1892, according to the *Oil, Paint, and Drug Reporter*, the output approximated 500,000 gallons, 60 per cent of which was prepared at Killisnoo, Alaska. The yield of oil ranges from 1 to 4 gallons to the barrel of fish. The value on the Pacific coast is about 20 cents per gallon, and the dried scrap sells for about $25 per ton. This oil is usually quite clear, and the foots extracted in refining are nearly as white as spermaceti and sell for about 1 cent per pound less than tallow from sheep and oxen, being used largely by soap-makers on the coast.

When herring are taken in the fisheries of Europe in such quantities that they can not be profitably used for food, it is customary to convert them into oil and fertilizer. Herring oil is extensively manufactured in Norway and Sweden, and with the exception of that obtained from cod livers, it is now the principal fish oil of those countries. The manufacture in Sweden developed rapidly eight or ten years ago, due to the abundance and consequent cheapness of herring. According to Capt. J. W. Collins, the number of factories increased from 3 in 1891 to 22 in 1895, the output in the season of 1895–96 amounting to about 500,000 gallons of oil and 16,000 tons of fertilizer. The scarcity and consequent high price of herring since 1896 have greatly restricted the output of these factories.

In the preparation of sardines in Europe the heads, viscera, and other waste parts are generally utilized in oil-production. They are cooked and pressed, the oil separated, and the refuse used for fertilizer. This oil is employed in leather-dressing, cordage-manufacture, the preparation of paints for exterior surfaces, and, in some country districts, for illumination. Unfortunately, we have no data bearing on the total extent of the output.

The herring-oil industry in Japan is probably much older than its counterpart, the menhaden industry in America, but it was in a crude state up to about twenty years ago. The species of fish utilized—known as "iwashi"—is found in large schools along the Japanese coast, especially on the northern side of the main island, and very large catches are made in the fall and winter, when the fish are fat.

According to a recent report by Consul Van Buren, of Kanawaga, the principal fisheries are on the island of Yezo and the peninsula of Ava, near Yokohama. The method of extraction is similar to that employed in the United States. The fish are cooked and pressed and the residuum used for fertilizer. The process of refining is likewise similar to that employed in America, the oil being pressed "in small filtering bags of paper, outside of which are similar ones of strong cloth. A number of these are placed in a press, which forces out the oil through the pores of this double envelope."

Japanese herring oil contains an unusually large amount of foots, amounting to about 25 per cent, according to some refiners. On account of this, the weather-test of the crude oil is high, from 65° to 70° F. Before the introduction of kerosene in Japan, refined herring oil was employed largely for illumination, but that is greatly reduced. It is now used locally in the manufacture of soap, in leather-dressing, in cordage-manufacture, as a body for paints, and for other technical purposes.

Since 1881 large quantities have been exported to Europe, and also at intervals to the United States. At first it found little acceptance on account of its unpleasant odor, due to the crude method of extraction. Another objection was the form of the packages, consisting of second-hand 5-gallon kerosene cans, which proved a nuisance to users of large quantities. The Hamburg market price is about 40 marks per 100 kilograms for the light oil and 37½ for the brown. The foots, after the process of refining, sell at about 43 marks per 100 kilograms.

It is only when domestic fish-oils are high that Japanese herring oil can be profitably imported into this country, and on that account the imports fluctuate largely from year to year. The United States markets will receive it at 3 to 5 cents less per gallon than menhaden oil, but it can not be exported to this country with profit when the menhaden market is less than 26 cents per gallon, since the freights, insurance, import duties, brokerage, etc., would leave very little for the exporter. In 1885 the imports into this country amounted to 101,265 gallons, valued at $24,832; in 1886, 5,010 gallons, valued at $786; then they were insignificant until 1893, when 191,852 gallons, worth $30,746, were received. In 1894 the imports were 156,456 gallons, worth $24,656. Some very choice specimens of refined oil have been received from Japan for exhibition purposes, thus demonstrating what the factories there are capable of producing, but some of the product sent here for consumption could be improved upon.

OIL FROM WASTE FISH.

In addition to menhaden and herring, several species of fishes not suitable or available for food are used in oil-production. The use of sea-robin, skates, and bellows-fish taken with menhaden is noted in the account of the menhaden industry. Of these species, the sea-robin is the most desirable for this purpose, yielding about 8 gallons of oil to the ton of fish. Skates and bellows-fish yield comparatively little oil, amounting sometimes to less than 1 gallon to the ton. This is combined with the menhaden oil, no noteworthy difference being apparent. These fish are purchased by the menhaden factorymen at 50 to 75 cents per thousand, but it would not pay to handle them were it not for the fertilizer into which the solid tissue is converted after the extraction of the oil. The oil of the sun-fish (*Mola*) is used by some fishermen for the cure of rheumatism.

On the coasts of Alaska and British Columbia, and to a less extent in Washington and Oregon, there is secured a fish closely allied to the smelt and capelin of the Atlantic coast, which is of considerable value owing to its oil-yielding properties. This is the eulachon or oulahon (*Thaleichthys pacificus*), called also the "candle-fish," for the reason that the natives use it as a candle in their dwellings, it being capable of ignition and burning with good illuminating qualities. For many years, according to Dr. Tarleton H. Bean, an excellent quality of oil has been made from it by the Indians both for their own use and for trade with the whites. The weather-test of this oil is very high, and at ordinary temperature it is opaque and butyraceous; indeed, among the Indians it supplies the place of butter.

According to Dr. A. B. Lyons, of Detroit, eulachon oil contains "about 20 per cent of palmitic and stearic acids, 60 per cent of oleic acid, 13 per cent of an unsaponified substance, which is the most peculiar and interesting thing about it. This substance is of an oily consistency at ordinary temperature in summer, has much lower specific gravity than oleic acid or any other constituent of ordinary fats (specific gravity 0.865 to 0.872 at 59° F.[a]), and seems to resemble the unsaponifiable constituent of sperm oil."[b] According to Dr. Schaedler, when eulachon oil is mixed with sulphuric acid (1 volume of acid to 5 parts of oil) the temperature of the mixture rises to 121° F., whereas under similar conditions cod oil rises to 235° F. This acid does not impart to eulachon oil the beautiful purple color that it does to cod oil, but a deep brown, subsequently inclining to reddish yellow. Under saponification the precipitated fatty acids amount to about 95 per cent of the original bulk of the oil. Efforts have been made to introduce eulachon oil in the markets in competition with cod-liver oil for medicinal uses. It is claimed that it has nourishing and stimulating properties that adapt it to certain cases of malnutrition, and that it is more easy of digestion than cod-liver oil.

Large quantites of lampreys are used for oil-rendering in southern Russia. Prior to 1870 the lamprey was not an article of commerce there, except a small quantity used locally as candles in much the same manner as the eulachon on the Alaskan coast. It is now taken in large numbers on the Volga and Kur rivers. A small quantity is pickled for food, but the greater portion of them are used in oil-manufacture. It is reported that between Tsaritsin and Yenotayevsk, on the Volga River, about 50,000,000 lampreys are taken annually, yielding about 100,000 gallons of oil.[c] When properly prepared this oil is clear and transparent, but it contains a large quantity of glue, and consequently it is quite viscous.

OIL FROM FISH HEADS.

During the last twenty years the market has received considerable oil made from refuse at the salmon canneries on the Pacific coast. This was first prepared, about 1876, at a factory above Astoria, on the Columbia River. The heads alone were utilized. These were purchased at the canneries at the nominal price of 50 cents to $1 per 1,000, that quantity yielding from 30 to 35 gallons of oil.[d] The heads were cooked by steam and the oil expressed from the mass. This product was sold for use on the Pacific coast at prices varying from 22 to 35 cents per gallon according to the supply and demand. The output of salmon oil was small until 1895, when somewhat more than 50,000 gallons was received on the market. In 1899, according to Mr. W. A. Wilcox, two small establishments at Astoria for utilizing salmon refuse prepared 19,600 gallons of oil and 140 tons of fertilizer, and one factory at Anacortes, Wash., produced 22,000 gallons of oil and 350 tons of fertilizer. Only a small portion of this refuse on the coast is used. This oil compares favorably with that from menhaden and, being a waste product, can be prepared at a very low price. The vis-

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[a] The specific gravity at 59° F. is given by Dr. Schaedler as 0.907.
[b] Journ. Soc. Arts, 1884, p. 1107.
[c] Fishing and Hunting in Russian Waters, p. 27.
[d] See Fishery Industries of the United States, Sec. V, vol. I, p. 750.

cera of salmon yields such a small quantity of oil that usually it is not profitable to attempt its extraction.

In the United States the heads of halibut have been generally utilized for oil-manufacture since 1870. They are of no value as food and are discarded in dressing the fish for market. In Gloucester and Boston, the headquarters of the halibut fishery, they are collected by the oil-manufacturers, cooked, and pressed in the same manner as other waste products. They are placed in large receptacles and treated with steam until the tissues are thoroughly disintegrated, when the oil and water are extracted by subjecting the mass to hydraulic pressure, 1,000 pounds yielding about 20 gallons of oil. The annual product in Boston and Gloucester is about 12,000 gallons, valued at about 30 cents per gallon. When refined by treating with caustic potash, refrigerated, pressed, and sun-bleached, it looks as fine as choice whale oil and is commonly sold as a substitute therefor and at about the same price.

Sword-fish heads are usually very fat, a single head sometimes yielding one gallon of oil. As a rule, however, 100 heads yield about 65 gallons of oil. It is extracted in precisely the same manner as in case of halibut-head oil. The quantity prepared is small, probably not exceeding 1,000 gallons annually on the entire New England coast. It is clear and sweet and is probably sold as whale or cod oil.

The heads of other food-fish as a rule contain little oil. Cod and related species, for instance, contain practically none, and in utilizing them for fertilizer in this country, as well as in the British provinces and in Norway, no effort whatever is made to secure oil therefrom.

OIL FROM VISCERA OF FISH.

The quantity of viscera resulting from dressing food-fish at the markets, canneries, drying establishments, and the like in the United States amounts to upward of 100,000 tons annually. In certain species of fishes this material is very oleiferous, yielding as high as 150 gallons to the ton; but in most species the viscera are so poor in oil as to preclude their use for this purpose, the possible yield in some instances being as low as 4 or 5 gallons to the ton of crude material.

Probably the greatest yield of oil is from the viscera of the blue-fin white-fish and the chub or deep-water herring of Lake Michigan. The quantity ranges from 7 to 16 gallons of oil to the barrel and is much greater in winter than in summer. The average quantity of oil from the waste of lake trout is about 4 gallons to the barrel of 200 pounds. The yield from herring is small, probably not exceeding 1 gallon per barrel. The total quantity of oil contained in the viscera of all food-fish taken in the United States amounts probably to upward of 800,000 gallons. Only a relatively small proportion of this oil is saved.

Very few establishments exist in this country for utilizing the oil contained in the viscera of fish. A majority of these are on the shores of the Great Lakes, especially Lake Michigan, owing to the fatness of the waste from chubs (Hoy's white-fish) secured in great quantities in that lake. These establishments are small, the necessary pots or kettles, boxes, barrels, etc., not exceeding $300 in value. The viscera are usually saved by the fishermen in tight barrels furnished by the oil men, who receive this refuse for carting it away; water is added, and the whole mass cooked in large open pots or kettles for a length of time ranging from three to six hours. As the oil accumulates at the surface it is skimmed off and stored in suitable receptacles, the solid matter being discarded as of no value. When a barrel or two of oil has accumulated, it is reboiled and coarsely refined.

There are 8 or 10 of these oil-producing plants on the shores of the Great Lakes, and the total output probably does not exceed 20,000 gallons, whereas the total possible is upward of 200,000 gallons. One plant at Sheboygan, Wis., receiving the viscera from a catch of 296,365 pounds of blue-fin white-fish and chubs and of 110,260 pounds of trout in 1899, produced 1,180 gallons of oil, which sold for $301.

Considerable oil exists in various parts of the body of sturgeon, especially in the viscera and under the dorsal scutes or bosses. In the sturgeon fisheries of Russia it is customary to extract this oil and use it not only technically but also for culinary purposes and for food, especially to soften caviar when it is somewhat dry. A few hundred gallons of sturgeon oil are prepared in the United States each year, but no special properties are attributed to it. It sells for about the same price as menhaden oil and is used for similar purposes. As a general rule, owing to its preparation from fresh materials, this oil is clear and bright and of pleasant odor and flavor.

MISCELLANEOUS OILS.

Alligator oil is much used among the hunters and swampers of the Gulf States. It is employed as a lubricant, an illuminant, for softening leather, and in the treatment of rheumatism, scrofula, etc. Although this oil is rarely met with in commerce, there are probably few professional alligator hunters who do not lay in a supply each season. About fifteen years ago alligator oil was introduced in France for leather-currying and met with much favor, owing to its imparting greater weight to the leather than whale, seal, or cod oils. It was received from Mexico and Central America and sold in France at about one franc per kilogram, equivalent to about 70 cents per gallon. It is described as of a reddish color, of 0.928 specific gravity, and to consist chiefly of 60 per cent of olein, 32 per cent of margarine and stearin, 1½ per cent of free oleic acid, and 0.02 of iodine.[a]

In many parts of the world oil is extracted from various species of turtle or terrapin and used for medicinal or technical purposes. In the Chesapeake region certain remedial qualities are supposed to exist in the oil of the celebrated diamond-back terrapin. It has been

[a] See Oil, Paint, and Drug Reporter, 1889, June 15, p. 55.

recommended especially for rheumatism. But little of this oil finds its way into trade, being for the most part bottled and put away in the family medicine-chest for home use only. The oil from a variety of turtle found in Mauritius and the adjacent islands has had a local reputation for more than two centuries as an excellent remedy in several diseases. On the coast of India turtle oil is prepared for a number of purposes, especially in the composition of a cement or pitch for paying the seams of vessels. It has been highly recommended as a medicinal oil, principally in cases of scrofula and anæmia. It is not often refined, notwithstanding that the percentage of foots is large. When bottled, the solid part is precipitated in an opaque and yellowish-white mass, leaving the oil transparent and brownish in color. When slightly warmed, as by exposure to the sun's rays, the two parts amalgamate.

Considerable quantities of turtle oil are prepared in the West Indies, on the northern coast of South America, on the Seychelles in the Indian Ocean, etc. Not only is the fat of the animal used for this purpose, but likewise the eggs, of which large numbers are secured on the Amazon and the Orinoco. It is said that a single turtle may yield 6 gallons of oil, and that 3,000 eggs are required for an equal quantity. The eggs are crushed, covered with water, and submitted to the heat of the sun, whereupon the oil quickly floats to the surface. According to consular reports, Para receives upward of 50,000 gallons of this oil during some seasons, and a much larger quantity is consumed by the natives inhabiting the shores frequented by the animals.

Turtle oil is used for culinary purposes, and likewise for illumination, lubrication, and currying.

While the oils of the dugong and of the manatee are comparatively unknown in the United States, they are of considerable local importance in several tropical and semitropical countries, especially in Australia, New Zealand, and Brazil. The oil is obtained from the blubber situated beneath the skin, and each animal yields 5 to 20 gallons. No difference has been pointed out in the characteristics of the oils of these animals; although, obtained in widely separated countries, it is natural that different uses should have developed.

Dugong oil has no prominent odor, is of a pleasant flavor, and when in good condition is almost as limpid as water. It is used in place of butter and sometimes in preference thereto, and as a cooking oil it is said to be unrivaled; but it is employed principally as a medicine, its properties resembling those of cod-liver oil, without the unpleasant effects of the latter. It is valued by some medical practitioners in Australia and New Zealand even more highly than cod-liver oil. Dr. Hobbs, of Queensland, was the first to draw attention to its virtues in Australia, receiving a prize medal at the Sidney Exhibition in 1854. By some persons dugong oil is believed to be efficacious in the treatment of debility, dyspepsia, chronic dysentery, bronchitis, etc. Occasionally it may be found in this country put up in bottles with labels indicative of an oriental origin, and recommended as a cure for consumption and diseases of the chest and back.

The oil of the manatee is one of the few blubber oils which does not become rancid on exposure to the sun, and on the contrary acquires a fine flavor and agreeable odor through such exposure. On the west coast of Africa, in the West Indies, Guiana, and Brazil, it forms an important item of domestic commerce; it is used as a lubricator, as an illuminant, in cooking, and for the table.

Speaking of the American species (*Manatus americanus*), Dr. R. Brookes in his "Natural History" states:

> The fat which lies between the cuticle and the skin, when exposed to the sun, has a fine smell and taste, and far exceeds the fat of any sea animal. It has this peculiar property, that the heat of the sun will not spoil it, nor make it grow rancid. The taste is like the oil of sweet almonds, and it will serve very well in all cases instead of butter. Any quantity may be taken inwardly with safety, for it has no other effect than keeping the body open. The fat of the tail is of a harder consistence, and when boiled is more delicate than the other.

The fat obtained from beaver is made into an ointment by the Indians, to which they attribute many curative and medicinal properties, especially its power to prevent frost bites, the anointed parts of the body not being affected even when exposed to the most extreme cold. An old treatise of 1685, credited to Joanne Mario, attributes marvelous curative properties to beaver oil:

> It is efficacious in all maladies which affect the nerves. It is useful in epilepsy, and prevents apoplexy and lethargy; stops spasms and convulsions, and is of great help in giddiness, toothache, asthma, dysentery, and strains.

On the Macquarie Islands, the coast of Patagonia, and several other places in the cold regions of the Southern Hemisphere, large numbers of penguin are caught and used in oil rendering. On Macquarie Island the royal penguin and the king penguin are used, while on the Patagonian coast the jackass penguin is the principal species, with smaller numbers of macaronis and red bills. These birds are found on the shores in great numbers and are easily killed with clubs. In some localities the breast skin, with the attached blubber, is the only part cooked, the rest being discarded; but usually the entire body is placed in pots and cooked. When thoroughly disintegrated the mass is pressed and the oil thus extracted.

SPERMACETI REFINING AND MANUFACTURE.

Spermaceti is the solid portion of the crude oil of sperm whales and of certain other cetaceans. As noted in the chapter on sperm-oil rendering, it occurs in a state of solution in special cavities of the skull and to a much less extent in various parts of the body, especially in the core of the dorsal hump. The process of its extraction and the separation of the oil therefrom have already been noted in the account of rendering sperm oil, and it now remains to describe the subsequent treatment of the crude and refined spermaceti.

After the extraction of the "taut-pressed-oil" the crude spermaceti is heated in vats or tanks, refined, and "whitened" by the introduction of some alkali, as a weak solution of caustic soda or caustic potash, to saponify any adhering oil. Care must be taken during this process that the spermaceti does not saponify, any tendency to do so being overcome by the addition of brine. The refined product is then molded into suitable shapes for marketing. Most of it is formed into blocks measuring 10 by 12 by 14 inches, and weighing about 62 pounds each. It is also molded into cakes weighing 1 pound, half-pound, quarter-pound, or of any other desired weight.

Spermaceti is white, semitransparent, unctuous or talcose to the touch, of a slight fatty taste and odor. A fracture of a cake reveals broadly foliated, crystallized pieces resembling quartz. According to Brannt, its specific gravity is 0.943 at 59° F. It yields nothing to water, and very little to cold alcohol, but is readily soluble in ether, chloroform, and bisulphide of carbon. It melts at about 125° F. and congeals immediately below the melting point. Its component parts, according to the same chemist, are carbon, 80.03 per cent; hydrogen, 13.25 per cent, and oxygen, 6.72 per cent.

It is not easy to adulterate spermaceti without detection, since its characteristic properties are readily diminished, the compound being harder, with decreased nacreous luster and smaller foliated crystals. Tallow is readily detected by the odor given off in melting, and also by the compound making fat stains on paper, which is not the case with pure spermaceti. Stearin renders it harder and smaller foliated, and its presence is readily detected by boiling the sample in a soda solution, effervescence occurring in the adulterated article. If exposed to the air for a long time spermaceti becomes yellowish and somewhat rancid, but when remelted and treated with diluted caustic soda or potash it regains its original condition.

In the early history of the sperm-whale fishery spermaceti was considered of great value for medicinal purposes, and was recommended for many ills of the body, but was employed principally for internal applications, especially in cases of inflammation. It was so much in demand before the full development of the fishery as to sell at times for its weight in silver. As it became better known, however, it occupied a minor position in materia medica, chiefly in the preparation of ointments, and its principal use was in candle-making.

The beginning of candle-making in America dated from about 1750. The number of factories increased rapidly, and in 1761 there was a total of eight in New England and one in Philadelphia. In 1772 the first candle factory was established at Nantucket, then the headquarters of the whale fishery, and the number increased until there were 10 in existence on the island in 1792, and an equal number then existed at New Bedford.[a] The business of preparing spermaceti was then separate from the general whale-oil refining industry, the candle-

[a] New Bedford Medley, Nov. 30, 1792.

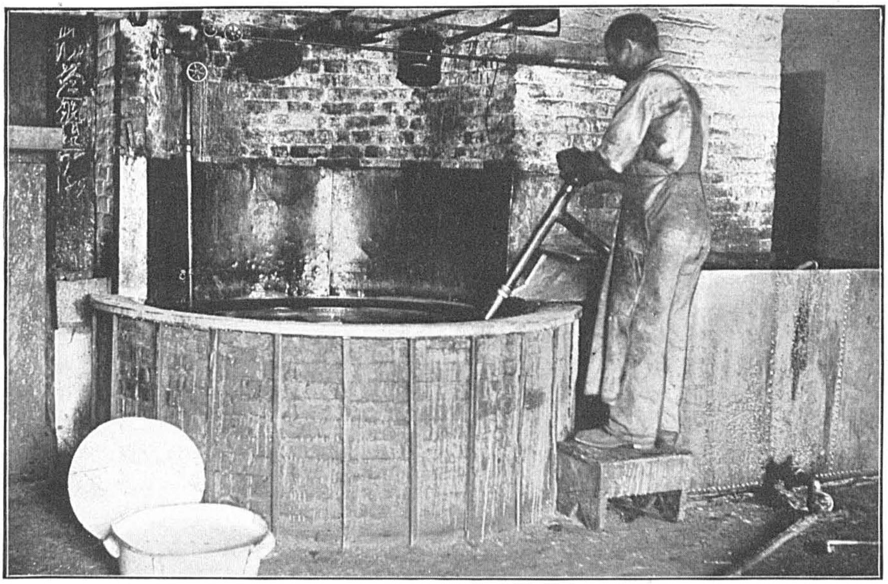
makers purchasing the crude head matter only. But gradually the two industries were combined to their mutual advantage. When the sperm-whale fishery developed to its full capacity, the production of spermaceti was very large, averaging more than 3,000,000 pounds annually from 1835 to 1845. With the decrease in extent of the fishery, there was a corresponding decrease in the yield of spermaceti, reaching its lowest product in 1890, when less than 200,000 pounds were prepared.

Spermaceti is among the very best materials for candle-making, the product being beautifully semitransparent and nacreous, burning with great regularity and with white light of high illuminating power; yet owing to the cheapness of other materials, especially paraffin, only a small percentage of the candles used at present are made of this material. To reduce the tendency of spermaceti to crystallize in molding and consequently lower its friability, it is customary to add a little paraffin wax, tallow, stearin, beeswax, or cerasin. The clear natural color of the refined spermaceti is usually preferred in candles, but sometimes coloring material is introduced, in so small a quantity, however, as not to destroy the transparency of the spermaceti. A yellow tint is imparted by adding gamboge, a red by carmine, and a blue by prussian blue. Owing to the cheapness and excellence of paraffin candles, the consumption of spermaceti in candle-making has been greatly reduced. The quantity thus used at the present time bears no relation to the extensive use of petroleum wax for that purpose, the consumption of which in Great Britain alone amounts to upward of 50,000 tons annually.

Sperm candles are at present the standard used by the principal gas-examiners for photometric measurements. The rules for the preparation of standard sperm candles for photometric purposes, published by the Metropolitan Gas Referees, of London, prescribe that, for the purpose of rendering the spermaceti less brittle, best air-bleached beeswax, melting at about 144° F., shall be used exclusively, and that the proportion of beeswax to spermaceti shall not be less than 3 per cent nor more than 4½ per cent; the spermaceti itself to be so refined as to have a melting-point lying between 112° and 115° F.[a]

The production of spermaceti in 1901 in the United States was about 400,000 pounds, worth $100,000. Of this amount probably 70 per cent was exported to Germany, England, and other foreign countries. Its principal foreign use is in the making of candles, large quantities being made in England and Germany for ecclesiastical use, especially in southern Europe. Minor uses are as an ointment for medicinal purposes, in laundries for producing a polish on linen, and for self-lubricating cartridges. Of the domestic consumption, probably 5,000 pounds are used in candle-making and the rest for medicinal and industrial purposes.

[a] Journal Society Chemical Industry, 1894, p. 65.



SPERMACETI REFINING. VAT FOR BOILING AND REMOVING SEDIMENT.

PACKAGES OF BLOCKS, CAKES, AND CANDLES OF SPERMACETI.

During the year 1901 the value of spermaceti greatly decreased, sales during November being made at 22 cents per pound, the lowest price reached in the last ten years.

No exact figures are available to show the product of spermaceti during a period of years, but the approximate yield may be determined from the figures on page 204, showing the yield of sperm oil, remembering that about 25 pounds of spermaceti is obtained from a barrel, or 31½ gallons, of sperm oil. It should be noted, however, that considerable crude sperm oil is exported and the spermaceti extracted abroad.

AMBERGRIS.

Ambergris is a wax-like substance found at rare intervals, but sometimes in relatively large quantities, in the intestines of the sperm whale. With the exception of choice pearls and coral, it is the highest-priced product of the fisheries, selling at upward of $40 per ounce. It has been a valuable object of commerce for hundreds of years. It appears to have been prized first by the Arabians, by whom it was called amber, and by this name it was first known among the Europeans. The name was later extended to the fossilized gum, the two being distinguished by their respective colors as amber gris and amber jaune.

In the writings of early travelers to the shores of the Indian Ocean and to southern Asia, references to ambergris are by no means infrequent. Before the time of Marco Polo (1254–1324), Zanzibar was famous for its ambergris. So plentiful was it on the shores of Indian Ocean in the sixteenth and seventeenth centuries that the name was given to various islands, capes, and mountain peaks of that region. It was also found on certain shores of the Pacific, notably the coast of Japan. From their station in Batavia the Dutch traders kept Europe supplied, and also exported it to Asiatic markets.

Though ambergris was a valuable commercial article, little or nothing was known of its origin before the eighteenth century. Some supposed it to be the "solidified foam of the sea," others that it exuded from trees and flowed into the sea, or that it was a "fungoidal growth of the ocean analogous to that on trees."

It is now generally conceded that ambergris is generated in either sex of the sperm whale, but far more frequently in the male, and is the result of a diseased state of the animal, caused possibly by a biliary irritation, as the individuals from which it is secured are almost invariably of a sickly appearance and sometimes greatly emaciated. It is not of frequent occurrence, many whalemen with half a century's experience never having seen any. The victim of the malady may eject the morbific substance, thus furnishing the lumps which have been found on the shores or floating on the seas frequented by sperm whales.

Although ambergris is of such rare occurrence, the sperm-whalers always search for it, especially in diseased or emaciated whales. It is found in all parts of the intestinal canal, but more generally at 2 to 6 feet from the vent. The instrument used in the search is a common cutting-spade. The presence of the prize is detected by the peculiar feeling or impression on striking it, very much like the cutting of cork or rubber, and also by its sticking or adhering to the spade, or by its floating out upon the water when the intestines are opened.

Ambergris occurs in rough lumps varying in weight from less than 1 pound to 150 pounds or more. It generally contains fragments of the beak or mandible of squid or cuttle-fish, which constitutes the principal food of the sperm whale. When first removed from the animal it is comparatively soft and emits a repugnant odor, but upon exposure to the air it grows harder, lighter in color, and assumes the appearance it presents when found floating on the ocean. It is light in weight, opaque, wax-like, and inflammable. Its color ranges from black to whitish gray, and is often variegated with light stripes and spots resembling marble somewhat. When dried—the only curing process it undergoes—it yields a subtle odor faintly resembling that of honey. It softens under heat like wax, and in that condition may be easily penetrated by a needle. A proof of its good quality is a polished needle meeting with no obstacle when thrust through it, and if the needle be red hot the substance will exude an oil. It fuses at 140° to 150° F., and when heated to 212° F. it dissolves into a blackish, thick oil, and gradually evaporates, leaving no trace of its presence. When stored for a length of time it becomes covered with dust like chocolate. It contains some moisture that gradually evaporates, reducing its weight, but increasing its intrinsic value.

The amount of ambergris produced annually from all sources varies greatly, scarcely an ounce being obtained in some years, while in others the product may exceed $50,000 in value. The small compass within which a very valuable quantity may be stored without attracting attention, and the ease with which it may be brought in where it is deemed advisable to preserve secrecy concerning a find, render it exceedingly difficult to follow closely the imports of the article. However, a brief account is here given of some of the principal masses obtained. In this compilation we are indebted to Mr. Francis H. Sloan and to Messrs. J. and W. R. Wing for information.

Probably the most valuable piece secured previous to the last century was a 182-pound lump purchased in 1693 from the King of Tydore by the Dutch East India Company for the sum of 11,000 thalers. Its origin is unknown. Probably it was found afloat on the sea or drifted ashore. It is stated that the Grand Duke of Tuscany offered 50,000 crowns for it—with what success is unknown.

An American fisherman is credited with finding a piece that weighed 130 pounds in a whale secured in 1782 about 150 miles southwest of Windward Islands. This sold for £500, the low price leading one to fancy that the reported weight is exaggerated.

Captain Coffin, a British whaling master, stated before a committee of the House of Commons in 1791 that—

He had lately brought home 362 ounces, troy, of this valuable substance. He had taken this from the anus of a female sperm whale captured off the coast of Guinea, and which he stated was very bony and sickly. At the time he brought this quantity to England the ambergris was selling for 25s. an ounce, but he stated that he sold his for 19s. 6*d*. per ounce to a broker, who exported it to Turkey, Germany, and France, among the natives of which it appears to have been long celebrated for its aphrodisiacal properties.[a]

The schooner *Watchman*, of Nantucket, is credited with bringing home from the Bahama Islands, in 1858, the largest mass ever found, weighing nearly 600 pounds. This was on the market for many months, as the owners were unwilling to divide it and dealers were adverse to taking the whole lot, but finally it was sold for $10,500.

The bark *Sea Fox*, of New Bedford, in 1866, secured a 30-barrel sperm whale off the eastern coast of Arabia. A long-handled cutting spade was thrust into the region of the anus and a piece of ambergris fell out. Some of the men proceeded to cut open the large intestine, which was about 10 feet long and 3½ inches in diameter, and for the entire length it was literally filled and closely packed with ambergris. They cleand out the stomach and found two large pieces weighing, respectively, 40 and 41 pounds. The ambergris in the large intestine, to all appearance, was originally composed of globular pieces, which, owing to pressure from all sides, were compressed into irregular shapes. The two large pieces found in the stomach were of a different shape from those found in the intestine. They measured about 36 inches in circumference, were flat on both sides, about 8 inches in thickness, and of a superior quality. The entire mass weighed 150 pounds and was sold to the Arabs of Zanzibar for $10,000 in gold.

During the year 1878 the bark *Minnesota*, in the same locality, found 18 pounds of ambergris in a whale, which was sold in Zanzibar to the agents of the Sultan for $150 per pound.

The bark *Adeline Gibbs* in 1878 brought in the most valuable lot of ambergris obtained by an American vessel up to that time. It was taken from a 50-barrel bull sperm whale south of St. Helena, weighed 132¾ pounds, and was sold for $23,231. This piece was the only one that a fleet of 12 vessels had taken in 45 years. About the same time the *Bartholomew Gosnold* secured 125 pounds in the vicinity of New Holland, which sold for about $20,000, and the *Lettitia* brought in 100 pounds, worth $17,500.

In 1882, the bark *Falcon*, in latitude 16° 55′ S. and longitude 11° 00′ W., secured a 28-barrel male sperm whale, which was apparently in healthy condition and without unusual appearance. A spade was accidently thrust into the abdomen, revealing the presence of ambergris in the viscera. A large piece of an ovate form, weighing about

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[a] Beale on the Sperm Whale, p. 183.

60 pounds, and several smaller pieces, irregularly shaped, were found in the intestinal canal. Some of the ambergris was brownish black on the outside and some of a grayish yellow cast; the exterior coating was filled with the mandibles of squid. The gross weight was 136 pounds, and it sold for $14,000.

Doubtless the most valuable lot ever secured was a mass weighing 162 pounds 11 ounces, obtained in 1891, known as the "Bank" lot, which sold in London for about £10,000. The following communication from the brokers who effected the sale of this remarkable find furnishes an excellent description of the lump and of the state of the ambergris market:

About the end of August, 1891, a gentleman called to consult us as to the best means of disposing of some ambergris which had been consigned to his firm. We suggested that if it were brought to us we could examine it and report upon its value, but when we were informed that the case which contained it weighed close on 224 pounds and was too large to go inside a cab our first feeling was one of incredulity as to the consignment being ambergris at all. It was finally decided that the case should remain in the strong room of the bank in which it had been deposited for safe custody and that we should go there to inspect it. This we did, and were shown a box measuring about 2 feet 4 inches in each direction and which we were told had with its contents been insured for £10,000.

In the presence of the merchant who had consulted us and the bank officials the lid of the case was opened, with the immediate result that everyone beat a hasty retreat from its vicinity, for the horrible smell which issued from the box was overpowering. When the odor had lost somewhat of its intensity, we began to take out the packing and found that the case (which was tin-lined) contained one huge mass of a blackish substance, measuring 6 feet 4 inches in circumference, nearly spherical, and which was undoubtedly ambergris. On being turned out of the case it was found to be saturated with moisture, as were the packings of paper and old gunny which had been put around it to prevent it from chafing to pieces during the voyage; and it was the liberation of the gases generated by the salt water and the animal matter which had caused the stench alluded to. By proper treatment this smell was eventually completely got rid of, and the ambergris obtained in marketable condition. The mass was next weighed and the certificate signed by the interested parties, the exact weight being at that time 2,603 ounces, or 162 pounds 11 ounces. This is probably the largest piece of ambergris which has ever been seen by anyone living, and approaches nearly in weight to the lump of 182 pounds purchased by the Dutch East India Company two hundred years ago.

The next thing to do was to split the lump, so as to see what the interior was like. This was accomplished with the aid of long chisels and crowbars. We then saw that the substance consisted of layers or laminæ rolled around a central core, the laminæ varying a good deal in texture, color, and flavor. Speaking generally, the outer layers were thin, friable, and shelly; dark, almost black in color, and mixed to a considerable extent with the beaks of the cuttle-fish, on which the whale feeds. As the layers approached the center they were denser, grayer in color, thicker, and of better flavor, until the core itself was reached. This core really consisted of two pieces, one the shape of a rifle bullet, but with a deepish depression like the "kickup" of a wine bottle in the base. It was from 10 to 11 inches high, with a diameter of about 6 inches at the bottom, tapering upward to about 2 inches at the top, which was slightly flattened. It was detached from the surrounding layers with the greatest ease, and stood alone, a pure, solid lump of the finest gray ambergris, weighing 83¼ ounces. Beside this magnificent piece was a smaller one, almost spherical in shape and about the size of a very large orange. It was rather darker in color and not of quite so fine a flavor, but was as easily detached from the surrounding layers as the other. Neither of these pieces contained any of the beaks which were so common in the outer layers, and it is almost needless to say that they realized by far the highest price which was obtained for any portion of the mass. The layers nearest to the core were of much finer flavor than the outer and darker. One of them was quite 4 inches in thickness, and the ambergris of which it consisted was of a silvery-gray color, different from the whitish gray of the core, and was of lower specific gravity. The layer outside this again was striated in places with the darker exterior, and the beaks began to show, though not to the same extent as in the black, shelly, exterior layers.

It is a matter of some regret to us that we did not secure a photograph of this extraordinary lump, but the fact weighed heavily upon us that if the real truth about it leaked out the depression of the market would be so great that we should not be able to do justice to our clients, and, consequently, as few people as possible were let into the secret. It is true that reports about it were rife for a month or two, but as nothing authentic could be ascertained they gradually died out, and we have ourselves been repeatedly assured that the thing was a myth altogether, one gentleman going so far as to tell one of our partners, about three months afterwards, that he held three-fourths of the total quantity of ambergris in London, not knowing that we were controlling about 1¼ hundredweight.

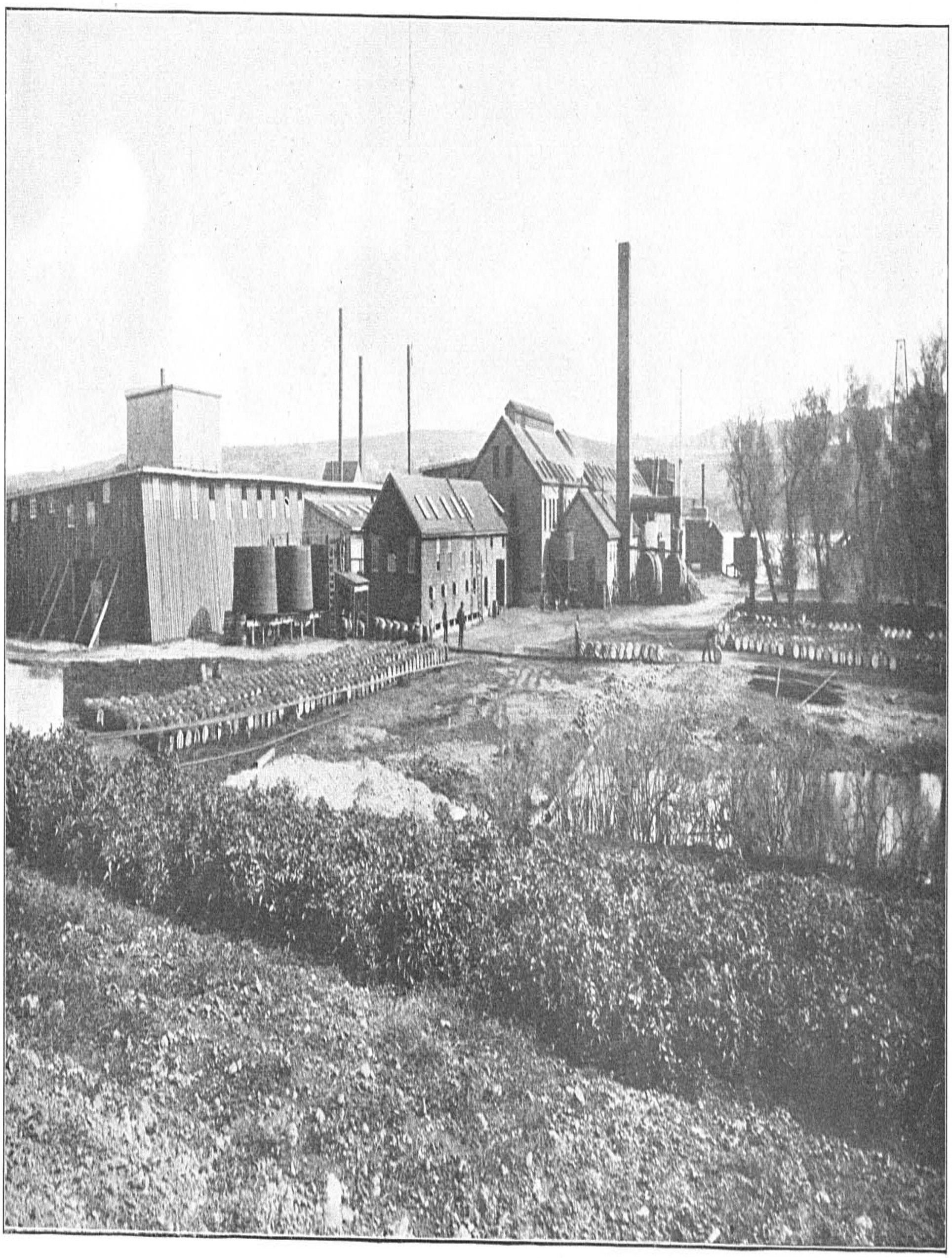
Probably the finest lot of ambergris received in America was taken in 1894 by the schooner *Adelia Chase* from a 50-barrel whale near Cape de Verde Islands. It weighed 109⅝ pounds and sold for about $26,000, the best parts fetching $350 per pound. No large finds have been reported since 1894. In 1899 50 pounds of poor quality was secured by the bark *Charles W. Morgan* off the coast of Japan. In 1900 the *Morning Star* secured 7 pounds, and in 1901 the same ship brought in 20 pounds of medium quality.

Ambergris has been used for centuries in the sacerdotal rites of the church, and, in connection with fragrant gums, it was formerly burnt in the apartments of royalty. It was formerly used in cookery, especially in the East, being added to flavor certain dishes. This custom spread through western Europe to a limited extent. Macaulay refers to rumors in connection with the death of Charles II of England that "something had been put into his broth, something added to his favorite dish of egg and ambergris." The principal use of ambergris, however, was as a medicine and as a perfume, especially in Asia and Africa. Until recently it held a place in pharmacy, being regarded as a cardiac and antispasmodic, somewhat analogous to musk, and was recommended in typhoid fevers and various nervous diseases.

The principal and almost the only use of ambergris at present is in the preparation of fine perfumes, furnishing an important ingredient in the production of choice bouquet of "extracts." It also acts as a "fixer" and serves to impart homogeneity and permanency to the different ingredients employed. For perfumers' use it is generally made into an essence or tincture by dissolving 4 ounces in a gallon of alcohol. This is facilitated by first crushing and mixing it with sand.

Perfumers exercise much care in the selection of the ambergris which they use. The wholesale dealer grades his stock of the material according to its odor, appearance, etc. But this is by no means sufficient for the trained olfactory sense of the perfume-manufacturer. Before determining the use of a special lot he tests it by his own standards, and these tests may extend over a month, especially for durability of perfume. Some manufacturers prize most highly those lots and grades which another manufacturer would not accept. The selection of just the proper quality to produce the desired bouquet forms one of the niceties of the perfumer's art.

The value of ambergris depends largely on its scarcity at the time and its freedom from impurities. During the last thirty years it has varied in price from $5 to $40 per ounce. At the present time it is quoted at $8 to $30 per ounce. In 1880 crude ambergris brought home by the whalers was sold at $10 an ounce and the dried article at $20 an ounce. In 1876 the value, dried, was $25 an ounce. In the London *Price Current of Colonial Produce* in 1807 ambergris is quoted at 40*s*. to 45*s*. per ounce for "gray, fine." Considering the respective purchasing powers of money two centuries ago and at the present time, that price is quite equal to the average value in recent years.



MENHADEN FACTORY AT TIVERTON, RHODE ISLAND.

AQUATIC PRODUCTS AS FERTILIZERS.

GENERAL REVIEW.

A fertilizer is any substance added to the soil for the purpose of producing a better growth of crops. The food required by plants is supplied in part from the atmosphere, but principally from the soil. If the supply of any one of the necessary ingredients be deficient, a small crop is the result; and the purpose of fertilizers is to supply the plant-foods lacking in the soil.

The general use of fertilizers is of comparatively recent origin, yet the preparation of these substances supports an extensive industry, employing a large amount of capital and many thousands of men. Compared with the immense quantities of barnyard materials, phosphate rocks, etc., the use of aquatic products for fertilizer is relatively small, yet it is by no means unimportant in the fishery industries.

Fish, seaweeds, shells of mollusks and crustaceans, and various other aquatic products have long been known to possess rich fertilizing properties. All kinds of fish can be used for this purpose; but, owing to the greater value of choice species as food, only the non-edible ones and the waste parts are utilized. The menhaden is the only fish taken in great quantities in this country especially for conversion into fertilizer. The output of this species is very large, amounting to 30 per cent of the total catch of fish in the United States, and its capture maintains one of the most extensive and vigorously prosecuted of the American fisheries. Compared with that from menhaden, the quantity of fertilizer made from other fish is small, and only such are used for this purpose as can not be profitably employed in any other way.

The original use of fish for fertilizing purposes was in a fresh or green state, and they were added to the soil directly after their capture, although, of course, no special effort was made to preserve their freshness. Before the advent of the colonists in America, the Indians were accustomed to manure their small crops of corn by placing one or more fish in each hill or by spreading them broadcast over the field, and this practice was followed by the early settlers. Owing to the original richness of the soil and the limited agricultural operations, the use of fertilizers was of comparatively small extent until the latter part of the eighteenth century. It appears that fish were then employed for this purpose all along the Atlantic seaboard from Maine to North Carolina wherever they were obtainable in sufficient quantities.

Fresh fish contain usually from 65 to 80 per cent of water and from 1 to 16 per cent of oil. Neither of these has any value as a fertilizer. On the contrary they decrease the portability and storage qualities of the constituents, and the presence of the oil is prejudicial to the decomposition of the fertilizer when applied to the soil.

Early in the nineteenth century the fishermen occasionally extracted the oil from the fish when the latter were unusually fat, thus removing an injurious ingredient, for which valuable uses were found. This resulted gradually in the establishment of factories for removing the oil, and likewise most of the water, so that the fertilizing substance might be in better condition for transportation. At present most of the fish used for fertilizer are treated in this manner, even the farmer-fishermen finding it more profitable to sell their catch at the factories and purchase the scrap; but large quantities of fish in a fresh state are yet used precisely as was the custom three hundred years ago.

Owing to its great abundance, combined with its nonedible qualities, the menhaden is the principal fish used for fertilizer in this country, and the quantity used annually is about 800,000,000 in number, or 240,000 tons round or live weight. Of these fully 99 per cent are handled at the factories, and the remainder are used in a fresh or green state. With the menhaden are taken some skates, sea-robins, bellows-fish, and other waste fish. Aside from a few that may be taken with the menhaden, and occasionally some river herring or alewives, no other fish are captured in the United States especially for fertilizer to any great extent.

Formerly nearly all the waste produced in dressing fish for market was thrown away as useless; but in recent years, in the fisheries as in other industries, the utilization of waste material has been made a subject of careful investigation, and many substances formerly considered refuse are now found to contain elements of commercial value. The dressings at the fish markets and at the fishing centers, the refuse of canneries and boneless-fish factories, and even the carcasses of whales are turned to account in the production of fertilizer. In addition to these materials, the farmers use large quantities of seaweeds, horseshoe crabs, oyster shells, clam shells, etc.

The total annual product of menhaden fertilizer in the United States according to the latest returns amounted to 85,830 tons, for which the producers received $1,539,810. It is difficult to approximate the quantity of other fishery products used for fertilizer, but it is estimated that the waste fish of all kinds amount to about 20,000 tons, worth $200,000; horseshoe crabs, shells of shrimp, etc., 800 tons, worth

$16,000; shells and agricultural lime, 60,000 tons, worth $150,000, and seaweeds, 250,000 tons, worth $312,500, making a total estimated output for this country per year of 416,630 tons, worth $2,118,310.

THE MENHADEN INDUSTRY.

The menhaden belongs to the *Clupeidæ* or herring family, and is about the size of the common herring of the New England coast, but somewhat deeper and more robust. It is not considered a food-fish and is rarely eaten, owing to the abundance of bones, although the flavor is not unpleasant. However, it is one of the most important of all of the species on the coast, being the principal source of bait during the summer, in addition to its use in the manufacture of oil and fertilizer.

The menhaden occurs all along the Atlantic coast of the United States from Maine to Texas, and most abundantly between Cape Cod and Cape Henry, except that during certain years it seeks the coast of Maine in enormous quantities. It appears on the approach of warm weather, ranging from March and April in Chesapeake Bay to May and June on the Maine coast, and remains until late in autumn. Its bathymetrical range extends from the inland limits of salt water to the Gulf Stream, but probably 95 per cent of the catch is made within 2 miles of the coastal line. It is captured principally by means of purse seines, operated from steam vessels with carrying capacity for several hundred thousand fish.

About a quarter of a century ago several important reports relative to the menhaden were issued. The first was that of Messrs. Boardman and Atkins, made to the Maine board of agriculture in 1875.[a] Three years later was issued the report of Mr. Luther Maddox.[b] Each of these related especially to conditions existing in the State of Maine.

In 1879 the United States Fish Commission published the important report of Dr. G. Brown Goode, containing voluminous notes on the natural and economic history of the menhaden, with many extracts from previous reports on the subject.[c]

Many changes have been made in the methods of utilizing the menhaden since those papers were written, but they are yet the principal authorities in regard to the natural history of the subject, and the present writer is prepared to add little. Indeed, such additional matter would scarcely be in place in this paper, which is restricted to the economic use of menhaden in the preparation of oil and fertilizer.

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[a] The Menhaden and Herring Fisheries of Maine as Sources of Fertilization, by Samuel L. Boardman and Charles G. Atkins, 1875, pp. 67.

[b] The Menhaden Fishery of Maine. Portland, 1878, pp. 46.

[c] The Natural and Economic History of the American Menhaden, by G. Brown Goode. Report U. S. Fish Commission, 1877, pp. 1-529.

HISTORY AND EXTENT OF THE INDUSTRY.

A century and more ago, when a much larger number of the home requisites were prepared by consumers than is the case at the present time, it was a part of the duties of many farmers along the Middle Atlantic coast to devote a few weeks each spring to taking menhaden for the purpose of fertilizing the cultivated land. Large shore seines made of cotton twine were employed, and in some localities these were owned jointly by several farmers of the vicinity. The length of some of these seines was 3,000 feet or more, and frequently the catch at a single haul numbered several hundred thousand fish, although the average quantity was nearer 10,000 or 12,000. This farmer-fishery has continued up to the present time, but its extent is now very much reduced, owing to the ease with which prepared fertilizers may be purchased.

Following upon the development of this use of fresh or green menhaden came the discovery that the oil was valuable for painting, leather-dressing, etc. Some of the farmers would provide a few casks or hogsheads which they partly filled with fish, adding water to cover them, and with weighted boards placed on top to keep the mass down. On the disintegration of the fish through putrefaction they were occasionally stirred with a long pole to break up the mass and liberate the oil, which floated to the surface of the water and was skimmed off from time to time. After several weeks the oil ceased to flow, and the residuary mass was used as fertilizer. For many years the extent of this business was very small and the product was entirely for home use.

The first improvement in the above process consisted in boiling the fish in kettles to facilitate the extraction of the oil, the boiled fish being then placed in casks, as above noted, resulting in a much larger product. By 1830 the cooking of the fish was quite general among the few persons engaged in extracting oil from menhaden. The oil was dark and crude, and used only for rough painting and leather-dressing, the market being restricted to the neighbors of the manufacturers. The use of kettles, however, involved a great waste of heat, and the business was of very little consequence until the introduction of steam in cooking the fish. The first steam factory, according to the late Capt. E. T. Deblois, was a small one built in 1841 near Portsmouth, R. I.

In 1850 Daniel Wells built a factory on Shelter Island, New York. That was the first factory of considerable size on the coast, and the quantity of fish handled amounted to 2,000,000 or 3,000,000 in number annually. In 1853 Mr. Wells built a new factory on Shelter Island, and the old one was removed to Groton, Conn., being the first steam factory in that State. The first factory in Maine was put up in 1863 at South Bristol, and in 1866 eleven factories were built in Maine. In 1869 the factory at South Bristol, Me., was removed to Fairport, Va., and was the first factory in that State.

In the meantime the purse-seine had been improved and adopted in the menhaden fishery, permitting the capture of fish in much larger quantities, and without which the menhaden industry could never have reached its present proportions. The next improvement consisted in pressing the scrap to extract a greater percentage of the oil. The first press, operated by hand power, was built by Charles Tuthill at the Wells factory, on Shelter Island, in 1856. This worked so satisfactorily that soon all the factories were pressing the scrap, and in 1858 hydraulic presses were introduced for the purpose. The high price of oil during the sixties, when it reached $1.40 per gallon, resulted in much profit in the business and a large increase in the number of factories, their location extending from Maine to Virginia. Then came the preparation of the scrap in the form of portable fertilizer, the adoption of large cooking-tanks instead of kettles, and the introduction of steam vessels in the fishery.

In 1876 floating factories were introduced. These consisted of boilers, cooking-tanks, presses, etc., mounted on steamers, sail vessels, or scows, for convenience in going from place to place to follow the movements of the fish. Probably half a dozen of these were in use in 1880; but owing to the lack of convenience for drying and handling the scrap, this form of factory was soon abandoned. Another disadvantage of a floating factory is that the constant movement of the vessel prevents the oil from settling, and it remains cloudy and fails to fetch the best market price.

The business continued to expand until it reached high-water mark in 1884, when 858,592,691 fish were caught, yielding 3,722,927 gallons of oil and 68,863 tons of scrap, valued at $2,800,000. Since that time great improvements have been made in the methods of the industry, but owing to the low price of oil and scrap, resulting from competition with other products, the profits have not been so great, and many factories have been dismantled. The largest catch of fish in any one year, according to figures of the U. S. Menhaden Oil and Guano Association, was 858,592,691, taken in 1884; the smallest was 223,623,750, secured in 1892, and the average catch during the last thirty years approximates 500,000,000 annually. The incomplete returns for 1902 indicate that the catch exceeded 900,000,000, a greater quantity than for any previous year.

There are two separate and distinct sets of figures showing the extent of the menhaden industry during recent years. The first comprises the returns made by the U. S. Menhaden Oil and Guano Association, organized in 1873, and covers the operations of the factories in the United States during each year from 1873 to 1898, inclusive. The second series represents the returns made by the agents of the United States Fish Commission for certain years from 1880 to 1902. Slight differences exist in these figures, but in the main they agree closely.

The following summary shows the returns made by the United States Menhaden Oil and Guano Association:

Statement of the extent of the menhaden industry of the United States in each year from 1873 to 1898, inclusive, according to the returns of the United States Menhaden Oil and Guano Association.

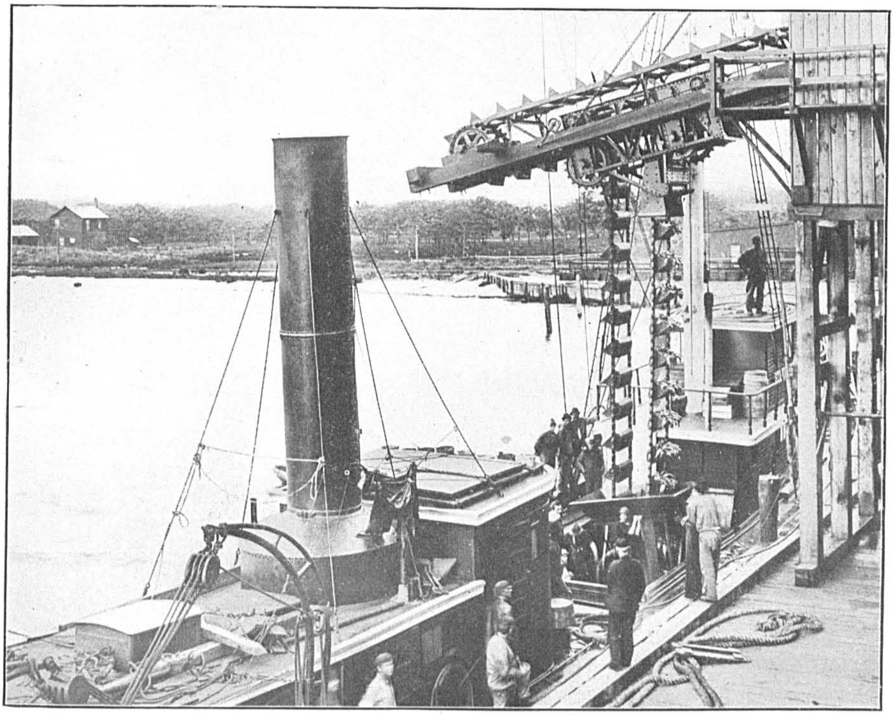
Year.	Factories.	Men employed.	Vessels employed.		Capital invested.	Fish received.	Oil made.	Scrap made.	
			Steamers.	Sail.				Dried.	Crude or acidulated.
	No.	*No.*				*No.*	*Gallons.*	*Tons.*	*Tons.*
1873	62	2,306	20	300	$2,388,000	397,700,000	2,214,800	....	36,299
1874	64	2,438	25	283	2,500,000	492,878,000	3,372,847	....	50,976
1875	60	2,633	39	304	2,650,000	563,327,000	2,681,482	....	53,625
1876	64	2,758	46	320	2,750,000	512,450,000	2,992,000	....	51,245
1877	56	2,631	63	270	2,047,612	587,642,125	2,426,589	5,700	49,744
1878	56	3,337	64	279	2,350,000	767,779,250	3,809,233	19,377	64,342
1879	60	2,296	81	204	2,502,500	637,063,750	2,258,901	20,563	37,496
1880	79	3,261	82	366	2,550,000	776,875,000	2,034,940	25,800	19,020
1881	97	2,805	73	286	2,460,000	454,192,000	1,266,549	25,027	7,592
1882	97	2,313	83	212	2,338,500	346,638,555	2,021,316	17,552	10,029
1883	78	2,427	69	136	2,651,000	613,461,776	2,166,320	34,216	10,920
1884	52	2,114	59	157	1,534,756	858,592,691	3,722,927	58,433	10,430
1885	50	2,064	78	84	1,314,500	479,214,415	2,346,319	33,910	7,225
1886	26	1,154	45	74	1,234,000	283,106,000	1,805,544	14,597	4,298
1887	28	2,499	46	38	1,000,000	333,564,800	2,273,566	17,262	5,368
1888	24	3,568	45	42	3,000,000	439,388,950	2,051,128	15,638	12,406
1889	29	4,400	46	84	2,500,000	555,319,800	8,327,030	24,859	25,859
1890	28	4,368	52	27	2,500,000	533,686,156	2,939,217	20,339	21,173
1891	27	2,985	54	13	1,775,000	355,138,873	1,946,642	12,608	15,069
1892	29	2,002	55	10	1,756,000	223,623,750	1,329,644	8,400	10,815
1893	33	2,235	57	27	1,721,000	366,406,625	1,269,002	13,150	15,465
1894	44	2,356	56	28	2,000,000	533,361,900	1,999,506	20,057	27,582
1895	42	2,276	48	35	1,600,000	461,747,000	1,767,754	18,682	21,965
1896	35	2,115	53	38	1,376,500	401,425,800	1,741,530	14,280	21,484
1897	41	2,750	60	45	1,871,000	584,302,930	2,147,113	18,430	34,372
1898	40	2,470	51	20	2,500,000	542,500,000	2,450,000	17,360	34,120

The following summary shows the extent of the menhaden industry according to the latest returns of the United States Fish Commission. The figures for Connecticut, New Jersey, and Virginia for 1902 are not yet available, and there have been no operations in Texas since 1901:

States.	Year.	Factories.	Fish received.	Oil made.		Dried scrap.		Acidulated scrap.		Total value of product.
		No.	*No.*	*Gallons.*	*Value.*	*Tons.*	*Value.*	*Tons.*	*Value.*	
Rhode Island	1902	1	114,757,900	897,188	$225,912	....	....	15,727	$203,906	$429,818
Connecticut	1900	2	19,975,700	118,750	30,475	450	$12,000	1,450	23,450	65,925
New York	1902	3	187,671,300	1,397,583	353,279	9,030	218,217	7,410	92,765	664,261
New Jersey	1901	6	27,000,000	109,789	25,440	1,131	52,046	....	....	77,486
Delaware	1902	1	84,869,100	394,119	96,724	1,642	39,069	8,871	110,668	246,461
Virginia	1901	15	378,727,331	723,215	164,465	21,130	517,872	10,591	135,388	817,725
North Carolina	1902	7	70,167,800	102,052	22,730	1,884	40,214	4,804	64,128	127,072
Texas	1901	1	26,806,500	69,639	14,654	1,710	30,087	....	....	44,741
Total	......	36	910,065,631	3,812,335	933,679	36,977	909,505	48,853	630,305	2,473,489

Although very small quantities of other fish are used, practically the entire catch in the menhaden fishery consists of that species alone. The principal species other than menhaden are sea-robin, skates, and bellows-fish. These are secured mostly in pound nets, especially in those set in Gardiner Bay. They sell for 50 to 80 cents per 1,000, and two or three million are used each year. The sea-robin yields

DISCHARGING MENHADEN FROM VESSEL BY MEANS OF TUBS.



DISCHARGING MENHADEN FROM STEAMER BY MEANS OF BUCKET ELEVATOR, AT PROMISED LAND, NEW YORK.

3 or 4 quarts of oil to the barrel. This oil is of good color and is readily sold for menhaden oil, but the scrap is not quite so desirable for fertilizer as that from menhaden. Skates and bellows-fish are comparatively dry, yielding less than one pint of oil to the barrel of fish.

Owing to much contention resulting from the claim that with the menhaden large quantities of choice food-fish are taken and rendered at the factories, the United States Fish Commission, in the season of 1894, made a thorough inspection of the catches made by two representative steamers of the fleet. This examination showed that in a catch of 27,965,756 fish only one-third of 1 per cent were food-fish, and only a very small proportion of this percentage was of choice and popular varieties. "As a general thing not enough desirable food-fish are taken by the menhaden steamers to keep the vessels' crews regularly supplied with fresh fish. As a rule, all the food-fish caught are eaten either by the crews or by the factory hands, but it occasionally happens that schools of blue-fish, butter-fish, shad, river herring, etc., are taken and more fish are thus provided than can be consumed."[a]

The menhaden factories are distributed along the coast at points convenient to the fishing-grounds. They vary in size and equipment according to the amount of invested capital and the degree of modernness. Some are of primitive type, consisting of two or three large kettles or try-pots and a simple press, the whole, with the accompanying equipment, costing only a few hundred dollars, and are capable of handling only 300,000 or 400,000 fish annually. From that they increase in size and capacity until the amount of invested capital in a single plant reaches half a million dollars, giving a working capacity of 200,000,000 fish annually.

COOKING AND PRESSING THE FISH.

The following account of the methods of the menhaden industry represents observations and inquiries made by the writer during the last four years, and especially in the season 1901. Most of the factories were visited either in 1901 or previously, and all details in the process of manufacture were inspected. The writer wishes to acknowledge in this connection the courtesy of Capt. N. B. Church, general manager of the Fisheries Company; Mr. H. H. Luther, superintendent of the Promised Land plant of that company, and of Capt. J. F. Bussels, of the Atlantic Fisheries Company.

There are two principal processes involved in the manufacture of oil and scrap from menhaden, viz, (1) cooking and pressing the fish and (2) drying or otherwise preserving the scrap, the methods varying according to the facilities of the plant. The great bulk of the fish are handled at large factories thoroughly equipped with modern machinery, including bucket elevators, automatic conveyors, continuous steam-cookers, hydraulic presses, artificial driers, etc.

Some of the factories, especially in Virginia, are quite small, with

[a] Bulletin United States Fish Commission for 1895, p. 297.

primitive methods of work. In one of them a fire is made under four cast-iron stationary boiling vats holding about 2 barrels of fish each. By means of a trough leading from a pump, water is permitted to run into the vats. After sufficient cooking, the fish are scooped out with large dip nets and put on a platform, whence they are pitched into tub presses having a lining of coarse canvas. By means of a vertical screw operated by a horizontal lever, pressure is applied to the mass, and the exuding oil runs through a trough to the oil vats. Another Chesapeake factory has six iron cooking-vats, in which are suspended an equal number of iron latticed baskets containing the fish. After cooking, the baskets are transferred by means of a crane and the fish placed in an hydraulic press. This method of cooking was formerly in general use all along the coast frequented by the menhaden.

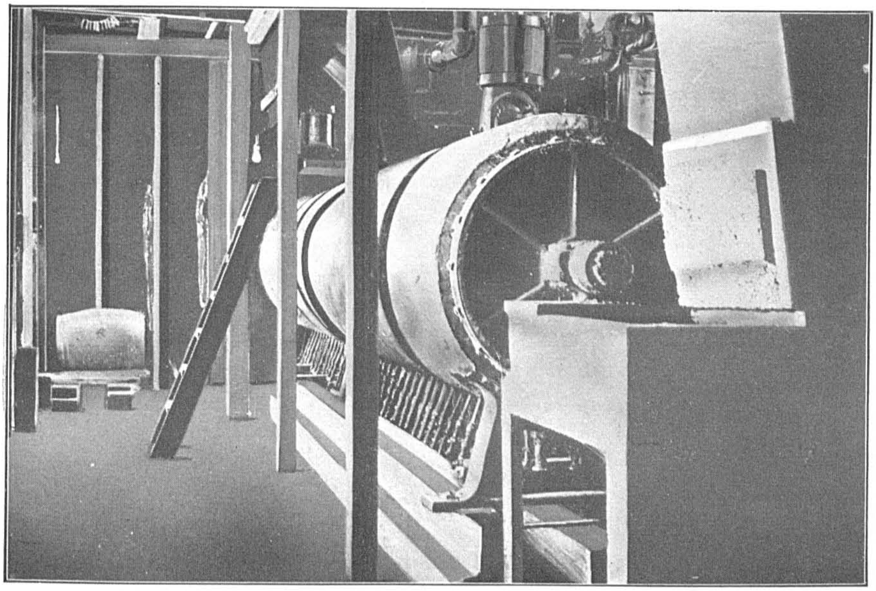
In the best-equipped factories the fish are removed from the hold of the steamer, where they have been stowed in bulk, by means of a bucket elevator. This contrivance, so important in the handling of grain and coal, was not introduced in the menhaden business until 1890, when a factory at Tiverton, R. I., was equipped with one. At present, however, they are in use in all the principal factories. Before their adoption the fish were shoveled into measuring tubs in the vessel's hold, and these raised and dumped in elevated receiving bins, or into cars holding 15 or 20 barrels each and running on inclined tramways to the receiving bins, requiring five or six hours to discharge 1,000 barrels. By using the bucket elevator, with four men to feed it, 1,000 barrels of fish may easily be discharged in an hour. This decrease in length of time required for discharging is frequently a matter of great importance when fish are abundant, as it enables the steamers to speedily return to the fishing-grounds.

The elevator dumps the fish into one of a pair of automatic weighing hoppers, with a dial-scale indicator of 1-ton capacity. When the required weight is in the hopper, by means of a lever the incoming fish are directed into the other hopper, and the bottom of the full one is dropped, thus dumping its contents into a conveyor, which deposits the fish into a receiving bin with capacity of 6,000 or 8,000 barrels.

The weighing of the fish is necessary to secure a record of the quantity received, furnishing a basis for compensating the captains of the vessels, and for other purposes. It thus appears that this method of discharging changes the standard of measurement from bulk to weight. Although it is customary to reckon the quantity of menhaden by so many thousand, the fish are not counted. An arbitrary size of 22 cubic inches is the standard measurement for each fish, or 22,000 cubic inches to the thousand. Two hundred pounds represent one barrel, and 3⅓ barrels represent 1,000 fish. The size of the fish varies considerably, and the actual number required to make "one thousand" in measure ranges from 500 to 2,000 in number.

The floor of the large receiving bin slants toward the longitudinal

RECEIVING-BIN FOR FISH AT MENHADEN FACTORY.



CONTINUOUS STEAM-COOKER, USED BY FISHERIES COMPANY AT PROMISED LAND, NEW YORK.

middle, where is stationed a trough or chute with a covering movable in sections of short length. In this trough runs a conveyor, consisting of two parallel endless chains, between which, at intervals of 2 or 3 feet, are attached pieces of board which act as buckets to push the fish along through the trough when a section of the covering is removed. This trough with endless carrier is in use in practically all the large factories, irrespective of the method of cooking. It carries the fish to the cooking bins, or to the steam cooker in case the latter is employed, traps or slides in the bottom of the trough permitting the distribution of the fish into any of the tanks desired.

The cooking bins or tanks are large rectangular wooden boxes having capacity of from 50 to 100 barrels each and arranged with a lattice platform, about 4 inches above the bottom, on which the fish rest. Between the lattice platform and the bottom there is a nest of steam piping connected with a pipe leading from steam boilers. A water pipe also leads into the bin, through which salt water for cooking the fish is pumped into the tanks to a depth of about 1 foot or more. For convenience in handling the materials, the bins are commonly arranged in two adjacent rows, and above them runs the endless carrier conveying the fish from the receiving bin. On the outer side of each of the two rows of tanks runs a track leading to the presses, to be described later. When the bins are filled with fish, steam is turned into the piping in the bottom and heats the water, thus cooking the fish, reducing them to pulp, and breaking the oil cells. The amount of the cooking determines the extent to which the oil is removed. If carried to an extreme point, nearly all the oil can be pressed out. But severe cooking results in greatly damaging the quality of the oil and in loss of a certain amount of the nitrogenous compounds so important in determining the commercial value of the scrap. It is, therefore, important that the heat be so regulated as to extract as much oil as practicable without injuring the quality and with a minimum loss of nitrogen. The requisite degree of cooking is reached when the fish crumble to pieces easily. A high degree of temperature is maintained for about fifty minutes, when the mass of fish is broken up and then permitted to simmer for four or five hours. The free oil and water are then drawn off and the fish permitted to drain for several hours.

During the last two or three years the largest factories on the coast have been using continuous steam cookers. The most popular form is constructed so that a conveyor transmits the fish into a steam-tight receptacle, into which a large number of jets of steam are introduced, which thoroughly cooks the mass. The process is continuous, requiring about fifteen minutes for the fish to pass through, and the capacity of each cooker is about 600 barrels per hour. From the cooker the mass of fish is carried by means of a screw conveyor into an upright elevator casing, whence a bucket elevator carries it to receiving tanks, where it drains overnight. These tanks are usually about 10 feet square and 5 feet deep. Most factories use for this purpose the bins used in cooking before the adoption of the steam cooker. One factory has a total of 52 tanks for draining the fish.

The oil and water draining from the cooked fish is pumped or led off through pipes or troughs into the oil room, where it is received into large vats. After draining for ten or twelve hours, the mass of cooked fish is forked out of the tanks and thrown into curbs for pressing.

The curbs are of various designs. The most common form is a cylindrical tub with a hinged bottom firmly attached to axles, which are provided with wheels so as to run on a tramway. The staves are made of metal slats and are held together by stout bands. They are set at a convenient distance apart to allow the oil and water to pass through, and increase in width from the center to the bottom enough to overcome the enlargement of the opening between the slats consequent upon their outward slant. This outward slant commences at about the middle of the curb and extends to the lower end, and its effect is to give the curb an increasing diameter as the bottom is approached, so that the hard cake remaining after pressure is relaxed can be readily forced out at the bottom. Through the center of the curb runs a hollow core, stoutly constructed of metal slats. The bottom is attached by means of hinges to the lower end of braces, which are firmly fastened to the lower band of the curb, the axle, and the middle band. The opposite side of the bottom is suspended by means of latches which are caught and held by a bolt sliding freely within the braces and actuated by a lever pivoted upon the axles. The axles are also braced by stays on either side of the tub, which pass from one axle to the other, and, being curved to fit closely to a section of a band, are firmly attached thereto. The capacity of each curb is about 7 barrels. A metal shield surrounds it to protect the workmen from the spattering oil and water when pressure is applied.

The curb, having been filled with cooked fish, is run along the rail and placed under a solid stationary head made to fit closely inside the curb and against which the fish are pressed as the curb is slowly raised by a powerful hydraulic press. This forces out most of the remaining oil and water, which exudes from between the slats, and by means of troughs and pipes is conveyed to the oil room. On relaxing the pressure the curb resumes its position on the railway and is moved from the press stand and the core removed; the bottom is swung out of the way, and the hard cake remaining in the tub is forced through the bottom, falling into receptacles underneath.

Under ordinary conditions from 5 to 7 per cent of the oil is left in the pressed fish, it being difficult to remove all the oil and water, owing to the gelatinous or gluey state of the fish as a result of the cooking. In some factories the chum or pressed fish is washed with hot water and then repressed, but this is scarcely profitable if the first pressing is properly performed. The chum now passes to the scrap room and its further treatment is described on pp. 265–268.

About two-thirds of the total amount of oil obtained runs from the cooked fish while it drains in the vats, the remaining one-third being extracted by the presses. The former is a trifle better than the latter, as it is somewhat lighter in color. The two grades are sometimes kept separate, but such is not the general practice.

Among the many methods of extracting the oil which have been tried but not adopted is the use of fumes of benzine or bisulphide of carbon. When these are brought in contact with the fish in air-tight chambers, they absorb the oil, the liquid result collecting in tanks at the bottom of the receptacle and the benzine being subsequently expelled by evaporation.

Much attention has been paid to devising a continuous process of cooking and pressing, in which the elements of labor are reduced to a minimum. When the Stanley process was invented, about five years ago, it was thought that the problem was solved and the patent rights were sold for a very large sum of money. In this process the fish are cooked in boiling water in a large, comparatively shallow, semicylindrical tank, the lower portion of which is fitted with a worm conveyor, while near the top is a perforated plate or grating, above which the fish or other solid matter can not pass, but through which the water and oil rise. The material is fed in through a hopper at one end and is discharged at the other end, being carried forward by the worm conveyor, which also reduces the material to a finely divided state, thus enabling the action of the water upon all parts of the material freely to liberate the oil. The oil rises to the surface of the water in the cooking vessel and escapes through a pipe in the end into a settling tank. From the bottom of this tank whatever water has come over with the oil is pumped back into the cooking vessel, entering at the opposite end from the outlet through which the oil flows and at a point near the surface of the level at which the water in the boiler is constantly kept, thus creating a current which carries the oil constantly forward toward the outlet. The scrap from which the oil has been liberated is carried forward to an outlet in the bottom of the cylinder by the worm conveyor and falls into an upright elevator casing having elevator buckets running upon an endless chain, which carry the material up and over, dumping it into a receptacle suitable for removing for further treatment. The liquid matter is carried up by the elevator buckets, drains through them, and returns to the liquor in the cooking apparatus. This process, however, has not yet been found sufficiently practical for general adoption.

As long ago as 1858 the Ocean Oil and Guano Company, of Southold, N. Y., used a steam cylinder cooker somewhat similar to the continuous cooker now in use. This is said to have been invented by a Frenchman named De Molon, and is described in a pamphlet issued by the above company in 1860 as follows: The raw fish, in quantities of 1$\frac{3}{4}$

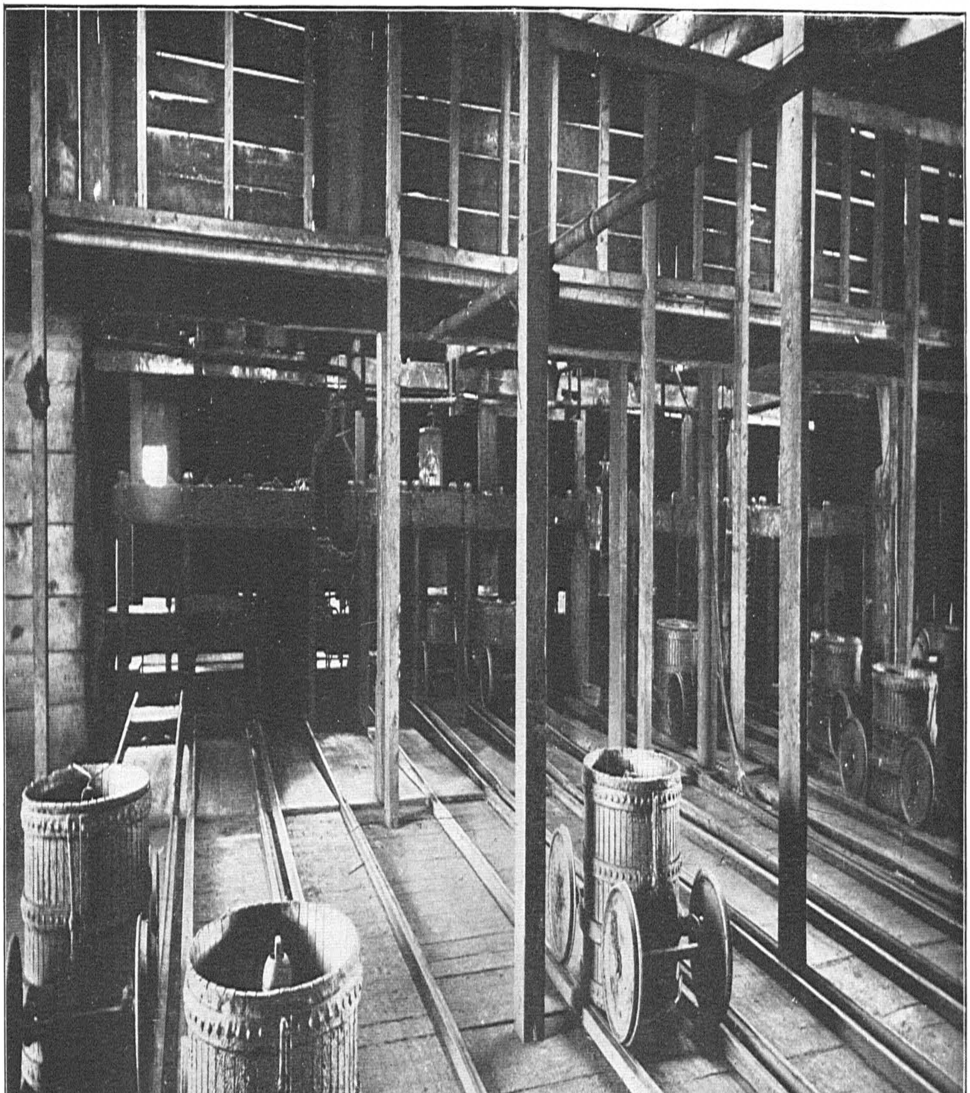
tons, are placed in the inner chamber of a revolving cylinder, with double walls, the space between the inner and the outer walls being filled with steam at about 80 pounds pressure. Before admitting steam the cylinder is put in motion, so that as it revolves each fish is constantly changing its position. A uniform temperature is maintained by means of one head of the inner cylinder being perforated to permit the steam generated in the mass to escape through a safety valve.

In the oil room of the menhaden factories is a series of receptacles into which the oil and water are received from the draining tanks and the presses. The combined mass of oil and water is first subjected to a temperature of 150° F., which causes them to separate, the oil rising to the surface. It is permitted to overflow to other tanks containing hot water, where it is brought to the boiling-point by means of injected steam. It is important that the oil be separated from the water before the impurities begin to ferment, fermentation causing it to be dark and of lower grade. After settling for a while the oil is withdrawn into another tank and thence pumped into the storage tanks.

A contrivance for withdrawing the oil from the surface consists of a jointed pipe with open end at top, which in some cases is funnel-shaped. This passes up through the bottom of the vat, and the top of the pipe is so arranged that it may be raised or lowered to any desired distance beneath the surface to receive and guide the surface oil into the next vat. Sometimes there is a series of as many as 5 vats, from one to another of which the oil passes, each time becoming purer and purer as it is cooked and drained. The oil is led into the first of the cooking vats through the bottom, the pipe leading nearly to the surface. A second pipe passing through the bottom and terminating with an open top not a great distance above the bottom carries off the water-oil or less pure oil as it settles and conducts it to near the top of the second vat, where the oil and water are further separated.

At the bottom of each settling tank is deposited a quantity of finely-divided fleshy substance known as "gurry." This is removed from the tanks to the gurry room, where it is treated or sprinkled with sulphuric acid to facilitate the separation of the oil from the flesh fiber. It is then placed in bags, 2 gallons to the bag, and these placed in pairs under a press and subjected to great pressure, resulting in a small quantity of oil. The residuum in the bags, consisting of a hard cake, is broken up and either discarded or mixed with the scrap.

When thoroughly separated from the water, the oil is pumped into suitable storage tanks or barreled. The refining or bleaching of the oil is rarely done at the factories, but is performed by the oil-refiners of New York, New Bedford, Boston, etc., and the methods and results have already been described on p. 234.



PRESS-ROOM OF MENHADEN FACTORY, SHOWING ARRANGEMENT OF TRACKS, CURBS, PRESSES, ETC.

The yield of oil varies greatly, ranging from less than 1 pint to as much as 15 gallons or more per thousand fish, or rather for each 22,000 cubic inches of fish. As a rule, it is much greater in the autumn than in the spring, and also greater in Northern than in Southern localities. Even in the same locality the fish are very much fatter throughout some years than in others. For instance, the average yield of the fish taken in Chesapeake Bay in 1887 was nearly 6 gallons to the thousand, whereas in 1888 it was a little over 2 gallons, and early in that season it was less than 1 pint to the thousand fish. Some years ago one of the Shelter Island factories secured from one lot of fish a yield of 24 gallons to the thousand. The largest yield brought to the notice of the writer was derived from some menhaden that had been inclosed in Shinnecock Bay late in autumn. By feeding in the brackish water of that bay these became so fat that they yielded at the rate of 48 gallons of oil per thousand fish. Considering the entire Atlantic coast for a series of ten years ending in 1898, it is found that each thousand fish yielded 4.59 gallons of oil and 138 pounds of scrap containing 10 per cent of moisture. During the ten years ending in 1888 the yield per thousand fish was 4 gallons, and during the six years ending in 1878 it was 5.26 gallons.

The table given on page 233 shows the total yield of menhaden oil on the Atlantic coast of the United States and the average yield per thousand fish for each year since 1873. From those figures it appears that the largest yield per thousand fish was 6.84 gallons in 1874. The yield in 1887 and also that in 1886 were large, being 6.81 and 6.38 gallons, respectively. The smallest yield per 1,000 fish was in 1880, 2.62 gallons, and in 1881, 2.79 gallons.

Not only does the yield of oil vary from year to year, but it also differs greatly in different sections of the country. As a rule, the Northern fish, or rather those taken in Northern waters, especially off the Maine coast, are the fattest, while those from off the southern coast yield the smallest quantity. In the year 1900, for instance, the yield of oil at the Rhode Island factories was 5.76 gallons per 1,000 fish; in New York it was 6.39 gallons; in Delaware 4.92 gallons, and in Texas 3.51 gallons to the 1,000 fish. The menhaden taken off the coast of Maine are by far the fattest, and in the few seasons when fish are obtainable there the menhaden fishermen from other States hasten to that coast. In 1888 the Maine fish yielded 11.85 gallons of oil per 1,000; in 1889, 10.83 gallons, and in 1898, 9.73 gallons to the thousand measure. Menhaden have not been taken to any extent on that coast since 1898.

TREATMENT OF THE SCRAP.

As it leaves the press, fish scrap contains 45 or 50 per cent of water, which can not be removed by compression owing to the gelatinous condition of the fiber. Although suitable for immediate application as a fertilizer, the moist condition of this scrap renders it undesirable for economic transportation or for storage for a great length of time, and necessitates further treatment. Previous to 1875 most of the scrap was sold in a green state, just as it came from the press, but since 1878 practically all of it has been dried or treated with sulphuric acid.

Formerly in drying it was customary at all the factories to spread the green scrap upon platforms, where it was exposed to the action of the sun for several days. While this is the common method at present, most of the large factories have discarded it and are using artificial driers. The platforms are made of tight or matched boards laid flat upon a stout framework or upon the level ground, and are sometimes of large area, covering 2 or 3 acres. The scrap is transferred from the bin beneath the presses by means of screw conveyors and carried to a receiving bin, where it is dumped into hand carts with capacity of one-half ton each and carried to the platform. It is there spread to a depth of from 3 to 6 inches and is frequently turned or raked over, so as to expose all particles to the sun's influence. In threatening weather and when the night dews are heavy, the scrap is raked into windrows or heaps and, if necessary, covered with canvas to protect it from moisture. After two or three days' drying it is piled in heaps and left to sweat for a time, and then is again spread to evaporate the free moisture generated in the heaps. This second drying reduces the amount of moisture in the scrap to about 10 per cent, and the material may be safely bagged and stored for market, though that operation is usually deferred until immediately before its shipment. Frequently the dried scrap is ground, especially when it is to be sold direct to the farmers without further treatment, in order that it may be sown in drills with wheat and other grains.

If good weather could always be depended on, platform-drying would possibly be the most economical and satisfactory method; but owing to uncertainties of the weather much difficulty is frequently experienced in this process, resulting in a great waste of material and extra expenditure of labor and loss of ammonia in the scrap. This has resulted in the adoption of artificial driers at the largest factories. Several forms of apparatus have been employed, but the principle in most of them is similar, the scrap being subjected to a current of heated air by means of a blower. The drier adopted in the largest factories consists of an iron cylinder about 30 feet long and 5 feet in diameter, so mounted as to revolve horizontally. On the interior surface are shelves or paddles which, as the cylinder revolves, lift the scrap fed in at one end and permit it to fall to the bottom. A strong current of heated air is forced through the cylinder, extracting the moisture and gradually driving the scrap out at the further end.

Another form of drier in use consists of a large double cylinder of iron set on an incline, into which the scrap is fed through an opening at the higher end and guided along to the lower end by means of a revolving screw. The space between the inner and outer walls of the cylinder is filled with steam, which heats the scrap, thereby evaporating most of the moisture.

Labor-saving devices make the handling of the scrap almost automatic. From the presses it is transferred to the drier by means of screw conveyors and bucket elevators, and is fed intermittently in quantities of 200 pounds at intervals of 45 to 60 seconds. The capacity of a drier is 2½ to 3 tons per hour, and the largest factories usually have 2 drying machines. From these the scrap is conveyed to the storage room.

Although the term "dried" is popularly applied to all scrap from which a large portion of the moisture has been removed by evaporation, its use in a technical sense refers to scrap containing not to exceed 12 per cent of moisture. In modern factories, green scrap fresh from the presses contains from 45 to 50 per cent of water. When desiccated so that only 10 per cent of its weight is water, each ton of chum or green scrap yields about 1,156 pounds of "dried scrap." It is not always that so large a quantity of water is eliminated, and sometimes the finished scrap contains 25 and even 35 per cent of moisture. Owing to its tendency to lose nitrogen in the form of ammonia and its unsuitability for storage or transportation, the scrap containing a high percentage of moisture is for use principally in the vicinity of the factories.

Not all the scrap, however, is dried, a large percentage being treated with sulphuric acid for the purpose of "fixing" the ammonia, preventing fermentation, and dissolving the bones. To every ton of scrap, from 80 to 200 pounds of sulphuric acid of about 50° strength is added and thoroughly commingled, the quantity of acid used depending to some extent on the state of the weather and the extent of decomposition of the fish. This is conveniently done by depositing the green scrap in handcarts of 1,000 pounds capacity, wheeling these to an elevated platform and dumping the contents beneath, when the heap is immediately sprinkled with about 60 pounds of sulphuric acid contained in a leaden pot. After a short while the bones dissolve and the mass becomes homogeneous and of a rich brown color, instead of the former grayish color. The ammonia is fixed by the acid and the tendency to decomposition overcome. The scrap is then conveyed to the storage room and shipped in bulk as required.

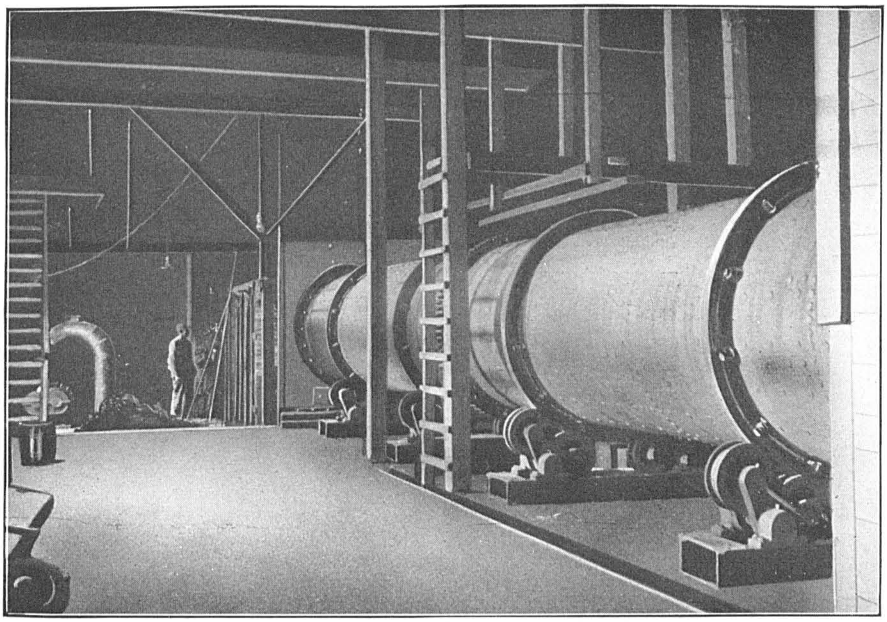
Instead of sulphuric acid, the solid granular sodium sulphate has been used to mix with the scrap, about 90 pounds being thoroughly combined with each ton. While this method is somewhat cheaper than applying sulphuric acid, it is not so satisfactory, and sodium sulphate is now little used for this purpose.

Owing to the difficulty in drying the scrap, most of that prepared at the Northern factories is acidulated, while the bulk of the Southern product is dried. In the last year for which data are available, the product of the entire coast was 48,853 tons acidulated and 36,977 tons dried, with a total selling value of $1,539,810. Of the 45,711 tons produced from Delaware northward, 33,458 tons were acidulated and 12,253 were dried, the average price of the former being $12.87 per ton and the latter $26.22 per ton. South of Delaware the product of green and of acidulated scrap combined, according to the latest returns, was 15,395 tons, while 24,724 tons were dried, the respective values per ton being $12.95 and $23.79.

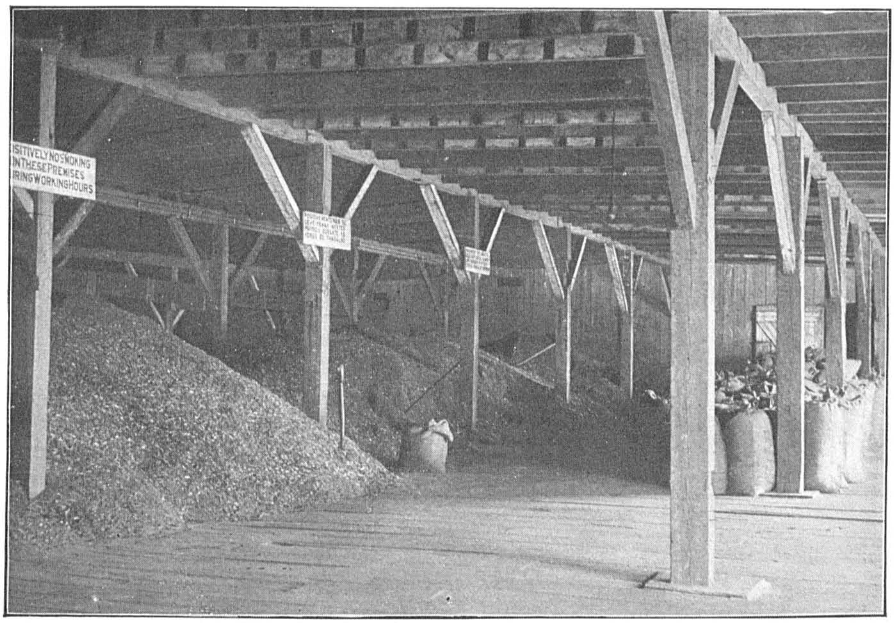
Only a small percentage of the fish scrap is used by the farmers in the condition in which it leaves the factories; most of it is ground and serves as an ingredient in compound or so-called "complete" fertilizers. Compound fertilizers are prepared at some of the menhaden factories, but as a general thing their preparation is in the hands of persons who have nothing to do with catching and rendering the fish.

The value of commercial fertilizers is dependent mainly on their content of nitrogen and phosphoric acid, which are the most important plant foods usually lacking in the soil. The nitrogen necessary is supplied mainly by fish scrap. Various other materials are also used, as dried blood, meat scrap and other slaughter-house refuse, cotton seed, sulphate of ammonia, nitrate of soda, Peruvian guano, etc. The phosphoric acid is supplied by fish scrap to some extent, but principally by the phosphate rocks, boneblack from the sugar refineries, bone meal, etc., the solubility of the phosphate being increased by treatment with sulphuric acid, thus making superphosphates. The value of fish scrap varies according to the percentage of ammonia and phosphoric acid contained therein. As a general rule, dried scrap contains about 8 per cent of nitrogen and 8½ per cent of phosphoric acid. On a selling basis of $24 per ton, the nitrogen costs about 10 cents per pound and the phosphoric acid about 3½ cents per pound for compounding purposes. Other necessary plant foods are potash, lime, magnesia, sulphuric acid, and iron. These usually exist in sufficient quantities in the soil itself, but are added under special conditions, especially the potash. The nature of the ingredients and the respective proportions required vary according to the soil and the crop for which the compound is intended.

Although the agricultural value of dried fish scrap is nearly equal to that of Peruvian guano, the market price is much below that article. In explanation of this fact it may be stated that fish scrap is not in such compact and good mechanical condition for shipment and general use. Its value as a fertilizing agent has not been so widely known as that of Peruvian guano, and thus its principal use is largely limited to the manufacturers of superphosphates, who are forced by competition to exercise great caution in the cost of manufacture. And, furthermore, there is a tendency to reduce the quantity of ammonia and increase that of phosphoric acid and potash in complete fertilizers to meet the requirements of the soil. Other ammoniated materials now compete with fish guano in the making of superphosphates, among



ARTIFICIAL DRIER IN FACTORY OF FISHERIES COMPANY, PROMISED LAND, NEW YORK.
(SEE P. 266.)



FERTILIZER ROOM IN FACTORY OF THE FISHERIES COMPANY, PROMISED LAND, N. Y.

which are cotton seed, sulphate of ammonia, nitrate of soda, tankage, meat scraps, slaughter-house refuse, etc.

The product of fish scrap, reduced to basis of dried weight, produced from 1873 to 1900 approximates 1,048,000 tons, or an annual average of 37,428 tons. As it is estimated that in a ton of compound fertilizer ready for the soil the usual proportion of fish scrap is 25 per cent, it is seen that the industry has contributed the ammoniate for 4,192,000 tons of fertilizer, or at the rate of 149,712 tons annually. In growing cotton, for which these fertilizers are largely used, 250 pounds are generally employed to raise one bale.

FERTILIZERS FROM FISH WASTE OR REFUSE.

Even in the food-fisheries large quantities of materials are obtained which can not be used for food. This includes not only non-edible species, but also those edible varieties which are not marketable, owing to such unusual conditions as lack of transportation facilities or a glut in the market. It likewise includes the refuse in dressing fish for the markets and for canning, drying, salting, etc.

Formerly, when the markets were overstocked during warm weather, large quantities of fresh fish spoiled and were suitable only for fertilizer. Even so choice a variety as the mackerel has been used for enriching land when taken in larger quantities than could be used for food purposes. In 1880, for instance, when the total catch of mackerel in New England approximated 132,000,000 pounds, 500,000 pounds of small fish were reported as having been used in Massachusetts as fertilizer.[a]

Previous to 1870, according to Capt. N. B. Church, many thousand barrels of scup and sea bass, taken in trap nets between Cape Cod and Montauk Point, were purchased by the farmers and spread on the land. Mr. A. B. Alexander states that large quantities of shad taken in the Columbia River are used for fertilizer. With the development of fish freezers and the improved means of communication and transportation this waste is much reduced. Yet the aggregate quantity of food-fish received in bad condition, or which "goes bad" in the markets, in the course of the year is very large in any populous city. During 1899, according to the *Fish Trades Gazette*, the quantity of fish condemned by the officers of the Fishmongers' Company in London was 1,520 tons, of which 232 tons were plaice, 228 tons Norwegian herring, 169 tons haddock, 94 tons mussels, 80 tons skate, 70 tons welks, and 60 tons of periwinkles. In New York City the quantity of spoiled fish condemned during the summer amounts to several hundred thousand pounds each year.[b]

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[a] Report U. S. Fish Commission, 1881, p. 219.

[b] During the interval between Wednesday, June 30, and Wednesday, July 14, the authorities of the health department of New York City condemned as unfit for food 41,650 pounds of fish. Of this amount, 39,650 pounds were seized in the Fulton Fish Market, the remaining 2,000 pounds being condemned by the local inspectors among the retail dealers in various sections of the city. (*The Fishing Gazette*, 1902, p. 458.)

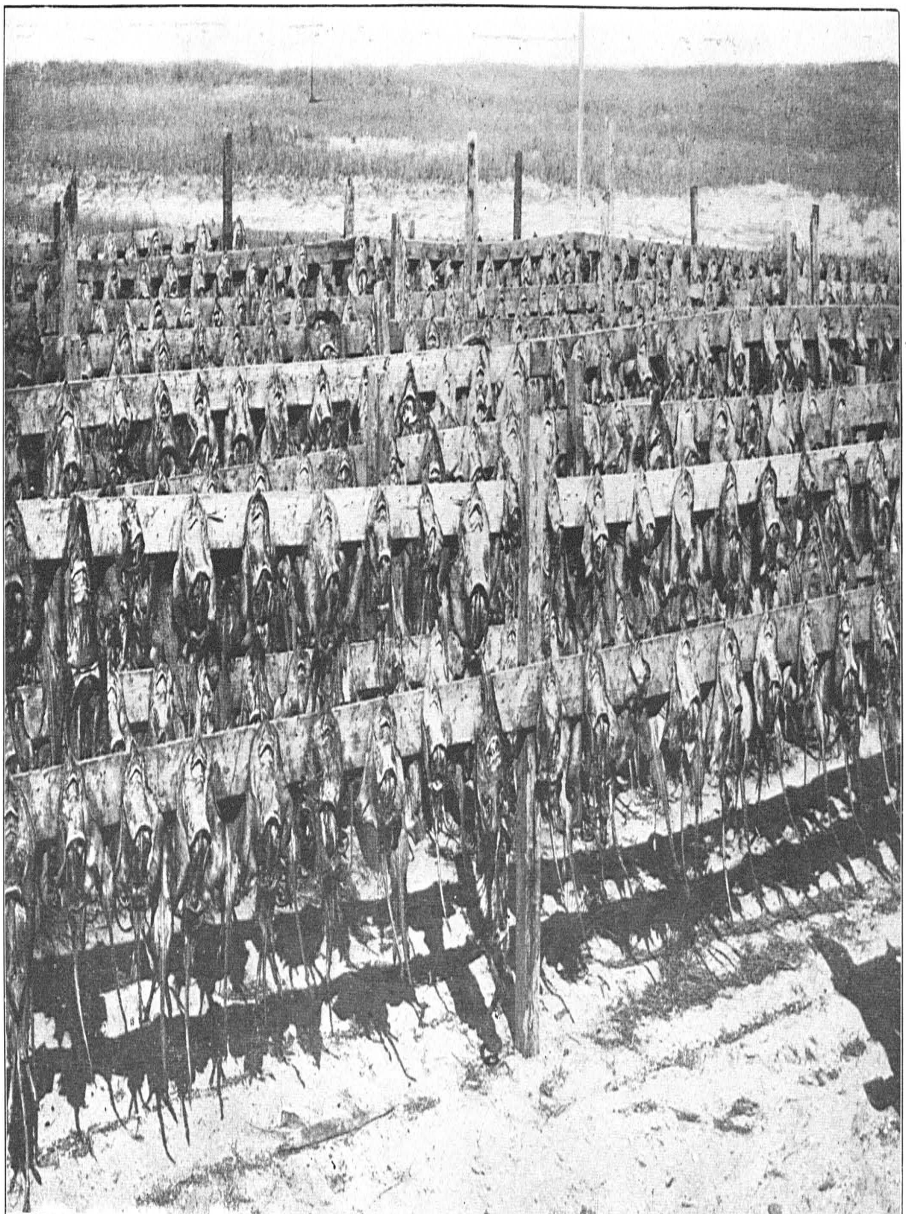
Before the development of the sardine industry in Maine, the small fish taken in connection with the smoked-herring business were commonly converted into oil and fertilizer. After the oil had been extracted by boiling and pressing, the chum was broken up, spread on a board platform, and dried by the action of the sun. It was then ground, bagged, and sold at $12 to $16 per ton.

About fifteen years ago a factory was established at Pillar Point, on the shore of Lake Ontario, for converting the surplus alewives occurring in that lake into fertilizer. The fish, obtained by means of seines and pound nets, were cooked for about 20 minutes in steam chests, permitted to drain for an hour, and then subjected to pressure in circular curbs holding about 5 barrels of chum each. The scrap was dried and ground and sold to the farmers for about $20 to $25 per ton. It is reported that in 1886 1,000,000 fish were utilized, yielding 500 gallons of oil and 63 tons of fertilizer. Along the shores of the Great Lakes and other waters, quantities of dead fish have been washed up in windrows, furnishing a harvest for the farmers in the vicinity.

In the pound-net fisheries of Cape Cod many skates and other "poor" fish, taken incidentally with the food-fish, are converted into fertilizer. If these contain much oil, it may be extracted by boiling and pressing. Ordinarily, however, the fish are dried without previous treatment. Especially is this the case with skates, which in some instances are suspended in rows above the ground until thoroughly dry, and are then ground fine. A large quantity of these fish hanging from a series of flakes or rails presents a very curious sight.

The quantity of waste and spoiled fish, however, is small compared with the very large amount of viscera and other offal resulting from dressing fish. The decrease in weight in dressing ranges from 15 to 35 per cent of the round weight, according to the species of fish and the season of the year. Assuming an average decrease of 25 per cent, it appears that in dressing the 900,000,000 pounds of food-fish produced in the United States each year the refuse amounts to 225,000,000 pounds, or 112,500 tons. While this is a very large amount in the aggregate, it is so widely distributed that the quantity at any one place is not of great importance, and usually its disposal is a sanitary problem rather than a source of revenue. In dressing fish at sea the waste is almost invariably thrown overboard. In the cities this material is usually combined with and handled in the same way as other market refuse. At the canneries where large quantities of fish are dressed, as in the salmon canneries of the Pacific coast, and the sardine canneries of Maine, the refuse is now in many cases rendered into oil and fertilizer. This has already been noted in the chapter on the preparation of oils from waste products in the fisheries. (See pp. 240–242).

In case the fish dressings contain little oil the inducements for utilizing them are not great. Water constitutes a very large proportion of the viscera, the quantity ranging from 65 to 90 per cent,



DRYING SKATES FOR MANUFACTURE INTO FERTILIZER, OPPOSITE PROVINCETOWN, MASS. (SEE P. 270.)

according to the species and the season. Even when the moisture is largely removed the quantity of fertilizing substances in the dried material is small. However, if the quantity of oil in the waste is sufficient to pay the cost of its extraction, it is usually profitable to perform the slight additional labor necessary to make the material suitable for fertilizer. The manurial content of fish heads is relatively large, and whenever they are accumulated in large quantities their conversion into fertilizer is profitable.

A convenient process of converting a small quantity of refuse from dressing fish into fertilizer is to store it in a receptacle made in the ground. This should be about 5 or 6 feet deep, with the area depending on the amount of refuse, but usually about 6 feet square. It should be dry and if the soil is sandy some clay should be spread at the bottom. First is placed a layer of wood ashes a few inches deep and then an equal layer of fish refuse covered by a sprinkling of lime. Then follow another layer of ashes, one of fish refuse sprinkled with lime, and so on until the hole is full. It should be covered with earth or sod and these covered with weighted boards and permitted to so remain for several months. The fish refuse quickly disintegrates and becomes mixed with the ashes, forming an excellent fertilizer.

Since 1875 the skins and bones resulting from the preparation of boneless codfish have been used for fertilizing purposes. After desalting them and extracting the glue, the remaining material is dried and sold for $15 or $20 per ton. The annual product amounts to about 3,000 tons. Most of this is produced at Gloucester, Mass., with smaller quantities at Boston, Provincetown, Portland, and Vinal Haven. According to analyses, this fertilizer contains about 10 or 12 per cent of phosphoric acid, 8 or 9 per cent of nitrogen, and 5 or 6 per cent of moisture.

The refuse in preparing oil from livers of cod, sharks, and related species, from heads of halibut, sturgeon, and sword-fish, and from other materials is also dried and sold for fertilizer. The liver scrap formerly sold at $8 or $10 per ton, but at present its market value is only about half of that amount. Fertilizer made from fish heads is especially rich in phosphoric acid. A sample of guano made in Boston from fresh cod heads showed 20 per cent of phosphoric acid, 6¼ per cent of nitrogen, and 3½ per cent of moisture, and a sample of that made from fresh halibut heads contained 13 per cent of phosphoric acid, 5¼ per cent of nitrogen, and 5 per cent of moisture.

An important fish fertilizer in Norway is made from the refuse in dressing cod for drying, consisting principally of heads and backbones. These are merely dried by spreading them on the rocks and are then broken and ground to the condition of coarse bone-meal. In some localities the refuse is first steamed, to facilitate the drying and grinding. The utilization of these materials for fertilizer was begun about 1855, and the industry is centered at the Lofoden Islands, the location of the principal cod fishery of Europe. The present annual production is said to be upward of 10,000 tons of prepared scrap, about 20,000,000 cod heads being utilized for the purpose.

According to a report made by Consul-General Crowe, of the British service, the heads and bones are first partly dried in the open air and then cut into small pieces and thoroughly dried in a kiln. When all but 12 or 15 per cent of moisture has been driven off, the materials are crushed and then ground between millstones to the fineness of corn meal. The heads and bones are crushed separately, but are mixed together before the grinding process, the usual proportion of the mixture being one part of the backbones to five parts of the heads. Chemical analyses indicate an average content of water 13 per cent; organic substances 49.3 per cent, of which 8 per cent is nitrogen and 7.6 per cent ammonia; and inorganic substances 37.7 per cent, of which 14.9 per cent is phosphoric acid.

In utilizing whales at the Norwegian stations established in connection with the taking of these cetaceans, the flesh and bones are commonly prepared as fertilizer after the extraction of the oil. The blubber and the fat-lean are first removed from the flesh for oil-rendering, and then the flesh is cut into strips or minced in a machine and boiled with steam under pressure. As described by Michael Winnem, in *Chemische Revue*, the receptacles for boiling the flesh are horizontal iron cylinders provided with close-fitting openings. They are also provided with two outlet pipes, one at the very bottom, for removing the water, and the other about 4 inches higher up, for drawing off the oil. The flesh is spread on three superimposed perforated trays or false bottoms, and subjected within the cylinder to steam at a pressure of 40 or 50 pounds to the square inch for ten or twelve hours. At the end of that period the flesh is removed and placed in drying ovens. These are built of brick, 20 to 25 feet high, and fitted with internal sheet-metal trays, which are mounted alternately on the sides of the oven and on a central revolving shaft. The latter carries a number of slanting scrapers which revolve once in 5 minutes and slowly force the flesh from one tray to the next lower ones in succession. The descending flesh is dried by the heated air from a coke fire, which enters the oven at the top and passes out through an opening at the bottom.

The process is somewhat slow, the output during twenty-four hours not exceeding 2 tons for each oven. If desired, the fertilizer may be ground in a mill. The bones are broken and treated in much the same manner as the flesh. After boiling they are crushed in a disintegrator, ground in a bone-mill, and mixed with the flesh scrap. An analysis, made by Krocker, of Norwegian whale fertilizer indicated 7.63 per cent of nitrogen, 13.45 per cent of phosphoric acid, 16.49 per cent of lime, and 0.15 per cent of magnesia in a sample containing 5.35 per cent of moisture. The market price is about £5 per ton. In the bottle-nose fishery the oil is commonly extracted at sea, as in case of the American whale fishery, and consequently it is not practicable to utilize the flesh and bones as fertilizer.

FERTILIZER DEPARTMENT, RUSSIA CEMENT COMPANY'S GLUE FACTORY, GLOUCESTER, MASS.

FERTILIZERS FROM CRUSTACEANS.

Among the most curious of the marine products used for fertilizer is the horseshoe crab (*Limulus polyphemus*), which is found in comparative abundance at several points on the Atlantic coast and especially on the shores of Delaware Bay. The use of this fertilizer dates back at least a hundred years, old records indicating its employment by the farmers of Cape Cod in the eighteenth century. It is reported that they were first used in the Delaware Bay region about fifty years ago. In that section they are taken during May and June, when large numbers visit the shallow waters for spawning purposes. During the remainder of the year they are scarce inshore, although a few may be obtained. They are secured by picking them up at night on the shore either by hand or with pitchforks, or they are taken in pound nets constructed especially for that purpose. The pound nets cost $25 to $75 each, and they secure by far the greater number. At present the catch is very much less than it was twenty years ago. In 1880, according to the returns of the United States Fish Commission, the total catch in Delaware Bay amounted to 4,300,000 in number, worth $16,300. In 1890, it was only 1,939,670, worth $8,580, and in 1897 it was still further reduced to 1,206,095, worth $8,393. The value of the horseshoe crabs ranges from $4 to $8 per thousand and the weight averages about 2 pounds each.

In preparing them for fertilizer, the entire crabs are sometimes merely stacked in piles until they putrefy and become somewhat dry, when they are broken into fragments and composted with muck, lime, or other suitable materials. Two or three small factories exist at which the crabs are dried and ground, or they are ground while green and then mixed with sodium sulphate or sulphuric acid. The product sells for $15 to $25 per ton, and is an excellent fertilizer for grain and fruits. The output in 1880 approximated 1,950 tons, in 1890 it was reduced to 880 tons, and in 1901 it was still further reduced to 500 tons.

When lobsters were canned on the coast of Maine, a desirable grade of fertilizer was made from the shells and other refuse of the canneries. This refuse was sold at a nominal price at the factories, or given away for the hauling. The farmers collecting it would usually dry and grind it and then spread it on the land. Letters patent were issued to William D. Hall, in 1865, for the preparation of this fertilizer, but his rights in the matter were never protected. This waste is thus utilized at the present time at the lobster canneries in Nova Scotia and New Brunswick.

The shells of shrimp produced in the fisheries of California and Louisiana are used to a considerable extent for fertilizer, which is employed by the Chinese not only on the Pacific seaboard but also in the Orient. The shells are removed from the dried shrimp and sold at about $5 per ton. In California they are especially valued in strawberry and vegetable culture, while in China their principal use is as fertilizer for rice, tea plants, etc. In strawberry culture, from 300 to 400 pounds are commonly applied to each acre. It has also been used in wheat-growing, being spread broadcast on the land after the first plowing.

AGRICULTURAL LIME FROM MOLLUSK SHELLS.

The shells of oysters, clams, mussels, etc., have long been valued for agricultural purposes. All along the Atlantic coast of the United States, the extinct oyster beds, the old shell heaps, and even the living oyster reefs have long been resorted to by the neighboring farmers as a storehouse for top-dressing for their fields. In the Gulf States the most luxuriant vegetation along the shore is upon the shell mounds and marl deposits. Most of the material, however, is obtained from the shucking establishments where mollusks are opened in large quantities. Previous to the discovery of the limestone resources of Pennsylvania and other States, large quantities of shells were burned for lime; but at present their use for this purpose is confined largely to localities where the shells are unusually abundant and cheap.

An article in the *Country Gentleman*, volume 7, page 155, refers to the use of mussel shells for manure with especial reference to Essex County, Mass., as follows:

> Thousands of cords of mussel shells are annually taken from the beds of the streams bordering on the sea and used on cultivated ground. I have repeatedly witnessed the value of this fertilizer in the growing of carrots and onions. The very best crop of carrots I saw the last season, more than 34 tons to the acre, had no other fertilizer applied to the land. For the last thirty years I have known it applied to lands on which onions have been grown, with a product varying from 300 to 600 bushels to the acre. It sells, delivered several miles from where it is dug, at $4 to $5 the cord. It is usually gathered in the winter months, taken to the shore in scows or gondolas, and thence to the fields where it is used. Sometimes it is laid in a pile of several cords together, and after it has been exposed to the frosts of winter, distributed from 4 to 8 cords to the acre. At other times it is laid out in heaps of a few bushels only, which remain for a time exposed to the frost.

According to Storer, "lime is not a fertilizer in itself, but is of indirect value on land in unlocking the available potash, phosphorus, and nitrogen in the soil." It also renders heavy, compact soils looser in texture and tends to bind particles of loose, leachy soils.

It is difficult to approximate the sum total of value which shells confer on agriculture, owing to the extensive use of marl deposits. Of refuse shells from shucking-houses and the like, the quantity used in this country is doubtless upward of 60,000 tons annually.

The prepared lime is generally preferred to the ground shells. Analyses indicate that the organic matter contained in shells is well-nigh free from nitrogen, and there is no evidence that it is of any use as manure. It appears, therefore, that there is no need for the expense of grinding the shells and of carting the useless constituents which can be expelled by burning. Since grinding does not reduce the material to so fine a state as burning does, the ground shell is not so active chemically.

The most popular manner of utilizing shells is to burn them and slack the product with water. The slacking may be done in heaps covered with moistened earth, and the fine powdery hydrate of lime spread directly upon the land; or the lime may be used in the compost heap; or the quicklime may be left to become air-slacked by exposure to the air, and the product be applied to the land instead of leached ashes.

AQUATIC PLANTS AS FERTILIZERS.

Although it does not appear that the many properties of aquatic plants have been fully exploited, their uses are far more numerous and diversified than is generally supposed. Their most widely known economic value is as furnishing thousands of tons of fertilizer and a great variety of nutritious and wholesome foods. In addition thereto, they are utilized in the production of many chemicals, especially iodine and bromine, and as a constituent in glues and gelatines, and as a basis for trade fruit-jellies. They also serve in sizing fabrics, in refining beer, as a mordant in dyeing, as composition in cement for covering boilers, for stuffing upholstery, packing porcelain, in making paper, fishing-lines, ropes, buttons, handles for cutlery, as tents in surgical operations, etc. The gathering of seaweeds in Great Britain early in the present century is said to have given employment to about 100,000 persons, the product being used in the manufacture of carbonate of soda.

On the coasts of France and the British Isles thousands of tons of seaweeds are collected annually for fertilizing the crops. In China and Japan they have been used as fertilizer for many centuries, but in recent years the employment of seaweeds for this purpose has been much reduced, owing to their more extended use as food and in the chemical and manufacturing industries. In the New England States they are probably the most important fertilizing material used on those farms immediately adjoining the sea. According to Storer, with the exception of the farms of the Connecticut Valley and those enriched by fish scrap or by manures received from the cities, "the only really fertile tracts in New England are to be found back of those sea beaches upon which an abundant supply of seaweeds is thrown up by storms." In the Middle Atlantic States the use of seaweeds as fertilizer is not so extensive, but in the aggregate very large quantities are employed. Elsewhere in the United States their use is of less importance.

There are three principal groups of aquatic plants used in this country for fertilizer, viz, rockweeds, kelp, and eelgrass or grass rack. Rockweeds are the large dark-colored plants furnished with small bladders or snappers, which constitute at least 75 per cent of the covering of rocks and stones between high and low water marks on the coast from Nova Scotia to New York. There are two prominent species of these, the round-stalked and the flat-stalked. The principal species of kelp, viz, the ribbon-weed and the broad ribbon-weed or devil's apron, are common on the rocks at and below the low-water mark from Newfoundland to the New Jersey coast. In the north of Europe both of these species are used for food to a considerable extent. Dulse, Irish moss, and other species may also be used for fertilizer, but the quantity obtained is so small that they are of little importance in this connection.

The principal fertilizing agencies in aquatic plants are nitrogen and potash; the quantity of phosphoric acid is very small, amounting to only about 10 per cent as much as the above two combined. Seaweeds also contain considerable quantities of lime and magnesia. By the addition of some material containing a large percentage of phosphoric acid, as bone meal, for instance, a "complete fertilizer" is formed. This is frequently very important in order to secure the full value of the nitrogen and potash contained in the seaweeds.

According to analyses made by the Rhode Island Agricultural Experiment Station,[a] the average percentage of fertilizing constituents and of water contained in various aquatic plants in the fresh state collected at different seasons on the coast of Rhode Island is as follows. For convenience of comparison, analysis of average barnyard manure is appended.

Materials.	Nitrogen.	Phosphoric acid.	Potash.	Water.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Rockweed, flat-stalked	.38	.12	.65	76.55
Rockweed, round-stalked	.24	.08	.64	77.28
Broad ribbon-weed, or devil's apron	.23	.06	.31	87.50
Ribbon-weed, kelp, or tangle	.17	.05	.16	87.99
Dulse	.37	.09	1.07	86.25
Irish moss	.57	.13	1.02	76.03
Eelgrass	.35	.07	.32	81.19
Barnyard manure	.49	.32	.43	

The total quantity of the fertilizing ingredients in plants is very small in proportion to the weight of the material, this being due principally to the large content of water. Usually at least 75 per cent of the weight of aquatic plants consists of water, and about 80 per cent of the remainder is a soft, easily decomposable form of organic matter. The plants decompose rapidly, and the water separates from them quickly, the weeds left in heaps on the beach being reduced to one-half or one-third of their original bulk in a few weeks. Since much of the fertilizing constituents, especially the nitrogen, wastes away in this process, it is important that the plants be used within as short a time as practicable after they have been collected. For the same reason it is much better to collect weeds directly from the rocks, or

[a] Bulletin No. 21 of Rhode Island Agricultural Experiment Station, January, 1893.

those just thrown up by a storm, rather than those which have lain on the beach for a considerable time.

The large content of potash makes sea plants, particularly rockweeds, especially favorable to the growth of clover. Storer refers to the abundant natural growth of red clover upon the tract of country back of Rye Beach, Maine, which has been manured with these plants since the settlement of the country. Seaweeds are also excellent for wheat, and are used for parsnips, turnips, and to some extent for potatoes, although it is claimed that they impart a somewhat unpleasant flavor to the last-named. The general opinion in this country is that potatoes grown with seaweeds are much less liable to be affected by scab than those grown with barnyard manure, but they are less mealy and of inferior flavor.[a] Seaweeds have been strongly recommended for tobacco-culture, but owing to their effect on the quality of the leaf, they are not much used for this purpose. They are also highly recommended for cauliflower and cabbages. They act very quickly, and the effect of their application is confined largely to the season in which they are used, having little action upon the second and succeeding crops.

Owing to their small content of fertilizing materials and the large amount of moisture, aquatic plants are usually rather expensive for fertilizer if long cartage is required, at least 4 tons of water being transported for every ton of dry material. This limits their value to the immediate vicinity of the beaches, and they are rarely used on land more than 10 or 12 miles from the coast.

However, the manurial value of seaweeds must not be regarded merely from the point of view of the fertilizing agencies which they contain. They have a mechanical action on the soil, tending to make it friable and binding its constituents together; but the manufacture of soil is rather expensive where there is so much good land available as in this country. They have an advantage over barnyard manure in the freedom from seeds of land weeds. Formerly it was considered desirable to apply the material in the form of a compost with lime or gypsum, but experience of recent years indicates that it does not pay as a rule to compost them, except possibly in case of eelgrass and also rockweeds, to be applied as a summer or autumn top-dressing for grass land.[b] The usual practice in applying them is to plow the seaweeds into the soil or to spread them upon the land as a top-dressing, the plants being in either case in as fresh a state as practicable. They also tend to prevent the crops from suffering from summer droughts, grass fields dressed with seaweeds frequently remaining green when adjacent fields are suffering.

So important is the crop of seaweeds in the Channel Islands that special laws are enforced to govern their collection and distribution. The cutting of weeds from the rocks is restricted to certain seasons comprising about four or five weeks each year. Those cast up on the

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[a] See Bulletin No. 21 of Rhode Island Agricultural Experiment Station, p. 20. [b] Ibid p. 8.

shores by the action of the waves are collected throughout the year and especially during stormy weather, furnishing employment to a large proportion of the inhabitants of Guernsey and Jersey. They are applied to the land not only in a green state, as in this country, but are also burned on the beach and on the cottage hearths and the ashes used as fertilizer.

Large quantities of seaweeds are also burned on the coast of France, especially in Brittany and Normandy, and on the coasts of Ireland and Scotland. In this process the plants are usually treated for the obtainment of iodine and salts of potassium and sodium, leaving the potash salts as the principal fertilizing agent. Although greatly reduced, owing to the production of iodine from South American caliche, the quantity of iodine made from the ashes of seaweeds is yet very large. The ashes of seaweeds are not used as fertilizer to any great extent, if at all, in this country, owing to the fact that, in burning, the valuable nitrogen is driven off and lost. However, for use at a greater distance than 12 or 15 miles from the coast it might be found practicable to burn them if this can be done with a small expenditure.

Several unsuccessful attempts have been made in this country to establish a profitable business in preparing commercial fertilizer from seaweeds. About thirty years ago a factory was built for this purpose at Boothbay, Me. Dried seaweeds were ground in a mill formed of 40 circular saws, 20 having teeth and 20 without. These were placed alternately on an iron shaft and so adjusted as to revolve in a concave trough fitted with 40 steel plates. The shaft weighed 1,000 pounds and made upward of 2,000 revolutions per minute. With this apparatus 3 tons per hour of the thoroughly dried seaweeds could be reduced to about the fineness of oats. There proved to be an insufficient market for the fertilizer, and its manufacture was discontinued in a few years.[a] Most of it was sold in Connecticut for the use of tobacco-growers. The average price at the factory for the prepared material was about $8 per ton.

Notwithstanding its relatively large content of nitrogen, phosphoric acid, and potash, as revealed by chemical analysis, eelgrass is of very little value as a fertilizer, owing to the difficulty in making those constituents available. According to Storer's well-known work on fertilizers (pp. 167–168, vol. 2):

> Eelgrass taken by itself has little or no fertilizing power. It will hardly rot anywhere, either in the ground, in the hogsty, or in the manure or compost heap. It is a distinctly inconvenient thing, moreover, to have in the way of the plowshare or the dungfork. It has long stood as a kind of reproach among the vegetable manures, much as leather scraps stand in the list of animal products. For mulching for covering bins or piles of roots as protection against frost, moldiness, and decay, and for banking up in autumn around stables, greenhouses, cisterns, cellars, and pumps, eelgrass has been found useful, and this is about all

[a] See The Fishery Industries of the United States, Sec. II, p. 69.

that could have been said in its favor until very recently. Considered as a manure, it was rejected by the farmers long ago. It has been tried and found wanting by numerous generations of men. Still, on analysis it appears that eelgrass contains a considerable proportion of fertilizing matters, and there can be no doubt that it will be found amenable to proper treatment and will eventually be prized as a manure. Besides 1⅛ per cent of nitrogen, air-dried eelgrass contains 1 per cent of potash and 0.25 per cent of phosphoric acid. The ashes of eelgrass contain 7 per cent of potash and 1½ per cent of phosphoric acid, which is about as much as is contained in ordinary house ashes from wood fires. The trouble with eelgrass is, as was said before, that it will not rot in the soil. It must be coerced in some way in order to make its fertilizing constituents available for crops. It might be burned, for example, to ashes in order to get the potash and phosphoric acid; or, much better, the organic matter may be disorganized by composting the grass with lime or with rockweed. That is to say, the eelgrass may either be thrown into heaps, with layers of lime interpolated, in order to reduce the resisting tissue to a manageable form, or it may be built into a heap, layer by layer, with fresh rockweed or sea manure, and so subjected to destructive fermentation.

It is quite impracticable to form a close estimate of the total quantity of aquatic plants used for fertilizer in this country. The latest returns of the United States Fish Commission show an output on the New England coast of 75,000 tons, worth about $1 per ton, but these figures probably do not show the total production. According to the Rhode Island census of 1885, $65,044 worth of seaweeds were used in that State alone during the census year, compared with a total of $164,133 worth of "commercial" fertilizers. This represents only a small percentage of the total quantity obtainable, it being possible to collect a thousand or more tons to the mile of that coast. The growth of the plants is rapid, and rocks scraped bare may be covered with kelp 5 or 6 feet long the following year.