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# THE FISH-SCRAP FERTILIZER INDUSTRY OF THE ATLANTIC COAST.

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## PURPOSE OF THE INVESTIGATION.

The present investigation forms a part of the general plan of the Bureau of Soils to survey the Nation's assets in fertilizer materials. The three elements which constitute the essential ingredients of most of the artificial fertilizers compounded and marketed in this country are phosphorus, potassium, and nitrogen. The former two occur in nature as the salts of phosphoric acid and potassium, respectively. The investigation of the Nation's resources in these, therefore, has had to do with the examination of known deposits and exploration for new. In this connection and under the direction of the Bureau of Soils, the phosphate fields of South Carolina, Tennessee, Florida, Utah, Idaho, Arkansas, and Kentucky have been surveyed by W. H. Waggaman;[1] the desert basins and certain saline lakes of Oregon, California, Arizona, New Mexico, and Nevada have been examined by E. E. Free,[2] in collaboration with J. G. Young and A. R. Merz, to determine the occurrence of potassium salts therein; W. H. Ross[3] has studied the decomposition of the feldspars with a view to the liberation therefrom of the combined potash; Waggaman[4] has investigated the decomposition of alunite and the extraction of potash therefrom; W. C. Crandall,[5] G. B. Rigg,[6] and F. M. McFarland,[7] have surveyed certain of the kelp groves of the Pacific coast to determine the amounts of those potash carriers available, while the writer has determined the potash content of a number of these sea plants collected from the coast of California, Washington, and Alaska;[8] the behavior of kelps when subjected to destructive

[1] Buls. Nos. 69, 76, and 81, Bureau of Soils, U. S. Dept. of Agr.
[2] Circ. No. 61, Bureau of Soils, U. S. Dept. of Agr., and a manuscript not yet published.
[3] Circ. No. 71, and a manuscript not yet published.
[4] Circ. No. 70, Bureau of Soils, U. S. Dept. of Agr.
[5] "Fertilizer Resources of the United States." Sen. Doc. 190, 62d Cong., 2d sess., 1912; Appen. N, p. 209.
[6] Ibid., Appen. L, p. 179.
[7] Ibid., Appen. M, p. 194.
[8] Turrentine, ibid., Appen. P, p. 217, The Composition of Kelps.

distillation has been studied in the experimental laboratories of Mr. John W. Hornsey, consulting engineer, 49 Wall Street, New York, with a view to the possible employment of such a process for the extraction of potash and useful by-products;[1] the writer,[2] in collaboration with W. C. Phalen, of the United States Geological Survey, and W. H. Ross, A. R. Merz, R. F. Gardener, and J. A. Cullen, of this bureau, has studied the composition of the salines, brines, and mother liquors from the principal salt-producing areas of the United States, of natural subterranean brines from various salt wells and oil and gas wells of the various sections of the country explored and prospected for the latter two, of brines and salt crusts from desert sinks or playas, and of mother liquors from certain solar refineries of ocean brine on the Pacific coast, with a view to their potash content and their utilization as a source of potassium salts; Free[3] has investigated certain desert areas where nitrates have been found; Waggaman has studied the peat beds of Florida, regarded as a possible source of combined nitrogen and of value as a filler for manufactured fertilizers, and has reported[4] on the production of ammonium sulphate.

Nitrogenous compounds, of fertilizer interest, to a greater extent than those of phosphorus and potassium, are of artificial derivation, though they likewise are obtained in natural deposits. The investigation has had to do further with the examination of those operations and processes which lead to the production of such nitrogenous compounds, generally as by-products, as may be used in the preparation of fertilizers.

The information sought in the present study has been in part statistical, to determine the history of the industry in terms of equipment and output, and its present and proposed development. In addition, information has been sought regarding the particulars in which the processes now in vogue could be improved, the means whereby the industry could be put on a more secure economic basis, and its possibilities for enlargement. The Department of Agriculture has been organized primarily to effect the advancement of the agricultural interests of the Nation, and it is believed that in advancing the interests of the manufacturers of fertilizers and in helping them to increase their output and to reduce the cost of manufacture, the interests of the farmers are enhanced. In other words, the interests of the manufacturer and of the purchaser of fertilizer

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[1] Turrentine, Proc. 8th Internat. Cong. Appl. Chem., 1912, vol. 15, p. 313.

[2] Composition of the Salines of the United States, J. Ind. Eng. Chem., 4, 828; ibid., 4, 885 (1912); ibid., 5, 19 (1913); Bul. No. 94, Bureau of Soils, U. S. Dept. Agr. (1913); Proc. 8th Internat. Cong. Appl. Chem., 1912, vol. 15, p. 319.

[3] Circ. No. 62, Bureau of Soils, U. S. Dept. Agr.

[4] Sen. Doc. 190, Appen. E, p. 119.

are closely allied. The accumulation of full information concerning the fish-scrap industry is essential as a preliminary step toward the furtherance of that industry.

## HISTORICAL.

The fish-scrap industry may be said to have had its inception even before the advent of white settlers on the American Continent. Practices were in vogue which led directly to that industry. The custom existed among the Indians of New England of fertilizing their crops by means of fish. It is stated that for fertilizing corn, one or two fish were placed in each corn hill. This practice was adopted by the colonists, and extended to the scattering of fish broadcast over the fields. In later years, where the latter practice was carried to an extreme, it was found that it resulted in serious detriment to the soil because of the accumulation therein of the undecomposed oil from the fish. Later, it was found that the oil could be readily removed from the fish without impairing their usefulness for fertilizer purposes. This was accomplished by placing the fish in hogsheads or barrels, covering with water, compressing with weighted boards, and allowing to stand for the putrefaction of the fish to release the oils. The oil rose to the surface and was skimmed off. The residue was spread upon the land. The oil thus obtained was put to various uses in the domestic enterprises of the farms. It was soon found that cooking the fish released the oils as effectually as disintegration through putrefaction, and very much more quickly and less offensively.

For the farmers living near the shore it became a part of the year's routine to prepare fish scrap and, incidentally, oil for the year's supply. As the spring was regarded as the best time for the application of this fertilizer, a few weeks of the spring were devoted to fishing and rendering. The apparatus necessary, seines and pots, often were owned and operated in common.

In time pot cooking was superseded by the adoption of steam cookers; the first factory for cooking by steam was a small one put up near Portsmouth, R. I., in 1841.[1]

In 1850 Daniel Wells built a factory on Shelter Island, N. Y. 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 11 factories were built in Maine. In 1869 the factory at South Bristol, Me., was removed to Fair Port, Va., and was the first factory in that State.[2]

The subsequent development of the industry was marked by the introduction of the purse seine,[3] facilitating the capture of fish in

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[1] Aquatic Products in Arts and Industries, Charles H. Stevenson. Appen. to Rept. of U. S. Fish Comm., 1902, pp. 177–279.

[2] Quoted from Stevenson, loc. cit.

[3] Further discussed under Technology.

greatly increased numbers, and the adoption of presses for separating the oil and increasing the yield of it, in the place of the older method of depending on the lighter specific gravity of the oil to effect a separation. Hand presses were introduced in 1856 by Mr. Charles Tuthill, of the Wells factory on Shelter Island. In 1858 hydraulic power was introduced as a substitute for hand power. In more recent years, however, steam presses have been introduced with such success that they are to be found in practically every new factory, and they are rapidly being installed in the old factories to take the place of those operated by hydraulic power. A further rapid development of the industry was made possible through the substitution of steamers for sailing vessels; this rendered the fishermen independent of the winds in searching for and overtaking the schools of fish and in returning to the factories with their cargoes. In spite of this self-evident advantage, it has been only within the last few years that the last sailboats of considerable size, fishing for menhaden, have been equipped with auxiliary engines.

The so-called "floating factory" was designed to obviate loss of time by the fishing boats in going back and forth between the factories and the fishing grounds, the idea being to carry the factory to the fish instead of taking the fish to the factory. Introduced in 1876, a number had been constructed and were in operation in 1880. They consisted of boats of various sorts equipped with the apparatus for rendering the fish, such as boilers, cooking vats, and presses. The lack of storage room for the products, the difficulty of loading and unloading at sea, and other considerations brought about their abandonment. The latest attempt to apply the floating-factory idea was in 1911, when a steamer of 5,000 tons was equipped with a complete set of the modern automatic apparatus for producing dried scrap.[1]

A form of fish-scrap fertilizer which could be shipped long distances or stored was prepared first by drying the scrap from the presses on platforms. Here the material was spread to dry and was manipulated in the meantime by hand rakes or hoes to expose fresh surfaces. In certain instances the platform drier is still in use, notably in those neighborhoods where the odor and smoke from hot-air driers develops a hostile attitude of neighboring communities. However, the dispatch and convenience with which scrap may be dried in the artificial driers have led to their almost universal adoption.

The business continued to expand until it reached its 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 the competition with other products, the profits have not been so great, and many factories have been dismantled. The largest catch

[1] For a description of this plant cf. section on Technology, p. 32.

of fish in any one year, according to the figures of the United States 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 30 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.[1]

The literature dealing with the fish-scrap industry is confined almost altogether to a small number of reports, prepared through State or Federal initiative. Conspicuous among these are two valuable reports by G. Brown Goode, on The Natural and Economic History of the American Menhaden,[2] and by Charles H. Stevenson, on Aquatic Products in Arts and Industries,[3] respectively. The present writer has drawn freely from these articles for supplementary information used in the present paper.

## PRESENT STATUS.

At present there are about 40 factories on the Atlantic seaboard which manufacture fish scrap. This number includes only those whose main output is fish scrap and fish oil. Thus are excluded those whose output in fish scrap is small and an entirely secondary matter, such as the concerns which manufacture glue from cod and other fish refuse. While residues from their cookers are sold for fertilizers and are essentially fish scrap, their output in scrap is too small to accord them more than mere mention in this discussion.

Of this number of plants, the distribution by States is as follows: Maine, 1; Connecticut, 2; New York, 3; New Jersey, 5; Delaware, 2; Virginia, 21; North Carolina, 11; and Florida, 1; from which it is seen that the Chesapeake Bay region in point of number of plants is the center of the industry.

In the following table are listed the factories of the principal producers of fish scrap and their location:

Table I.—*List of factories of the principal producers of fish scrap on the Atlantic coast and location.*

| Name of concern. | Location of plant. |
|---|---|
| Maine: | |
| Deep Cove Manufacturing Co | Deep Cove, Me. |
| Connecticut: | |
| Niantic Menhaden Oil & Guano Co | South Lyme, Conn. |
| Wilcox Fertilizer Co | Mystic, Conn. |
| New York: | |
| Atlantic Fertilizer & Oil Co | Promised Land, N. Y. |
| Neptune Fishing Co | Do. |
| Triton Oil Co | Do. |
| New Jersey: | |
| Atlantic Fisheries Co | Tuckerton, N. J. |
| Fifield Fish Oil and Fertilizer Co | Leesburg, N. J. |
| McKeever Bros | Tuckerton, N. J. |
| Monmouth Oil & Guano Co. (successors to the Vernon S. Vail Co.). | Port Monmouth, N. J. |
| New York & New Jersey Oil & Guano Co | Do. |

[1] Stevenson, loc. cit. [2] U. S. Fish Comm. Rept., 1877, pp. 1–529.
[3] U. S. Fish Comm. Rept., 1902, pp. 177–352.

TABLE I.—*List of factories of the principal producers of fish scrap on the Atlantic coast and location*—Continued.

| Name of concern. | Location of plant. |
|---|---|
| Delaware: | |
| Delaware Fish Oil Co | Lewes, Del. |
| Lewes Fisheries Co | Do. |
| Virginia: | |
| Bellows & Squires | Ocran, Va. |
| Coan River Oil & Guano Co | Lewisetta, Va. |
| Carters Creek Fish & Guano Co | Irvington, Va. |
| Davis Packing Co | Reedville, Va. |
| Davis Palmer Co.[1] | Palmel, Va. |
| Dennis Fish & Oil Co | Cape Charles, Va. |
| The Douglas Co | Reedville, Va. |
| The Edwards Co | Do. |
| The Edwards & Reed Co | Do. |
| The Eubanks-Tankard Co | Kilmarnock, Va. |
| Indian Creek Fertilizer Co | Byrdton, Va. |
| McNeal Edwards Co | Reedville, Va. |
| Menhaden Oil & Guano Co | Harborton, Va. |
| Morris Fisher Co | Reedville, Va. |
| Norfolk Fisheries Corporation | Seaford, Va. |
| Seaboard Oil & Guano Co. (successors to Haynie & Snow) | Reedville, Va. |
| Seaboard Oil & Guano Co. (successors to Hinton, Tolson Oil & Guano Co.) | Mila (near Reedville), Va. |
| Seaboard Oil & Guano Co.[1] | Chincoteague Island, Va. |
| Stringfellow Operating Co.[2] | Harveys Wharf, Va. |
| Wharton Fisheries Co., (Inc.) | Ocran, Va. |
| Taft Fish Co | Taft, Va. |
| North Carolina: | |
| Beaufort Fish Scrap & Oil Co | Beaufort, N. C. |
| Chadwick & Caffrey | Do. |
| C. P. Dey | Lenoxville Point (near Beaufort), N. C. |
| Doan & Bartlett | Beaufort, N. C. |
| Ocean Fisheries Co | Wilmington, N. C. |
| Nat. Russell | Swansboro (near Beaufort), N. C. |
| R. W. Taylor | Morehead City, N. C. |
| Taylor & Guthery | Do. |
| Charles S. Wallace | Do. |
| Do | Smyrna (near Beaufort), N. C. |
| A. T. Willis | Williston (near Beaufort), N. C. |
| Florida: | |
| Southern Menhaden Co | Fulton, Fla. |

[1] In course of erection, 1912. [2] Receivers for Menhaden Fishing Corporation.

The output, by States, during the year 1912, is given in Table II. The figures given in the compilation for the most part were obtained on or before November 1. While the catch for the balance of the season was estimated in certain instances, it is believed that the figures here given may be low.

TABLE II.—*The output of fish scrap, by States, 1912.*

| State. | Acid. | Dry. | State. | Acid. | Dry. |
|---|---|---|---|---|---|
| | *Tons.* | *Tons.* | | *Tons.* | *Tons.* |
| Maine | 100 | 256 | Delaware | 6,312 | 500 |
| Connecticut | 1,500 | 6,500 | Virginia | .......... | 34,000 |
| New York | 19,800 | .......... | North Carolina | .......... | 7,250 |
| New Jersey | 530 | 1,500 | Florida | .......... | 160 |

Announcement is made of the recent organization of the following companies to engage in the fish-scrap industry: The South Coast Oil & Fertilizer Co., to operate at Port Arthur, Tex., and E. E. Saunders & Co., to operate at Pensacola, Fla.

In Table III are given the statistics of the fish-scrap industry for the years 1873–1898, inclusive, taken from Stevenson's report.[1] Since the dissolution of the United States Menhaden Oil and Guano Association the statistics of the industry have not been made available.

TABLE III.—*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. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Steam. | Sail. | | | | Dried. | Crude or acidulated. |
| | | | | | *Dollars.* | | *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 | 29,563 | 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 | 3,327,030 | 24,359 | 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 MENHADEN.

### NAMES.

The menhaden, *Brevoortia tyrannus*, is commonly known on the various sections of the Atlantic coast by various popular names. In Maine it is called the "pogy," though sometimes the "menhaden"; likewise in Massachusetts it is spoken of as the "pogy" and the "menhaden," and occasionally as the "hardhead." In Rhode Island it is known as the "menhaden," while in Connecticut the names "bony fish" and "white fish" have been applied to it. In New York and New Jersey it is designated as the "mossbunker"; and as one passes southward the names "alewife," or "old wife," and "bug fish" (on account of a parasitic crustacean found in its mouth in certain regions) are encountered, until North Carolina is reached, when the names "fatback" and "shad" prevail. The name menhaden sup-

[1] Loc. cit.

posedly had its origin in the Indian word "munnawhatteaug," applied to that fish, as well as to others, which means "fertilizer" or that which "manures."[1] The other names for the most part are likewise descriptive.

### DESCRIPTION.

For a detailed description of anatomical characteristics and measurements of the *Brevoortia tyrannus* see the report by Goode, referred to above. The following description of the appearance of the adult fish is quoted from the same author:[2]

> The adult menhaden is a most beautiful fish. Its color is pearly opalescent, like that of the cyprinoid fishes from which the commercial "essence d'orient," or liquid pearl, used by artists, and in the manufacture of paste jewelry, is prepared. Each scale has all the beauty of a fine pearl, and the reflections taken from the mailed side of a fish just taken from the water are superb. The scales of the back and of the top of the head are of a purplish blue. The blotch of black upon the scapular region, just above the origin of the pectoral, is very constant, although I have seen fish in which it did not occur. Many, especially of the older and fatter ones, have a number of irregular, roundish, blue-black blotches upon the sides and flanks. The young fish are not so brilliantly colored, and, in general appearance, resemble the young of shad.

Other species of the genus Brevoortia are found in the Gulf of Mexico and on the shores of Brazil.

From a study of the young of related fish, it appears probable that the menhaden requires three or four years in which to attain full growth. At the end of the first year they are from 3 to 5 inches in length; at the end of the second, 7 to 10 inches; the third, 12 to 14 inches; and the full grown fish is from 16 to 18 inches in length. The largest specimen of menhaden recorded was 20 inches in length.

### OCCURRENCE AND MOVEMENTS.

The geographical limits of the northern menhaden seem to be the Bay of Fundy at the north and the southern coast of Florida at the south. It can be expected to make its appearance annually in the coastal waters of all the States from Maine to Florida (between the parallels 25° and 45° north). To the landward it is limited by brackish water; oceanward, by the Gulf stream.

The menhaden is regarded universally by fishermen as a migratory fish in the sense that it migrates northward in the spring and southward in the fall. The matter of its migration has been studied by Goode. Available information from numerous sources, as well as from a priori considerations, has been brought to bear on this interesting question.

Two sorts of piscatorial migration are recognized, equatorial and abatic. The former takes a northern and southern direction, like

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[1] Quoted from Goode, U. S. Fish Comm. Rept. 1877, 11.
[2] Goode. loc. cit. Cf. p. 33.

that of the migration of birds; the latter may be described as an up and down migration, or what amounts to the same thing, an off and on shore migration. The former is seasonal, while the latter may be seasonal, diurnal, or irregular. Fish migrate for various reasons: (1) To find water of an agreeable temperature and depth; (2) to find water of an agreeable temperature and depth in which food can be acquired; and (3) to spawn. By noting the temperature of the water of the various regions in which the menhaden have shown themselves, at the time of their appearance and of their departure, correlating figures have been obtained which are taken to indicate the extremes of temperature agreeable or bearable to the menhaden. The temperature thus indicated as most agreeable is 60° to 70° Fahrenheit. Where the temperature of the water in the spring reaches 50° F., the fish are likely to appear; and when it falls to that temperature in the autumn, they are equally apt to disappear. Apparent exceptions to the latter have been observed; it is believed, however, that the exceptional cases were caused by the detentions of the fish against their will by the contour of the coast line, or other such causes. This is taken as the lower limit of temperature bearable to the menhaden, while the upper limit is believed to be 75° to 80° F. Thus, the coolness of the night, or a cold wind lowering the temperature of the surface water, causes the schools to disappear beneath the surface.

Sensitiveness to temperature change, hypothesized for the menhaden, is not peculiar to that fish. On the contrary, the supposition of this sensitiveness is based on the definite knowledge that that characteristic is possessed by other fish.

Since menhaden disappear from northern waters during the winter to return again during the summer, it becomes necessary to account for their movements in the interim. Three courses are open to them: (*a*) To migrate to southern waters; (*b*) to hibernate in waters of great depth and low temperature; (*c*) to migrate abatically, or offshore, until waters of congenial temperature are reached.

The first suggestion is in conformity with the prevailing beliefs of the fishermen. They picture the northern migration as a movement of the whole body of fish, swimming at a great rate of speed, feeding as they advance and increasing in fat, the larger and stronger pushing on farther north while the smaller and weaker are left behind and tarry in the more southern regions; that in the fall they return, growing thinner as they advance, due to the development of the roe ("the fat all goes into the roe"), and that they remain south during the winter. This belief is logical to the extent at least that during the spring the schools frequently are seen actually swimming north and in the fall south. And it is known that they are to be seen in Florida waters during the winter.

However, this theory is scarcely tenable when it is remembered that the menhaden are never seen south of the southernmost point of Florida, and that during the winter they are never seen north of northernmost Florida. So the intervening stretch of coastal waters must accommodate the myriads of fish forming the immense schools visible farther north during the summer. The fact that there is only one fish scrap factory on the Atlantic coast side of Florida is abundant evidence that this is not the winter retreat of the Atlantic menhaden. The Florida menhaden, besides, possess different characteristics from the northern. They are unmistakably different in size and coloration. In fact, the fish caught on the different sections of the coast are peculiar to those sections; those in certain sections are infested with certain parasites not found on those from other sections. This fact is almost incontestable evidence that the fish thus characterized could not have been a part of a general migratory school the other members of which being entirely free from the parasites.

The size of the fish, as well as other characteristics, varies, those of a certain size being peculiar to a certain part of the coast. Roughly the largest fish, averaging about 12 inches in length, are found in the waters off the New England States; those taken in the Long Island region are about 10 inches; those off New Jersey and Delaware about 9 inches; those in the Chesapeake Bay region about 8 inches; and those found below Cape Hatteras about 6 to 7 inches in length.[1] It does not seem in the least to trouble the adherents of the coastal migration theory that the large fish characteristic of the New England coast always escape capture as they pass the southern coast twice a year.

With regard to the second hypothesis it should be said that in those instances where it is known definitely that fish hibernate in a state of torpidity it is generally where that course of action is forced upon them. Thus it is restricted to fish in those bodies of water which are thoroughly chilled during the winter. Their torpidity is induced by the low temperature. It is difficult to believe that a fish in the ocean, where all agreeable temperatures are to be had, would willingly search out a spot, at some great depth and corresponding pressure, where the temperature was sufficiently chilling to induce torpidity and where a radical change in habits would have to be undergone. In addition, a fish once rendered torpid in the depths of the ocean would remain there, as the conditions there would be permanent.

The third alternative, the assumption that the fish, while migrating equatorially to a limited extent during the season of warm coastal water, migrate abatically for their winter's sojourn in the warmer

[1] Hathaway, Bull. Bureau of Fisheries, 1908, Part I, p. 271.

water lying oceanward, appears more plausible. An exploration of ocean temperatures has shown that there are strata lying offshore and at a depth of 50 to 100 fathoms whose temperature is about 50° to 55° F. It is suggested that the fish swimming oceanward at the beginning of cold weather, and being driven downward by the chilled surface water, strike the warm strata and are held there during the winter by the surrounding barriers of colder strata. In the spring, with the removal of these barriers, they swim shoreward again to their accustomed feeding grounds. This accounts, furthermore, for their prompt appearance offshore as soon as the water there reaches a temperature of 50° F. Their emaciated condition in the spring would show the scarcity of food in the region of their winter's stay. Indeed, they are so "thin" that a thousand spring fish frequently yields only a half gallon of oil as compared with 10 to 15 gallons of oil produced by an equal number of fall fish.[1]

### HABITS.

The menhaden swim in schools made up almost always of large numbers. Schools have been reported 20 miles in length, but this size is exceptional. The fish in the schools are densely massed, not only side by side but one above the other. They produce a rippling in the water which is discoverable at a distance and which betrays the presence of the schools to the fishermen. Their location is indicated also by flocks of gulls which follow the schools.

The schools frequent the larger bays and inlets such as Chesapeake and Delaware Bays and Long Island Sound; these and other similar waters formerly constituted the main fishing grounds. But they are found also in deeper waters opposite the entrances to bays and sounds and off promontories. Thirty years ago it was their habit also to ascend rivers as far as the brackish water would permit. This they no longer do to a conspicuous degree. While they are not so much in evidence perhaps near the shore, there is no evidence that they are decreasing in numbers. They appear to be the most numerous fish on the Atlantic coast. The maintenance of the catch year after year, however, can not be taken as proof that the menhaden is not decreasing in numbers, unless it be shown that the maintenance of the catch is not the result of increased skill in fishing.

### FOOD.

The examination of the stomach contents of a large number of menhaden at various times and from numerous localities has revealed only large quantities of dark material, resembling the silt such as is found on the bottom in sheltered and quiet water near river mouths.

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[1] "Occasionally fat fish are taken in the spring, indicating that food is not always absent from the winter abode of the menhaden." Kendall, Bureau of Fisheries. Private communication.

An examination of bottom mud has shown it to contain large quantities of living and dead microorganisms, making up more than half of its bulk. This is supposed to constitute the food of the bivalves and other aquatic animals of similar habits. It has been shown by Peck [1] that the menhaden is provided with a mechanism, situated upon the anterior edge of the gill arches, and known as "gill rakers," by means of which it is able to strain out from the water in which it swims the microorganisms which live there. "These minute organisms furnish directly the food of the menhaden. * * * The whole food supply of this fish is obtained by filtering out from the surface stratum of water the organic life there suspended." [2]

### SPAWNING.

Very little is known definitely of the breeding habits of the menhaden. Numerous theories are entertained by the fishermen. Some confess ignorance; others believe they spawn in southern rivers; others, that they spawn "on the edge of the Gulf stream."

The large number of young which appear on the coast of North Carolina in early spring indicate the nearness of the spawning ground to that region and of the spawning season to that time. The absence of a developed roe in the fish of that region in the summer and its appearance only in late fall and winter mark the time of spawning there as the winter or early spring. As the fish have disappeared from the coast at that time, except along the Carolinas and Florida, the spawning ground must be on the shores of either the Carolinas or Florida. Evidence is lacking that they enter the rivers at this time in sufficient numbers to represent a concerted movement toward a spawning ground, such as is shown by other fish, occurring in much smaller numbers than the menhaden, in the spawning season.

Hathaway [3] states that he has examined many hundreds of menhaden caught between Cape Lookout, N. C., and Georgetown, S. C., from the 20th of November to the 10th of December, among which there was not one that did not show a roe development such as to indicate that it would spawn within 30 to 60 days.

Smith has shown that menhaden have been taken on the coast of North Carolina in November from which spawn was running showing conclusively that menhaden may spawn in November,[4] and states that in spring and early summer the menhaden spawns in abundance on the northern part of the middle Atlantic and the southern part of the New England coast, and in late autumn and early winter on the southern part of the middle Atlantic and the northern part of the south Atlantic coast.

[1] "On the Food of the Menhaden," Bull. U. S. Fish Commission, 1893, p. 113.
[2] Peck, loc. cit. cf. p. 114.
[3] "The Menhaden Industry," American Fertilizer, 38, 44 (1913).
[4] Smith, Hugh M., Fishes of North Carolina, N. C. Geol. and Econ. Survey, p. 132.
[5] Hathaway, Bull. Bureau of Fisheries, 1908, Pt. I, cf. pp. 277–278.

In this connection the following statement, quoted from Smith,[1] is of great interest:

> By the first week in November the development of the reproductive organs had progressed so far that the approach of the spawing period appeared to be imminent in the fish caught close to land on the ocean shores of Maryland, Virginia, and North Carolina. On November 6 large hauls of menhaden off the Maryland coast contained fish from 9 to 12 inches long that were very nearly ripe, and on November 7, 9, and 13 small quantities of eggs or milt could be forced by gentle pressure from most of the fish examined, taken on the same grounds. On November 13 a female menhaden 11 inches long, caught in a school off the Virginia coast appeared to be spent, November 16 a similar specimen with shriveled and empty ovaries was found among some almost ripe fish on the North Carolina coast. In the latter part of November eggs or milt could be forced by gentle pressure from nearly all menhaden caught south of Cape Henry.

Investigations, carried on by the Bureau of Fisheries during the summer of 1895, extending from June 29 to August 6, showed that the menhaden were spawning in the waters off the coast of Maine during that period. It is the belief of the fishermen of that region that they spawn throughout the summer.

#### PREDATORY ENEMIES.

The immense and clumsy schools of menhaden, swimming in open water, fall an easy prey to all the large carnivorous aquatic animals frequenting the Atlantic coastal waters. Beginning with the whales, the largest of these, the destruction by them in former years was considerable, a single mouthful of a whale representing, perhaps, a hogshead of fish. The larger sharks attack them, but destruction by them is slight when compared with that of the dogfish moving and attacking in schools. Other fish, such as the horse mackerel, the pollock, the striped bass, the sea trout, the swordfish, the bayonet-fish, and, possibly, the codfish, are counted among their destructive enemies. The bluefish and the bonito, however, are regarded as the greatest destroyers of the menhaden, as they not only consume great numbers of them, but wantonly cut and destroy countless others. A school of bluefish are credited with attacking a school of menhaden with such ferocity as to leave a wake of blood and mangled fish for miles, and destroying the school utterly. Baird[2] estimated the number of bluefish over 3 pounds in weight in New England waters at one thousand million. Each fish he credits with the destruction of 10 fish, or 2½ pounds, per day. During the four summer months, he calculates, this number of bluefish

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[1] Smith, Hugh M., Notes on an Investigation of the Menhaden Fishery in 1894, with Special Reference to the Food Fishes Taken, U. S. Fish Comm. Bul., 1895, p. 285.

[2] Natural History of Important Food Fishes of the South Shore of New England. II. The Bluefish. U. S. Fish Comm., Rept. 1871–2, p. 235.

devour ten thousand million fish, or twenty-five hundred million pounds, per day; and for the four months, twelve hundred million fish, or three hundred thousand million pounds. Goode[1] applies this approximation to the menhaden. He takes the number of menhaden as one quarter of the total destruction considered by Baird, and supposes that the other predaceous fish combined destroy a number equal to that devoured by the bluefish. This justified a division of Baird's estimate by 4 and a multiplication by 2. The coast of New England, further, is taken as one-quarter of the Atlantic coast of the United States. The number, therefore, should be multiplied further by applying the estimate to the winter months also during which the destruction by bluefish and the others continues in southern waters. Goode finally multiplies Baird's estimate by 10, to obtain a figure representing the annual destruction of menhaden on the entire coast. The product is three thousand million million!

These figures are mere estimates. They serve, however, to show that the destruction of 900,000,000 of menhaden by man is insignificant when compared to the probable destruction wrought by the predaceous inhabitants of the ocean.[2]

## OTHER FISH USED IN THE PREPARATION OF FERTILIZERS.

### WASTE FROM DRESSED FISH.

The discussion of this topic, it should be said in the beginning, will have to do with the possible use of other fish in the preparation of fertilizer, rather than with the actual use, for the amount of fertilizer produced on the Atlantic coast from other fish than the menhaden is almost negligible.

With the exception of the menhaden there are no fish sought on the Atlantic coast besides the food fish. As a source of scrap from fish other than the menhaden, one would have to look, then, to the waste from the food-fish fisheries and to useless fish taken incidentally in these.

According to the statistics of 1908, the latest year for which statistics are available, 703,525,500 pounds of food fish were caught in the Atlantic and Gulf fisheries of the United States. In the dressing of fish the waste represents an average of 25 per cent of the "round" weight of the fish of the above catch; then, 175,881,375 pounds, or 78,518 tons, of fish refuse suitable for the preparation of fertilizer were produced. This amount would be further augmented by the portion of the catch thrown away because of having spoiled in the market or because of lack of market and the large number of useless fish, mostly dogfish, taken incidentally. On the supposition that this material, consisting of the heads and viscera, contains 10

[1] Loc. cit., p. 109.

[2] In this connection see Kendall, Bull. Bureau of Fisheries, 1908, Pt. I, p. 281, and Hathaway, ibid., p. 271.

per cent solid matter (round fish have been shown to contain 19 per cent solid matter[1]), the quantity of refuse would produce 7,852 tons of dried fish scrap.

The utilization of any considerable portion of this waste for the preparation of dried scrap, it will be seen, is economically impossible when it is remembered that the fisheries are scattered the length of the coast, that many fish are shipped to the various markets undressed and are dressed either there or by the consumer, and that the fresh fish marketed dressed frequently are prepared on board the fishing boats and the waste is thrown overboard. At present it is true that practically all of the fish heads and offal available for fertilizer purposes is the comparatively small amount produced at the canneries. The fish-canning industry is carried on on the Maine coast more actively than at any other locality on the Atlantic seaboard, where a number of different sorts of fish, but principally herring, are preserved. To a certain extent the waste from these industries, known as "fish cuttings" and consisting of the heads and viscera, is treated for the recovery of its oil and the preparation of fish pomace or raw scrap.

Concerning the practice at the herring canneries of the Passamaquoddy region of maine, Hall[2] states:

> The "fish cuttings" and refuse fish which accumulate at the canneries are made into pomace and sold for fertilizer. When the herring are cut for sardines the "cuttings," which include the heads and viscera, are first deposited in barrels. They are afterwards removed to the press room and emptied in a heap on the floor, being spread in layers and covered with salt to prevent them from decomposing. The quantity of salt used is about 3 bushels to 5 barrels of cuttings. After remaining in the salt a short time they are put into three-quarter hogshead tubs and thoroughly cooked with steam. * * * The tubs are kept covered while the fish are cooking. After being cooked, the cuttings are dipped with scoop nets from the tubs into the pomace presses. There are usually two of these presses used in each cannery. * * * The pressure is applied with a jackscrew operated by hand. While the fish are being pressed the oil and water which they contain are carried off into an oil tank by means of an open spout. The pomace, when taken from the press, is packed into barrels which are made for that purpose and hold about 275 pounds each. It is sold largely to farmers in the vicinity at an average of about $9 per ton. The oil is skimmed off the water in the tanks and put in barrels for shipment. The price received in 1895 was about 14 cents per gallon. * * *
>
> It requires about 3 hogsheads of fish to yield 1 hogshead of cuttings and 5 hogsheads of cuttings to make 1 ton of pomace. It is generally estimated that the yield of oil to each ton of pomace is from 20 to 23 gallons, but the proportions in which the two products are sold show the average quantity of oil to the ton of pomace to be a little less than 16 gallons.

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[1] Cf. p. 32.

[2] The Herring Industry of the Passamaquoddy Region. U. S. Fish Comm. Rept., 1896; cf. p. 479.

In 1895, according to the figures compiled by this authority, 36,496 hogsheads, or about 36,496,000 pounds, of herring were utilized in the canning industry of the Passamaquoddy region. In the same year 325 gallons of oil, 31 tons of pomace, and 2,704 barrels of waste fish, which were not rendered, were produced.

In 1905, 33 establishments were engaged in canning sardines. Fifty tons of pomace and 1,000 gallons of oil were produced. The former fetched $8 per ton and the latter 15 cents per gallon.[1]

Small amounts of the waste produced at the fish-dressing establishments of the fishing centers of Massachusetts are utilized by the renderers of garbage and other city wastes of those sections. These amounts are irregular and of small consequence. Undoubtedly they could be increased. In the neighborhood of Pensacola, Fla., a plant recently has been established for the utilization of the fish scrap and waste fish available in that region. It is said on good authority that large quantities of mullet, caught on the Florida coast south of Tampa, annually are permitted to go to waste for lack of suitable market. In previous years skates and other useless fish taken in the pound nets at certain places on the New England coast were dried in the sun, without rendering, and subsequently were pulverized for use as fertilizer.

### REFUSE FROM NEWFOUNDLAND COD.

The large production of fish waste from the extensive cod industry prosecuted on the Newfoundland shores has been the object of much speculation in the past. An investigation of the industry has shown that about 150,000 tons of refuse is produced there annually. If this be regarded as containing 15 per cent solid matter, it would be equivalent to over 20,000 tons of dry scrap. This amount of fish scrap would be an important addition to the present output from the Atlantic fisheries. It has been shown, however, that the scrap is produced in small amounts over a long line of shore, that it is thrown away as fast as produced, thus requiring to save it a radical change in the present methods of work, and that it is produced at a time when all the available labor is busily engaged in dressing the cod. Its recovery accordingly constitutes a problem which so far has not been solved economically and offers scant hope of solution.

### DOGFISH.

Perhaps the most probable extension of the fish-scrap industry through the employment of other fish for that purpose will prove to be the utilization of dogfish. This supposition is based on the consideration of the general hatred for the dogfish entertained by the

[1] Statistics of the Fisheries of the New England States for 1905, U. S. Fish Comm. Rept., 1906.

fishermen and the consensus of opinion there that their destruction is imperative. The insistence that State or Federal initiative be applied toward their destruction combined with a realization of their utility when captured may possibly lead to their large use as a source of fertilizer.

In 1904 the Canadian Government brought about the erection of three plants for the rendering of dogfish, one at Clarks Harbor, one at Canso, Nova Scotia, and the other at Shippigan, on Chaleur Bay, New Brunswick. These were operated on the basis of Government ownership of rendering plant, and cash payments to the fishermen, by the ton, for dogfish delivered at the docks.

With regard to one of these plants the Massachusetts Board of Fish Commissioners has to say:[1]

This establishment * * * was designed to reduce about 10 tons of dogfish or fish offal daily. The machinery used * * * is of the type generally used in the menhaden factories in this country, and with certain modifications in the whale factories of Newfoundland. At the time of beginning operations, Mr. Cox was obliged to make a week's trip among the fishermen to explain the plan and to induce them to bring in the dogfish caught. As soon as shipments began to come from points outside of Canso, e. g., Arichat, Petit de Grat, etc., the Canso fishermen began to save their dogfish. The result was a great surprise to all. It had not been realized how many dogfish had been hooked and thrown overboard again. One of the fishermen had two trawls set with 1,500 hooks on each. He tended the first trawl as soon as the second trawl was set, and nearly every hook had a dogfish. On October 2, in spite of the fact that notice had been sent out the two days previous that, on account of the overwhelming quantities which came in, no dogfish would be received until October 4, we saw eight loads from steamers, small schooners, and dories brought and landed upon the dock. Three dories brought 7 tons, three small schooners brought 17 tons, and one small steamer brought 8 tons, a total of 32 tons. The price paid for the fish delivered on the dock was at that time $6 per ton if livered and $5 if unlivered. These prices include the livers. Even at $4 per ton the dogfish would have been a bonanza for the fishermen. Two men in a dory could easily make $7 to $8 a day per man catching dogfish within 1 mile of their homes.

With regard to the success and present status of these Government-owned rendering plants, the deputy minister of marine and fisheries of the Dominion of Canada, under date of February 21, 1913, has to say:

As the dogfish became a very serious menace to the successful operation of the fishermen, it was decided in 1904 to test the feasibility of combating the nuisance they caused by converting them into fish scrap and oil. To this end three reduction works were established, which were equipped with machinery manufactured by the American Process Co., of New York. It was the hope of the department that it could be shown that the utilization of dogfish in such a way could be made to pay and that private enterprise would after a few years take up the venture. The works have been operated only during the

[1] Report of the Commissioners on Fisheries and Game. Damage Caused to the Fisheries of Massachusetts by Dogfish During the Year 1905.

season that dogfish are on the coast in large numbers, but it has been found impossible to make them pay with the price that has been paid for the raw material, $4 per ton. The works were established at Clarks Harbor, Nova Scotia; Canso, Nova Scotia; and Shippigan, New Brunswick. Owing to the manner in which fishing is carried on in the vicinity of Shippigan it was not found possible to get any large quantities of dogfish there, and the works at that place have consequently been closed. Last year at Canso over 1,000 tons of dogfish were treated, which yielded about 125 tons of scrap and about 13,500 gallons of oil. At Clarks Harbor 360 tons of raw material were handled, which yielded 48 tons of scrap and over 2,600 gallons of oil. The amount of raw material collected at both these works varies from year to year, depending on the plentitude of dogfish. At Canso the average quantity used yearly would be 1,000 tons, and at Clarks Harbor slightly less.

There is no doubt, however, that such works could be made to pay if located at places where fish offal is also available in considerable quantities and the dogfish were procured at a smaller price.

It has been stated by Field[1] that the two dogfishes, the smooth and the horned, are tremendously destructive of lobsters and of such food fish as the mackerel and herring. The Massachusetts State Board of Fish Commissioners have estimated that the annual loss from the destruction by dogfish of food fish and fishing gear in the State of Massachusetts alone amounts to $400,000. A proportionate loss from their depredations probably obtains for the other States bordering the Atlantic, and a proportionate benefit would accrue from their destruction.

The method of reproduction of dogfish is quite different from that of fish of the herring family, in that fertilization of the eggs of the dogfish is internal and the young fish are brought forth in a fully developed condition. Each female produces from 4 to 12 young at a time. The eggs of a single menhaden, if permitted to hatch, would produce many thousand young fish. When the enormous rate of their increase is considered, it is readily seen how the menhaden are able to persist in spite of the destruction of such vast numbers of them by their various enemies. The dogfish, on the other hand, apparently has but few enemies powerful enough to effect his depletion. Undoubtedly their destruction by natural causes is comparatively slight, so that their comparatively low rate of reproduction is sufficient for the maintenance of their numbers. Their low rate of reproduction makes them particularly vulnerable to the attack of their artificial enemies. Their depletion by a concerted and organized attack of the fishermen therefore should be possible. Before such an attack can be expected, however, a ready market must be provided for the dogfish caught by hook or seine.

From the foregoing it appears reasonable to believe that dogfish may prove an abundant source of material for the preparation of

[1] Field, Sea Mussels and Dogfish as Food. Fourth International Fish Congress. Bull. Bureau of Fisheries, vol, 28, Pt. I, 243 (1908); cf. p. 247.

fish scrap and oil. If caught in very great numbers their depletion would seem to be inevitable. Therefore they can not be regarded as a source possessing both permanence and abundance.

### CRUSTACEANS.

Horseshoe crabs, it has been reported by Stevenson, have been used in large numbers in certain localities for fertilizer purposes. The heads and shells of shrimps are used, likewise, though their use is both local and unimportant. The shells obtained at lobster and crab canneries have been found to be admirable as "fillers" for finished fertilizers. Besides carrying a certain percentage of nitrogen, they contain a large amount of lime of high agricultural value. At one fertilizer mixing plant on Chesapeake Bay over 250 tons of ground crab shells are used annually.

### THE ALLEGED DESTRUCTION OF FOOD FISH IN THE MENHADEN INDUSTRY.

It has been believed by many that not only menhaden have been utilized by the operators for the manufacture of fish scrap, but that any fish available or that could be caught in the seines were so employed, and that in this way great numbers of food fish were destroyed annually. It was asserted that so great was this destruction that the decrease in the supply of food fish along the shores was quite appreciable. In contradiction it was maintained by the fishermen that the number of food fish taken with the menhaden was insufficient to supply the crew with fresh fish and therefore the charges were quite groundless.

In 1894 the Bureau of Fisheries investigated the question of the alleged destruction of food fish by the menhaden fishermen. The results obtained were unqualifiedly corroborative of the claims of the menhaden fishermen. In spite of this investigation and its positive results, the belief is still maintained among certain people that food fish are destroyed in the menhaden fishery. For that reason this brief discussion of the Bureau of Fisheries' investigation is included in this report.

An agent of the bureau mentioned was placed on each of two vessels, one a "double-gang" steamer, equipped with two purse seines and crew requisite for their manipulation, and the other a "single-gang" steamer. The investigation covered the entire fishing season of those steamers, during which time they took about 28,000,000 fish, or one-twentieth of the entire catch of the season.

The fishing operations covered the entire coast from Maine to North Carolina, inclusive of the bays and sounds. The seines were hauled a total number of 1,078 times, 132 of which failed to catch any fish. The number and haul of fish other than menhaden taken in these hauls are set forth in detail in the subjoined table:

TABLE IV.—*Number and kind of fish taken by two menhaden fishing steamers.*

| Kind of fish. | Number. |
|---|---|
| Alewives or herring (Clupea pseudoharengus, C. aestivalis) | 86,898 |
| Amber fish (Seriola Dumerili lalandi) | 1 |
| Anchovy (Stolephorus mitchilli) | 2 |
| Bluefish (Pomatomus saltatrix) | 2,274 |
| Bonito (Sarda sarda) | 35 |
| Butterfish (Stromateus triacanthus) | 811 |
| Catfish (Ameiurus albidus) | 2 |
| Cero (Scomberomorus regalis) | 3 |
| Cod (Gadus morrhua) | 1 |
| Croaker (Micropogon undulatus) | 134 |
| Cunner (Ctenolabrus adspersus) | 4 |
| Cutlas fish or hairtail (Trichiurus lepturus) | 2 |
| Drums (Pogonias cromis, Sciaena ocellata) | 11 |
| Filefish or foolfish (Alutera schoepffi) | 9 |
| Flounders (Paralichthys dentatus, Pleuronectes maculatus, Achirus fasciatus, Limanda ferruginea) | 369 |
| Gar (Tylosurus, species) | 6 |
| Goosefish (Lophius piscatorius) | 11 |
| Haddock (Melanogrammus aeglifinus) | 23 |
| Hake (Phycis chuss) | 40 |
| Hickory shad (Clupea mediocris) | 9 |
| Kingfish (Menticirrhus saxatilis) | 1 |
| Lamprey (Petromyzon marinus) | 11 |
| Lumpfish (Cyclopterus lumpus) | 8 |
| Mackerel (Scomber scombrus) | 631 |
| Pipefish (Siphostoma fuscum) | 7 |
| Pollock (Pollachius virens) | 1 |
| Pompano (Trachinotus carolinus) | 8 |
| Rudder fish (Seriola zonata) | 1 |
| Sculpins (Cottus, species) | 19 |
| Scup (Stenotomus chrysops) | 73 |
| Sea bass (Centropristis striatus) | 39 |
| Sea herring (Clupea harengus) | 5 |
| Sea horse (Hippocampus hudsonius) | 4 |
| Sea raven (Hemitripterus americanus) | 1 |
| Sea robins (Prionotus carolinus, chiefly) | 43 |
| Shad (Clupea Sapidissima) | 1,816 |
| Sharks (Carcharinus obscurus, Squalus acanthias, Sphyrna zygaena, Carcharias americanus, Mustelus canis, Alopias vulpes, Squatina squatina) | 388 |
| Skates and rays (Raia erinacea, R. eglanteria R. laevis, Dasyatis centrurus, Rhinoptera quadriloba) | 372 |
| Spanish mackerel (Scomberomorus maculatus) | 150 |
| Spot (Leistomus xanthurus) | 20 |
| Squeteague or weakfish (Cynoscion regalis, C. maculatus) | 498 |
| Striped bass (Roccus lineatus) | 1 |
| Swellfish, swelltoads (Chilomycterus geometricus, Tetrodon turgidus) | 6 |
| Tautog (Tautoga onitis) | 17 |
| Whiting or silver hake (Merlucius bilinearis) | 30 |
| Total | 94,795 |

In addition to those enumerated, a number of large schools of alewives were captured but were released after they had been identified. The alewife, or herring, is useful for the same purpose for which the menhaden is sought, and, besides, is regarded as a food fish. It might be argued that these, released after capture, should have been counted in the returns, as the investigation had to do with the number of fish captured, as well as retained, especially as no evidence was adduced to show that it was the invariable custom of the fishermen to release other fish than the menhaden, suitable for fish scrap and oil purposes, when caught in such large numbers.

TABLE V.—*Showing disposition made of catch.*

| Species. | For oil and guano. | Eaten. | Salted by crew. | Sold for bait. | Thrown over-board, etc. |
|---|---|---|---|---|---|
| Menhaden | 27,732,355 | | 25,000 | 199,900 | 2,500 |
| Alewives | 71,888 | 24 | | 10,000 | 5,000 |
| Amberfish | | 1 | | | |
| Anchovy | | 1 | | | |
| Bluefish | 410 | 1,292 | 572 | | |
| Bonito | 2 | 16 | 17 | | |
| Butterfish | 356 | 393 | 50 | | 12 |
| Catfish | 2 | | | | |
| Cero | | 3 | | | |
| Cod | 1 | | | | |
| Croaker | 44 | 86 | | | 4 |
| Cunner | 2 | 2 | | | |
| Cutlas fish | 2 | | | | |
| Drum | 8 | 3 | | | |
| Eel | 5 | | | | 6 |
| Filefish | 9 | | | | |
| Flounders | 246 | 93 | 20 | | 10 |
| Gar | 5 | 1 | | | |
| Goosefish | 8 | | | | 3 |
| Haddock | 15 | 8 | | | |
| Hake | 28 | 12 | | | |
| Kingfish | | 1 | | | |
| Lumpfish | 8 | | | | |
| Mackerel | | 631 | | | |
| Pipefish | 7 | | | | |
| Pollock | | 1 | | | |
| Pompano | 6 | 2 | | | |
| Rudder fish | 1 | | | | |
| Sculpins | 19 | | | | |
| Scup | 36 | 37 | | | |
| Sea bass | | 41 | | | |
| Sea horse | | | | | 4 |
| Sea raven | | | | | 1 |
| Sea robin | 43 | | | | |
| Shad | 266 | 161 | 712 | | [1] 675 |
| Sharks | 388 | | | | 13 |
| Skates and rays | 368 | | | | 4 |
| Spanish mackerel | | 150 | | | |
| Spot | 20 | | | | |
| Squeteague | 31 | 231 | 236 | | |
| Striped bass | | 1 | | | |
| Swellfish | 6 | | | | |
| Tautog | | 17 | | | |
| Whiting | 22 | 8 | | | |

[1] Released alive.

## TECHNOLOGY.

### FISHING.

The time of fishing for menhaden is determined, of course, by the habits of the fish. Since they appear in northern waters in April and disappear in November, the fishing season then is delimited by those months. As one goes farther south, the season is lengthened; in the Carolinas the boats are not put out of commission until the latter part of December, though fishing does not begin much earlier there than in the northern region. In the southern region the spring and fall fishing furnishes most of the raw material, there being a dull season in midsummer when catches are rare and unimportant. In Florida waters the fish are present throughout the winter.

The range covered by the fishing boats is determined by the habits of the fish, the situation of the factory to a slight extent, and by the power and speed of the boats themselves. As the menhaden rarely are found north of Cape Cod, that point may be said to be the northernmost limit of the fishing grounds, though often in former years fish have been found farther north than that. At times big catches have been made in Cape Cod Bay and Boston Harbor. The Chesapeake boats, perhaps, cover the wider range, as they habitually fish from Nantucket to Hatteras. This is determined in part by their more central location and in part by the Virginia fishing laws which prohibit boats owned by nonresidents of the State from fishing in the waters controlled by the State of Virginia. As most of the fish are caught within the 3 mile from shore limit, this law rather discourages the boats of the northern fisherman from coming that far south. Since similar laws are not enforced by the other coastal States, the Virginia fishermen enjoy a range not permitted to the boats from other States. At least, the law reserves Chesapeake Bay for the Virginia fisherman.

The boats used in the fishing industry are by no means uniform in construction, though the modern boats built especially for fishing are constructed after a certain general model. (Pl. I, fig. 1.) Without entering into a detailed description of their lines, it may be said that in general they are constructed high at the bow and low amidships. The former adds to their seaworthiness and gives the additional advantage that from the pilot house situated thereon a wider range of vision is afforded. The latter adds to the facility with which the fish may be transferred from the seines to the hold of the boat. The pilot house and quarters are situated in the bow of the boat, while the engine room, boilers, and bunkers are placed toward the stern, the middle portion of the boat being constructed as the receptacle for the fish. This part is provided with large hatches to facilitate loading and unloading. The arrangement is somewhat the same in the small auxiliary schooners, the galley and quarters being situated forward and the engine room aft, the hold for receiving the fish occupying again the middle of the vessel. The larger steamers have a capacity of 750,000 fish and carry a complement of 50 men. (Pl. I, fig. 2.) The auxiliary sailboats have a capacity of about 250,000 fish.

Each boat carries two purse boats. These are towed, being tied together and fastened in closely, so that their bows touch the stern of the fishing steamer or schooner. The purse boats, so named because they are used in spreading and otherwise manipulating the purse seines, were formerly of the whaleboat type, somewhat modified. They are constructed to possess the qualities of steadiness in the water, as considerable active moving about within them is occasioned by manipulating the seines, and of being easily towed and rowed. Formerly, they were of a lap-streak construction, but now one finds a smooth-bottom boat, with battened seams, in general use. The more flaring sides of the whaleboat have given way to a straighter and more nearly perpendicular shape. The boat might be described as long, deep, and narrow. These changes are said to give greater speed and greater durability on account of the closer seams; and the smooth sides and bottom prevent the entanglement of the twine of the seines. They are 30 to 35 feet in length and are provided with a platform, running their length, with elevations fore and aft.

The purse seine is in general use among the menhaden fishermen. Its adoption marked an important stage in the development of the industry due to its great superiority over the older forms. The seine is about 1,500 feet long by 180 feet wide. When extended in the water it is supported by a row of corks fastened along its top. The distinctive feature of this form of seine is the arrangement provided for drawing it together, pursewise, at its bottom. At frequent intervals along its lower edge are suspended metal rings, about 3 inches in diameter (which also serve as weights to keep the seine fully stretched), through which passes a rope. The ends of this purse line are held in the purse boats. When the fish have been surrounded and the two ends of the seine brought together by hauling on the purse lines the bottom of the seine is drawn together. This prevents the fish from escaping by diving beneath the bottom of the net. As the seine is carried partly in one boat and partly in the other, to spread it it is necessary only to row the two boats in opposite directions, paying out the seines as the boats separate. (Pl. II, fig. 1.) In fishing this is done in such a way as to intercept and surround a school of fish. When the two boats have met on the side of the school opposite to that from which they started the purse line is hauled in to draw the seine together at the bottom, and the fish are secured. The seine is then hauled in to force the fish into a smaller compass. Following that the steamer is brought alongside and the fish are dipped from the seine by means of a large dip net, operated by an arrangement of block and tackle, and emptied into the hold. (Pl. II, fig. 2.)

### UNLOADING.

Unloading at the docks was formerly effected by means of tubs filled by hand and hoisted to the docks by means of block and tackle. This has been supplanted at practically every factory by one or two elevators. These are bucket elevators and are an adaptation to the handling of fish of the apparatus employed in unloading wheat. The elevator is fed partly automatically through the fish sliding toward it of their own weight and partly through the aid of three or four members of the crew armed with shovels.

The elevator deposits the fish in an automatic measuring device, which is of different form at different factories. It may have the form of two bins provided with a device for diverting the stream of fish into the other when the one has attained a certain weight, the bottom of the loaded bin being opened at the same time. A form is frequently found which has the shape of a cylinder divided into segments and mounted so as to revolve horizontally on an axis. When one segment of the cylinder has received a definite weight of fish the cylinder is revolved through an angle, a new section is brought into position to be filled, and the one filled is emptied.

Measuring the catch is an important operation, as upon it is based the bonus to be paid the fishermen. In the North the captain of the steamer and perhaps his first officer are paid on the bonus basis, while in certain parts of the South the entire crew are so compensated. While fish are rated in thousands, less frequently in barrels, actually they are not counted at all but are measured in bulk. The space occupied by a single menhaden arbitrarily is taken as 22 cubic inches; however, since they vary so widely in size the volume of an individual may be far from that. A thousand, accordingly, are considered to occupy 22,000 cubic inches. This bulk of fish, whether occupied by 500 or 2,000, is rated as a thousand, weighs 666 pounds, and is equal to $3\frac{1}{3}$ barrels.

From the measuring apparatus the fish are deposited in storage bins from which they are carried as needed to the cookers. The transfer may be made by cars or by automatic conveyors, depending on the equipment of the plant.

The operations so far mentioned are typical and are in vogue, with slight modifications, in practically every plant on the Atlantic coast. The subsequent treatment of the fish, however, varies widely with respect to apparatus, though it follows in general one of two methods which may be styled the old or discontinuous method and the new or continuous process. Due to the gradual displacement of the old apparatus by the new, all combinations of the two processes are found.

## COOKING (OLD METHOD).

The old method of cooking in open vats is still in vogue in such a number of factories as to justify its description here. The vats employed are usually situated on the second floor of the factory so that the oil and water subsequently to be pressed from the cooked fish can follow its prescribed course through the plant without the assistance of pumps. They are constructed of wood or cement, with a false bottom, beneath which are placed steam pipes. The individual vats may have a capacity of about 20,000 fish, and the entire set of vats, 300,000 fish. They are arranged generally in two adjacent longitudinal rows. Above them runs the track conveying the tramcars or the

FIG. 1.—FISHING STEAMER.

FIG. 2.—CARGO AND CREW OF FISHING STEAMER.

FIG. 1.—ILLUSTRATING THE OPERATION OF A PURSE SEINE.

FIG. 2.—BAILING THE FISH FROM THE SEINE INTO THE STEAMER.

automatic conveyor which supplies the fish to be cooked, while along either side of the double row are placed other tracks running to the presses.

Fish are dumped into the vats in quantities depending on the capacity of the vats, usually 50 to 100 barrels, some water is added, and the steam is turned on. They are cooked about 20 minutes, or a sufficient length of time to cause them to break up easily, but not long enough to disintegrate them entirely. The object of the cooking is to break the oil cells or to bring about that condition which admits of a more ready expressing of the oil. If the cooking is too prolonged this is accomplished also, but the flesh is so thoroughly disintegrated that it becomes a mush from which it is difficult to separate the oil. The oil, water, and fine particles of flesh would squeeze out of the presses together.

### PRESSING (OLD METHOD).

The cooked fish are thrown from the vats into the curbs of the presses by means of a modified shovel which retains the solid matter and permits the water to run back into the vats. The curbs are mounted on trucks and are brought alongside the vats by means of the track, spoken of above, which parallels the rows of vats. The curbs are generally tubs, whose cross section is a circle, constructed of metal slats with an outward slant. The spaces between the slats are of a suitable width to permit the water and oil to escape when the pressure is applied, but to retain the solid matter. The spaces are of the same width from top to bottom, since the outward slant of the slats is compensated for by the increased width of the slats. The bottom is hinged, and, while securely fastened, its lock is readily manipulated and the bottom easily released. An iron shield is generally placed around the curb to protect the workmen from the jets of water and oil which escape from the curb when pressure is applied.

The curb, when it has received its charge of fish, is rolled back beneath the press and the power is applied. In certain of the smaller factories in the Beaufort region screw presses, manipulated by hand, are still in use. Most of the other plants using the older, discontinuous method of expressing the fish, however, are equipped with hydraulic presses.

The escaping water and oil is caught by the properly slanting floor as is also that escaping from the curb during charging and conveyed to the oil room for settling and further treatment. When the maximum pressure has been applied and no more liquid is being forced out the pressure is released, and the curb is rolled over an opening in the floor for emptying. The bottom is then released and swings downward, and the mass of fish scrap falls in a solid cake to the floor below. The slanting sides of the curb are designed to facilitate the discharge of this cake; the curb being larger at the bottom than at the top, the cake falls out readily. At this stage, the scrap contains about 50 per cent water, by weight, and about 6 or 9 per cent of oil. In its warm and moist condition it makes an ideal breeding place for various flies and for the growth of decay-producing bacteria. Unless it is to be immediately dried, it is treated with crude sulphuric acid ("about a dipper full (3 quarts) to a cart-load") in small but sufficient amount to discourage the development of insect and other life therein. The acid, besides acting as a preservative, brings about a disintegration of the flesh and bones of the scrap. It is claimed to "dissolve" the bone and to "fix the ammonia." It does render a larger proportion of the phosphoric acid of the bones "available" and may possibly convert some of the nitrogen of the complex organic bodies in the flesh into ammonia, to form ammonium sulphate. What is meant by this fixation probably is that the decay of the fish, leading to the loss of nitrogen or possibly to the actual liberation of ammonia, is prevented. This so-called "acidulated" or crude scrap may be sold as such, or, as opportunity presents, finally may be dried.

### DRYING (OLD METHOD).

The old platform dryer has been supplanted in almost every factory on the Atlantic coast by the modern and more rapid hot-air dryer. As must be inferred from the name, the platform method consists merely in spreading the scrap on a platform, where it is exposed to the air and sun. The platform in some cases is built of boards raised a few inches from the ground and in some cases is made of concrete. The scrap is frequently stirred either by hand rakes or hoes or by scrapers drawn by horses. At night, or when rain is threatened, the scrap is raked into heaps and covered with canvas. Under favorable conditions, three days drying is required. The product obtained by this method of treatment is a much lighter brown in color than that dried by hot air. Its odor is also less marked. It is said that considerable ammonia is lost by thus exposing the scrap so thoroughly and for such a long time to the air. Whether fish scrap loses nitrogen on exposure to air when in a nearly dry condition and when no recognizable decay is taking place is a mooted question. Experiments bearing on this point are under contemplation in this laboratory.

### COOKING (NEW METHOD).

The new method of cooking fish has largely supplemented the old because of its speed and efficiency and the saving in labor which it effects. The apparatus employed is essentially a long, narrow, iron cylinder (Pl. III), of varying length, but frequently about 40 feet, and about 2 feet in diameter, through which the fish are passed by means of a screw conveyor, being subjected the while to the cooking action of steam. These usually are constructed for a capacity of 100,000 fish per hour and may be purchased at a cost of about $1,200.

There are several forms of this apparatus, differing from each other principally in the manner in which the steam is admitted to the cylinder. Thus, it may be admitted through perforations in the hollow shaft of the screw conveyer; the blades of the conveyer may be displaced by sections of iron pipe, arranged screwwise around the axis, through perforations in which the steam may enter the chamber; or it may be admitted through numerous pipes projecting through the casing along its bottom. The second and third methods mentioned are regarded by the operators as more efficient, as they admit the steam within the mass of fish, instead of above it, and thus effect more thorough and uniform cooking.

The fish are conveyed automatically from the storage bins and are dumped continuously into the hopperlike mouth of the cooker. This, in certain forms, is provided with a special device for regulating and assisting the feeding. The cooked fish, together with the water and oil cooked from them and the water resulting from the condensed steam, are passed from the end of the cooker into the buckets of a conveyer and are transported to the presses.

### PRESSING (NEW METHOD).

The modern power press employed in the fish-scrap industry has the shape of a truncated cone placed in a horizontal position. It is essentially a curb constructed of iron, with slatted sides. Through its center passes a horizontal shaft on which is built up a screw, tapered to fit closely inside the cone-shaped curb. The rotation of the screw carries the fish forward into the smaller end of the curb, and as the material can not rotate with the screw or slip on the curb it is subjected to pressure. By adjusting the size of the opening in the smaller end, through which the expressed material is ejected, the pressure on the mass may be increased or decreased. The pressure is gradual, increasing from the larger end toward the smaller. The water and oil are squeezed out between the slats and are caught by the metal shield surrounding the press and are conducted thence into pipes leading to the oil room.

The mouth of the press is hopper shaped. The fish are fed into this by a mechanical conveyer. In some forms of the press a chopper is placed in the mouth to reduce the size of the pieces of fish entering. From the smaller end of the press the fish scrap usually is allowed to fall into the buckets of a conveyer.

One hundred pounds of the mass coming from the cookers contains 22 pounds of fish and 78 pounds of water. In the press 56 pounds is removed. This leaves a mass of 44 pounds, 22 pounds of which is fish and 22 pounds (50 per cent) water.

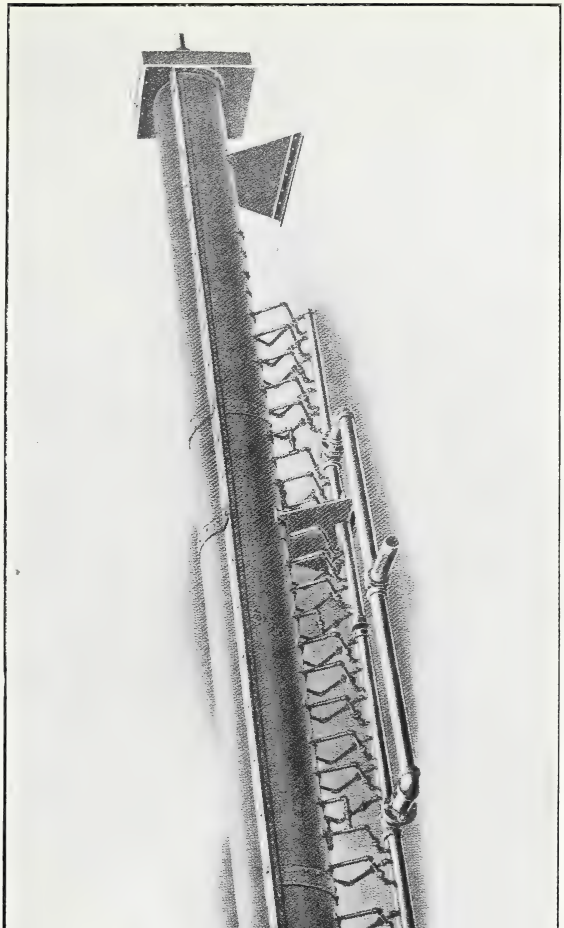
The 18-foot power press is obtainable at a cost of $5,000, set up complete. (Pl. IV.) This has a capacity of 80,000 to 100,000 fish per hour. A smaller press, 12 feet in length and with a capacity of 40,000 fish per hour, may be purchased, complete and set up, for $3,500.

The advantages of this system of ridding the fish of their water and oil are obvious. Its speed and the fact that it is continuous and automatic, requiring no labor, have enabled it to displace the discontinuous hydraulic press in a number of old factories and have brought about its adoption in practically all of those recently constructed.

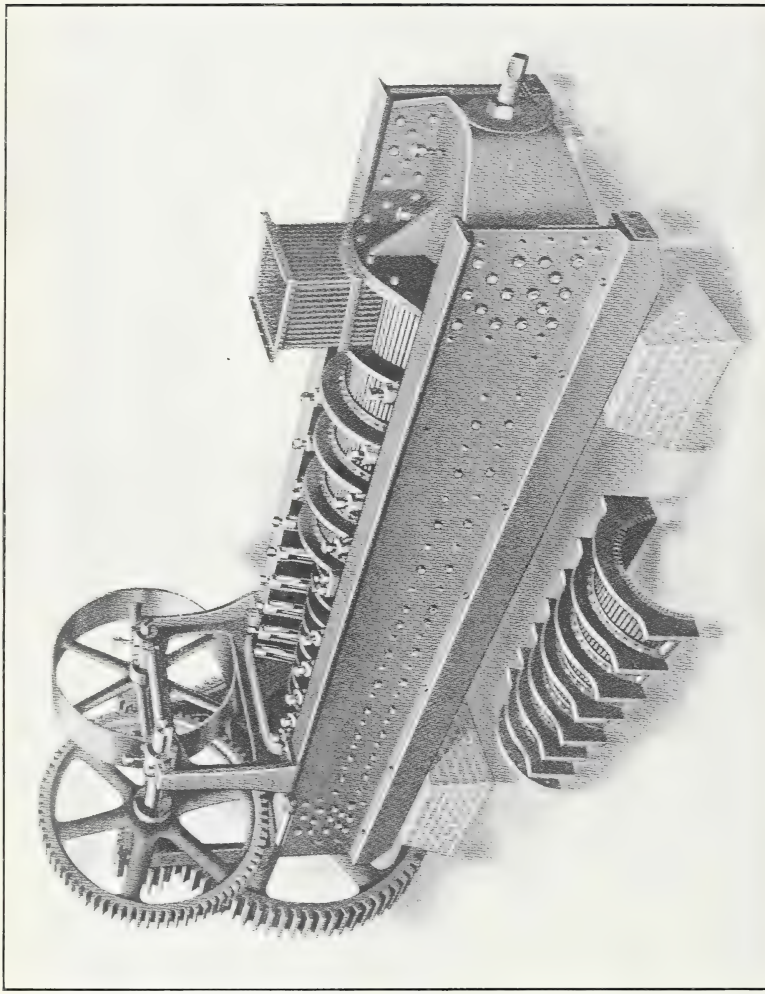
### DRYING (NEW METHOD).

The hot-air drier is now in use in all but four of the fish-scrap factories on the Atlantic coast. In at least two of the factories it has not been adopted because of the hostility of the residents of the neighborhood occasioned by the odor arising from the factories, increased during the actual operation of the drier, and exhibited by frequent suits at law.

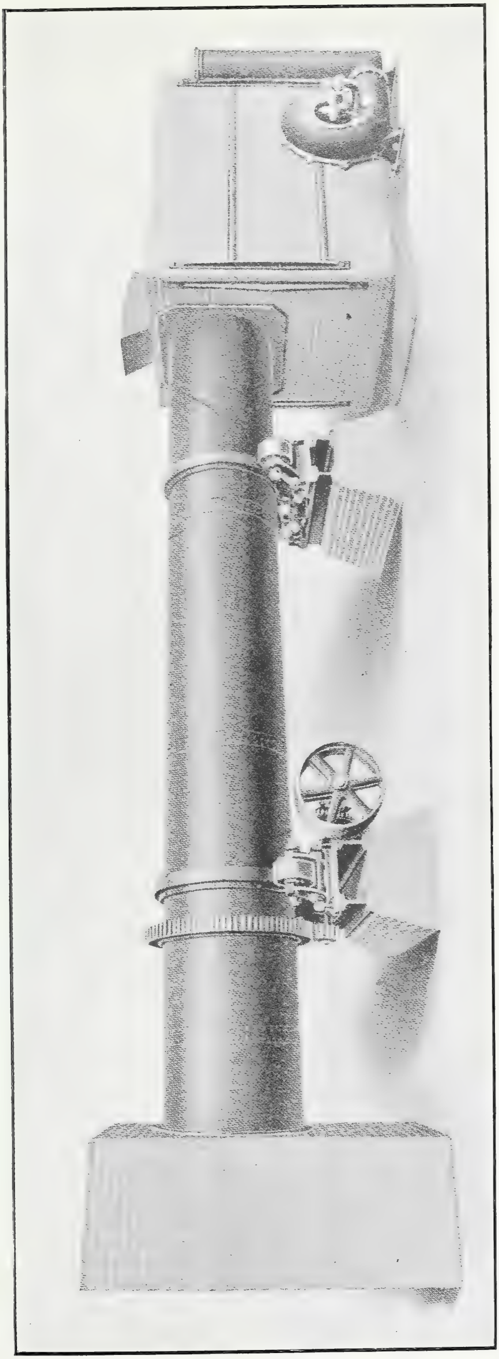
The modern drier (Pl. V.) is an insulated iron cylinder, about 6 feet in diameter and 30 or 40 feet in length. It is provided on the inside with a series of iron flanges or shelves, about 8 inches wide and running the length of the cylinder. These are designed to lift the scrap and spill it again through the stream of hot air. The cylinder is mounted slightly out of the horizontal and is supported by a device consisting of two jointless steel tires or rings encircling the cylinder toward each end and resting on steel rollers or wheels. These rollers are rotated by suitable gearing, driven by an electric motor, and they in turn rotate the cylinder. Its higher end, which is the front end, enters a brick chamber, the bottom part of which constitutes a fire box. Suitable openings are provided for stoking, etc., and an electric fan is also provided to produce a forced draft. The wet fish scrap is charged at this end, being allowed to drop directly into the swift stream of hot gases entering the cylinder from the furnace. The forced draft serves also to blow the scrap through the kiln as it is repeatedly lifted and dropped in the rotation of the kiln. The finer particles, which are more quickly dried, are blown more rapidly out of the zone of fiercer heat. The movement of the scrap through the kiln is induced, then, both by the draft and by the slope of the cylinder. The lower end likewise enters a brick chamber, practically cubical in shape, designed to fill the threefold purpose of catching the scrap as it falls from the cylinder, of acting as a sort of dust settling chamber, and of serving as a rather inefficient chimney. From this chamber the scrap is conveyed,



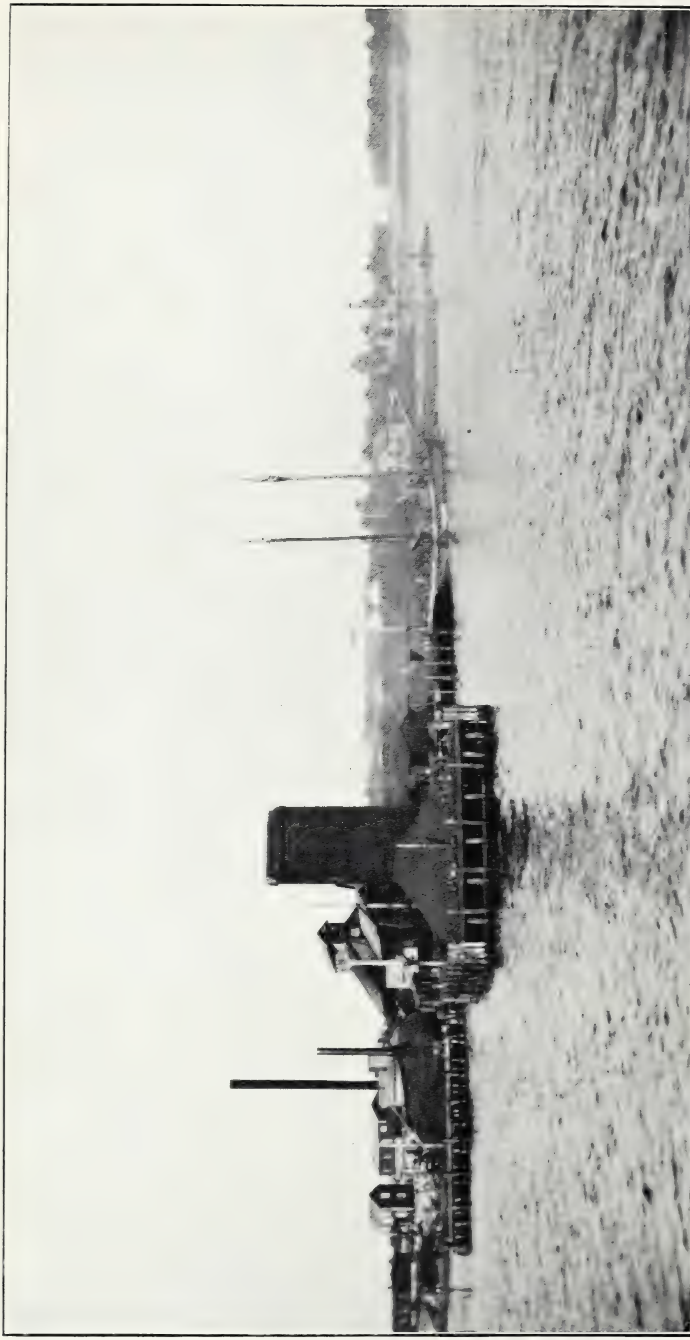
AUTOMATIC STEAM COOKER.



AUTOMATIC POWER PRESS.



HOT-AIR DRYER.



FISH FERTILIZER AND OIL FACTORY NEAR REEDVILLE, VA.

again by bucket conveyer, to the warehouse where it is stored, ground, and bagged. The transit through the drier consumes from 3 to 20 minutes, depending on the force of the blower, the rate of rotation of the kiln, and the degree of fineness of the lumps of scrap on entering the kiln. The moisture content is reduced to about 7 per cent. As some of the kilns are being operated, about 5 tons of coal per day is consumed. According to the various estimates of the operators, a million fish produce 75 to 85 tons of dry scrap; 12,000 to 15,000 fish are required to make 1 ton of scrap. The drier, complete and set up, may be purchased for $3,000, inclusive of blower, bricks, etc.

The hot-air drier for fish scrap is a useful piece of apparatus, and its introduction marks an epoch in the fish-scrap industry. It has rendered it almost altogether unnecessary to acidulate scrap, since the drier practically always is able to handle the output of the cookers and presses. In the plant equipped with a full set of the improved machinery the fish are not moved by manual labor from the time they are fed to the elevator in unloading until the dry scrap is being bagged. The whole operation requires less than an hour.

Theoretically, the hot-air drier is inefficient. Theory requires that in drying the drying agent shall be passed over the material being dried in a direction opposite to that in which that material is moving. Thus, in drying by a stream of hot air, the hottest and driest air is brought into contact with the driest material, and as it becomes more heavily charged with water vapor, passes progressively over wetter and wetter material. In this way the maximum moisture absorbing power of the air is made of use. In the drier in use in the fish-scrap industry, the opposite arrangement obtains, the hottest and driest air is brought into contact with the wettest and coldest fish, and the wettest and coldest air into contact with the driest and warmest fish. The objection raised to the former procedure is that the dried scrap is inflammable and a careful regulation of the temperature would be required to prevent the scrap from catching fire. There is little danger of this with the present scheme. However, it would be a simple enough matter to lower the temperature of the drying gases far below the ignition temperature of the dried scrap by introducing a sufficiently large volume of cold air into the gases from the furnace; or the fire could be largely reduced in size. Certainly the same amount of drying could be effected with a smaller consumption of coal, or with the same consumption of coal more efficient drying and, possibly, more rapid drying could be made possible by the use of a larger volume of air, and the process could be made as automatic as the present process.

A more serious objection to the present practice in drying scrap is the undoubted destruction of a part of the scrap in the drying.

As was stated, the wet scrap is dropped directly into the white-hot gases from the furnace. The scrap as it enters is in the form of lumps varying in size from the smallest particles to masses several inches in diameter. With a heat intense enough to dry the larger lumps in a maximum of 20 minutes, it is evident that the finest particles must be utterly consumed. The greater speed with which they travel must save much of that in the form of the less fine particles. This is an a priori conclusion, but is practically indisputable. Whether the loss is serious or not can not be said until more experimental evidence is adduced.

When there is much combustion of the fish the fact is further attested by the odor of the smoke which emerges from the "stack" of the drier. This is then a heavy smoke, largely mixed with steam and distillation products and smelling most offensively of scorched flesh. It carries also numerous fine particles of scrap, which in the course of a year's run must represent a considerable loss.

In certain neighborhoods where the majority of the residents are not in sympathy with the industry the hot-air driers are not used at all, or if used, are operated only at night or when the wind is offshore. A tall stack, while an expensive adjunct to a plant, to a considerable extent would alleviate this objection to the use of the drier.

### GRINDING AND BAGGING.

After drying it remains only to bag and ship the fish scrap. Some scrap is shipped in bulk, being transferred by conveyer directly to the hold of the transporting vessel. Much is bagged without further treatment; some is ground to a meal before bagging. For the ground scrap a slightly higher price is obtained, representing little more than the cost of grinding. In certain mills the scrap is mixed ("manipulated") with phosphate and potash carriers to produce a so-called complete fertilizer, and is thus marketed under brand names. Other companies are planning an extension of their present operations in that direction. In certain other instances the scrap is shipped to manipulating plants owned and operated by the fish-scrap company. In all other cases, with the exception of the small amounts used locally and as chicken feed, the scrap is shipped directly to the mixers of finished fertilizers.

### THE FACTORY.

In locating a factory for the manufacture of fish scrap an attempt is made to obtain a combination of deep water, protected harbor, and nearness to fishing grounds. (Pl. VI.) An effort is made further to find a location that is sufficiently isolated to obviate the danger of litigation on the grounds of being a nuisance because of odors at times created at the plant. Since fish almost invariably are unloaded from vessels of considerable tonnage and draft, proximity to a water course of sufficient depth is essential to permit the fishing boats to approach their docks. In the case of most of the plants, docks of only moderate length have been required. In one instance the entire factory has been built over the water.

The elevators and other hoisting and unloading devices are situated on the ends of the docks. The storage bins likewise may be built on the docks, though more generally they are to be found closer to the factory. If the former, they are so situated with respect to the elevator that they are supplied directly from the measuring apparatus forming a part of the elevator; if the latter, they are fed by cable cars or automatic conveyers. The bins are situated at such an elevation that the fish after leaving them again do not have to be raised to any considerable height. In accordance with this arrangement, the cookers and presses are placed on the second floor of the factory, the cooker at a greater elevation than the press, and the drier on the ground floor.

The equipment of the average factory consists of one dock, elevator, bin, cooker, press, and drier, with a capacity for the factory of about 100,000 fish per hour. The largest factory on the coast has two cookers, each of 500 barrels per hour capacity, and six presses. The usual rate of operation of this plant is 600 to 900 barrels fish per hour. It has produced oil at the rate of 75 barrels per hour.

Besides the equipment mentioned there is required also a steam and power plant to supply steam for the cookers and oil boilers and to furnish power for driving the machinery. For the average plant, of one working unit, a boiler capacity of about 300 horsepower is adequate. Certain plants generate their own electric power, and at least one has installed separate electric motors for driving the various pieces of apparatus with moving parts.

Capacious storehouses are provided to hold the dried scrap. These usually are built as a separate part of the plant to reduce fire risks, and often are capable of holding the season's output. Bagging is usually done by hand at times when the rest of the plant is lying idle, and is carried on in this building. The output of a plant is determined, not by its capacity but largely by the number and success of the boats fishing for that plant. The average number of steamers operated by a factory is 3. One company operates 27 steamers, 11 of which carry their catches to one factory, while certain manufacturers depend for their supply entirely on the fish sold to them by fishermen working independently. The price of raw fish varies from season to season; during the summer of 1911 $2.25 was paid for 1,000, while during 1912 raw fish brought $1.50 to $2 per 1,000. Since so much depends on the fortunes of the fishermen, the supply of fish is uncertain and irregular. No plant runs constantly at capacity. Some may stand idle for months in the midst of the fishing season. The fish are worked up as received. This is especially necessary in warm weather, when the fish often bruised and softened by the crushing produced from their own weight, are sure to spoil rapidly. Accordingly, the factories are operated intermittently. A much higher daily capacity is maintained therefore than would be necessary in handling a raw material of a more permanent character, or one supplied with greater regularity.

### THE FLOATING FACTORY.

The perfection of the automatic apparatus for handling fish scrap with dispatch has been followed by another attempt to manufacture scrap in a vessel capable of following the menhaden during the season. In July, 1911, the *Mills* was put into commission. This steamer is a converted steel dredge of 5,000 tons, which has been equipped with two elevators, one on each side, with a capacity of 1,500 barrels of fish per hour. These deposit the fish into receiving bins of 5,000 barrels capacity. A continuous and automatic cooker is provided and a rotary press. Storage room, with adequate fire protection, is reserved for the dried and bagged scrap, and likewise storage tanks capable of holding as much as 3,000 barrels of oil. A wireless outfit is likewise provided.[1]

## COMPOSITION OF FISH AND FISH SCRAP.

### OLD ANALYSES.

Since fish scrap is sold on the basis of its nitrogen content, a great many analyses of it have been made, both by the manufacturer of the finished goods and the inspectors of fertilizers. Many of these have found their way into the literature. In addition a number of analyses of the entire fresh fish are to be found in the literature. Certain of these are quoted below.

In the following table is given the analysis of fresh menhaden by Cook:[2]

TABLE VI.—*Analysis of fish.*

FRESH.

| Constituent. | Proportion. |
|---|---|
| | *Per cent.* |
| Water | 77.150 |
| Oil | 3.914 |
| Dried fish | 18.936 |

[1] Dismantled at close of season of 1912.

[2] Geol. of N. J., 1868, p. 497.

TABLE VI.—*Analysis of fish*—Continued.

DRIED.

| Constituent. | Proportion. |
|---|---|
| | *Per cent.* |
| Lime | 8.67 |
| Phosphoric acid | 7.78 |
| Silicic acid | 1.33 |
| Potash | 1.54 |
| Soda | 1.02 |
| Magnesia | .67 |
| Chlorine | .69 |
| Organic matter and loss | 78.30 |
| | 100.00 |

Browne[1] reports the results of an examination of the composition of sprats, "a well-known fish." A specimen was bruised in a mortar and dried at 212° F. One hundred parts of this contained: Water, 63.65; oil, 18.60; solids, 17.75. Of the solids, nitrogen constituted 11.53 per cent, equivalent to 1.94 per cent of the original sample, and ash, 2.21 per cent. The composition of the ash is given in the following table:

TABLE VII.—*Composition of the ash of two samples of sprats, taken in 1847 and 1848.*

| Constituent. | 1847 | 1848 | Constituent. | 1847 | 1848 |
|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | | *Per cent.* | *Per cent.* |
| $SiO_2$ | Trace. | 0.30 | Potash | 17.23 | 21.89 |
| Phosphoric acid | 43.52 | 40.49 | Soda | 1.19 | ........ |
| Sulphuric acid | Trace. | 1.40 | Chloride of potassium | ........ | 2.31 |
| Lime | 23.57 | 27.23 | Chloride of sodium | 11.19 | 2.31 |
| Magnesium | 3.01 | 3.42 | | | |
| Peroxide of iron | .28 | .65 | Total | 100.00 | 100.00 |

Of interest in this connection are the results of analysis of the flesh and bones of the whale given in Tables VIII and IX. The analysis is by Stockhardt.[2]

TABLE VIII.—*Analysis of flesh of the whale.*

| Constituent. | Raw. | Perfectly dry (including fat). | Without fat and entirely dry. |
|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* |
| Water | 44.50 | ........ | ........ |
| Fat | 22.81 | 40.70 | ........ |
| Flesh | 32.10 | 57.44 | 96.80 |
| Mineral constituents (ash) | 1.04 | 1.86 | 3.20 |
| Nitrogen | 4.86 | 8.68 | 14.60 |

TABLE IX.—*Analysis of steamed bones of the whale.*

| Constituent. | Proportion. |
|---|---|
| | *Per cent.* |
| Water | 3.84 |
| Cartilaginous mass (glue) | [3] 34.60 |
| Fat | 1.34 |
| Bone phosphate of lime | [4] 51.66 |
| Carbonate of lime | 8.56 |

[1] American Muck Book, 1856, p. 273 et seq.
[2] Chem. Ackersmann, **16**, 52 (1870).
[3] 3.5 per cent nitrogen.
[4] 23.66 per cent phosphoric acid.

The following table contains a number of analyses of fish fertilizers, reported by Atwater: [1]

TABLE X.—*Analysis of commercial fish scrap, quoted from Atwater.*

| Kind of fertilizer. | Moisture. | Organic matter. | Ash. | Phosphoric acid. | Nitrogen. | Ammonia equivalent to nitrogen. | Oil. |
|---|---|---|---|---|---|---|---|
| DRY GROUND FISH. | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Ground fish, G. W. Miles | 18.74 | 61.82 | 19.44 | 7.65 | 8.06 | 9.78 | 6.71 |
| Fish guano, G. W. Miles | 21.96 | 50.99 | 27.05 | 8.66 | 6.07 | 7.36 | .......... |
| Charles Island guano, G. W. Miles | 8.63 | 71.79 | 19.41 | 7.74 | 8.84 | 10.73 | .......... |
| Allyn's fertilizer | .......... | .......... | 16.37 | 6.17 | 8.80 | 10.68 | 6.35 |
| Do | 6.34 | 71.31 | 22.35 | 7.90 | 7.88 | 9.56 | 7.33 |
| Dry ground fish, Quinnipac Fertilizer Co | 14.64 | .......... | 22.23 | 6.67 | 7.50 | 9.11 | 7.68 |
| Do | 10.85 | 68.40 | 20.75 | 7.21 | 7.38 | 8.97 | .......... |
| Do | 13.45 | 63.97 | 22.58 | 7.55 | 7.96 | 9.66 | 6.63 |
| Do | 8.22 | .......... | 20.41 | 8.11 | 8.25 | 10.00 | 8.94 |
| Acidulated fish, Quinnipac Fertilizer Co. (dried fish scrap) | 36.53 | 39.89 | 23.58 | [1] 7.09 | 4.11 | 4.99 | .......... |
| "Dry fish," Green Bros | 11.04 | 64.01 | 24.95 | 10.51 | 8.60 | 10.44 | 3.93 |
| "Dried fish" | 9.37 | .......... | 19.92 | 7.10 | 8.13 | 9.86 | .......... |
| "Dry fish" | 11.00 | .......... | 20.17 | 7.12 | 7.46 | 9.05 | 8.29 |
| "Fish scrap" | 7.74 | .......... | .......... | .......... | 7.10 | 8.61 | .......... |
| "Dry fish" | 7.59 | .......... | .......... | .......... | 7.79 | 9.46 | .......... |
| "Dry fish" (half dry fish scrap) | .......... | .......... | .......... | .......... | 7.65 | 9.28 | .......... |
| Fish scrap, "half dry" | 40.95 | 43.06 | 15.99 | 6.23 | 5.33 | 6.47 | .......... |
| Fish scrap, "half dry" (crude fish pomace) | 25.10 | 56.17 | 18.73 | 7.49 | 5.49 | 6.66 | 11.99 |
| "Fish scrap" | 56.83 | .......... | .......... | .......... | 3.63 | 4.41 | .......... |

[1] Per cent soluble in water, 1.76; per cent soluble in ammonium citrate, 2.47.

Additional analyses of fish fertilizers, reported by Johnson,[2] are quoted in the subjoined table:

TABLE XI.—*Analysis of commercial fish scrap, quoted from Johnson.*

| Kind of fertilizer. | Moisture. | Nitrogen. | Nitrogen in water-free fish. | Oil. |
|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Dry ground fish scrap | 10.75 | 8.52 | 9.54 | .......... |
| Do | .......... | 8.21 | .......... | .......... |
| Dry ground fish scrap: | | | | |
| Old, 1876 | 16.59 | 7.35 | 8.81 | .......... |
| New, 1877 | 23.95 | 7.30 | 9.59 | .......... |
| Dry ground fish scrap | .......... | 9.26 | .......... | .......... |
| Do | .......... | 8.77 | .......... | .......... |
| Do | 19.57 | 7.98 | 9.92 | .......... |
| Do | 9.03 | 8.04 | 8.83 | .......... |
| Do | 11.38 | 8.51 | 9.60 | .......... |
| Do | 10.74 | 8.43 | 9.44 | .......... |
| Do | 9.76 | 7.77 | 8.61 | 8.94 |
| Do | 11.19 | 8.78 | 9.88 | 7.30 |
| Average | 13.66 | 8.24 | 9.36 | 8.12 |
| Fish by Adamson's process | 4.91 | 10.78 | 11.32 | 2.07 |
| Do | 3.67 | 10.74 | 11.15 | .......... |
| Fish by Goodale's process | 11.45 | 10.24 | 11.56 | 4.64 |

### NEW ANALYSES.

A small number of samples of fish scrap were taken for the most part in person by the writer during the fall of 1912. No attempt was made to obtain a complete series from all the plants visited.

[1] Atwater, W. O., Conn. Agr. Expt. Sta. Rept., 1876, p. 63.
[2] Conn. Agr. Expt. Sta. Rept., 1877, 41.

Those obtained may be regarded as typical. The samples were gotten from open heaps of scrap in the storage house, or from bags by means of samplers, or by opening the bags. They were shipped in canvas sample sacks. Before analysis, the entire sample was ground to a powder that would pass a sieve of 16 apertures per linear inch.

## METHODS OF ANALYSIS.

Samples of 2 grams were dried to constant weight in an electric oven at a temperature of about 100° C. The loss in weight was recorded as moisture. In this connection it should be said that it is believed that possibly some oil also was lost in this operation. Oil was determined by extracting with ether a 2-gram sample, previously dried to constant weight. Following the extraction, the sample again was dried to constant weight and the loss was taken as oils. For the extraction a Soxhlet apparatus was employed. In the determination of nitrogen the official, modified Gunning method was applied, and in that of phosphoric acid the official gravimetric method was used. The analyses were made by E. G. Parker and J. R. Lindemuth, whose results are recorded in the subjoined table. The eleventh analysis is reported in this table merely for convenience. It is the analysis of pulverized crab shells used as a filler for mixed fertilizers. The particular adaptability of this material for that purpose is brought out by the analysis.

TABLE XII.—*Analysis of fish scrap, by E. G. Parker and J. R. Lindemuth.*

| No. of sample. | Location. | Description. | Nitrogen. | Phosphoric acid ($P_2O_5$). | Moisture. | Oils. |
|---|---|---|---|---|---|---|
| | | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 1 | Kilmarnock, Va | From Eubanks Tankard Co. Dry scrap (from 6 sacks). | 8.93 | 6.17 | 6.48 | 5.91 |
| 2 | Taft, Va | From Taft Fish Co. Dry scrap (sample of 525 tons). | 8.96 | 7.75 | 6.18 | 6.81 |
| 3 | Irvington, Va | From Carter's Creek Fish Guano Co. Dry scrap, dried in hot air and steam driers (from one sack). Fall product. | 7.70 | 5.22 | 11.68 | 6.62 |
| 4 | Cape Charles, Va | From Atlantic Fish & Oil Co. Dry scrap, ground (from 3 sacks). | 9.29 | 6.12 | 7.86 | 5.38 |
| 5 | do | From Dennis Fish & Oil Co. Dust from grinders. | 8.80 | 5.21 | 7.17 | 7.55 |
| 6 | Beaufort, N. C | From Beaufort Fish-scrap & Oil Co. Dry scrap, hydraulic presses. Sample from heap. | 8.82 | 5.95 | 6.13 | 8.57 |
| 7 | Morehead City, N. C | R. W. Taylor. Dry scrap from open heap. | 8.49 | 5.95 | 9.12 | 8.23 |
| 8 | do | From Chas. S. Wallace. Scrap, dry, from hydraulic presses. | 7.76 | 9.65 | 8.15 | 7.56 |
| 9 | Lenoxville, N. C | From C. P. Dey. Ground scrap, sun dried, hydraulic presses. Sample from heap. | 7.81 | 5.85 | 7.46 | 7.89 |
| 10 | do | From C. P. Dey. Scrap, dry, ground, hydraulic presses. Sample from heap. | 8.29 | 9.00 | 7.00 | 5.40 |
| | Average | | 9.13 | 7.25 | | 6.99 |
| 11 | Crisfield, Md | From L. E. P. Dennis & Son. Ground crab shells, used as filler. | 3.82 | 4.55 | 6.95 | 2.11 |

## USES.

### FERTILIZER.

Fish scrap, from the inception of the industry, has met with great success as a fertilizer, until to-day it constitutes one of the main sources of organic nitrogen used in the fertilizer industry. Its nitrogen is in a form from which it is readily rendered available by the bacterial and other action taking place in the soil. The organic matter, which serves as the carrier for the nitrogen, in fish scrap as in other organic nitrogenous substances is a beneficial adjunct not enjoyed by the inorganic nitrogenous substances.

A small amount of fish scrap is used directly as fertilizer without admixture with other fertilizer ingredients or fillers. Its success when used alone has not been unqualified. Its continued application has led to a condition of the soil in which it would no longer respond to that fertilizer. A larger portion is mixed ("manipulated") by the manufacturers of the scrap to form a so-called complete fertilizer and is sold, generally locally, under brand names. During the past year (1912) about 10,000 tons were thus employed. This practice is growing.

By far the larger proportion of the output of the East is sold directly or through the medium of brokers to the larger manufacturers of fertilizers, by whom it is worked up into the various grades of finished goods marketed by them.

### CHICKEN FEED.

This use of fish scrap at present is so slight in the East as scarcely to deserve mention. Only a few tons, and these by a small number of chicken growers, are thus utilized; but the success of those so using it, evidenced by their yearly increasing orders, would seem to justify its exploitation by experiment stations and its trial by other poultry raisers.

The following paragraph is quoted, with excisions, from Goode:[1]

> At a meeting of the Maine Board of Agriculture and Farmers' Convention, Mr. Wasson gave an interesting account of the use of "pogy chum" as a food for sheep and poultry, stating that he had used it for five years. * * * Sheep thus fed showed an average increase each of one pound and a quarter of wool, while they were constantly fat and brought heavy lambs. Hens also ate the scrap with avidity. Boyd stated that hens, ducks, and turkeys preferred it to corn, and became large and heavy when fed upon it. It is customary to discontinue the scrap and feed them on corn three or four weeks previous to killing them.

### CATTLE FEED.

The use of fish scrap as a feed for cattle has met with such success, seemingly, in those instances where it has been tested that it is surprising that its adoption for this purpose has not become more

[1] Loc. cit. Cf. pp. 140–141.

general. It is reported that in the Shetland Islands dry salt fish constitute the main feed for cattle and sheep, and are even fed to horses.

The most rational method of utilizing fish for manure, and the one which it seems to me must prove by far the most profitable way of economizing our waste fish products, is by feeding them to stock.[1]

The following paragraphs are quoted from a paper by the eminent nutrition expert and food chemist, the late W. O. Atwater, which has been published as a part of the report by Goode:

The earliest accounts which I have met of fish as food for domestic animals is the following extract from the Barnstable (Mass.) Journal of February 7, 1833:

"The cattle at Provincetown feed upon fish with apparently as good relish as upon the best kinds of fodder. It is said that some cows, kept there several years, will, when grain and fish are placed before them at the same time, prefer the latter, eating the whole of the fish before they touch the grain."

In 1853, Mr. J. B. Lawes, of Rothamsted, England, reported several extensive series of experiments "On the Feeding of Pigs," in which were tested the effects of beans, lentil, Indian corn, and barley meals, bran, and dried Newfoundland codfish as foods for fattening. * * * In speaking of the series in which the fish was fed with maize, barley, and bran in different proportions, Mr. Lawes says:

"In the series * * * where we have * * * a comparatively small amount of nonnitrogenous matter consumed, the food consisted in a large proportion of the highly nitrogenous codfish; and in both of these cases, we had not only a very good proportion of increase to food consumed, but the pigs in these pens were very fat and well ripened. * * * This result is in itself interesting, and it may perhaps point to a comparatively greater efficiency in the already animalized protein compounds supplied in the codfish than in those derived, as in the other cases, from the purely vegetable diets."

The value of fish as food for domestic animals has been attested by experienced and intelligent farmers in our own country.

As early as 1864, if not in fact previous to that date, the attention of members of the board of agriculture (of Maine), and farmers generally was called to the value of fish pomace or scrap as a feeding stuff for sheep, swine, and poultry. In a communication to the board[2] Mr. William D. Dana, of Perry, spoke in high tones of its value as a feed for domestic animals, in which he said:

"Fish pomace, or the residuum of herring after the oil is pressed out, is greedily eaten by sheep, swine, and fowl; and probably pogy chum would be eaten as well. Smoked alewives and frost fish also furnish a food palatable to cattle. Sheep thrive well, get fat, and yield heavier fleeces when fed on this pomace than when fed on anything else produced in this section of the State. Careful and observing farmers, who have fed it, assert that it is of equal value with good hay, ton per ton, and that its value for manure is in no degree diminished by passing it through the living mill, and thus reducing it to a much more convenient state for applying. If it could be sufficiently dried, without other substances, to prevent putrefaction, it would form a valuable article of cattle feed in regions from which it is now excluded by the expense of transportation and its own odoriferous nature."

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[1] Goode, loc. cit. Cf. p. 248.

[2] Agriculture of Maine, 1864, p. 43.

It is apparent that the scrap spoken of here as used in these feeding experiments is the undried scrap as taken from the presses. No reason suggests itself why the dried scrap should not be as nutritious as the wet as, theoretically, the drying causes no chemical change in the organic substances of the scrap but merely removes water. The advantages of the dry over the wet scrap as a feed are numerous and great.

Feeding experiments were conducted by Farrington at the experimental farm of the Maine College of Agriculture. Two flocks of lambs, of five each, were chosen, and during a period of 16 weeks one flock was fed corn and hay and the other fish scrap and hay. During the first four weeks of the experiment "the corn-fed flock, weighing 340½ pounds, ate 335 pounds of hay and lost 19 pounds in weight. The flock eating fish, weighing 338 pounds, ate 338 pounds hay and lost 1½ pounds." During the 16 weeks of the experiment the sheep were fed about 2 ounces of fish scrap per head per day and the same amount of corn; in that time the corn-fed flock gained 48 pounds, or 15⅛ per cent, and the fish-fed flock 47½ pounds, or $15\frac{1}{26}$ per cent. As the fish scrap was unground and contained bones, it was not entirely eaten.

On the whole, then, these experiments [and others[1] described in the report by Atwater, but omitted here[2]] bear unanimous and convincing testimony in favor of the easy digestibility and high nutritive value of animal foods in general and of fish guano in particular when fed to sheep and swine. How far they could be made profitable for other herbivorous animals than sheep has not yet been tested. In the nature of the case there is no reason why they should not be as nutritious for neat cattle as for sheep. As Voit has justly observed, all mammals are at one period of their lives, when living upon milk, carnivorous. * * *

In short, we have every reason, from practical experience, from actual experiment, and from what we know of the nature of the case, to believe that the immense amount of animal waste produced in this country from our slaughterhouses, and especially from our fisheries, can be utilized with the greatest ease and profit to supply the most pressing need of a most important part of our agriculture—nitrogenous food for stock.

The ingredients of fish may be made more available for plant food and their value for manure increased by * * * feeding to stock, thus putting it through a process similar to that by which Peruvian guano has been formed. In this way it can be used to enrich the manure made on the farm, and thus made one of the best aids to successful farming.

Concerning the utilization of fish scrap as cattle feed, Henry, in "Feeds and Feeding," says:

Along the coasts of Europe the waste parts of fish as well as entire fishes not used for human food are fed in dried form to animals. Spier, of Scotland,

[1] By Wolff, Wildt, Kellner, and Weiske, described in Die Landwirthschaftlichen Versuchs-Station, J. f. Landwirthschaft and Landwirthschaftliche Jahrbücher, 1876 and 1877.

[2] Note inserted by writer, J. W. T.

reports no bad influence on milk when reasonable quantities of dried fish are fed to dairy cows. Nilson found that 80 parts of herring cake could replace 100 parts of linseed cake in the ration for cows. The better grades of dried fish meal should be used for feeding farm animals.

In a trial by Schrodt and Peters bran and rape cake were gradually replaced by equal quantities of flesh meal until the allowance of the latter reached 2.2 pounds per head daily. It was found that the customary shrinkage in live weight when in full milk flow did not occur, and there was an increase in the total quantity of milk as well as in the total solids and fat. Flesh meal effected a saving of 2 pounds of feed per head daily, and the cows learned to relish it highly.

According to Kuhn, milk and butter of normal quantity were produced on a daily allowance of 2.3 pounds of fat-free fish scrap supplied with a variety of other feed, no deleterious effects resulting.

The universally affirmative results of all the recorded experiments with fish scrap as a cattle feed leaves little room for doubt as to its efficiency. It is, indeed, surprising that its use as a feed has not been more generally introduced. This is doubtless due to the lack of exploitation on the part of the manufacturers, the ones most vitally interested financially.

It will be recalled that in the beginning of the cottonseed-oil industry the expressed cake was a by-product which found use only in the fertilizer industry. Its subsequent exploitation as a cattle feed gave it a much enhanced value. To-day it is produced in immense and constantly increasing quantities, and the portion of it which enters the mixed fertilizer is proportionally less than the amount used as cattle feed. We should not be surprised if in that particular the history of fish scrap will parallel that of cottonseed meal; that the time will soon come when it will be recognized by both manufacturer and farmer that its preparation and use as a cattle feed is more profitable to both than when employed only as a stimulator for growing plants. And fitting, indeed, it would be that even a small part of the millions of pounds of combined nitrogen carried seaward annually by the rivers should be returned, and after a short cycle again should be rendered suitable for man's consumption.

## POSSIBILITIES IN THE DEVELOPMENT OF THE FISH-SCRAP INDUSTRY.

A number of elements, all speculative in character, enter into the question of the possible development of the fish-scrap industry. A discussion of this topic should consider the past history of the industry and the present supply of fish, and should have regard for the probable future demand for nitrogen, for the probable increased demand for fish for food, and for the possibly more complete utilization of waste from canneries.

This topic will be considered briefly in the light of the principal influences liable to affect it. The opinions expressed are based on observations so far made, which in many particulars are necessarily incomplete. A fuller study of the subject doubtless will cause a certain revision of these opinions.

### IN THE LIGHT OF THE PAST HISTORY OF THE INDUSTRY.

From the table on page 7, setting forth the statistics of the fish-scrap industry for the years 1873 to 1898, inclusive, it may be seen that the industry has been on its present basis since 1885. The annual catch has varied, the variation being determined as much, perhaps, by the success of the fishermen—"fishermen's luck"—as by the status of the industry, and the annual output in oil and scrap has not varied greatly from 70,000 tons of scrap and 35,000 barrels of oil. There has not been that growth in the recent past which would warrant a belief in a growth in the future.

During the last year there was quite an impetus noted in the industry, due largely to the very successful season of the preceding year, 1911. While there were a number of new plants under construction or beginning operations in 1912, whose establishment was attributable largely to the prosperous season of 1911, there were others which did not share in this prosperity and were either out of commission or in the hands of receivers.

The greatest change in the fish-scrap industry of the last 25 years has been the introduction within recent years of improved machinery for manufacturing the scrap. The success of this move has been pronounced. This success has been almost too recent to enable one to say what effect it will have on the industry. But since the main expense involved in the industry lies in the operation of the boats and the main profit in the success of the boats, it is evident that changes in the factory proper can not have a far-reaching influence on the industry as a whole.

### IN THE LIGHT OF THE SUPPLY OF FISH.

Repeated inquiries among the menhaden fishermen with respect to the decrease in the number of fish have failed to reveal any important indication that the menhaden are any less abundant to-day than in times past. Occasionally the opinion is expressed that they have decreased; but frequently this opinion is based on the disappearance of the fish from certain inclosed bodies of water from entering which they are prevented by the large number of fishing steamers operating at the entrance to such bodies of water. As has been pretty conclusively indicated, the number of fish caught by the fishermen is hardly significant when compared with those destroyed by the carnivorous fish which prey upon them. It is not to be expected, therefore, that even increasing fishing will impair their numbers, unless, indeed, certain movements or habits of the schools, which in the past have served to protect them from their predatory foes or have enabled them to reproduce, are interfered with by the fishermen. If fishing off the entrances to the various bays and sounds along the coast prevents the menhaden from entering these waters, this fact may assist in their destruction by keeping them on the high seas, where, presumably, they are more open to attack than when feeding in the more sheltered bays and river mouths.

So long as the fish are not interfered with at the time of their spawning season, however, there is little danger of their number being impaired seriously by man, since their rate of reproduction is so enormous. It is maintained that but few spawning fish ever are caught by the fishermen, and that the spawning season begins at about the time the fishing season ends. This is not quite true of the season in North Carolina, where the fishing season and spawning season overlap, and is open to doubt at other places. While many fish are caught containing roe, so few are taken from which the spawn is running that it is probably true that the spawning of the menhaden is not seriously interfered with.

Doubtless fishing methods will continue to be improved so that more effective fishing will be possible. The development of the fishing end of the industry will have to take place in that direction rather than in an increase in the number of steamers fishing; for the larger the number of the latter, the more will they interfere with each other by frightening and scattering the schools, and to a corresponding degree will they impair each other's efficiency. Since the operation of the steamers is the most important part of the industry, a fair catch is imperative if the industry is to pay.

It frequently has been suggested that the number of menhaden could be increased by decreasing the number of their foes. This is doubtless true; but if the number of the menhaden is not appreciably decreased from year to year by the most vigorous fishing, it would appear equally impossible to decrease their foes by applying the same method. Something, possibly, could be accomplished by attacking the predaceous fish at their spawning beds. Since the most important of the predaceous fish, excepting the dogfish, are among those highly valued for food, it would scarcely be feasible to destroy these food fish to preserve the others commonly not so regarded.

The number of menhaden now available doubtless represents a state of equilibrium between their natural tendency to multiply by procreation and their destruction by the hordes of other fish whose main food they constitute. This equilibrium doubtless has existed for ages. It is improbable therefore that it will now be upset by any natural cause.

A word of warning, however, should be given those operators whose crews take menhaden in the late fall and the winter, that if they catch spawning fish they are running the risk of decreasing the supply. Serious interference with the fish at their spawning season means the inevitable depletion of the schools.

### IN THE LIGHT OF THE FUTURE DEMAND FOR NITROGEN.

Certainly it is true that there will continue to be a use for nitrogen compounds for fertilizers for many years to come, and that for a time, at least, this use will be a rapidly increasing one. Whether there always will be such a demand is impossible to say and idle to speculate. The understanding of fertilizers and their action in the stimulation of plant growth now is only in its incipiency. Subsequent investigation may show, and doubtless will, that some of our agricultural practices are based on misconceptions. Subsequent investigations may show that certain of the materials now used as fertilizers are not as good as certain others yet to be tested, for it is known definitely that many other substances besides compounds of nitrogen, potassium, and phosphorous produce a stimulation similar, or, at least, analogous, to that produced by the present ingredients of commercial fertilizers regarded as essential.

The general scarcity of nitrogenous compounds has stimulated the investigation of processes for "fixing" the nitrogen of the atmosphere so that to-day there are at least three distinct methods of bringing about reaction between nitrogen and other substances which have been made the base of nitrogen-fixing industries. These are methods for oxidizing the nitrogen of air to nitric acid, for bringing about a union between the nitrogen of air and calcium carbide to form calcium cyanamide, and for inducing a reaction between the nitrogen of air and hydrogen to form ammonia. These industries are only in their infancy, so to speak, having been in operation only a few years. The rapid development of and improvement in the processes, growth in number and size of plants, and corresponding increase in output show that already they are on a satisfactory commercial basis and bespeak for them a successful future. Whether they will find it commercially advantageous or possible to market nitrogenous compounds at a lower price than now obtains or at a price with which the manufacturers of fish scrap can not compete remains for the future to disclose. With an unlimited and easily accessible supply of raw materials and a practically inexhaustible source of power for operation the manufacturers of the atmospheric products certainly are in a position to supply immense quantities of nitrogenous fertilizers.

The present great source of combined nitrogen in this country is ammonium sulphate from the by-product coke oven. The unrecovered ammonia, liberated in the old form of coke oven, the beehive, is more than enough to supply the fertilizer trade with all the fixed nitrogen it demands. Should this amount be rendered available by a sudden improvement in the coking process, the preparation of fish scrap for fertilizer use doubtless would become commercially infeasible. It is more probable that the increase in the output of ammonium sulphate will keep pace with the increase in demand therefor, and that the price fluctuations will be gradual and slight.

In recapitulation, then, it may be said that while the demand for nitrogen compounds of animal or vegetable origin undoubtedly will continue to increase, the prospects for the supply of inorganic nitrogenous compounds are quite bright. While the fertilizer industry, perhaps, prefers the former, it is quite independent of them so long as the supply of the latter is ample. So, should the price of fish scrap be increased, it appears probable that increased amounts of ammonium sulphate, and, in the future, atmospheric products would take its place. In the light of these considerations, then, it does not appear reasonable to believe that the demand for and the price offered for fish scrap for fertilizer purposes will materially increase.

#### IN THE LIGHT OF THE POSSIBLE INCREASED DEMANDS FOR FISH FOR FOOD.

The fact is forced upon our attention daily that the cost of food is increasing. This can only mean either that food is becoming more scarce in proportion to population, or that the expense of getting it to the consumer is increasing, or both. The decrease in the exportation of American food products is an indication that the former is true, and the continued elaboration and extension of the middleman system of handling produce undoubtedly makes the latter true. A number of possibilities may be realized which will operate to increase the abundance and availability of farm produce, so that the increase in production of food can keep pace with the increase in population for a great many years to come. However, should this increase in production not come to pass, the increasing scarcity of food in general, and of nitrogenous food in particular, will make it imperative that the fish of the sea be more economically utilized. This will mean at first a gradual stimulation of the present fisheries engaged in catching the so-called food fishes, especially those whose catches are preserved for shipment long distances and for consumption at times and places in which fresh fish are not available.

The menhaden commonly are regarded as nonedible fish. The fishermen, when asked why the menhaden are not edible, reply that they are "too boney" or "too oily"; others acknowledge that the menhaden, when freshly caught and properly cooked, have as good a flavor as any other fish. It is true that choicer fish are usually at hand and are chosen at the expense of the menhaden, and in that sense they are not edible. In short, it appears undoubtedly true that they are edible and palatable, but are not as choice as a number of other fish usually to be had, and therefore as a usual thing they are not eaten. At times they have appeared in the fish markets of the East and have brought prices comparable with those fetched by other fish recognized as food fish.

In former years it has been the practice among the people inhabiting the coastal sections of the United States to preserve a number of barrels of menhaden in salt for home consumption. At times salted menhaden have been prepared in fairly large quantities for exportation and as a sort of substitute for salt mackerel. This has been true especially in seasons of scarcity of other fish. The statistics of the Bureau of Fisheries of 1905 covering the fishing activities of the New England States show that only 8,600 menhaden, valued at $252, were salted during that year; these were in the State of Massachusetts. Smith[1] has stated that 25,000 menhaden were salted for their own use by the crews of two steamers of the menhaden fleet of 1895. It is presumable that this was not peculiar to these two steamers alone and that a similar practice was in vogue to a proportionate extent on the other 54 steamers and 28 sailing vessels in use that year.

Menhaden have been prepared as sardines and have been declared a complete success when so used. It has been demonstrated that a meat extract can be prepared from their flesh equal in flavor and nutritive value to the well-known extract of beef. While this fact has been known for many years, the process of extraction so far has failed of development on a commercial scale. The extract is said to equal 20 per cent of the weight of the fish. The expressed flesh and the oil are obtainable as by-products, the former for fertilizer purposes and the latter for the uses to which it is now applied. In short, past experience has shown that the menhaden are available as food fish to be used fresh, where marketable, for preserving in oil as sardines, or in salt, as mullets and herring are now preserved, or as a source of meat extract, as the exigencies of the food supply should demand.

At present there is no indication that the consumption of menhaden for food for man is on the increase.

[1] Notes on an Investigation of the Menhaden Fishing in 1894, with Special Reference to the Food Fishes Taken. Bull. U. S. Fish Comm., 1895, p. 285.

**IN THE LIGHT OF THE MORE COMPLETE UTILIZATION OF THE WASTE FROM CANNERIES AND OF WASTE FISH.**

The aggregate annual waste from the dressing of fish is undoubtedly great. About 25 per cent of the weight of the "round" or fresh fish is discarded in dressing. With the exception of the canneries, there are few places where enough fish are dressed to make the treatment of the cuttings for the preparation of fertilizer economically feasible. Practically all of the small fish to be found on the market fresh are sold "round"; the dressing is done by the individual consumer. The waste thus produced finds its way into the garbage and is disposed of in that manner. In some fishing centers it is the custom to remove the viscera of the fish before marketing, but not the heads. In this case the fish are usually dressed on board the fishing boats and the waste is thrown overboard. Once the habits of the fishermen in this regard are overcome, and a plant for its treatment established at a convenient point of call for the fishing fleet, it is possible that a great deal of this material could be saved and converted into fertilizer. It is the custom at present in this manner of dressing fish to save the livers. The remaining viscera probably are low in their content of oil, possibly too low to make an extraction profitable; and the remainder is of a rather watery nature, containing little solid matter. However, the solid matter that is present is highly nitrogenous and therefore of fertilizer value. Furthermore, it is believed that to throw this material overboard is injurious to the fisheries, causing the desirable fish to forsake the waters thus polluted and attracting large numbers of dogfish inimical to the food fish. This practice is sufficiently undesirable to merit prohibition by law. At the same time, in such a contingency, plants suitable for its disposal should be assured by the same power.

There is a distinct possibility that enough of this product is recoverable at certain points to enable small rendering plants to operate; and at present, it is known to the writer, it is planned to make use in some manner of the offal obtainable from at least one fleet of about 50 fishing boats. But there is not a large enough number of fishing centers where the practices are such as described, nor is there enough material available at any one point to make the amount of fertilizer produced from that source of any great significance.

The cuttings from herring and other fish canned at the center of the fish-canning industry on the Atlantic coast, it has been shown in a previous paragraph, amounted to 36,496 hogsheads, yielding 31 tons of wet scrap in 1895, and an amount of cuttings which gave 50 tons of wet scrap in 1905. While data showing the completeness with which the scrap of that neighborhood is utilized are lacking, it is presumable that since the equipment for its rendering has been installed, all that is readily available is so employed. Similar material is produced in large amount by the extensive fisheries on the Great Lakes, but there again it is so badly scattered that its treatment to any considerable extent is impracticable. These sources then scarcely can be looked to for increasing the Nation's output in fish scrap.

Among the so-called waste fish, fish commonly regarded as unfit for food and applied to no other use, the dogfish are perhaps most numerous in coastal waters and most easily caught. The interest of the various fisheries rather demand that the number of dogfish be reduced; and the experience in Canada, where through Government initiative they are being converted into fertilizer, shows that they are a potentially large source of fish for fish-scrap purposes, and in their utilization one reasonably may expect a development of the fish-scrap industry.

This discussion has been confined to conditions as they have been observed on the Atlantic coast and do not apply at all to the Pacific coast. The salmon canneries on the Pacific coast produce very large amounts of refuse, representing, roughly, 30 per cent of the "round" weight of the salmon taken. The salmon-canning industry by no means is confined to the States, but is carried on quite extensively in southeastern and southwestern Alaska. A considerable amount of the refuse now produced in the States is made use of in the preparation of fertilizers, a practice which is on the increase. In Alaska practically none of the refuse is saved. A discussion of the salmon-cannery waste is not in place in this report, since it is the intention of this bureau to conduct an investigation during the coming summer with a view to the more complete utilization of this material for fertilizer purposes. Since nature has provided an abundant growth of the self-perpetuating and highly potassic kelp in the neighborhood of many of the canneries, it is hoped that the two materials can be combined and a fertilizer, containing the three most desired ingredients—nitrogen, phosphoric acid, and potash—be manufactured with profit.

## OILS.

### DEVELOPMENT.

Fish oils for many years have been among the important products taken from the sea. The whale constituted the first important source of the so-called fish oils and to-day yields about 3,000,000 gallons annually. In addition to these, other aquatic animals, such as the porpoise, the blackfish, seals, walrus, and the livers of cod, have been made a fruitful source of the animal oils.

Menhaden oil, the true fish oil, and by far the most important oil produced on the Atlantic coast of the United States, first appeared on the market in considerable quantity in the early sixties. The large prices obtained in the early days of the industry led to a rapid development in the industry and a consequent overproduction in oil. In the seventies the annual production exceeded 2,000,000 gallons, a figure which it closely has maintained on the average ever since. The annual production since 1873 is given, by years, in Table III, on page 7.

### PRICES.

The range in prices since 1863 of the various grades of oil is given in the subjoined table. The data for the years 1863 to 1902 are taken from the report by Stevenson, previously quoted; those for the following years from the Oil, Paint, and Drug Reporter.

During the past year the oil has varied in price from 23 cents to 28 cents per gallon.

TABLE XIII.—*Statement of the range of prices for crude northern menhaden oil in the New York market from 1863 to 1911, inclusive.*

| Year. | Lowest. | Highest. | Year. | Lowest. | Highest. |
|---|---|---|---|---|---|
| 1863 | $0.75 | $1.00 | 1888 | $0.20 | $0.32 |
| 1864 | 1.10 | 1.35 | 1889 | .21 | .32 |
| 1865 | .80 | 1.40 | 1890 | .22 | .30 |
| 1866 | .70 | 1.135 | 1891 | .255 | .30 |
| 1867 | .45 | .70 | 1892 | .30 | .38 |
| 1868 | .50 | .95 | 1893 | .33 | .40 |
| 1869 | .625 | 1.025 | 1894 | .21 | .33 |
| 1870 | .40 | .68 | 1895 | .19 | .25 |
| 1871 | .35 | .55 | 1896 | .18 | .23 |
| 1872 | .36 | .65 | 1897 | .18 | .25 |
| 1873 | .32 | .605 | 1898 | .225 | .24 |
| 1874 | .35 | .475 | 1899 | .225 | .27 |
| 1875 | .305 | .485 | 1900 | .25 | .27 |
| 1876 | .30 | .50 | 1901 | .26 | .30 |
| 1877 | .30 | .46 | 1902 | .26 | .29 |
| 1878 | .23 | .45 | 1903 | .22 | .27 |
| 1879 | .24 | .35 | 1904 | .21 | .25 |
| 1880 | .29 | .43 | 1905 | .17 | .21 |
| 1881 | .30 | .395 | 1906 | .24 | .26 |
| 1882 | .32 | .42 | 1907 | ........ | ........ |
| 1883 | .35 | .48 | 1908 | .24 | .27 |
| 1884 | .26 | .475 | 1909 | .21 | .30 |
| 1885 | .21 | .30 | 1910 | Contract. | Contract. |
| 1886 | .20 | .26 | 1911 | .23 | .28 |
| 1887 | .19 | .21 | | | |

### TECHNOLOGY.

The mixture of oil and water running from the cooked fish in the presses is conducted into the first and uppermost of a set of tanks arranged one somewhat above the other. In this vat the mixture on standing a short time separates into a stratum of oil floating on an aqueous layer. The separation may be assisted by heating the mixture. For this purpose steam coils are provided. The oil thence is allowed to flow by a suitable arrangement of weirs successively through the series of receptacles, in which by means of stronger heating by steam it is gradually purified from its contained water and small particles of flesh. The greater part of the fine particles of flesh separate in the first vat, settling to the bottom. This fine mush is known as "gurry," and sometimes is sold to the manufacturers of soap without further treatment, and in some cases is placed in stout canvas bags and subjected to pressure to recover the oil which it still contains. The residual solid matter is added to the scrap. As this is free from bones, its nitrogen content is correspondingly higher than that of the ordinary scrap.

The oil that has been put through the simple process of separation and purification described is run directly into barrels for shipment or into large storage tanks from which it is drawn off as desired for shipment. It usually is sold in bulk to oil refiners by whom it is prepared for the various uses to which it is adapted.

### YIELD.

The yield in oil varies (1) with the year, (2) more decidedly with the locality from which the fish are taken, and (3) most widely with the time of the year when taken. The fish taken in northern waters as a rule are fatter than those from southern waters. "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."[1] When the fish appear in the spring they frequently are so thin that no recoverable oil at all is obtained from them. The fish taken in the fall, on the contrary, yield on the average 12 gallons per 1,000 and frequently 15 gallons per 1,000. The variation in yield per thousand from year to year, therefore, probably is determined by the relative number of fish caught in the spring and fall.

### PROPERTIES AND USES.

Crude menhaden oil varies in color from light amber to dark brown. This wide range in color is due to the variation in the manner of treatment of the fish and the preliminary purification of the oil. Its viscosity is determined largely by temperature.

Formerly menhaden oil was used principally as an illuminant and in currying leather. In addition, it long has been used as a paint vehicle, as a lubricant, and as a soap-making grease. Its use in currying leather and as an illuminant has been supplanted to a considerable extent by that of mineral oils, while its employment in the other manners mentioned has increased. Large quantities now are used in the paint manufacturing industry and in tempering steel. For the latter purpose a large amount is sold directly to the manufacturers of steel articles.

Important contributions to the knowledge of fish oils as paint vehicles have been made by Toch.[2] This paint and oil specialist regards menhaden oil as the best of the fish oils. He differentiates

[1] Stevenson, loc. cit.

[2] Toch, J. Ind. Eng. Chem., 3, 627 (1911).

strictly between menhaden oil and other so-called fish oils, such as those obtained from the whale, porpoise, and seals, as those from the latter three sources lack those qualities possessed by menhaden oil to a marked degree, which would classify them as drying oils. Their admixture with drying oils, such as tung and boiled linseed oils, does not avail, for while they may appear to have dried they become sticky again in the presence of humid air.

In the subjoined table are given the specific gravities and iodine numbers of several oils commonly classed as fish oils. The iodine numbers are determined by the method of Hubl.

Table XIV.—*Specific gravities and iodine numbers of fish oils.*

| Kind of oil. | Specific gravity at 20° C. | Iodine number. | Kind of oil. | Specific gravity at 20° C. | Iodine number. |
|---|---|---|---|---|---|
| No. 1. Crude whale oil | 0.9195 | 136.1 | Menhaden oils: | | |
| No. 1. Filtered whale oil | .9168 | 125.0 | Extra bleached winter | 0.9237 | 150.4 |
| No. 2. Filtered whale oil | .9187 | 142.9 | Bleached, refined | .9273 | 161.2 |
| Cod oil | .9196 | 147.3 | Regular | .9249 | 165.7 |
| Porpoise body oil | .9233 | 132.3 | Dark brown | .9250 | 154.5 |
| Seal oil, water white | .9227 | 143.0 | | | |

The authority quoted says further:

The oil that gives the best and most lasting results for paint purposes is the menhaden oil, and the winter-bleached variety is the one that should be recommended. This is an oil fairly pale in color, with an iodine number of 150 or over, and with little or no fishy odor; in fact, I might say that in the purchasing of fish oils for paint purposes it is well to beware of a fish oil that has the so-called characteristic fishy odor. I have not yet satisfied myself as to the cause of this odor, but, so far as I have reached in my investigation, I am inclined to believe it is due to phosphorous decomposition compounds. The results which I have obtained from the proper grades of fish oil—and I am glad to say that there are several manufacturers sufficiently intelligent to market the oils that are very desirable—warrant me in saying that fish oil in the hands of an intelligent manufacturer, and used up to 75 per cent, produces excellent results for exterior purposes. For interior purposes fish oil does not seem to be desirable, for it gives off noxious gases for a long time.[1]

It is recommended that for exterior work three parts of fish oil be mixed with one part of linseed oil. The mixture is nonhygroscopic—when dry it remains dry—and the results obtained with it are described as excellent and lasting. The iodine number, it is maintained, is an index of the suitability of fish oils for paint purposes. It profitably may be substituted for linseed oil in a number of applications. It is more resistant to the action of heat than linseed oil, and hence is especially adaptable to use in painting ironwork such as boiler fronts and smokestacks. It holds up better in a moist climate, such as that existing in proximity to the seashore. Its use is

[1] Toch, loc. cit.

recommended especially for replacing linseed oil in the manufacture of patent leather and similar products and printing ink. The patent leather resulting is more flexible and less liable to crack, though it possesses a somewhat less glossy surface. An objection to its use in this manner, however, is a peculiar efflorescence which its presence causes to form on the surface of the preparation. Its moderate use in the manufacture of baked japans also has been found highly advantageous.

Menhaden oil should, of course, be used with a drier, and for that purpose the best results are obtained by means of a tungate drier. A tungate drier is one in which tung oil, or China wood oil, is boiled with a lead and manganese oxide, and when the solution is complete this is then mixed with a properly made resinate of lead and manganese. Such a drier becomes soluble in the oil at temperatures over 100° C., and hardens the resulting paint very thoroughly. For fabrics, however, fish oil must be heated to a temperature of over 200° C., and if air is injected at such a temperature the glycerides are expelled and thick oil is produced which, in conjunction with the drier just named, is equally good for printing inks. It is advisable, however, to add at least 25 per cent of either a heavy bodied linseed oil or a raw linseed oil which does not break before the manipulation just referred to is begun.[1]

The manipulation requisite on the part of the manufacturers to render their oils immediately usable for paint vehicles involves merely the addition of the drier and boiled linseed oil to the fish oil. The product should be sold directly to the paint manufacturers. The advantages gained are a higher price gotten because of this manipulation and because of the elimination of the middleman, and the assurance which the paint manufacturer has that the oil purchased directly from the manufacturer of fish oils probably is the pure product.

In this connection it should be added that undoubtedly there are certain other ways, and probably many more, in which the value of the menhaden oil easily might be enhanced. The considerable portion of the time when, because the fish-rendering plant is lying idle, the employees are unoccupied, should make it possible for the operators to expend more labor on their oil with a view to the improvement of its quality, and to manipulate it to render it suitable for special purposes, without greatly adding to the cost of manufacture.

[1] Toch, loc. cit.

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