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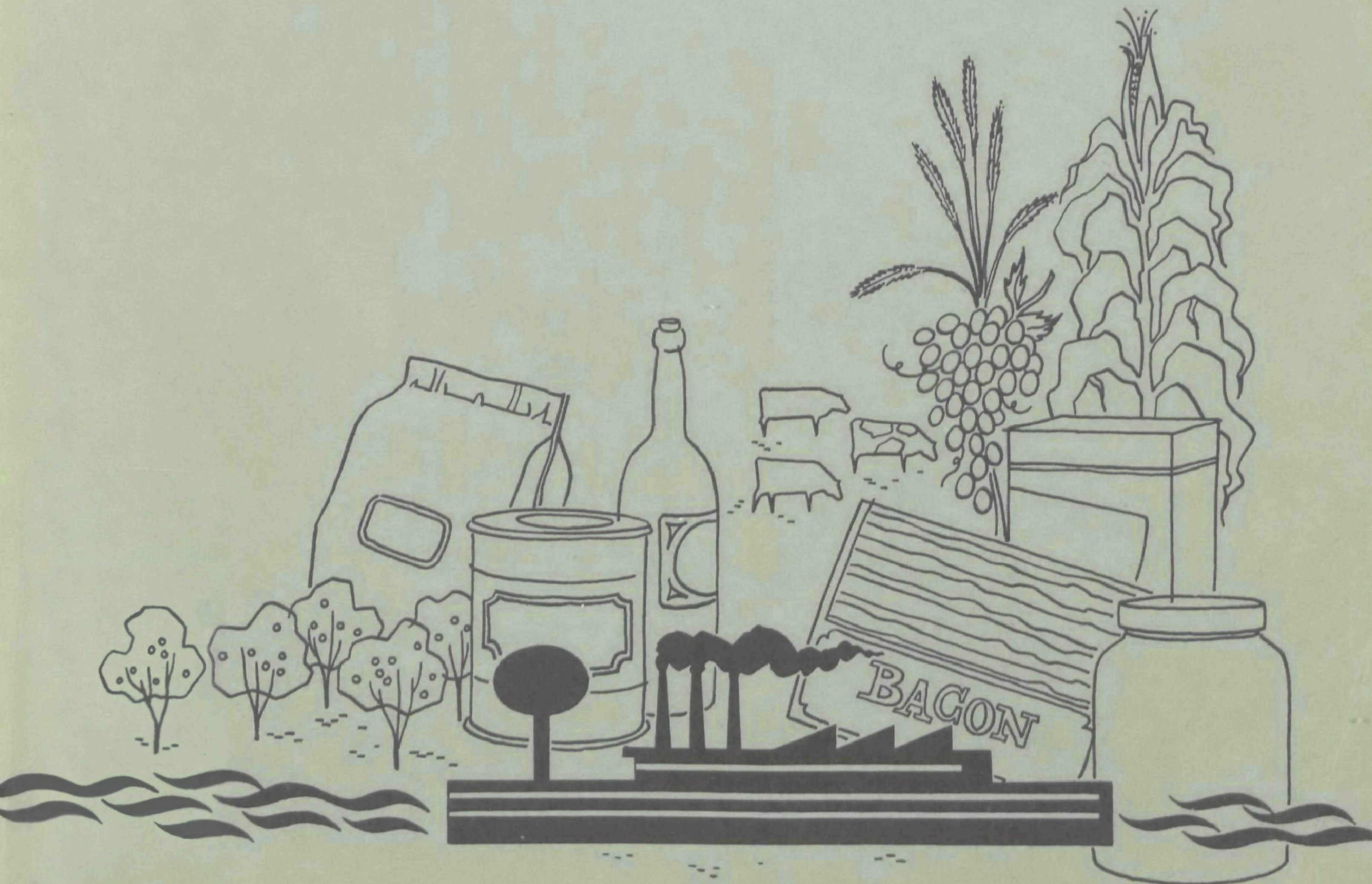
Current Practice in Seafoods Processing Waste Treatment



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Current Practice in Seafoods Processing Waste Treatment

by

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ABSTRACT

This report contains discussions of the processing of the major United States seafoods species, the resultant wastewater strengths and flows, solid wastes magnitudes, current treatment and by-product recovery methods, and current and recommended research in water pollution abatement. The geographic distribution of fish and shellfish landings and products is described. The report is based on a comprehensive literature review and extensive on-site investigations of current research, processing and treatment activities in the major seafoods centers of the United States.

This report was submitted in fulfillment of Project 12060ECF under the partial sponsorship of the Federal Water Quality Administration.

Key Words: By-product, canning, characterization, disposal, fish, food processing, freezing, industrial wastes, processing, research, seafoods, shellfish, state of the art, treatment.

CONTENTS

FIGURES

TABLES

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The survey of the seafoods industry and the concomitant literature review demonstrated generally that the water pollution problems generated within the industry are, with a few isolated exceptions, not as critical as those of some other industries. There are two basic reasons for this conclusion. First, seafood processing plants generally discharge their wastes into estuaries or open waters, which often results in considerable dispersion and dilution. In those marine environments which are well mixed, the soluble pollutant levels are quickly reduced. Secondly, in many cases the processing plants are located in sparsely populated areas where other industrial wastes and domestic wastes are of limited magnitudes, minimizing the competition for the assimilative capacities of the watercourses. This is not to say that seafoods processing pollution problems can be justifiably ignored; it is to say rather that it is possible, indeed advisable, to attack the problems directly and develop reasonable solutions systematically and in a rational manner.

In the opinion of the authors, based on personal experience and the concensus expressed in the literature, seafoods wastewaters are readily amenable to biological treatment and should present no special difficulties from the standpoint of toxicity. The problem with treatment and/or utilization, therefore, remains basically one of economics, not of technology.

Economics also seems to be the major concern in the disposal of solid wastes. Solid wastes, unlike most liquid wastes, are of potentially significant economic value and this potential should be recognized and exploited wherever possible in future research and development efforts.

The seafoods industry consists of a myriad of processing centers located along United States coastlines. The plants are frequently autonomous, intensely competitive, and notably lacking in cooperative spirit. Common problems are seldom handled jointly. Organizations such as the National Canners Association, National Fisheries Institute, Pacific Fisheries Technologists and others are striving to reverse this trend, but with only limited success to date. One outstanding exception to this pattern is the current cooperative effort being mounted by the crab processors of Kodiak, Alaska. This undertaking involves the common collection of solid wastes followed by utilization and disposal at a single sanitary landfill. Hopefully, this activity is indicative of a developing awareness within the industry of the advantages of attacking in concert the water pollution problems common to all.

The lack of geographic concentration of the industry will tend to influence the types of research undertaken. Solutions which rely on combining the effluents (or solid wastes) from several plants or that from a single plant with the wastes of a sizable municipality, will not always be appropriate. Many of the major offenders are remotely located, with few, if any, other industries near at hand, and with only a handful of residents nearby, most of whom are employed by the cannery. This situation, of course, is not always the case, but nonetheless, is common enough to warrant consideration.

The diversity of the industry is an added factor which must be considered when planning waste utilization and treatment research. Unlike some of the single-commodity food processing industries, the seafoods processors produce wastes which, while all highly organic and nitrogen-rich (excluding cooling waters), vary from negligible quantities to staggering volumes.

Funding alternatives, both for research and for the ultimate full-scale utilization of the research findings, are an especially important consideration in this case. The industry, as most of the foods industry, is a characteristically low profit margin enterprise. This fact, compounded by the current stationary production posture and increasing pressures from foreign competitors has already forced many small plants to discontinue operation. Significant increases in expenses, whether for in-house research or water pollution control, are likely to be untenable to many of the remaining smaller processors. Public research and demonstration project funding and treatment facility subsidies (in the form of tax credits or similar arrangements) will probably be necessary to permit the industry to survive in its present form.

Recommendations for Solid Wastes

Waste solids probably present the most serious pollution problem to the seafood industry. Disposal into estuarine environments can produce serious esthetic, physico-chemical and ecological damage, an extreme case being the Kodiak Harbor example (see page 55). Dictates of pollution control agencies in the near future will undoubtedly limit discharge of solids in areas now using this method of disposal. Therefore, research is required on solids removal, by-product utilization and disposal methods.

Solids removal. Past research has shown that the most effective on-site solids removal systems are screening and flotation; flotation is undoubtedly the more expensive. However, with biological treatment requirements to be imposed ultimately, the higher BOD removals attainable with flotation may offset the added expense. More pilot plant or full-scale unit operation data from these two processes, including removal efficiencies and cost comparisons, are required.

The ideal solution to the solids problem is disposal at sea, as is commonly practiced in some areas for scallops, halibut viscera, and shrimp heads. Floating canneries are just now being placed into operation (59). Other possibilities of dressing fish and shellfish on-board ships should be encouraged by the Bureau of Commercial Fisheries and the FWQA jointly. The economic advantages of these systems from the standpoint of wastes reduction should not be overlooked when their performances are analyzed. These advantages definitely should be analyzed with an eye to future, more stringent water pollution control standards; not simply those regulations now being enforced.

By-product utilization. The manufacture of by-products from solid residues has been extensively researched, especially with regard to salmon. An evaluation of these methods as potential waste reduction techniques leads to the conclusion that only those which utilize all or most of the solids are helpful. Animal feeding and other whole-waste utilization methods should be stressed.

Work with flesh separators, for instance, has indicated, at least in a preliminary fashion (26), that significant solids recoveries can be realized. Perhaps full-scale demonstration of this concept should be encouraged. Similarly, the high-speed meal plant data discussed on page 117 (57) could be applied to fish waste utilization and the economics compared with those of conventional disposal methods.

Perhaps more basic by-product development work is needed in the crab and shrimp industries, but, in general, the economic aspects of the operations should be emphasized. Market surveys are needed and transportation alternatives should be evaluated to determine the economic feasibilities of various approaches.

Disposal methods. Landfill of waste solids will undoubtedly become the most common method of disposal because of its lower costs. The isolated locations of many seafood processors will encourage this method. No technical problems are foreseen for areas where suitable land is available.

Deep sea disposal by barging will probably be another popular choice. This method is sometimes used in coastal communities for digested sewage sludge disposal. Due to the short seafood processing seasons, the possibility of harm to the marine ecology would be minimized. Direct disposal, either in a landfill or at sea, should only be considered as a last resort, but in instances in which deep sea disposal is the only acceptable alternative, perhaps investigations of methods, economics and consequences should be carried out.

Incineration could effectively reduce waste solids volumes, but cursory economic considerations indicate that this method would be prohibitively expensive.

Recommendations for Wastewaters

Wastewater disposal for the seafoods industry will be a difficult problem in the future. To solve this problem research is required on environmental effects of partially-treated waste discharge, reduction of water usage, wastewater characterization and evaluation of treatment processes.

Untreated discharge. Wastewaters from seafoods processing are currently discharged untreated in all geographic regions of the United States. In many cases these discharges create no visible signs of adverse effects on the environment; in others the effects are serious. It is the opinion of the authors that the discharge of wastewaters should be allowed if solids are removed, domestic treatment is not available, and serious problems do not result.

Most states' water quality standards are phrased in terms such as "...water quality shall not be impaired to the detriment of legitimate existing or forseen water uses...". Since a treatment facility design is based on anticipated efficiencies (in terms of BOD and suspended solids removals), the level of treatment must be pre-defined. This requires a thorough knowledge of the effects of the wastes on the aquatic environment. Therefore, studies of the effects of seafood plant wastes on marine and estuarine environments should be conducted. In-depth investigations of dissolved oxygen depletion, temperature effects, benthic disturbances, tidal effects, effects on primary and secondary productivity, effects of highly variable and shock loadings, degree of and rate of off-season recovery and many other variables should be conducted.

Reduction of water use. The seafood industry uses large quantities of water, especially sea water. When, in the future, treatment of these wastewaters in municipal plants is required, the sea water flows will usually necessarily be eliminated and fresh water quantities reduced. Detailed studies should be undertaken to recommend processing alterations necessary to implement these requirements.

Characterization. Before demonstration-scale projects can be intelligently designed the designer must be familiar with the characteristics of the wastewaters with which he is dealing. Definitive studies of seafoods processing wastes are scarce, especially for shrimp and crab processing. Further work in this area should be supported.

Treatment processes. The applicability of standard treatment methods is generally well accepted, but has not been sufficiently demonstrated; nor have the optimum operational characteristics been defined for each major type of primary and secondary process. This should be done at full (demonstration) scale for sedimentation, flotation, biological filtration, perhaps activated sludge and ultimately aerobic and anaerobic digestion.

Joint municipal-industrial waste treatment should be utilized whenever practical, for the same advantages inherent in joint treatment of other industrial wastes apply here: dilution, equalization, the economies of size, etc.

Innovative techniques and new treatment methods, while not critical to the immediate solution of the problem, should nonetheless, be encouraged.

Priorities

The authors have rated the recommended research projects listed in the preceding section in the following order of importance:

1. Determination of removal efficiencies and economic factors of flotation and screening for on-site solids removal.

2. Characterization of seafood processing wastewater flows.

3. Evaluation of and/or development of process alterations to reduce wastewater flows.

4. Determination of economics of various methods of solid waste disposal (such as landfill, deep sea disposal or incineration.)

5. Demonstration of applicability of standard treatment methods.

6. Investigation of the effects of seafood wastes on the estuarine environment.

7. Determination of economics of various solid waste utilization techniques and markets available.

INTRODUCTION

The present fish, mammal and shellfish harvest from the ocean is approximately 60 million tons per year (1). Ninety percent of this catch is comprised of fish, the remainder being whales, crustaceans and mollusks. From 1850 to 1950 the world harvest increased at an average rate of 2.5 percent per year. During the 1950's and 1960's this rate jumped to 5 percent per year (1). Some observers believe that even with present methods of fishing, the yield can be increased 5 to 10 times. Other more conservative analysts estimate a possible increase of 2 to 3 times the present yield (2).

The recently increased catches were distributed among several nations, mainly Peru, Japan, and the Soviet Union, as shown on Figure 1. However, the annual catch in the United States has been declining; since 1962 a 20 percent decrease in U.S. fish harvests has been realized. The reasons given for this decrease include low harvesting efficiencies, inadequate and expensive labor supplies and governmental restrictions (3). Thus, based on recent performance, this industry is not expected to expand rapidly in the near future.

The annual U.S. catches (cleaned) average approximately 4 billion pounds (4). These fish are utilized as follows: 35 percent are rendered, 30 percent are marketed fresh, 20 percent are canned, 10 percent are frozen, 1 percent are cured and the remaining 4 percent are handled by miscellaneous means (5). Frozen fish products have been increasingly popular items and a 150 percent increase in frozen fish sales in the next 15 years has been predicted (6).

The U.S. consumption of fishery products has continued to rise, as shown on Figure 2. However, this increase has been supplied by imports. The increase in consumption has been almost totally due to the population increase; the U.S. per capita consumption of seafood products has remained at approximately 11 pounds per year for the past 20 years (4).

Significant portions of the fishes and shellfishes processed are wasted. These percentages of wastage range from zero for whole-rendered fish such as menhaden to 85 percent for some crabs. The average wastage for all fish and shellfish is about 30 percent. In addition to the large volumes of solid wastes, large wastewater flows result from the butchering, washing and processing of the product. The volumes of solids and wastewater vary widely with species and processing method.

Using the average 30 percent wastage value, one can calculate the total annual volume of solid wastes generated to be roughly 1.2 billion pounds. A large portion of these wastes is rendered for animal feeds; the remainder is discarded to municipal or private disposal sites or to adjoining waters. The pollutional strength per pound of fish waste solids has been estimated as 0.2 pounds of five-day biochemical oxygen

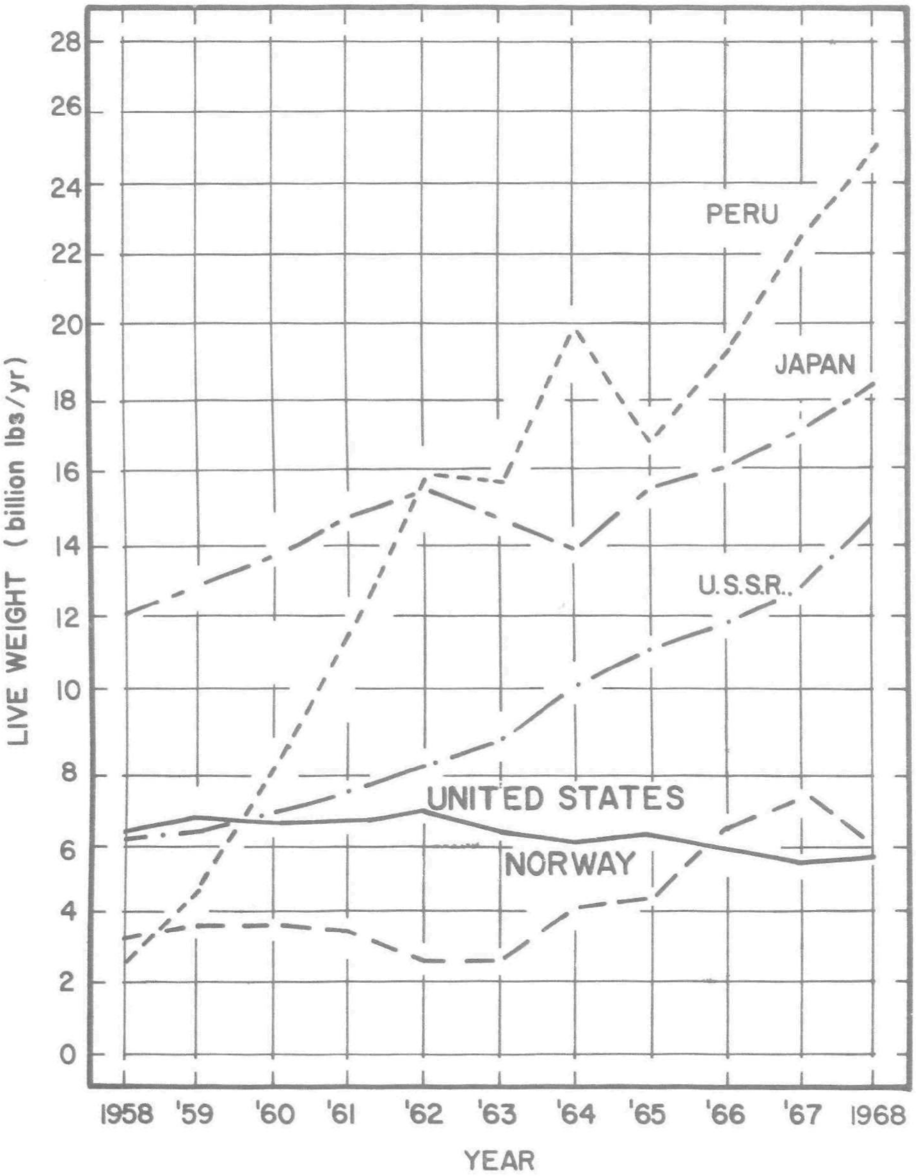

FIGURE I. WORLD CATCH, BY LEADING COUNTRIES, 1958-1968 (4).

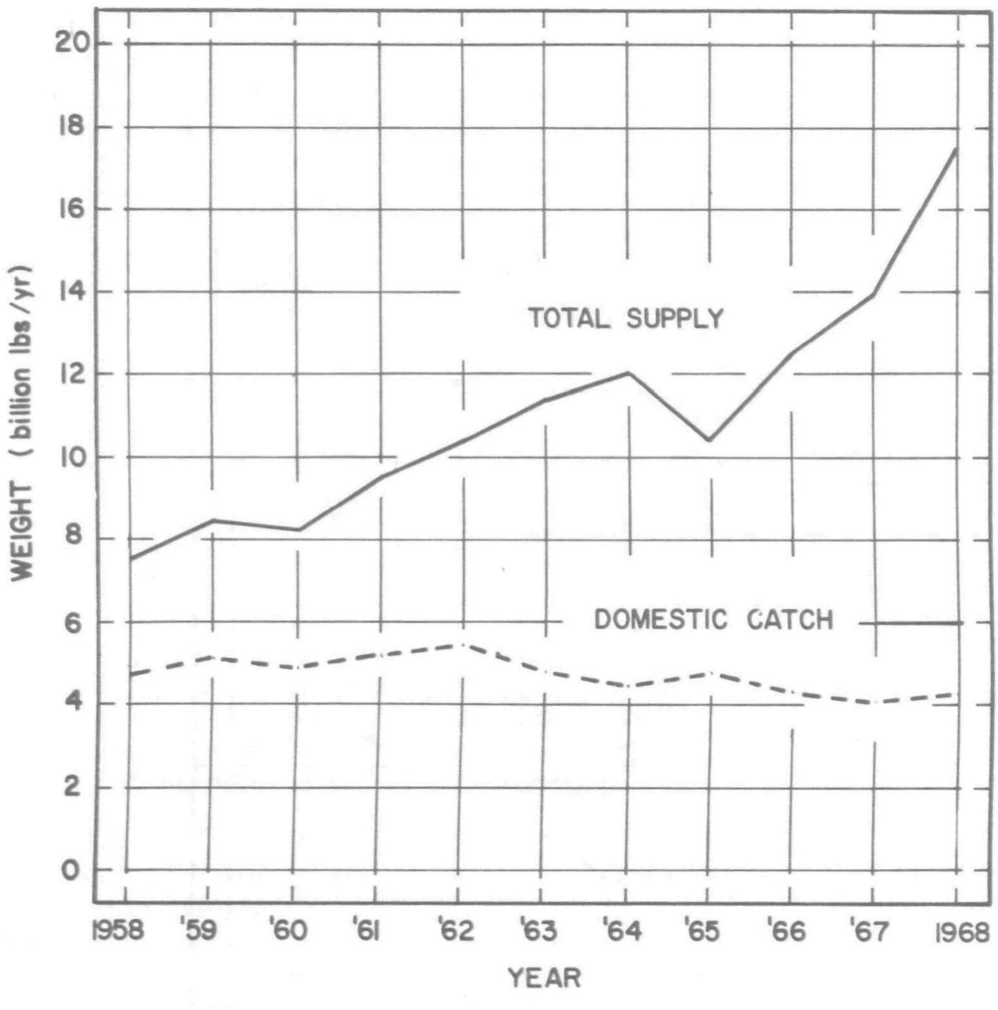

FIGURE 2. U.S. TOTAL SUPPLY OF FISHERY PRODUCTS 1958-1968 (4).

demand (BOD_5), or approximately 1 daily population equivalent (7). Thus, assuming that 50 percent of the fish wastes are rendered, the population equivalent of this industry is two million people. The population equivalent of fish processing wastes, solid and liquid, has been estimated by another source to be from 66 to 1020 per ton of fish (8). On a national basis, the population equivalent (based on these figures) can be calculated to be 0.23 to 3.6 million. These figures are deceptively conservative, for a major segment of the U.S. seafoods production takes place during short seasons, intensifying the problems. The industry is not typified by a constant output month after month.

The fish processing wastes problem has become serious in certain areas. Waste treatment will often be necessary in the future to meet federal and state water pollution control regulations. The purpose of this report is to evaluate the present state of the art of fish processing waste treatment and by-product recovery and to suggest research necessary to advance this technology to meet future needs.

THE INDUSTRY BY SPECIES

Bottom Fish

The most important bottom fish species are listed by Slavin and Peters (9) as haddock, cod, ocean perch, whiting (silver hake), flounder, hake and pollock. Halibut are regarded technically as bottom fish, but will be considered separately. Approximately 80 percent of the industry is located in the North Atlantic region.

Processing

The fish are usually caught in otter trawls. In a typical operation the fish are spread upon the trawler deck, sorted and iced. Perch, flounder and whiting are stored whole, whereas cod, haddock and pollock are sometimes eviscerated on deck. The viscera and blood are washed overboard.

At the wharf, unloading is usually accomplished by pitching the fish into a basket that has been lowered into the hold. The fish are then weighed, washed and iced in tote boxes. In some larger plants, mechanized unloading methods are used to maintain quality.

In small plants, the fish are processed by hand. The fillets are cut on a wooden board next to a sink, washed and immediately iced in boxes for distribution.

Most plants processing fillets use mechanized equipment. First, the fish are washed by water sprays in large rotating tumblers. Next the fish pass to filleting machines or hand-filleting tables. Filleting machines only operate on certain fish sizes and shapes, but considerably reduce labor costs and increase yields, over hand-filleting. The skin is removed from the fillet by hand or machine. The solid wastes from filleting and skinning operations are usually rendered for pet food or animal meal.

Figure 3 outlines a typical bottom fish filleting operation. On this figure (and subsequent flow sheets) the product is depicted (in black) as flowing through the unit operations from the top of the page to the bottom. The water, wastewater and solid waste flows are depicted on the diagram as flowing from left to right. The liquid flows are shown in red; the solid in black. Where one flow is indicated as dividing and moving in two different directions, as are the cases with liquid wastes and with some solid wastes, this is meant to illustrate that either route (or, in some cases, both) may be followed. Wastewaters from a bottom fish filleting process, for example, may be treated or may pass directly to the receiving waters.

The skinned fillets are transported by conveyor belt through a washing tank and, in some cases, a brining tank. After inspection the fillets

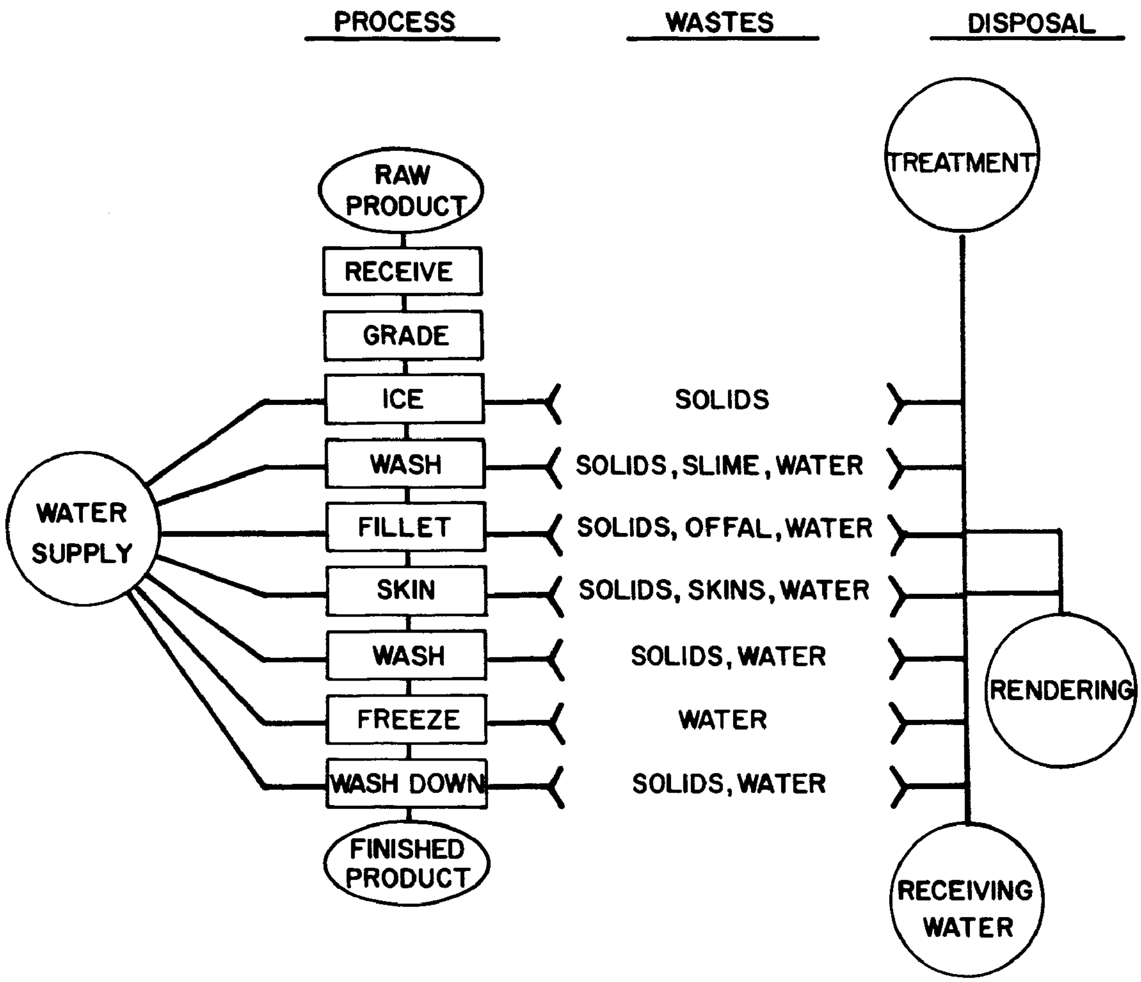

FIGURE 3. BOTTOM FISH FILLETING (10).

are packed into containers by hand or frozen and then packed. Fillets are marketed frozen (fresh or breaded), chilled, or fresh.

Steaks are cut from the eviscerated fish perpendicular to the backbone. These steaks are marketed frozen or fresh.

Recent Catch and Product Quantities

The Bureau of Commercial Fisheries listed recent U.S. catch statistics for several bottom fish species as shown on Table 1. In 1968 the catch exceeded 465 million pounds with a value of 46 million dollars. The Atlantic yield contributed 192 million pounds or 41 percent of the total catch.

Table 1. Recent Bottom Fish Catches (4).

	1967		1968		5-Year Average (1962-1966)
Species	Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)
Bass, striped	10.5	1.7	11.2	2.3	8.7
Blue fish	4.3	0.5	5.3	0.8	5.3
Butterfish	5.3	0.5	3.4	0.4	8.2
Cod, Atlantic	44.4	3.6	48.6	3.5	41.6
Croaker	2.5	0.2	4.6	0.4	3.1
Cusk	1.7	0.1	1.5	0.09	2.1
Flounder	112.5	13.7	112.9	13.9	124.1
Haddock	98.5	11.1	71.3	9.3	131.6
Mullet	34.3	2.4	30.5	2.6	41.4
Ocean perch, Atlantic	71.4	2.8	61.5	2.4	97.3
Pollock, Atlantic	7.3	0.4	6.4	0.3	12.9
Porgy	19.8	3.2	14.5	2.5	38.2
Sea Bass, Atlantic	4.7	0.8	4.2	0.8	8.1
Snapper, red	12.9	4.3	11.5	3.7	13.4
Whiting	69.5	2.2	77.9	2.7	93.0
TOTAL	499.6	47.5	465.3	45.7	628.9

The same agency listed the production of packaged fillets and steaks from certain species of bottom fish in 1968 as shown on Table 2. No data were listed for the quantities marketed fresh.

Table 2. Packaged Bottom Fish Products, 1968 (11).

Species	Quantity (lbs x 10^6)	Value ($ x 10^6)
Cod	13.9	5.3
Cusk	0.5	0.2
Flounder	43.5	20.6
Haddock	22.3	11.2
Ocean perch		
Atlantic	15.6	4.0
Pacific	3.7	1.1
Perch, Pacific	0.4	0.1
Pollock	2.7	0.7
Sea bass	0.3	0.2
Snapper, red	0.4	0.5
Whiting	2.0	0.4
TOTAL	105.3	44.3

Projected Catches

The domestic supply of bottom fish fillets and steaks has been steadily declining since the 1940's (4). Production was at a low of 55,000,000 pounds in 1968 after a steady decrease from 140,000,000 pounds in 1949. During this same period imports rose from 48,000,000 pounds to 390,000,000 pounds. This happened during a period of expanding markets; several new products were successfully introduced. The major reason for the drop in domestic production seems to be lower fishing yields in Atlantic Coast waters.

Waste Quantities

In most filleting operations, the fish are not eviscerated. The unfilleted portions are discarded or recovered for by-products. Water is used continuously in the spray washers and during filleting and skinning for bacteriological control. Blood and small pieces of fish flesh are entrapped in this flow. Other waste flows include the packing ice and the cooling water (see Figure 3).

The Oregon State Department of Environmental Quality estimated the bottom fish solid waste fraction to range from 35 to 40 percent by weight (10).

Using the 40 percent value and noting that cod, haddock and pollock are eviscerated at sea, the total waste quantity for bottom fish in 1968 was calculated to be 140 million pounds, based on the data of Table 1.

Thurston (12) determined the composition of waste from sole and flounder processing. Composite samples were prepared from the nonedible parts of 214 fish. The average composition was: moisture, 77.4 percent; oil, 5.68 percent; protein, 13.6 percent; ash, 3.84 percent; sodium, 0.16 percent; and potassium, 0.22 percent. Although the nonedible parts of sole and flounder had lower values for protein and ash than did those of other salt-water species, they were judged to be of high enough quality for by-product utilization. The fish analyzed averaged 72 percent waste.

Needler (13) estimated filleted haddock to contain 51 percent waste.

Landgraf (14) found the composition of pollock fillet wastes from a spring Alaskan catch to be 79.7 percent moisture, 14.1 percent protein, 2.6 percent oil and 4.3 percent ash. The essential amino acid content was quite similar to that of beef liver.

Catfish

Since 1965 the production of farm catfish has increased steadily. Four species (channel catfish, blue catfish, white catfish, and brown bullhead catfish) have been grown and managed successfully in ponds. Catfish are considered a delicacy in the southern and south-central states and markets are continuing to expand.

Processing

Several authors (15, 16, 17, 18) have described in detail the raising of catfish in ponds. The process involves planting six-inch fingerlings which are fed a commercial feed ration until maturity. The fish are harvested by draining the ponds and are shipped alive in tank trucks to processing plants. Live hauling eliminates the need for meat preservation before processing, but generates the problem of disposal of the feces-contaminated holding water.

Figure 4 depicts the processing method and the wastes resulting. The fish are held in live tanks until processing, which results in more feces-contaminated water.

The fish are first stunned, commonly with electric shock, and then butchered. The butchering process, which includes skinning, beheading, and eviscerating,, can be either manual or mechanical. Catfish traditionally have been skinned before marketing. Research has shown this process to be necessary to reduce off-flavors in river catfish, but unnecessary in cultured catfish (19).

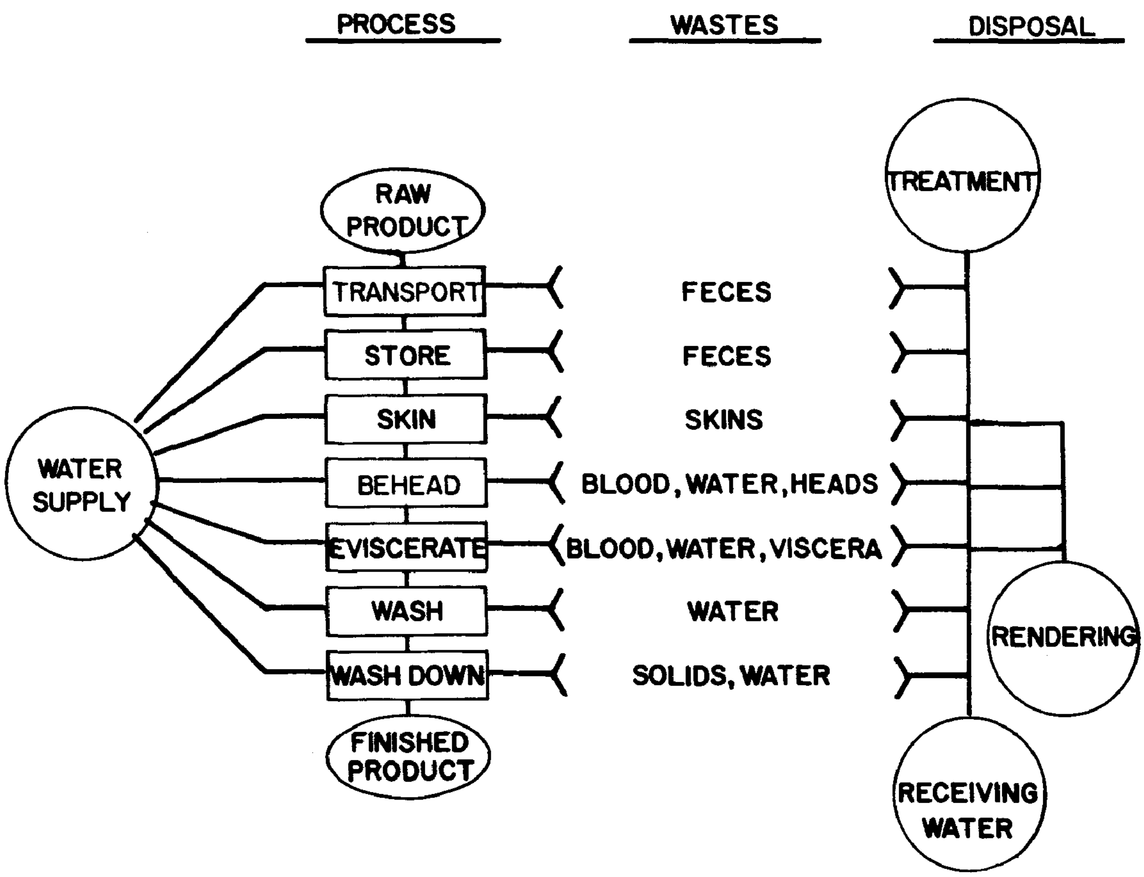

FIGURE 4. CATFISH PROCESSING (20).

Butchering machines remove only the outer layer of pigmented skin for esthetic reasons. This process results in solid wastes containing skins, heads and viscera and wastewaters containing blood, slime and flesh.

The processed fillets or steaks are marketed fresh and frozen (breaded or plain). Recently, liquid nitrogen freezing has proven successful in producing meats with improved quality (20).

Recent Catch and Product Quantities

The production of farm catfish has increased significantly in recent years, while the catch of "wild" catfish has declined slightly, as shown on Table 3. In 1968, the total harvest exceeded 64 million pounds (21).

Table 3. Recent Catfish Catches (21).

	1967	1968	5-Year Average (1962-1966)
Type of Catfish	Quantity (lbs x 10^6)	Quantity (lbs x 10^6)	Quantity (lbs x 10^6)
Wild	41.3	41.3	46.8
Farm	13.7	22.9	5.9
TOTAL	55.1	64.2	52.7

The Bureau of Commercial Fisheries (11) listed the 1968 total packaged production of catfish fillets and steaks at 133,000 pounds. In addition, considerable quantities of catfish were sold fresh locally or alive to commercial sport fisheries.

Projected Catches

Jones' projections of the catfish harvests of 1970 and 1975 (Table 4) indicate that catfish farming is a profitable industry and should increase in importance. Greenfields' economical analysis listed a 14 percent return on catfish farm investments for the central Mississippi delta states (17). The return, however, was very sensitive to price fluctuations.

Table 4. Projected Catfish Production (21).

Type of Catfish	1968 Quantity (lbs x 10^6)	1970 Quantity (lbs x 10^6)	1975 Quantity (lbs x 10^6)
Wild	41.3	45.0	47.5
Farm	22.9	48.0	93.8
TOTAL	64.2	93.0	141.3

Waste Quantities

Jones (21) estimated 45 percent of the whole catfish to be waste and the Bureau of Commercial Fisheries (22), 40 percent. Using the 45 percent value, the total waste quantity in 1968 was calculated to be 29 million pounds.

Several methods have been suggested for catfish offal disposal (20), and each should be considered on its economic merit. These methods include: rendering for pet food, catfish feed, fish meal and burial. Catfish offal has been rendered to a meal containing over 45 percent protein (23).

Crabs and Lobsters

The blue crab, which comprises 70 percent of the U.S. crab production, is harvested on the Atlantic Coast, principally in the Chesapeake Bay area (24). The remaining harvest takes place mainly on the Pacific Coast, where Dungeness crab is the leading species, followed by Alaskan king crab.

The lobster fisheries include the catch of the northern lobster of the North Atlantic region and the spring or rock lobster of the South Atlantic and Gulf states.

Processing

Crabs are harvested from shallow water in baited traps. Rapid and careful handling is necessary to keep the crabs alive; dead crabs must be discarded because of rapid decomposition.

At most plants, the whole crabs are steam cooked in retorts for 20 to 30 minutes (24). Pacific Coast Dungeness crab operations first butcher the crabs (remove the backs), and then cook them for 12 minutes or less.

Cooked crabs are marketed in the shell, butchered or whole, or the meats, picked from the shell, are marketed fresh, frozen, or canned. The majority of the Atlantic blue crab meat is marketed fresh or frozen, but the majority of the Pacific Coast crab meat is canned (25). A large quantity of Dungeness crab is sold in the shell and large quantities of king crab are butchered at sea (26); both practices minimize the quantity of butchering wastes to be handled at the processing plant.

The crabs are water cooled after cooking to facilitate handling. The backs are removed if the crabs were not butchered before cooking , and the remaining viscera are washed free. The cooking, cooling and washing waters contain considerable solids and organic pollutants (see Figures 5 and 6). The meat is picked from the shells by hand with a small knife. Mechanical methods have only recently been developed to extract the meat from the shells (28).

Crab meat quickly degrades in quality and must be chilled, frozen or canned. Chilled meats can be stored for only a few days; even frozen meats lose texture and flavor qualities rapidly. Canning of crab meat results in additional wastewater flows: retort and can cooling waters.

Lobsters are caught in large traps and must be kept alive until processed. Many lobsters are marketed alive. Some are shipped alive thousands of miles, carefully packed in moist seaweed and sawdust.

Lobsters are cooked, cooled and butchered in a manner similar to crabs. The cooking, cooling and washing waters are normally highly polluted (see Figure 7). A small number of cooked lobsters and meats are frozen for later marketing. Low storage temperatures and quick turnovers are necessary for maintenance of high quality. Little lobster meat is canned because of the rapid degradation of texture and flavor quality of the canned product.

Recent Catch and Product Quantities

Tables 5 and 6 list, respectively, the crab and lobster catches and the crab and lobster packs as reported by the Bureau of Commercial Fisheries. The total crab catch in 1968 exceeded 238 million pounds. By comparison the lobster catch was approximately 45 million pounds. The values of the crab catch in 1967 and 1968 demonstrated an instability in market prices. With a decrease in catch of 24 percent, the total value actually increased 47 percent from 1967 to 1968.

Projected Catches

Catches of the three main crab species seem to have reached a plateau. Production appears to be determined by the extent of the previous years' hatch. Future harvests should continue at levels dependent on survival of offspring.

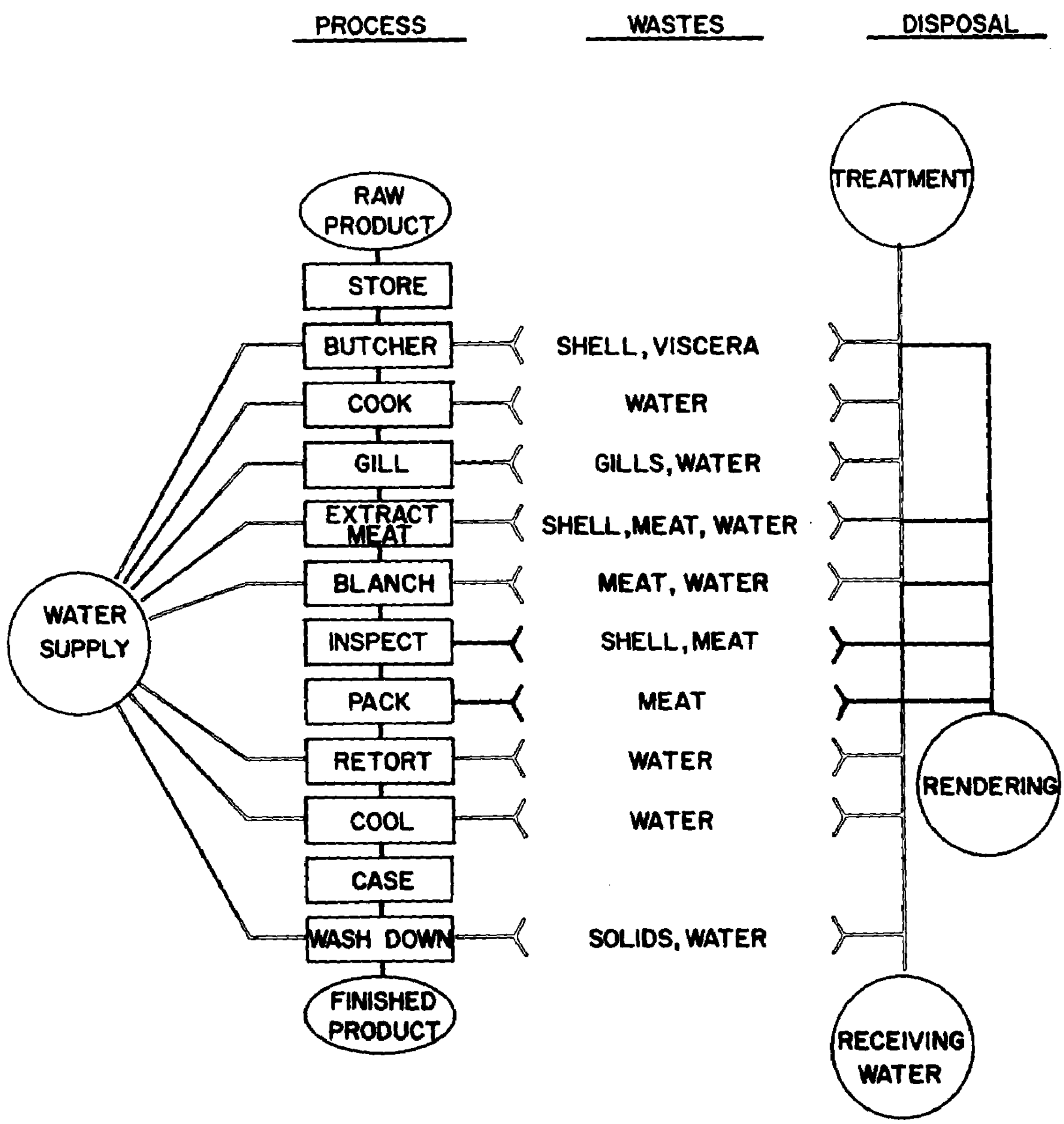

FIGURE 5. CRAB CANNING (27).

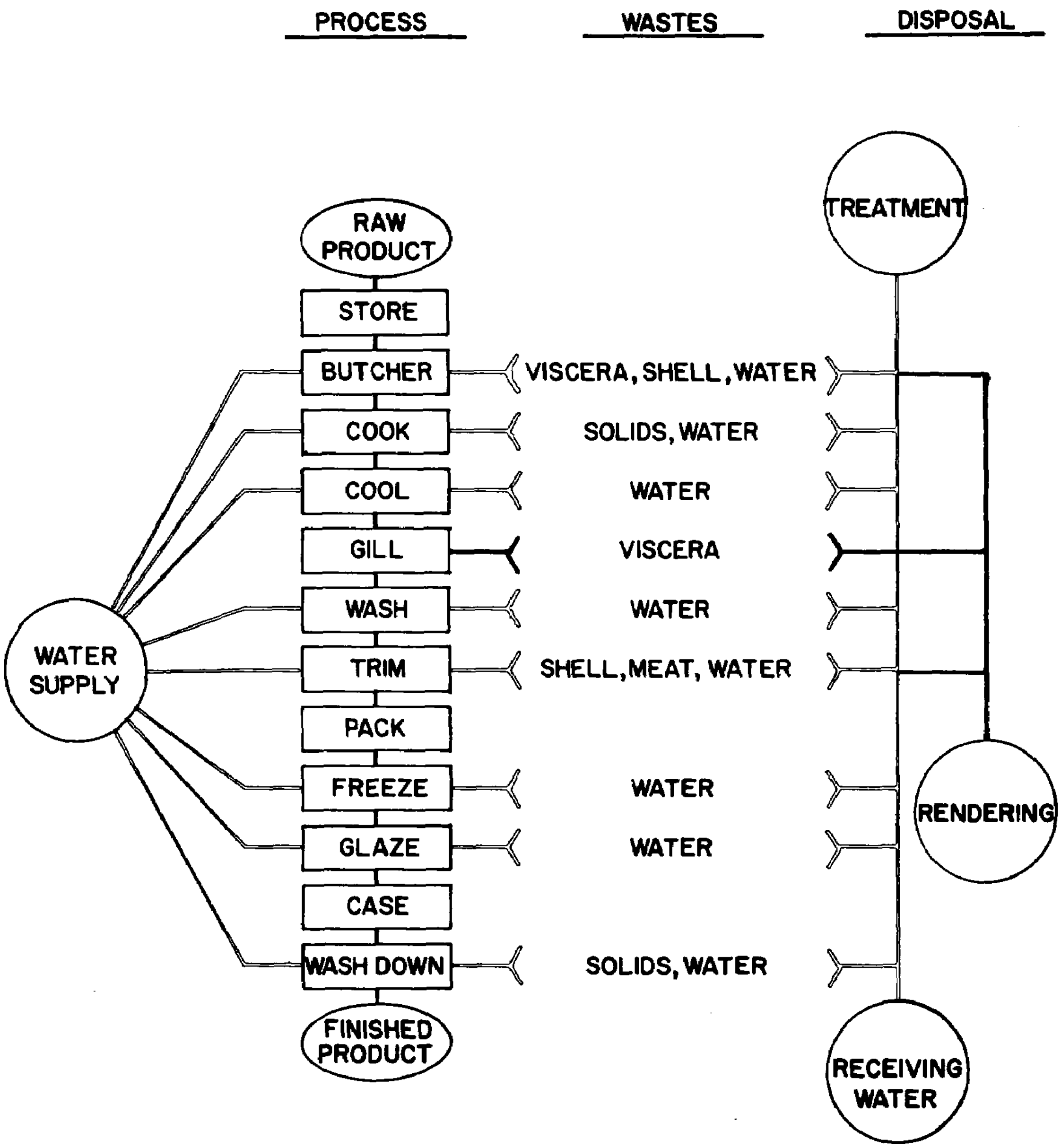

FIGURE 6. CRAB FREEZING (27).

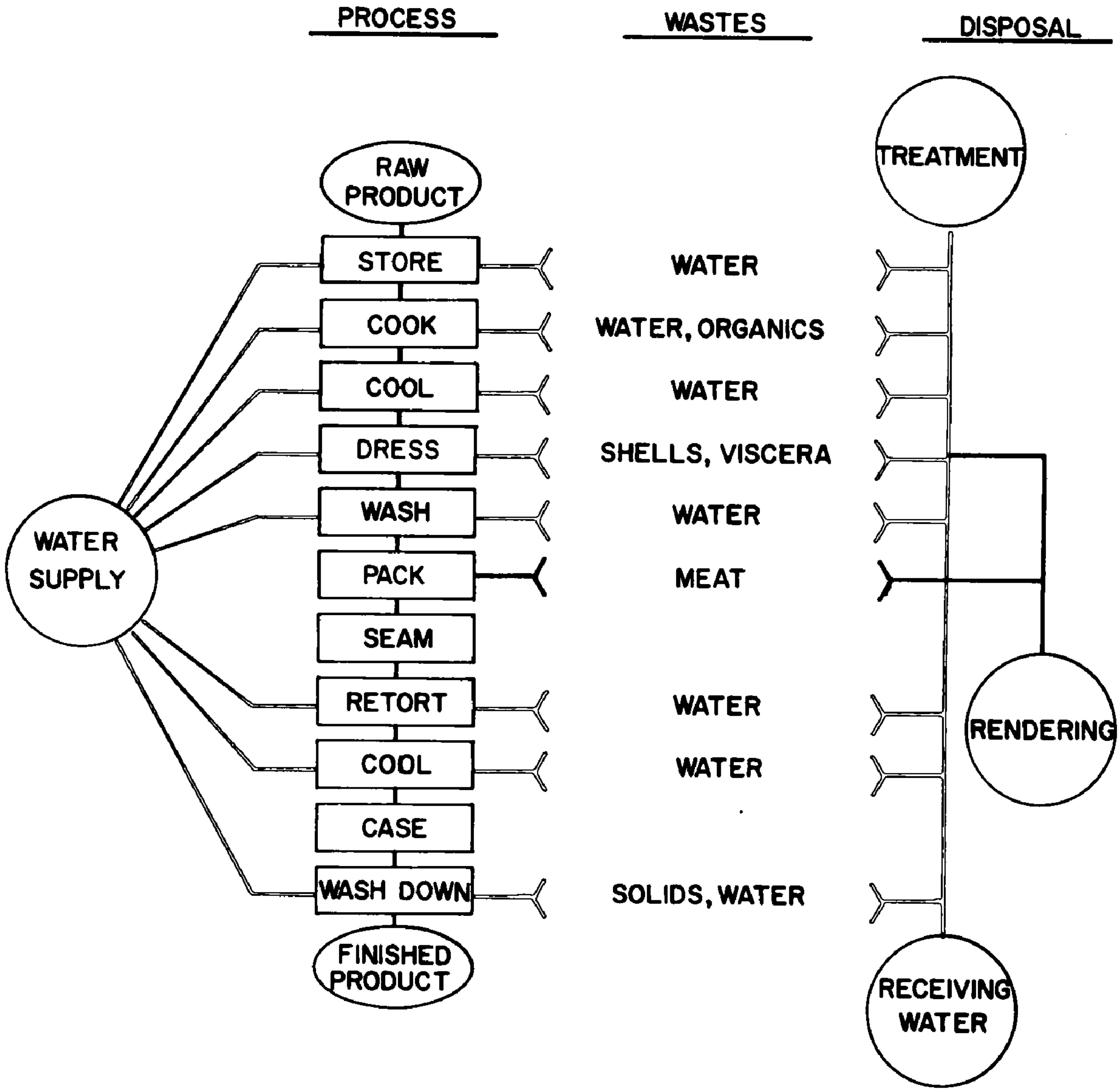

FIGURE 7. LOBSTER CANNING (25).

Table 5. Recent Lobster and Crab Catches (4).

Species	1967		1968		5-Year Average (1962-1966)
	Quantity (lbs x 10^6)	Value (\$ x 10^6)	Quantity (lbs x 10^6)	Value (\$ x 10^6)	Quantity (lbs x 10^6)
Crabs					
Blue	145.0	8.6	109.5	10.8	159.8
Dungeness	42.4	6.7	44.0	8.2	28.0
King	127.7	15.0	85.0	25.5	101.8
TOTAL	315.1	30.3	238.5	44.5	289.6
Lobsters					
Northern	26.7	22.4	32.3	25.2	30.1
Spiny	4.9	3.1	7.5	5.2	4.7
TOTAL	31.6	25.5	39.8	30.4	34.8

Table 6. Crab Meat and Lobster Tail Products (4, 29).

Species	Product	Quantity	
		1967 (lbs x 10^6)	1968 (lbs x 10^6)
Crab	Canned	9.7	3.8
Crab	Meat specialities	---	0.9
Crab	Frozen	6.6	6.7
Lobster, spiny	Frozen	0.3	0.5

Production of king crab may increase slightly due to stricter controls by the Alaska Board of Fish and Game (4). The controls established a king crab fishing season from five to seven months long in Alaskan waters. In 1969, all areas were closed from February 15 to August.

Tanner crab have been increasingly harvested in recent years as the king crab catch has declined. Abundant stocks exist off the northern Pacific Coast and production should rapidly increase (30).

Lobster utilization in the U.S. has apparently also reached saturation. Imports, furthermore, have been constant for the past five years at approximately 69 million pounds annually (4). A constant demand seems to exist, leading to stable market conditions.

Waste Quantities

The major portion of the crab is not edible, and, as a result, is wasted in processing. This waste consists of the shell and entrails, amounting to approximately 80 percent of the crab by weight. Large quantities of water are necessary for cooking, cooling and washing of the entrails from the body. The wastage of the total crab has been listed for blue crab as 86 percent (24); king crab, 80 percent (27); and Dungeness crab, 73 percent (31). Using these figures, the solid waste load from crabs in 1968 was calculated to be 190 million pounds as shown on Table 7. The actual waste volume from the processing plants would be less since some crab, especially Dungeness, are marketed whole or butchered to remove only the backs and entrails. As tanner crab harvests rise, the percentage wastage figures will increase proportionately in the North Pacific area, since the species yields less meat than the king and Dungeness crabs.

Table 7. Calculated Quantities of Crab Waste, 1968.

Species	Waste Fraction	Waste Quantity ($lbs \times 10^6$)
Blue	86%	94
Dungeness	73%	32
King	80%	68
TOTAL		190

The composition of shellfish waste is largely determined by the exoskeleton. The exoskeleton is composed primarily of chitin (a polysaccharide structural material), protein bound to the chitin, and calcium carbonate. While the major portion of the waste generally consists of exoskeletal materials, varying significant amounts of attached or unrecovered flesh and visceral materials are included.

The Ketchikan Technological Laboratory of the Bureau of Commercial Fisheries listed typical compositions of these wastes as shown on Table 8. The protein concentration is considered low compared to visceral fish wastes, discounting possible use as an animal feed.

Table 8. Typical Crab Waste Composition (32).

Species	Source	Composition		
		Protein (%)	Chitin (%)	$CaCO_3$ (%)
King crab	Picking line	22.7	42.5	34.8
Tanner crab	Leg and claw shelling	10.7	31.4	57.9
Tanner crab	Body butchering and shelling	21.2	30.0	48.8

Hoalihan (33) reported the cleaning loss of lobsters to be 80 percent. However, only a small percentage of the lobsters are cleaned before marketing; most are sold alive or cooked in the shell.

Halibut

The halibut is a large fish; the commercially-landed sizes vary from 20 to 50 pounds. They are caught near the sea bottom using baited longlines. The major halibut fishery is centered in the Pacific Northwest with the commercial season extending from April or May through October.

Processing

After being landed on the vessel, the halibut are dressed by removing the viscera and cutting away the gills. The halibut are then packed in ice in the hold. Halibut are ordinarily processed in relatively small plants. The fisherman usually unload and behead the fish before sale to the processors.

If the fish are not to be processed immediately, they are re-iced in the fish house (some are sold fresh, but most are marketed frozen). A continuous belt washer sprays the fish before freezing. The fish are frozen with a glaze protection at approximately -20°F. The filleting and freezing operations are diagrammed on Figures 8 and 9.

Halibut are cut into fletches (boneless and skinless pieces produced from fresh fish). This process divides the halibut into four or more trimmed meaty portions weighing from 5 to 20 pounds. The fletches are frozen and either glazed or packaged in moisture-proof wrapping. Other forms of fresh or frozen halibut include packaged fillets, roasts, and breaded fillets.

Recent Catch and Product Quantities

The halibut catch in 1968 was approximately 26 million pounds, off sharply from 1967, as shown on Table 9. The quantities of halibut fillets processed (in millions of pounds) were listed as 15.6 for 1967; 18.1 for 1968; and 22.3 for the 1962-1966 5-year average (4).

Table 9. Recent Halibut Catches (4).

1967		1968		5-Year Average (1962-1966)
Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)
39.8	6.4	25.7	4.3	43.0

Projected Catches

Jensen (27) estimated that halibut production in the near future will remain approximately at the 1968 level. This estimate was based on consumer demand, biological requirements for growth, and limits imposed by the International Pacific Halibut Commission.

Waste Quantities

Jensen (27) also estimated that 35 to 40 percent of the halibut is wasted. The viscera and gills are usually disposed of at sea; Dassow (34) estimated the remaining waste to be approximately 8 percent of the total weight. This included heads, skins, and fins. Using this 8 percent figure, the total waste in 1968 was calculated to be 2.0 million pounds. Stansby (35) estimated viscera to account for 2.5 to 5 percent of the total weight.

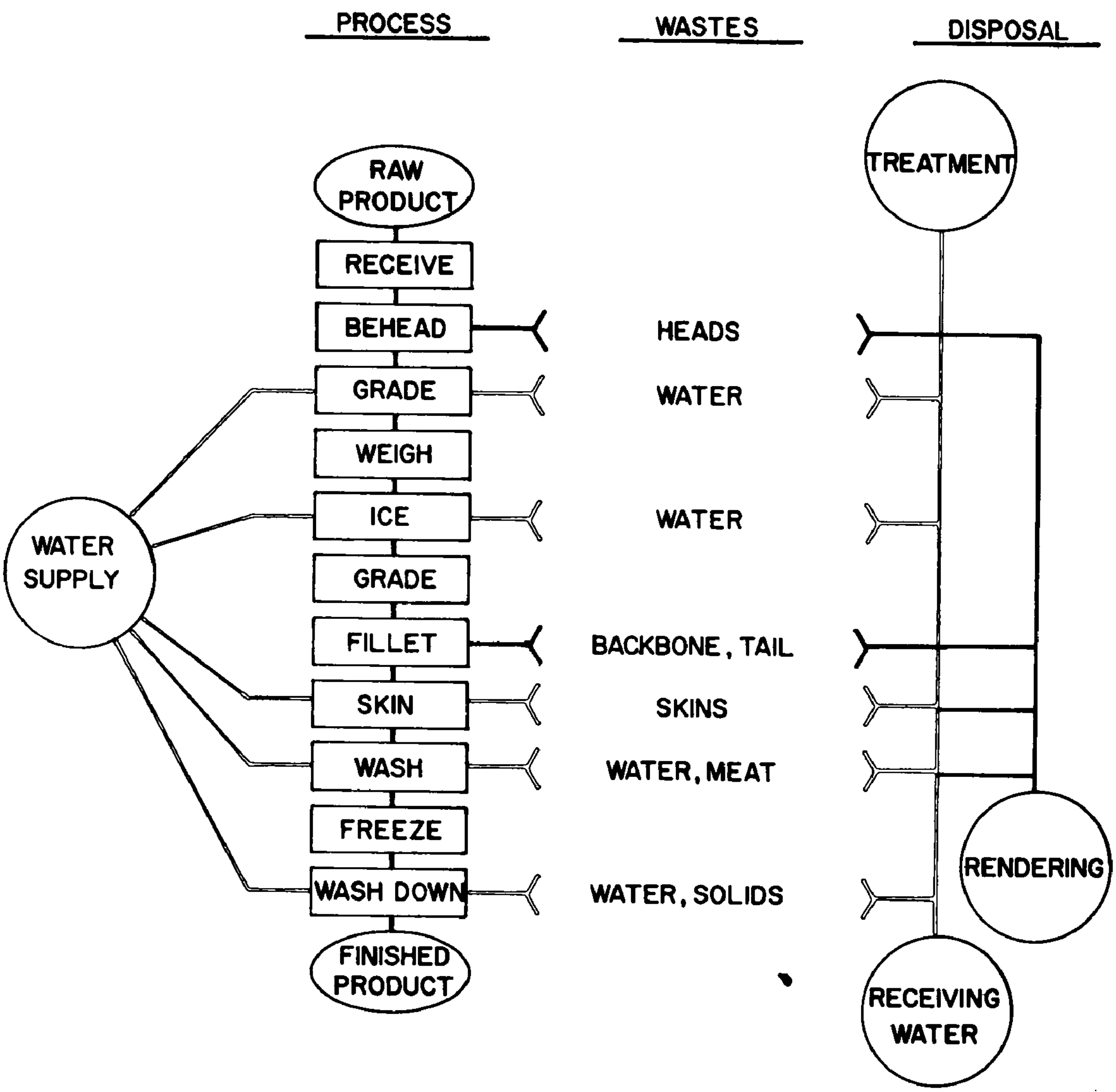

FIGURE 8. HALIBUT FILLET FREEZING (27).

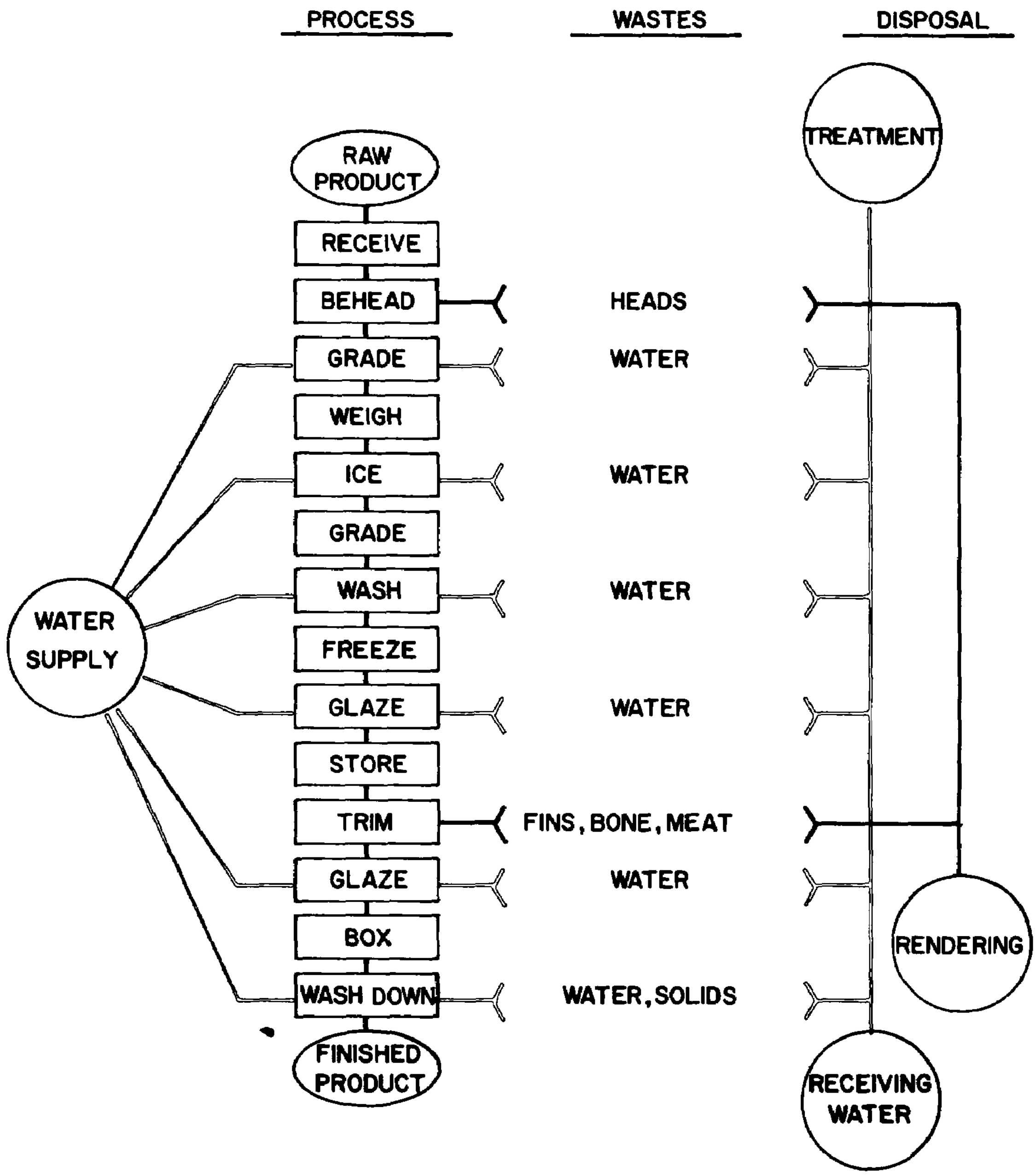

FIGURE 9. WHOLE HALIBUT FREEZING (27).

Menhaden

The menhaden is a small, oily fish of the herring family. This fishery, largest in the United States, is located mainly in the Middle Atlantic and Gulf states. Fishing normally takes place during the summer and fall.

Menhaden are used primarily for the manufacture of fish meal, fish solubles and oil. The process is (in most cases) highly mechanized.

Processing

Menhaden are caught in purse seines and loaded into the holds. Ice or refrigeration is used to preserve the fish if the trips exceed one day.

The fish are pumped from the holds, washed, automatically weighed and conveyed into the plant. Continuous steam cooking is normally employed. The fish are then pressed to remove the oil and most of the water. This press water is screened to remove solids and centrifuged to separate the oil. The remaining water, called stickwater, is discharged or evaporated to produce condensed fish solubles. The solid residual from which the water and oil have been pressed is known as pressed cake.

The pressed cake is dried to about 10 percent moisture and then ground for fish meal (36). Figure 10 shows the process as described.

Recent Catch and Product Quantities

The Bureau of Commercial Fisheries listed recent catches and production as shown on Tables 10 and 11. The catch volumes were large, over a billion pounds per year, but the unit price was low, approximately $0.13 per pound.

Table 10. Recent Menhaden Catches (4).

1967		1968		5-Year Average (1962-1966)
Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)
1,163.7	14.4	1,380.9	18.7	1,753.5

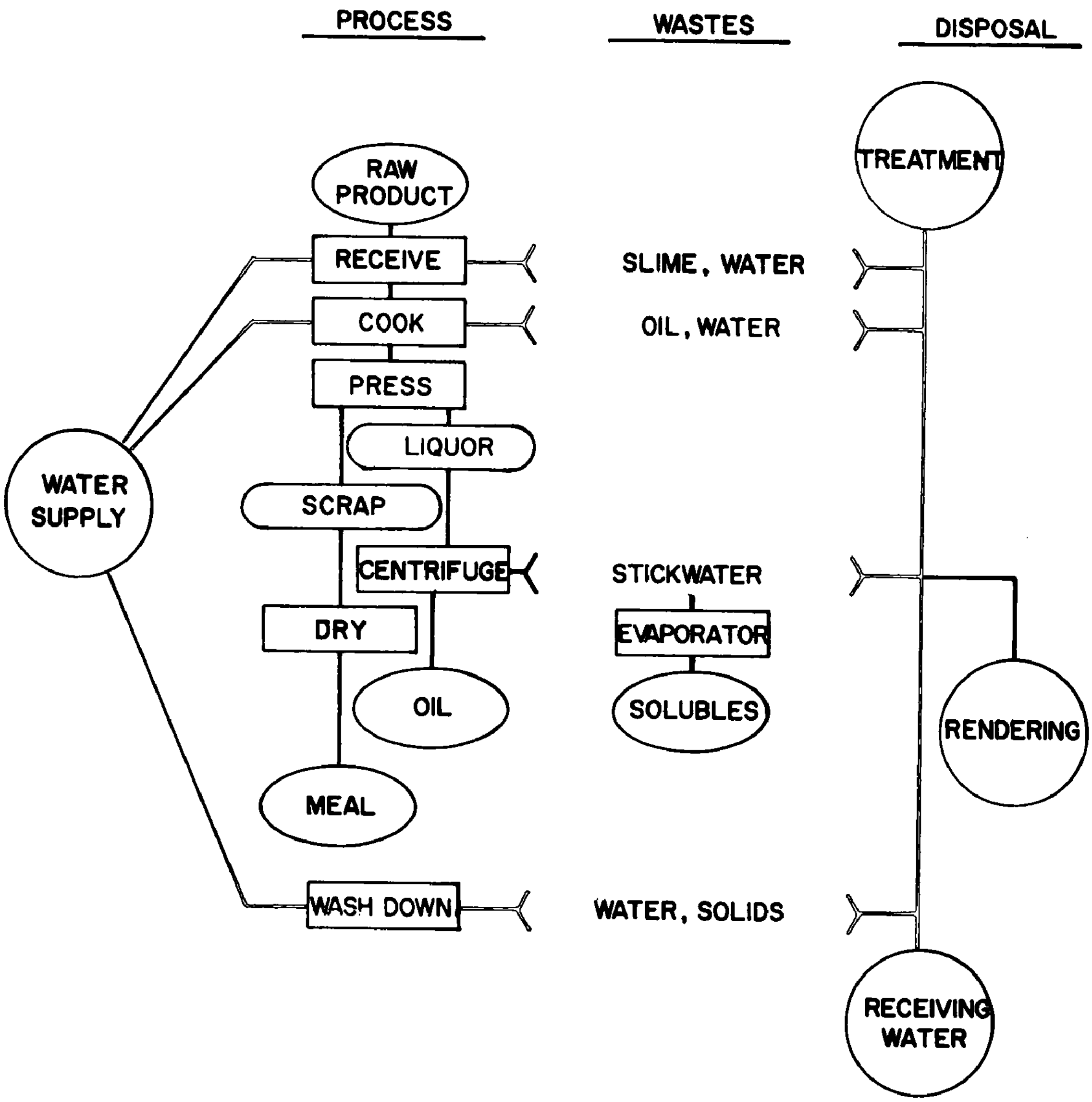

FIGURE 10. MENHADEN RENDERING (36).

Dried scrap and meal are the most highly valued products from menhaden, although oil production was the initial reason for processing. Most of the scrap and meal is used as an animal feed supplement.

Table 11. Menhaden Products, 1968 (37).

Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Dried scrap and meal	286.5	19.5
Oil	152.0	6.2
Solubles	106.5	2.7
TOTAL	545.0	28.4

Projected Catches

The menhaden fishing areas are largely fully exploited at present and the catch volumes in future years will depend on reproduction and survival factors.

Waste Quantities

In a properly managed menhaden processing plant, the quantities of waste should be small. The only inherently troublesome wastewaters are the fish pumping water and stickwater. The other wastes, listed by Paessler and Davis (38), result from spills and leakage which can be minimized.

In the past, stickwater was often discharged into the receiving waters, but now this practice is usually forbidden by law. Paessler and Davis listed the average BOD_5 of stickwater as ranging from 56,000 to 113,000 mg/l with solids concentrations to 5 percent (38). Fortunately, the fish processing industry has found the recovery of fish solubles from stickwater to be at least marginally profitable.

Oysters, Clams and Scallops

Oysters, clams and scallops are all bivalve mollusks. Harvesting results in large quantities of wastes and small quantities of highly-valued meat.

Processing

Oysters are marketed shucked or unopened (39). If marketed unopened, only washing, packing and chilling of the shellfish are required. Prior to shipment, the oysters may be stored in chlorinated water to minimize bacterial growth.

Most oysters are sold as shucked meats. The meats, when removed from the shells, are aerated in water to remove the sand and silt. After washing, the meats are graded and then packed into tins or glass containers (see Figure 11).

Before cleaning, clams must be washed free of sand and silt. Cleaning involves removing the shell, the visceral portion and trimming dark portions from the siphon tips. Clam meats are marketed canned as whole meats or minced clams or fresh as whole meats.

Scallops are shucked on board the fishing vessel and the large adductor muscles are removed. The adductor muscle is the only portion marketed; the remaining portions are discarded at sea. Scallops are marketed frozen, chilled or precooked.

Recent Catch and Product Quantities

More clams were harvested than oysters or scallops in 1968, with over 65 million pounds harvested. However, the lowest unit price was paid for clams: approximately \$0.30 per pound. The scallop catch was the smallest, but brought the highest unit price: approximately \$1.10 per pound as calculated from Table 12. The statistics listed on Tables 12 and 13 show that clams are mainly canned, whereas only a small segment of the oyster catch is canned.

Table 12. Recent Oyster, Clam, and Scallop Catches (excluding shell weight) (4).

	1967		1968		5-Year Average (1962-1966)
Species	Quantity (lbs x 10^6)	Value (\$ x 10^6)	Quantity (lbs x 10^6)	Value (\$ x 10^6)	Quantity (lbs x 10^6)
Clams	70.8	20.1	66.2	20.1	52.1
Oysters	60.0	32.3	55.6	29.8	56.2
Scallops	10.2	7.8	14.1	15.7	19.5
TOTAL	141.0	60.2	135.9	65.6	127.8

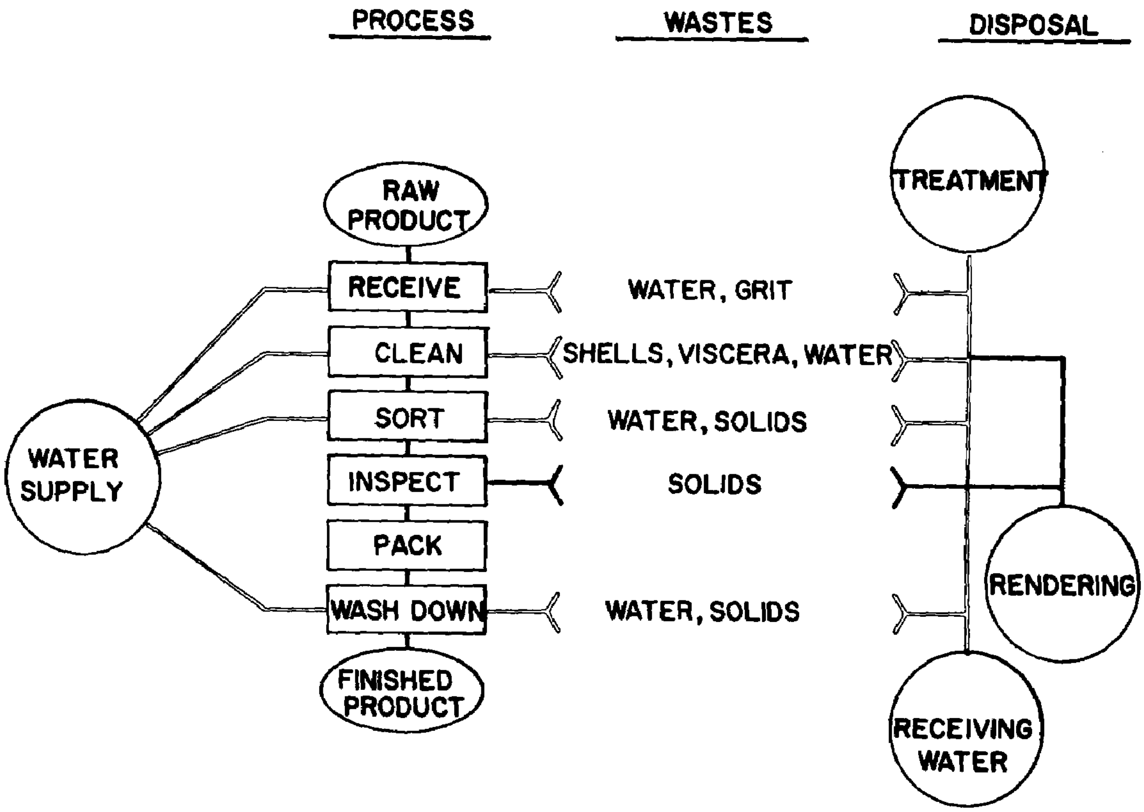

FIGURE 11. OYSTER PACKING (40).

Table 13. Clam and Oyster Canned Products, 1968 (29).

Species	Quantity (lbs x 10^6)	Value ($ x 10^6)
Clams	61.4	20.4
Oysters	4.5	5.6
TOTAL	65.9	26.0

Projected Catches

The present clam, oyster and scallop harvesting areas seem to be fully exploited and new areas or new species must be developed to substantially increase production. Therefore, it is expected that harvests in the near future will approximately parallel the 1968 values.

Alverson (30) stated that latent resources of clams and scallops exist in sufficient quantities to support commercial harvesting for weathervane scallops and for seven species of clams. Bullis and Carpenter (41) stated that clams and scallops constitute a major latent resource of the South Atlantic and Gulf regions. Particular interest was expressed in the calico scallop, sun-ray clam and hardshell clam.

Waste Quantities

The Oregon State Department of Environmental Quality (10) estimated oysters to be 75 percent waste by weight. However, this waste consists mainly of shells and can be used for several by-products. In most cases, the oyster is not eviscerated and thus the organic portion of the waste is small.

The Bureau of Commercial Fisheries (31) estimated clams to be 65 percent waste. This waste also includes the shells, but contains a much higher organic content than oysters because clams are totally eviscerated in processing. Liquid clam and oyster wastes could be used in the making of broth.

Scallop wastes present no terrestial disposal problems since they are discharged at sea. Utilization as fish food or crab bait could be considered if the solids were to be brought to the cannery.

Based on the above percentages, the total clam and oyster waste quantities were calculated to be as shown on Table 14. For each species these quantities exceeded one hundred million pounds annually.

Table 14. Calculated Clam and Oyster Waste Magnitudes, 1968.

Species	Quantity (lbs x 10^6)
Clams	120
Oysters	170
TOTAL	290

Salmon

The only significant commercial anadromous fishery in the United States is the salmon fishery. The five main species found in this country are chinook (king), sockeye (red), silver (coho), pink and chum. The major portion of the catch is canned.

Processing

The fish are caught fairly close to the canneries and are often stored in the boats without refrigeration. Canning operations are conducted for the most part employing standard cannery equipment in a conventional manner. The principal exception is the use of the "iron chink". The iron chink performs several functions in one operation by mechanically removing heads, fins, and viscera. During all the steps a strong stream of water continuously washes the blood away.

The remaining canning operations are somewhat standard, as shown on Figure 12. The fish are washed, inspected and cut into controlled-length pieces. These pieces are cut into can-length portions and the cans are filled mechanically. Finally, the cans are automatically sealed and retorted.

A Canadian firm markets a fish paste made from what would otherwise be waste salmon meat (42). The collar flesh (immediately below the head) is completely removed either by hand or with a specially-shaped knife on the iron chink. This meat is washed, inspected and ground and then canned as a paste. Spoilage can take place rapidly; therefore careful inspection and quality control are required.

Recent Catch and Product Quantities

The 1968 salmon catch, 300 million pounds, was substantially greater than those of immediately preceding years, but was still below the 1962-1966

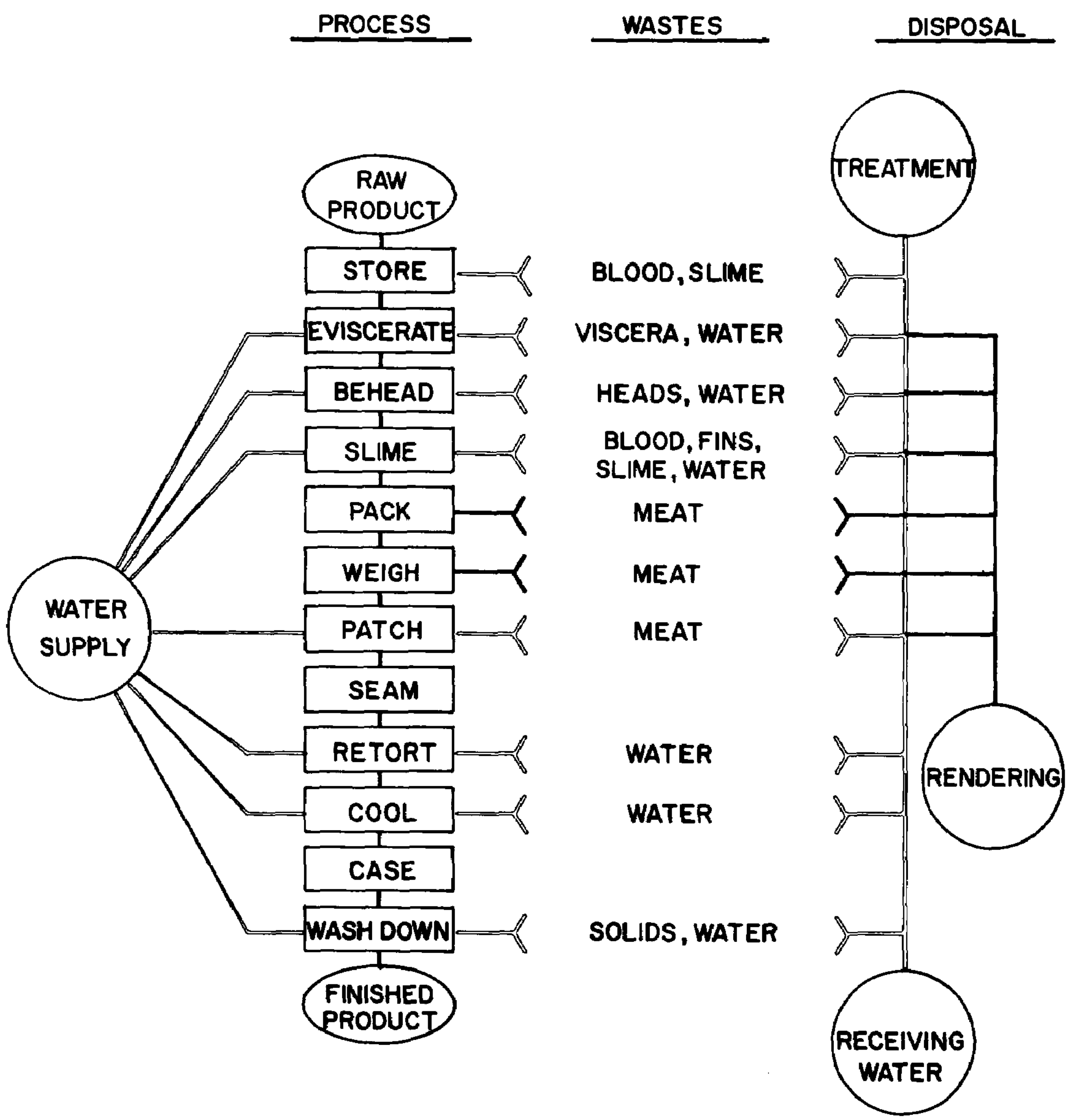

FIGURE 12. SALMON CANNING (27).

average value of 335 million pounds, as shown on Table 15. Pink salmon comprised over one-third of the domestic catch, closely followed in volume by chum salmon. The most highly valued species was the chinook, with a price of approximately $0.40 per pound. The average value of all species was approximately $0.18 per pound.

Table 16 indicates that over 98 percent of the production was canned. The canned product is a relatively high value product, priced in 1968 at $0.72 per pound. The smoked fish had the highest value: approximately $1.80 per pound.

Projected Catches

The Pacific salmon fishery is now advancing, after a general failure in 1967 (4). The future of this industry is largely dependent on market conditions, pressure from foreign competition and conservation practices. A major expansion of the domestic salmon industry is not anticipated; production at or near current levels is expected.

Waste Quantities

The quantities and possible uses of salmon wastes have been rather thoroughly researched. Magnusson and Hagevig (43) found salmon to consist of 34 percent waste. Other estimates include Brody's (44), 33 percent; Jensen's (27), 37 percent; and the Oregon State Department of Environmental Quality's (10), 30-35 percent. The Bureau of Commercial Fisheries (31) listed waste fractions by species as follows: chinook, 30 percent; sockeye, 33 percent; silver, 33 percent; pink, 35 percent; and chum, 33 percent. Using the Bureau of Commercial Fisheries values, the waste volumes for 1968 were calculated to be as shown on Table 17. The estimated total waste volume for 1968 was about 100 million pounds.

Salmon waste is composed of the various body portions excluding the flesh. The relative amounts of each portion for the five species are shown on Table 18. Each portion has distinct by-product possibilities and recovery value. The quantities of milt and roe vary with the time of year (43).

Table 15. Recent Salmon Catches (4).

Species	1967 Quantity (lbs x 10^6)	1967 Value ($ x 10^6)	1968 Quantity (lbs x 10^6)	1968 Value ($ x 10^6)	5-Year Average (1962-1966) Quantity (lbs x 10^6)
Chinook	26.2	9.5	24.6	9.5	27.5
Chum	24.5	3.9	80.0	9.0	50.6
Pink	51.7	6.3	105.0	11.5	141.0
Sockeye	66.0	16.1	55.3	13.2	81.8
Silver	38.3	12.7	36.5	11.7	34.2
TOTAL	206.7	48.5	301.4	54.9	335.1

Table 16. Salmon Products, 1968 (11).

Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Frozen fillets	0.6	0.5
Steaks	1.4	1.3
Canned	163.0	117.2
Smoked	0.1	0.2
Specialities	0.04	0.03
TOTAL	165.2	119.2

Table 17. Calculated Salmon Waste Quantities, 1968.

Species	Waste (%)	Quantity (lbs x 10^6)
Chinook	30	7
Chum	33	26
Pink	35	37
Sockeye	33	18
Silver	33	12
TOTAL		100

Table 18. Composition of Salmon Waste (45).

	Percent of Total Salmon Cannery Waste by Species				
Portion	Pink	Red	Chum	King	Coho
Head and collar	57	61	54	50	60
Tail and fins	16	14	11	11	11
Liver	5	5	5	3	4
Roe	8	9	16	15	8
Milt	5	5	6	4	6
Digestive tract	9	6	8	18	11
Heart	0.8	0.8	0.7	0.7	0.7

Table 18 shows that the major portion of the waste is composed of heads and collar sections. If the collar flesh were recovered, the value of the remaining waste would decrease substantially. Specific portions, such as the roe, are of high value, but segregation of these portions can amount to large added expense.

The analysis of salmon waste varies with canning operation, species, and degree of spoilage, as shown on Table 19. Animal feed can be readily made from the offal and viscera because of their high protein and vitamin levels.

Sardines, Mackerel, Anchovies, Herring and Alewives

Sardines, mackerel, anchovies, herring, and alewives are all classified as small, oily fishes. Sardines, anchovies and mackerel are used mainly for human consumption, whereas herring and alewives are most frequently used in oil and fish meal rendering and for bait. Herring are sometimes canned in the North Atlantic region as "sardines".

Processing

Sardines, anchovies, and mackerel are stored in water in the hold of the fishing vessel and are unloaded by pumping. The catch is then weighed and transferred to dockside holding tanks.

From the receiving tanks the fish are pumped onto the cutting tables, where the workers insert them into the slots of a conveyor belt. Revolving knives trim and slit the fish, and the viscera are removed by a suction process. The cleaned fish are then washed and canned (see Figure 13).

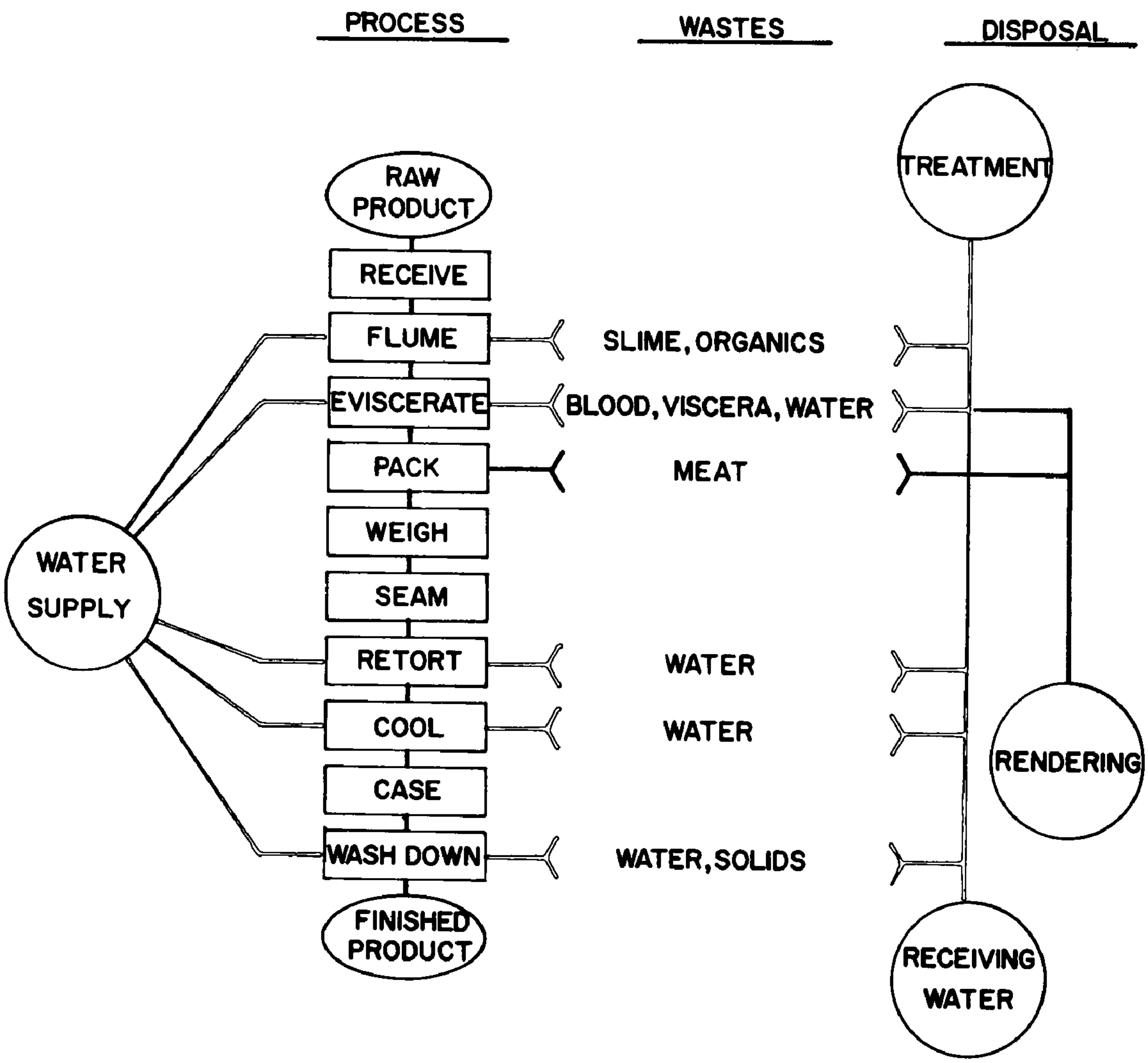

FIGURE 13. SARDINE, ANCHOVY, AND MACKEREL CANNING (47).

Table 19. Proximate Analyses of Salmon Wastes (46).

Waste	Proximate Analysis (%)				Vitamin Content (micrograms per gram, wet basis)		
	Water	Protein	Ash	Fat	Thiamine	Riboflavin	Niacin
Columbia River salmon viscera	75.1	20.0	1.8	4.4	0.45	11	31
Alaska pink salmon viscera	76.45	18.05	1.5	4.6	0.6	5	25
Alaska pink salmon offal	73.75	15.25	2.9	8.1	0.55	3	24
Spoiled Alaska pink salmon offal	74.4	16.24	3.4	8.9	0.5	2.5	25
Puget Sound pink salmon viscera	64.0	28.5	2.2	6.7	0.35	4	11
AVERAGE	72.9	19.6	2.4	6.5	0.5	5	23

The majority of the herring and alewives are rendered in a manner similar to the menhaden process.

Recent Catch and Product Quantities

Of these five species, herring were harvested in the greatest numbers in 1968 exceeding 107 million pounds, as shown on Table 20. The catch of Pacific sardines was only 100,000 pounds, having been taken incidently while the fishermen were fishing for other species. All species except sardines had a low value, ranging from $0.02 to $0.05 per pound.

Table 21 lists the product quantities for 1968 for the five species. The largest volumes were canned Maine sardines, totaling about 40 million pounds at a price of approximately $0.50 per pound.

Table 20. Recent Catches of Sardines, Mackerel, Herring, Alewives, and Anchovies (4).

	1967		1968		5-Year Average (1962-1966)
Species	Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)
Alewives	101.1	1.6	88.0	1.3	68.3
Anchovies, Calif.	69.6	0.7	29.3	0.3	16.1
Herring, sea	88.2	2.1	107.5	2.7	143.3
Mackerel	9.7	0.5	2.0	0.5	29.5
Mackerel, jack	38.2	1.4	57.4	2.3	76.5
Sardines, Pacific	0.1	0.03	0.1	0.03	7.7
TOTAL	306.9	6.3	284.2	7.1	341.4

Table 21. Oily-fish Products, 1968 (29, 37).

Species	Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Alewives	Canned	3.4	0.5
Alewives	Scrap and meal	3.3	0.2
Anchovy	Oil	0.9	32.0
Anchovy	Scrap and meal	5.5	0.3
Herring	Oil	9.5	376.0
Herring	Scrap and meal	30.8	2.1
Mackerel	Canned	22.3	4.1
Maine sardines	Canned	40.0	19.3
TOTAL		115.7	434.5

Projected Catches

The Pacific sardine industry was recently subjected to a two-year moratorium on harvesting in an effort to revive the fishery. Initiated by the California legislature, the embargo was scheduled to end in 1969. Sardine catches taken during the harvesting of mackerel were allowed, up to 19 percent of the catch (4). The 1970 catch will reflect the success of this legislated conservation. Alverson (30) stated that the decline in sardines was due to overfishing, environmental conditions and increased competing anchovy populations.

The U.S. mackerel catch has been recovering in recent years from a sharp decline suffered in 1966 (4). However, the canned pack is only 5 percent of the present U.S. market, revealing considerable foreign influences.

The herring production has been relatively constant in recent years, foreign competition having absorbed increased markets (4). Present U.S. production should only increase through improved international fishing cooperation.

The anchovy catch is limited by a California quota (4) and therefore should remain constant in the near future.

Waste Quantities

The Bureau of Commercial Fisheries estimated sardines and anchovies to be 15 percent waste; and mackerel, alewives and herring, 30 percent (31). The quantities of wastes listed on Table 22 were based on these figures as applied to the total canned product. There is virtually no solid waste from the rendering process.

Table 22. Calculated Quantities of Wastes from Sardines, Anchovies, Herring, Alewives, 1968.

Species	Quantity ($lbs \times 10^6$)
Alewives	1.5
Mackerel	9.6
Sardines, Maine	7.1
Sardines, Pacific	Insignificant
TOTAL	18.2

Shrimp

The shrimp industry is the most important seafoods industry of the Gulf of Mexico and South Atlantic areas. Shrimp are also found off the Pacific Coast in significant numbers. The season runs from April to early June and again from August to early October (48).

Processing

Shrimp are caught commercially in otter trawls to a distance of approximately 50 miles offshore. The shrimp are separated from the trash fish and stored by various methods. When short storage times will suffice, no preservation methods are used; the shrimp are taken directly to a processing plant or to a wholesale marketing vessel. When longer storage times are necessary, the shrimp are iced in the holds and re-iced every 12 hours. In some cases, notably the Gulf states, the shrimp are beheaded at sea and the heads discarded. Since the heads contain most of the active degradive enzymes, this practice retards spoilage. If the shrimp are beheaded within 30 minutes after being caught, the intestinal vein is readily removed with the head. This increases the value of the product.

The shrimp are unloaded from the vessel into a flotation tank to remove the packing ice, conveyed to a rotatory drum to remove surplus water and bits of debris, and then weighed. In some areas (Texas and the South Atlantic states), the shrimp are iced after the initial preparation to optimize peeling conditions.

Next the shrimp are peeled and picked, if the head is still attached, manually or by machine. Machine peeled shrimp are used mostly for canning (27). The machine-peeled shrimp are paler in color, and have poorer flavor and texture than the hand-picked product. By hand, a picker can peel from 100 to 400 pounds of shrimp per day as compared to a machine's capacity of 4000 to 12,000 pounds per day (48).

After peeling, the meats are inspected and washed. They are then blanched in a salt solution for about 10 minutes and dried by various methods to remove surface water. Again the shrimp are inspected and then canned. The process is outlined on Figures 14 and 15.

Shrimp are marketed fresh, frozen, breaded, canned, cured and as specialty products. An increasing amount is sold breaded or fresh-frozen (49), whereas the quantities of canned shrimp produced in recent years have been relatively constant. About 40 percent are sold frozen in the shell (50).

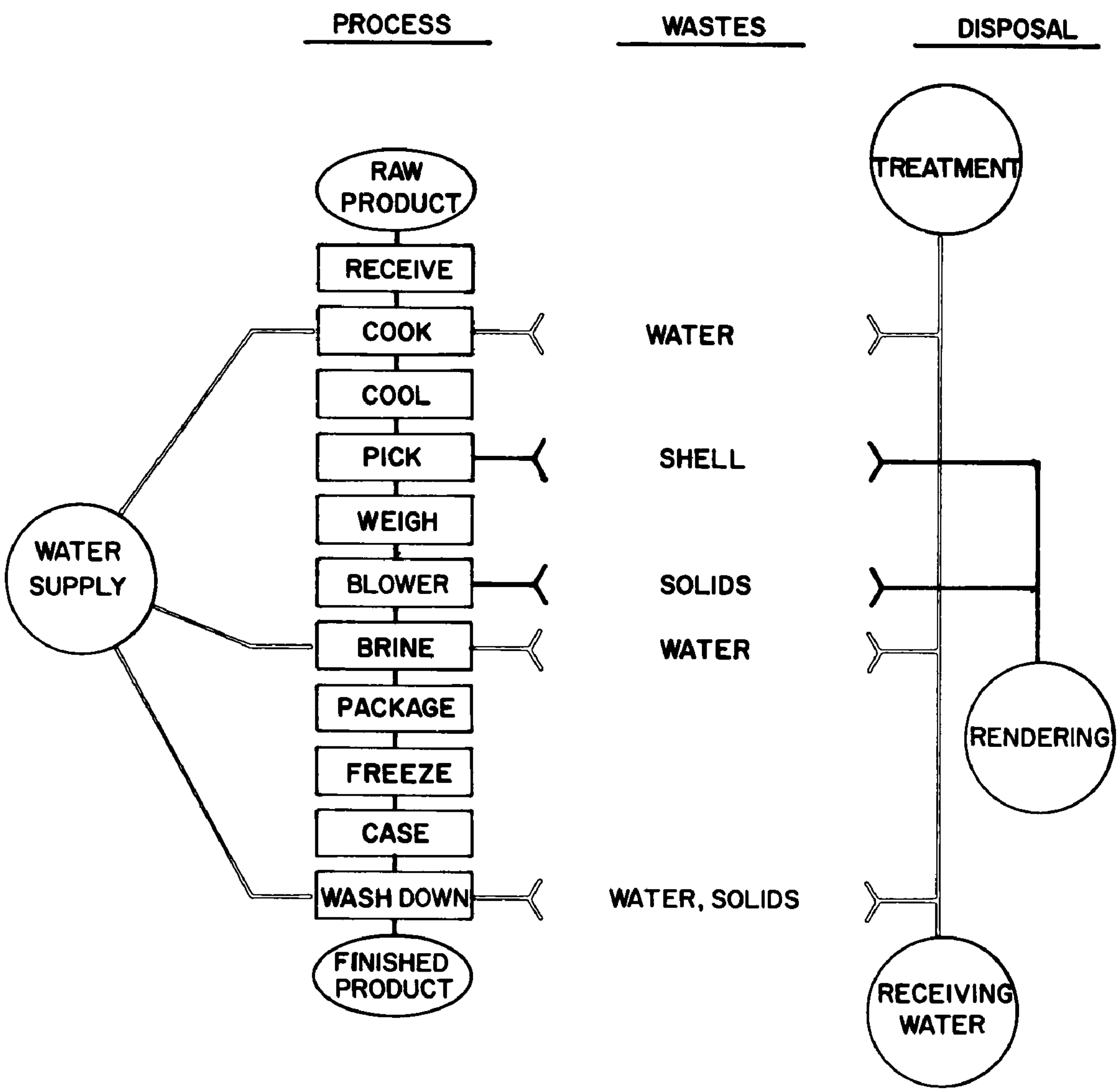

FIGURE 14. SHRIMP HANDPICKING (27).

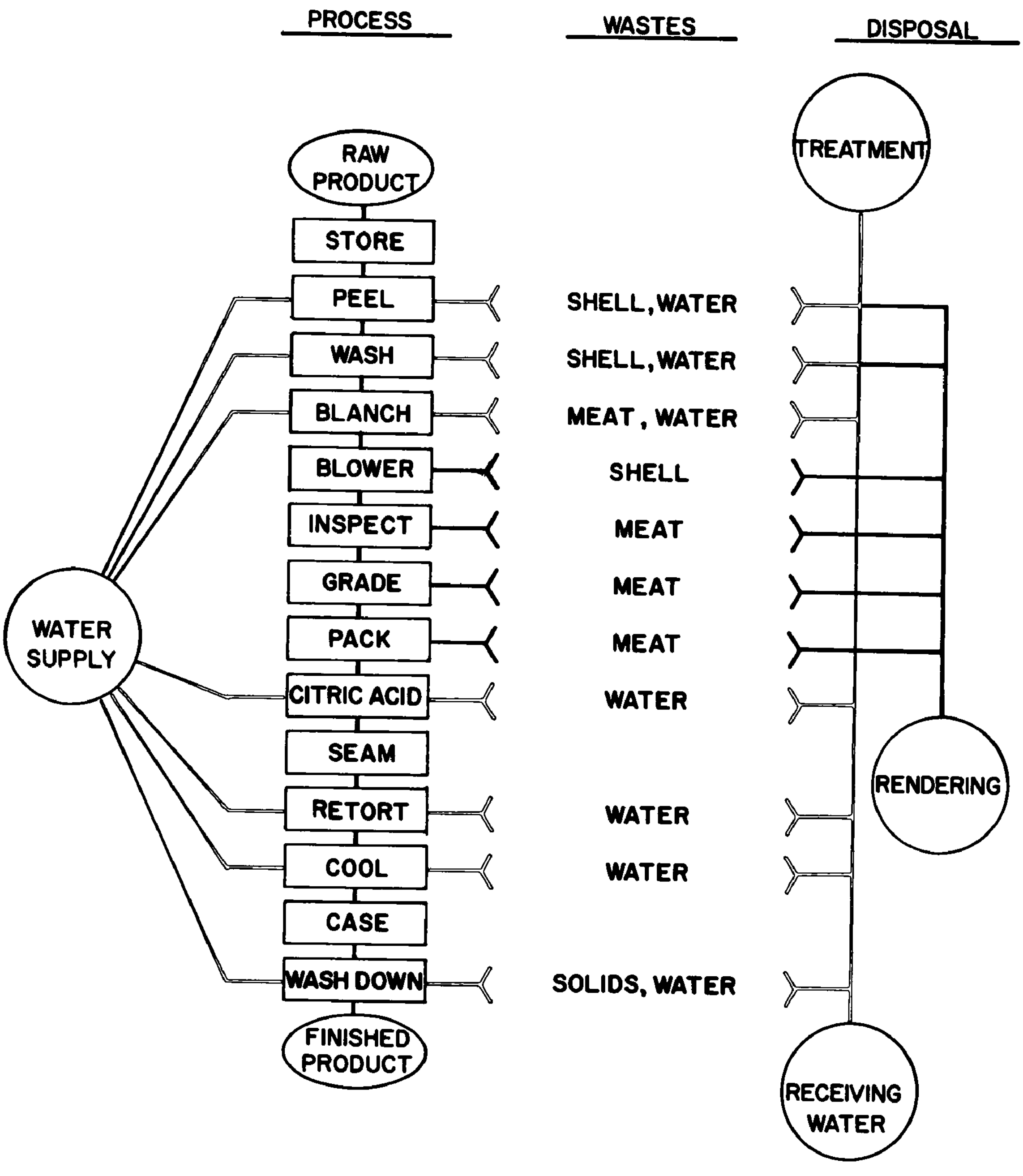

FIGURE 15. MECHANICAL SHRIMP PEELING (27).

Recent Catch and Product Quantities

Shrimp are an important United States fishery in terms of both tonnage and value. In 1968 the catch exceeded 290 million pounds with a value of more than 110 million dollars, as shown on Table 23.

Table 23. Recent Shrimp Catches (4).

1967		1968		5-Year Average (1962-1966)
Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)	Value ($ x 10^6)	Quantity (lbs x 10^6)
307.8	103.5	291.6	113.8	225.2

The most important finished products are frozen and breaded shrimp, as shown on Table 24. Both of these products were successfully developed during the 1950's and markets apparently are continuing to expand.

Table 24. Shrimp Products, 1968 (29).

Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Breaded	103.7	98.5
Canned	18.9	27.4
Frozen	127.0	(not reported)
Speciality products	0.1	0.4

Projected Catches

Except in Alaska, the fishing areas are apparently full exploited. Yearly variations in catch seem to be dependent on annual survival rates. The Alaskan catch, now about one-sixth of the national total, could expand substantially with further development (4). Alverson (30) predicted that the Alaskan stocks are capable of producing a catch equal to or exceeding 260 million pounds annually, or five times the existing catches.

Waste Quantities

Jensen (27) estimated that 78 to 85 percent of the shrimp is wasted in mechanical peeling and 77 to 84 percent in hand picking. The Oregon State Department of Environmental Quality (10) estimated 75 percent wastage for hand picking and the Bureau of Commercial Fisheries listed a cleaning loss of 55 percent (31). The low value of the Bureau of Commercial Fisheries was apparently due to ignoring the blanching loss, which ranges from 30 to 35 percent of the picked weight (48). Using a value of 80 percent, the quantity of shrimp wastes generated in 1968 was calculated to be 233 million pounds.

Vilbrandt and Abernethy (51) mentioned that the shrimp heads comprise 43 to 45 percent of the whole raw shrimp. Thus the estimated total shrimp waste would be reduced to approximately 132 million pounds, if all the catch in the Gulf and South Atlantic states were beheaded at sea.

The Bureau of Commercial Fisheries listed the composition of shrimp waste as shown on Table 25.

Table 25. Composition of Shrimp Waste (32).

Source	Composition (%)		
	Protein	Chitin	$CaCO_3$
Hand Peeling	27.2	57.5	15.3
Mechanical peeling	22.0	42.3	35.7

Tuna

Tuna ranks as the "number one" seafood in the United States; Americans consume over one billion cans of tuna per year (52).

Tuna are large, migratory fish. They feed on whatever small sea animals are most abundant and easiest to catch. Their distribution in the oceans is still nearly completely unknown, although research in this field is underway. The major runs are found off the Pacific coast.

Processing

Most tuna which are canned in the United States are caught in distant waters. A modern tuna vessel can hold from 150 to 300 tons of fish and has a range of 1,000 miles (53). Because of the long transport times, the fish are normally frozen aboard the fishing vessels.

The fish usually are unloaded (while frozen) by mechanical hoists and conveyed to the weighing station. After weighing the fish are inspected and thawed.

Tuna are eviscerated by hand in several steps. The body cavities are flushed with fresh water and all adhering viscera carefully removed. The viscera are used for fish meal or pet food and the livers are sometimes recovered for oil and vitamins.

After butchering, the fish are precooked in large, open chambers. The time of cooking varies with the body size, but is usually about 3 hours. Weight loss during cooking (attributable to oil and moisture loss) averages 22 to 26 percent (53).

The cooked fish are cooled for approximately 12 hours to firm the flesh. The meat is separated by hand from the head, bones, fins and skin. All dark meat is removed and usually recovered for pet food. The meat to be canned is placed on a conveyor belt and transferred to the "Pak-Shaper" machine.

The tuna slices are arranged lengthwise in the Pak-Shaper. This device molds the loins into a cylinder, fills the cans and trims the meat after filling. The machine can fill from 125 to 150 cans per minute (53).

Salt and vegetable oils are next added to the cans and they are vacuum sealed and retorted by standard procedures. The entire process is diagrammed on Figure 16.

Recent Catch and Product Quantities

The annual tuna catch averages approximately 300 million pounds, as shown on Table 26. The value averages approximately $0.15 per pound, or $45 million annually.

Most tuna are canned; the 1968 pack exceeded 290 million pounds with a value of $267 million (see Table 27). The bulk was canned as "chunk style".

Projected Catches

The tuna catch in the United States has failed to meet increased domestic demands. Import quotas have been regulated to 20 percent of the previous year's domestic catch (4), thereby stabilizing the domestic market.

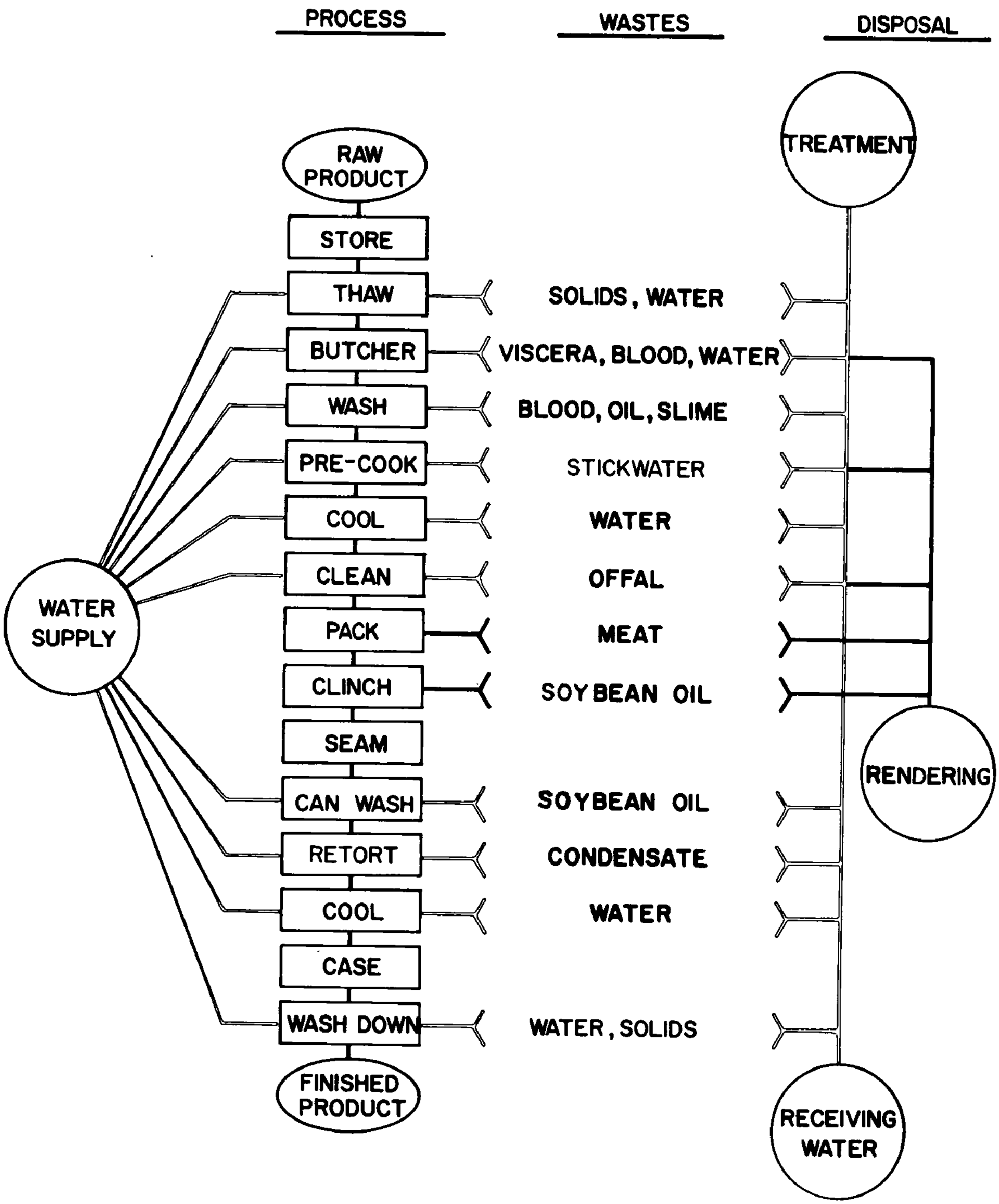

FIGURE 16. TUNA CANNING (10).

Table 26. Recent Tuna Catches (4).

Species	1967 Quantity (lbs x 10^6)	1967 Value ($ x 10^6)	1968 Quantity (lbs x 10^6)	1968 Value ($ x 10^6)	5-Year Average (1962-1966) Quantity (lbs x 10^6)
Albacore	48.4	9.5	56.0	11.4	45.8
Bluefin	18.7	2.5	15.1	2.5	34.2
Little	0.06	0.01	0.04	0.01	0.05
Skipjack	119.3	12.5	68.8	9.3	90.0
Yellowfin	142.0	19.6	153.9	24.1	135.4
Unclassified	0.02	0.01	-----	----	0.08
TOTAL	328.4	44.1	293.8	47.3	305.6

Table 27. Tuna Products, 1968 (29).

Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Canned, solid pack	99.3	75.8
Canned, chunk style	272.0	181.2
Canned, grated	20.8	10.2
TOTAL	392.1	267.2

Further use of scientific methods to follow fish migrations should increase future catches and enable the domestic market to expand; a slight upward trend has been evident for the past six years (54) and should continue.

Waste Quantities

The Oregon State Department of Environmental Quality (10) estimated that 65 percent of the tuna is wasted in the canning process. Using this figure, the 1968 quantity of waste was calculated to be 190 million pounds. The degree of wastage probably varies somewhat with species.

Alaska

Nearly half of the 36,000 mile coastline of Alaska is icebound most of the year. The remainder borders more productive temperate to sub-arctic seas. The continental shelf width varies considerably in these areas.

Salmon have historically dominated the fisheries of Alaska, but the harvest has declined in recent years, for reasons largely unknown. Halibut, herring, shrimp and crab comprise most of the remainder of the state's fisheries. Several fish species caught off the Alaskan coast are landed not only in Alaskan ports, but also in Oregon, Washington, and British Columbia. Therefore the discussion of Alaskan landings which follows does not include all the seafoods harvested in Alaskan waters, but only those which were received in Alaskan ports.

Recent Landings and Product Quantities

The Bureau of Commercial Fisheries (55) estimated the 1967 fish and shellfish landings in Alaska to be 361 million pounds, valued at $48 million. The 1968 statistics were 434 million pounds and $72 million (4). The record year for Alaska was 1936, in which 932 million pounds were harvested. The 1968 figures represented 11 percent of the total U.S. landings by weight and 15 percent by total dollar value.

The Bureau of Commercial Fisheries (55) cited the landings in 1967 by species as shown on Table 28. The quantities of wastes listed on Table 28 were computed from average waste values, giving a total of 190 million pounds.

The markets were dominated by canned salmon and fresh and frozen king crab, as shown on Table 29. Both products had relatively high values: approximately $0.75 per pound for crab meat and $0.60 per pound for salmon.

Projected Catches

Alverson (30) assessed in detail the future of the seafood industry in the Gulf of Alaska and Bering Sea regions. For bottom fish the maximum sustainable yield was estimated to far exceed the present utilization level. Shrimp stocks were estimated to be capable of yielding catches equal to or exceeding 260 million pounds annually. Currently, shrimp

Table 28. Major Alaskan Landings and Calculated Waste Quantities, 1967 (55).

Species	Landings (lbs x 10^6)	Waste (%)	Waste (lbs x 10^6)
Crab	139.4		
Dungeness	11.6	73	8.4
King	127.7	80	100
Tanner	0.1	80	0.1
Halibut	27.2	12	3.3
Herring, sea	11.5	0	0
Sable fish	2.1	40	0.8
Salmon	138.4		
Chinook	11.6	30	3.5
Chum	31.5	33	10
Pink	28.8	35	10
Red	53.5	33	18
Silver	13.0	33	4.3
Shrimp	41.8	80	33
TOTAL	360.4		190

Table 29. Major Alaskan Products, 1967 (56).

Species	Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Crab			
Dungeness	Fresh and frozen	6.2	2.6
King	Fresh and frozen	32.1	23.7
	Canned	7.8	13.2
Halibut	Fresh and frozen	1.0	0.7
Herring	Frozen bait	6.7	0.2
Salmon	Canned	80.3	52.1
	Caviar	6.3	7.3
Shrimp	Fresh and frozen	6.3	4.8
	Canned	2.5	3.0
TOTAL		149.2	107.7

harvests average approximately 40 million pounds per year. Both king and Dungeness crab were estimated to be approaching full utilization and higher yields were not expected, barring the harvesting of new stocks. The Bering Sea and Aleutian Islands for king crab and the southern Gulf of Alaska for Dungeness crab were said to hold some potential as fishing grounds. The report predicted greatly increased harvests of tanner crab in the future. It was furthermore concluded that a large population of scallops exists off the coast of Alaska and that it could support commercial harvesting operations. Actual quantities were not estimated.

The marine fishes in Alaskan waters that are commonly harvested include salmon and herring. The total salmon catch has declined steadily since the 1930's. Populations of mackerel, saury, anchovies, smelt and rock fish are known to exist. The potential for expanded yields from these species is obvious, but such activity in the foreseeable future appears doubtful.

Waste Magnitudes

The utilization of Alaskan salmon wastes has been thoroughly researched. The majority of the projects have been carried out by the Bureau of Commercial Fisheries in their several technological laboratories.

The National Canners Association (57) listed the major Alaskan salmon processing areas and estimated waste quantities from the 1966 pack. These data and the average canning seasons are summarized on Table 30. Alaska salmon processing generates about 100 million pounds of waste annually. In a highly productive year this figure may be doubled. Disposal problems are intensified by the short canning seasons, varying from ten days to two months. It has been estimated that from one-third to one-fourth of the salmon wastes are processed and sold each year (58).

Table 30. Alaskan Salmon Wastes, 1966 (57).

Region	Number of Canneries	Typical Season	Waste Quantity (lbs x 10^6)
Norton Sound	4	June 10-20	1.3
Bristol Bay	14	June 25-July 20	20.6
Aleutian Islands	3	June 10-Aug. 20	6.5
Kodiak Island	7	July 15-Aug. 20	13.8
Cook Inlet	9	July 5 -Aug. 15	9.7
Prince William Sound	3	May 15 -June 20 July 15-Aug. 15	8.9
Southeastern Alaska	18	July 5 -Aug. 15	39.5
TOTAL	58		100.3

When commercial shrimp production began in Alaska over 45 years ago, handpicking was the basic peeling method used. In 1958, automatic peelers were introduced. The tremendous expansion experienced by this industry in the last decade can be attributed mainly to the introduction of these mechanical peelers.

Table 31 lists the Alaskan shrimp processing regions and wastes generated in 1967. The shrimp season extends throughout the year, but the operation peaks from May through June. Over 10 million pounds of wastes are generated annually in Alaska by this industry, the major share in the Kodiak area.

Table 31. Alaskan Shrimp Wastes, 1967 (57).

Region	Number of Canneries	Waste Quantity (lbs x 10^6)
Aleutian Islands	1	0.9
Kodiak Island	3	7.8
Southeastern Alaska	2	1.6
TOTAL	6	10.3

The Alaskan crab production is also centered around Kodiak Island. The expansion of this industry has caused serious pollution problems in Kodiak harbor. Dumping of the wastes directly into the harbor over the years has led to high microbial populations and low dissolved oxygen (D.O.) concentrations, in spite of the low ambient temperatures. The problem has become so acute that, presently, inner harbor waters cannot be used in the processors' live crab holding tanks without serious mortality levels. The Alaskan Department of Fish and Game (7) reported D.O. levels during September, 1966 in Kodiak harbor below 3 mg/l. Normal D.O. levels in the live tanks vary from saturation to a low of 6.0 mg/l. To alleviate the problems, plans are being formulated by the crab processors for the development of a cooperative by-product development-landfill operation (59). Simon (60) described a total industrial and domestic waste inventory of Kodiak harbor showing 63 million pounds of waste discharged in 1967.

Table 32 lists the Alaskan crab processing centers and estimated waste quantities for 1967. Over 21 million pounds of waste were discharged, mainly in the Kodiak area.

Table 32. Alaskan Crab Wastes, 1967 (57).

Region	Number of Canneries	Waste Quantity (lbs x 10^6)
Aleutian Islands	4	5.7
Kodiak Island	9	13.9
Prince William Sound	1	1.0
Southeastern Alaska	5	0.9
TOTAL	19	21.5

Present Waste Disposal Methods

Since its inception, the Alaskan seafood industry has generally practiced the "hole in the floor" method of waste disposal. All solid and liquid wastes were discharged directly into the adjoining waters; often no outfall was used. Several factors have discouraged the utilization of these wastes. The isolated locations of most canneries seem to preclude consolidation and centralized processing. The short canning seasons appear to make justification of large capital expenditures for waste processing equipment difficult. The latter argument becomes less persuasive when one notes that the actual seafood processing equipment must be justified on the same basis. Other factors affecting waste utilization decisions include the variability of the raw product volumes, the highly perishable nature of the wastes and the high operating costs in Alaska (61).

Because of recent regulations instituted by the state government, some of the Alaskan canneries have installed equipment for grinding offal before discharging this material into the receiving waters (62). This process makes the waste more available for bottom fish and other scavengers. The process also adds considerably to the soluble and colloidal organic level and increases the surface area-to-volume ratio of the solids and therefore increases BOD_5 values and degradation rates. In some cases, this practice may actually reduce dissolved oxygen levels and further threaten the indigenous species of the area.

In a few cases, canneries have tended to become concentrated rather than dispersed. The most notable example of this is in Kodiak. This tendency is evident to a lesser degree in Wrangall and Ketchikan. Where such conditions exist, the concepts of consolidation of effluents and solid wastes and of joint treatment facilities become more attractive. To date, the only applications of these principles among Alaskan seafoods processors have been the Kodiak landfill project and a proposed by-products development project, both of which at this writing are still in the planning stages.

Oregon and Washington

The fisheries of Oregon and Washington are important to the economies of these states. Leading processing centers include Astoria, Oregon and Seattle and Bellingham, Washington.

The fishery economies of the two states are based largely on the five commercially-harvested species of salmon. Tuna and halibut are also landed in significant numbers. The Pacific oyster makes an important contribution to Washington fisheries and the production of Dungeness crab in both states is substantial.

Recent Landings and Product Quantities

The landings of fish and shellfish in 1967 were 92 million pounds in Oregon and 175 million pounds in Washington for a total of 267 million pounds. The corresponding values of these catches were $16 million and $25 million, respectively (55). The total landings decreased in 1968 to 220 million pounds, having a total value of $38 million (4).

As shown on Table 33, the largest landings included salmon, tuna, hake, and Dungeness crab. The hake is rendered for meal and oil; the remaining three species are large waste contributors.

Table 33. Major Landings and Calculated Waste Quantities in Oregon and Washington, 1967 (55).

Species	Landings (lbs x 10^6)	Waste (%)	Waste (lbs x 10^6)
Cod	9.2	40	3.7
Dungeness crab	19.1	73	14
Flounder	25.8	40	10
Hake	28.8	Rendered	0
Halibut	12.6	12	1.5
Ocean perch	15.4	40	6.2
Oysters	7.0	75	5.2
Rockfish	12.1	40	4.8
Salmon	70.7	33	33
Shrimp	11.2	80	9.0
Tuna	30.7	65	20
TOTAL	242.5		107.4

The most highly valued products are derived from salmon and tuna, especially the canned products, as shown on Table 34. A variety of products is marketed fresh, including several species of bottom fish, crab, shrimp and oysters.

Table 34. Major Products in Oregon and Washington, 1967 (56).

Species	Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Cod	Fresh and frozen	3.4	0.9
Dungeness crab	Fresh and frozen	3.0	3.7
	Canned	0.05	1.4
Flounder	Fresh and frozen	6.3	2.7
Halibut	Fresh and frozen	6.5	3.7
Ocean perch	Fresh and frozen	5.4	1.5
Oysters	Fresh and frozen	5.0	3.7
	Canned	0.7	1.0
Rockfish	Fresh and frozen	3.5	0.9
Salmon	Fresh and frozen	1.7	1.4
	Canned	29.2	24.0
	Salted	1.7	1.6
	Smoked	0.7	0.5
	Caviar	0.5	0.4
Shrimp	Fresh and frozen	1.4	1.8
	Canned	0.7	0.8
Tuna	Canned	31.7	22.7
	Animal food	2.3	1.4
TOTAL		103.7	74.2

Projected Catches

The major species now harvested along the Oregon and Washington coast appear to be fully exploited. The harvest of salmon has shown a slow decline in recent years, even with the increased utilization of hatchery systems. Alverson (30) stated that the Dungeness crab has also reached full utilization. He concluded that to achieve a large increase in landings, other species must be utilized. These under-utilized species include smelt, jack mackerel, pomferts, Pacific suary, squid, scallops, ocean pink shrimp, and several forms of rockfish and bottom fish.

Waste Magnitudes

The estimated waste quantities for Oregon and Washington were calculated to be 110 million pounds, or 44 percent of the total landed weight, as shown on Table 33. In Oregon, 35 seafood processors were estimated to produce 47 million pounds of waste annually (10).

Washington's 18 seafoods processors were listed as having an average wastewater volume of 0.19 mgd, with a range of 0.06 to 1.2 mgd (8). Based on the total landings in 1967, the water consumption of fish processors in Washington was calculated to be 1460 gallons per ton of raw product. This value is low compared to other food processing operations, which have an average water usage of 3000 to 8000 gallons per ton of raw product (63).

Present Waste Disposal Methods

Generally, the larger seafood processors recover the solid wastes for rendering. The Oregon State Department of Environment Quality (10) estimated that 60 to 70 percent of the solid wastes from fish processing in Oregon are recovered and 30 to 40 percent are discharged untreated. The only Oregon rendering plant is located at Warrenton. Several outlets for mink feed do exist, but these are decreasing in number. Land disposal is used at Garibaldi and Newport, Oregon, but this method poses the potential problems of odors and leachates. Nunnallee and Mar (8) stated that the fish processing solid wastes at Anacortes and Bellingham, Washington, are sent to reduction plants. One such plant is located at Westport, Washington. This plant handles mainly crab shell. The shell is ground, dehydrated and sold as a fertilizer.

Many small processors discharge all wastes untreated. All of the crab wastes from Pacific City to Brookings, Oregon, are discharged directly to adjoining waters (10).

California

The bottom habitat of the narrow shelf off the 700-mile California coast is only moderately productive (64). The surface environment, however, supports a variety of marine species.

Until recently, the major component of the California fishery economy was sardines. A record 1.5 billion pounds were harvested annually in the mid-thirties, followed by gradual reductions in catches to a low of 9 million pounds in 1953.

Recent Landings and Product Quantities

The California seafoods industry is based primarily on tuna, as shown on Tables 35 and 36. Other important species include bottom fish, Dungeness crab, anchovies, and jack mackerel. In 1967 the total California landings were approximately 507 million pounds and were valued at $51 million (55). A 14 percent decline in landings was reported in 1968, the total being 446 million pounds (4). The four species of tuna accounted for over 56 percent of the total 1967 landings, representing 69 percent of the total seafoods value.

Table 35. Major California Landings and Calculated Waste Quantities, 1967 (55).

Species	Landings (lbs x 10^6)	Waste (%)	Waste (lbs x 10^6)
Anchovies	69.6	Mostly rendered	0
Bonito	21.2	65	14
Dungeness crab	11.7	85	10
Flounder	3.3	40	1.3
Jack mackerel	38.2	30	11
Pacific mackerel	1.2	30	0.4
Rockfish	10.0	40	4.0
Sablefish	4.0	40	2.0
Salmon	7.4	33	2.4
Sea bass	1.5	40	0.6
Shrimp	1.4	80	1.2
Tuna	284.0	65	194.0
TOTAL	453.1		240.9

Tuna also dominates the finished products market. The tuna is sold canned and in most instances the waste products are rendered for animal food, meal and oil. Canned mackerel and fresh and frozen flounder and shrimp are also significant contributors to the seafood markets, as shown on Table 36.

Table 36. Major California Products, 1967 (56).

Species	Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Anchovies	Meal	11.2	0.7
	Oil	1.0	0.04
Dungeness crab	Fresh and frozen	1.4	1.6
Flounder	Fresh and frozen	6.1	2.3
Jack mackerel	Canned	12.6	2.3
Pacific mackerel	Canned	0.2	0.03
Rockfish	Fresh and frozen	2.4	0.7
Sablefish	Smoked	0.2	0.2
Salmon	Fresh and frozen	0.5	0.4
Sea bass	Fresh and frozen	0.1	0.07
Shrimp	Fresh and frozen	8.8	9.9
Tuna	Canned	188.2	116.3
	Animal food	35.4	18.8
	Meal	28.2	1.6
	Oil	4.1	0.2
TOTAL		300.3	155.1

Projected Catches

Smith (65) and Clemens (66) agree that the future of California fisheries is based on consumer demand, not on the supply of seafoods. The annual per capita consumption of seafoods in California is approximately 17 pounds, which requires approximately 32 pounds of whole fish to satisfy (65). This value is considerably higher than the national average of 11 pounds per year (4), so an increase in demand due to increased per capita consumption is not expected. However, assuming a continued population expansion in California and adjacent states and the continued ability of this state's fisheries industry to compete with foreign supplies, the industry should continue to grow.

Bell (64) stated that continued processing of fish mainly as a canned product in California, with the consumer demand increasing for easily prepared frozen products, has hampered the growth of the industry. A heavier emphasis, therefore, on frozen seafoods products should be evidenced in the future.

Clemens (66) has found no indication of over-fishing of tuna stocks, even though catches have decreased in recent years. The tuna catch seems to depend on the survival of the young and on their migratory habits, which may possibly be dependent on surface temperatures.

Ahlstrom (67) examined the growth potential of the California fisheries. He concluded that both the Pacific sardine and the Pacific mackerel are being over-harvested. Continued exploitation of the Pacific mackerel should bring decreased catches. Yellow fin tuna, shrimp, Dungeness crab, halibut and salmon populations were judged as being fully utilized and therefore catches should remain at present levels or may decline. Albacore, bluefin and skipjack tuna could withstand a moderately increased catch (less than double the present catch) and rock fish, sable fish, jack mackerel, bonito and anchovies were judged to be considerably under-exploited.

Waste Magnitudes

The total calculated solid wastes for 1967 are listed on Table 35 as 240 million pounds. Most of these wastes were from tuna processing, which can yield valuable by-products. Assuming complete utilization of the tuna scrap, the remaining waste to be handled would be about 50 million pounds, much less than the calculated value shown on Table 35.

Present Waste Disposal Methods

The general waste management practice in California is to remove the solids by screening the waste streams. The solids are ground and rendered for meal, oil and animal feed. Wastewaters from the various processing systems are usually discharged untreated to the adjoining waters. In some cases wastewater discharge regulations are enforced by the local governmental agencies.

Great Lakes Region

The U.S.-owned waters of the Great Lakes yield approximately 70 million pounds of fish annually. The various species include lake trout, whitefish, walleye, blue pike, yellow perch, ciscoe, alewives, hake, herring and sheepshead.

Recent Landings and Product Quantities

The Bureau of Commercial Fisheries (68) listed the total U.S. 1967 Great Lakes landings as 84 million pounds, with a value of only $6 million. The alewife was the species taken in largest numbers, as shown on Table 37. At 42 million pounds for 1967, this species comprised 50 percent of the total catch in the region. Alewives are rendered for meal and oil and thus yield low-value products.

Table 37. Major Great Lakes Region Landings and Calculated Waste Quantities, 1967 (68)

Species	Landings (lbs x 10^6)	Waste (%)	Waste (lbs x 10^6)
Alewives	41.9	rendered	0
Carp	6.7	40	2.6
Chub	11.3	40	4.5
Lake herring	3.8	15	0.6
Silver salmon	1.5	33	0.5
Sheepshead	2.6	40	1.0
Smelt	2.8	15	0.4
Whitefish	1.6	40	0.7
Yellow perch	5.8	40	2.3
TOTAL	77.9		12.6

The major products destined for human consumption are processed from chub, herring, salmon, whitefish, and yellow perch (see Table 38). A considerable quantity of fish is sold fresh and therefore is not listed on Table 38.

Table 38. Major Great Lakes Region Products, 1967 (56).

Species	Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Chub	Smoked	4.4	2.3
Herring	Salted	5.4	2.0
Salmon	Smoked	0.5	0.8
Whitefish	Fresh and frozen	0.3	0.3
	Smoked	0.08	0.05
Yellow perch	Fresh and frozen	2.4	1.6
TOTAL		13.1	7.0

Projected Catches

The quantity of fish harvested annually from the Great Lakes should not increase notably in the future. Species and harvesting areas are limited by the geographic isolation of the region, hampering expansion. The alewife catch could decline due to the growing numbers of the predator silver salmon.

Waste Magnitudes

Total solid wastes volumes were calculated (and are listed on Table 37) as about 13 million pounds for 1967. Because the alewives are rendered, they do not significantly contribute to the solid wastes problem. The stickwater from alewife rendering plants has an extremely high BOD and can result in serious water pollution problems and odors. Kempe, et al. (69) listed an average stickwater BOD_5 of 47,000 mg/l at a flow of 120 gallons/ton of fish processed.

Present Waste Disposal Methods

Billy (70) stated that the solid wastes from the fresh fish markets are directly discharged into the lakes. This waste contribution to the Great Lakes was judged to be negligible when compared to the total industrial discharge.

None of the fish meal plants in the state of Michigan discharge their effluents into Lake Michigan (70). One plant in the State of Wisconsin does presently discharge stickwater into Lake Michigan, but plans are presently being prepared for treatment facilities (71).

Mississippi River Basin

The fish in this twenty-states region are taken both from the rivers and from the many small lakes. Catfish, buffalofish, carp, sheepshead, and mussels are the principal species harvested (64). The annual production averages about 50 million pounds (72).

Recent Landings and Product Quantities

The 1967 landings, listed on Table 39, were somewhat evenly divided between several species. Carp and buffalofish were the predominant species. The landings for 1967 totaled over 80 million pounds, but had a value of only approximately $8 million (73). Spread over 20 states, the economic contribution per state was very small.

Table 39. Major Mississippi River Landings and Calculated Waste Quantities, 1967 (73).

Species	Landings (lbs x 10^6)	Waste (%)	Waste (lbs x 10^6)
Buffalofish	18.0	40	7.2
Carp	23.5	40	9.4
Catfish and bullhead	11.9	45	5.4
Crawfish	2.9	85	2.5
Mussel	13.5	75	10
Sheepshead	4.4	40	1.8
TOTAL	74.3		36

The seafood production is considerably larger than the landings due to large imports from the Great Lakes and the Gulf States. All Mississippi River Basin fishery products in 1967 had a value in excess of $13 million (56); the major products are listed on Table 40. The single most valuable product was shrimp, worth over $2.6 million.

Table 40. Major Mississippi River Basin Products, 1967 (56).

Species	Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Carp	Smoked	0.188	0.06
Catfish	Smoked	0.014	0.01
Crawfish	Fresh	0.154	0.270
Salmon	Smoked	0.013	0.01
Shrimp	Frozen	4.1	2.6
Whitefish	Smoked	0.076	0.025
Whiting	Smoked	0.053	0.024
Yellow pike	Fresh and frozen	0.054	0.042
TOTAL		4.8	3.0

Projected Catches

Because of the limited access to productive waters, future catches in this region should remain approximately at present levels, with the probable exception of farmed catfish. Jones (21) estimated that catfish production could double present levels by 1975, if economic incentives remain at the current high levels.

Waste Magnitudes

The percentages of wastage listed on Table 39 for all the species except catfish were estimated by fish or shellfish type. Buffalofish, carp, and sheepshead were considered as bottom fish; mussels as oysters; and crawfish as crabs. No waste quantities for these species were found in the literature. Using these crude waste estimates, the total annual waste quantity was calculated to be 36 million pounds.

Present Waste Disposal Methods

Seagran (72) described this fishery as being made up of many small processors with limited capital. Waste disposal is usually accomplished by discharge to the adjoining waterway. Increased catfish farming could provide a ready market for fish viscera meals if consolidation of this fishery were sufficient to justify the purchase of fish meal equipment.

Gulf States

The Gulf states region includes the 1400-mile coastline of Texas, Louisiana, Mississippi, Alabama and the west coast of Florida. The large shelf sustains shrimp fisheries of high value and menhaden fisheries of large volume.

Recent Landings and Product Quantities

The 1967 landings in the Gulf States were 1.2 billion pounds with a value of $127 million (74). The 1968 landings increased slightly to 1.3 billion pounds, but the value decreased somewhat to $125 million (4).

The two most important species processed, shown on Table 41, were menhaden and shrimp. These two species comprised 78 percent of the total landings volume and value. Blue crab and oysters both contributed significantly to the fishery markets.

Table 41. Major Gulf States Landings and Calculated Waste Quantities, 1967 (74).

Species	Landings ($lbs \times 10^6$)	Waste (%)	Waste ($lbs \times 10^6$)
Catfish and bullhead	3.8	45	1.7
Blue crab	27.5	86	23
Grouper	7.0	40	2.8
Herring	10.0	15	1.6
Menhaden	700.0	Rendered	0
Lysters	21.8	75	14
Mullet, black	28.2	40	11
Red snapper	11.9	40	4.8
Shrimp	225.7	80	180
TOTAL	1036.0		240

The fishery products market was dominated by fresh and frozen shrimp, as shown on Table 42. The menhaden products were large in volume, but had low values: approximately $0.05 per pound.

Table 42. Major Gulf States Products, 1967 (56).

Species	Product	Quantity (lbs x 10^6)	Value (lbs x 10^6)
Blue crab	Fresh and frozen	2.8	4.0
Grouper	Fresh and frozen	0.45	0.7
Menhaden	Meal	144.5	9.5
	Oil	61.6	3.0
	Solubles	48.8	1.8
Oysters	Fresh and frozen	11.6	10.8
	Breaded	0.9	0.8
Red Snapper	Fresh and frozen	0.2	0.2
Shrimp	Fresh and frozen	217.4	204.0
	Canned	13.2	19.9
	Meal	0.4	0.01
TOTAL		501.8	254.7

Projected Catches

The Gulf states' fisheries are dominated by shrimp production, which is basically a domestic fishery; no foreign vessels fish for shrimp along the U.S. coast. Longnecker (75) stated that the U.S. domestic shrimp fishery may be reaching the limit of sustainable yield. The domestic production has been relatively stable for the past 10 years.

Bullis and Carpenter (41) estimated that the present menhaden landings are one-fifth to one-third of the maximum sustainable yield. The bottom fish industry, too, has large stocks that could accommodate expanding markets. The blue crab fishery has wide areas for future expansion along the Gulf Coast. Table 43 lists the presently utilized and latent fishery resources of this region. The general conclusion of Bullis and Carpenter was that catches could increase substantially if expanded markets could be developed.

Table 43. Presently Utilized and Latent Fishery Resources, Gulf of Mexico (41).

Resource	Major Species	Present Quantity (lbs x 10^6)	Latent Quantity (lbs x 10^6)
Bottom fish (food)	Snapper, grouper	50	1,000
Bottom fish (industrial)	Croaker, sea trout	90	5,700
Coastal marine fish	Herring, sardines, anchovies	1,060	8,400
High seas marine fish	Sharks, tuna, flying fish	0	900
Midwater fish	Butterfish, bumper, scad	0	2,100
Shellfish	Scallops, squid, lobsters, crab	260	2,800
TOTALS		1,460	20,900

Waste Magnitudes

The calculated waste quantities for 1967, as listed on Table 41, totaled 240 million pounds. Seventy-five percent of this waste was contributed by shrimp processing.

The on-site survey segment of this study was limited by hurricane Camille (1969) to only one plant in the Gulf states area. This plant processed shrimp and oysters; shrimp were being processed at the time of the visit. The shrimp are usually beheaded at sea to remove most of the degradive enzymes. This procedure allows the boats to remain out of port for more extended periods. Removing the heads at sea reduces the waste quantities at the processing plant by 56 percent (51). This would reduce the shrimp waste estimate mentioned earlier (page 66) to 80 million pounds.

Present Waste Disposal Methods

Shrimp processing yields large volumes of solid wastes and wastewaters. In most cases the liquid wastes are discharged untreated to adjoining waters. Some solids are recovered by screening the wastewater, but this practice is not prevalent. The screenings are processed into meal which is sold as feed or fertilizer. The solids from mechanical picking contain less than 30 percent protein, resulting in a relatively low-quality meal (76). Approximately 10 pounds of meal are produced from 100 pounds of solid waste.

South Atlantic and Chesapeake Bay States

This area includes Chesapeake Bay, which is bordered by Virginia and Maryland, and the coasts of North and South Carolina, Georgia, and the east coast of Florida.

Most of the nation's lobster and blue crab harvests take place in this area. Menhaden processing for oil and meal results in the largest product volumes. Shrimp and catfish are two minor species utilized.

Recent Landings and Product Quantities

The Bureau of Commercial Fisheries (77, 78) reported the 1967 fish and shellfish landings in Chesapeake Bay and the South Atlantic states to be 740 million pounds, valued at $59 million. The 1968 landings were 772 million pounds with a value of $66 million (4).

The Bureau of Commercial Fisheries cited the landings in 1967 by major species as shown on Table 44. Over 56 percent of the landings consisted of menhaden; 16 percent was blue crab. Shrimp, oysters and alewives also yielded significant catches.

Table 44. Major South Atlantic and Chesapeake Bay Landings, and Calculated Waste Products, 1967 (77, 78).

Species	Landings ($lbs \times 10^6$)	Waste (%)	Waste ($lbs \times 10^6$)
Alewives	51.7	30	15
Blue crab	120.2	86	100
Catfish and bullheads	15.0	45	6.8
Herring	8.9	Rendered	0
Menhaden	417.0	Rendered	0
Oysters	29.0	75	21
Shrimp	20.6	80	16
TOTAL	662.4		159

The seafood product markets were dominated by blue crab, shrimp and oysters as shown on Table 44. The products from these three species had a combined value of over $77 million in 1967. Menhaden rendering yielded large volumes of meal, oil and fish solubles, but was valued at only $7 million.

Table 45. Major South Atlantic and Chesapeake Bay Products, 1967 (56).

Species	Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Alewives	Salted	8.9	1.3
Blue crab	Fresh and frozen	17.6	20.2
	Meal	6.7	0.2
Menhaden	Meal	76.5	4.7
	Oil	32.4	1.4
	Solubles	39.7	1.2
Oysters	Fresh and frozen	19.6	20.1
Shrimp	Fresh and frozen	36.2	37.1
TOTAL		237.5	86.2

Projected Catches

Bullis and Carpenter (41) listed present utilization and the latent fishery resources for the South Atlantic region as shown on Table 46. The totals show that a considerable increase in catch could be realized under proper market conditions.

Table 46. Present Production and Fishery Resource Potentials, South Atlantic Region (41).

Resource	Present Production Quantity (lbs x 10^6)	Latent Quantity (lbs x 10^6)
Bottom fish (human consumption)	18	500
Bottom fish (industrial)	9	2,800
Coastal marine fishes	222	2,800
High seas marine fishes	1	1,100
Midwater fishes	1	500
Shellfish	80	4,500
TOTAL	331	12,200

The shrimp, lobster, stone crab and oyster yields are considered to be near maximum at the present time (41). Clams and scallops are believed to offer the greatest potential for increased production.

Waste Magnitudes

The estimated waste quantities from the major species in this region were calculated to be 160 million pounds as shown on Table 44. The majority of the waste is generated by blue crab processing, because of the high volumes processed and the high percentage of wastage.

Present Waste Disposal Methods

The present waste disposal methods are similar to those practiced in the Gulf states region. Liquid effluents are discharged untreated or to municipal treatment facilities. Solids are recovered in some cases and processed for meal. The production statistics for meal from blue crab wastes, shown on Table 45, imply that the wastes are being partially utilized. The value of this meal was only 2.6 cents per pound in 1967.

North- and Middle-Atlantic States

This region stretches from Maine to New Jersey. The important fishing centers include Gloucester, Boston, and New Bedford in Massachusetts; Portland, Rockland, and Eastport in Maine; Lewes, Delaware; Port Monmouth, New Jersey; and New York City. This region has a wide continental shelf and close proximity to fishing areas off the coast of Canada (64). Furthermore, a large local market for fishery products exists.

The region's main products are lobster, cod, haddock, flounder and ocean perch. New Jersey is the nation's major clam-producing state. Sea scallop production has grown to be an important regional industry in recent years.

Recent Landings and Product Quantities

The North- and Middle-Atlantic fisheries yield substantial quantities of fish and shellfish. In 1967 the total landings exceeded 788 million pounds and had a value of approximately $94 million (79, 80). The landings increased slightly in 1968 to 819 million pounds and $101 million (4). These landings were significantly less than those of 1960, 1.6 billion pounds (4).

The landings in this region were widely diversified by species as shown on Table 47. Cod, flounder, haddock, perch and whiting were the major fishes and lobsters, clams and scallops were the major shellfishes harvested. Approximately 30 species were harvested for industrial fishery products, the most important being the black flounder.

Table 47. Major North- and Middle-Atlantic Landings and Calculated Waste Products, 1967 (79, 80).

Species	Landings (lbs x 10^6)	Waste (%)	Waste (lbs x 10^6)
Alewives	7.3	30	2.2
Clams	61.7	65	40
Cod	43.9	40	18
Flounder	103.2	40	41
Haddock	98.4	30	29
Lobster	26.5	80	21
Menhaden	46.5	Rendered	0
Ocean perch	71.4	40	29
Scallops	9.3	Discarded at sea	0
Scup	14.6	40	5.9
Whiting	69.4	30	21
TOTAL	552.1		210

The major finished products were fillets from the several species of fish mentioned, and fresh and frozen lobsters and clams (see Table 48). Lobsters had an extremely high market value: over $4 per pound; the market was affected by limited product availability (approximately one million pounds annually).

Table 48. Major North- and Middle-Atlantic Products, 1967 (56).

Species	Product	Quantity (lbs x 10^6)	Value ($ x 10^6)
Clam	Fresh and frozen	26.8	10.3
	Canned	6.9	6.2
Cod	Fresh and frozen	10.6	4.5
Flounder	Fillets	28.1	13.4
Haddock	Fillets	35.4	16.2
Lobster	Fresh and frozen	1.0	4.3
Ocean perch	Fillets	21.4	6.0
	Meal	11.4	0.8
	Oil	0.5	0.03
Whiting	Fresh and frozen	30.1	3.6
TOTAL		161.2	65.2

Projected Catches

Edwards (81) stated that the North Atlantic area is being intensively exploited. Serious overfishing of haddock was noted. The yields of some species such as redfish and herring can probably be increased, but an overall increase in catch volumes would not exceed 20 percent.

Carlson, Knudson, and Shanks (82) stated that in the last few years the population of shrimp off the New England coast has been increasing rapidly. Many of the plants are making equipment changes to handle this new product.

Waste Magnitudes

The calculated waste quantities from the major species landed are listed as 210 million pounds on Table 47. The actual waste quantities may have been up to 30 percent higher, based on the total landings, or 270 million pounds. Bottom fish and clams contributed significantly to these waste magnitudes.

Present Waste Disposal Methods

In the majority of cases the solid wastes are utilized in animal feed and meal plants. The flume waters, scales, blood, fish cuttings, and wash waters are discharged to municipal sewers (83). Generally, municipal treatment along the coast consists of only solids removal. The pollution from the seafoods industry is considered by local authorities to be small when compared to the total water pollution problem of the area.

In certain localities, however, the pollution from fish wastes is acute. The Clean Water Act of 1965 required fish processing plants to treat their wastewaters. In Gloucester, Massachusetts, court action to force compliance has been initiated by the Massachusetts Division of Water Pollution Control (82).

BY-PRODUCT UTILIZATION

Fish Meal

Fish meal is one of the products of fish rendering; the others are fish oils and solubles. In 1968, 127 plants produced over 469 million pounds of fish meal and scraps with a value of $30 million (37).

Fish meal was used primarily as a fertilizer prior to the 1930's, when research showed its possible value in feed rations (84). Fish meal has been shown to be a source of concentrated protein with essential and non-essential amino acids, B-vitamins, an unidentified growth factor, and trace elements, including phosphorus.

The most common species used for fish meals include menhaden, alwives, anchovies, Pacific and Jack mackerel, herring, and wastes from groundfish, crabs and shrimp.

Fish meal markets are dependent on the markets of all the fish rendering products. Lee (85) concluded that the production of fish meal is dependent on oil prices, not on fish meal prices.

Methods of Manufacture

Kempe, et al. (69) listed four classes of currently-used rendering processes: wet, dry, solvent extraction, and digestion. The wet process is over one hundred years old and is still the most prominent. The dry process is used only in small operations. The solvent and digestion processes are not used extensively.

Kempe, et al. (69) listed several new processes that have been developed to render fish. These include the Pravia process, Titan process, Harberger Eisen and Brouzewerke process, Kingan continuous rendering process, Chayen-Sharples process, DeLaval process, Corver-Greenfield process, Marsh process, Battelle-National Renderers' Association process and the U.S. Bureau of Commercial Fisheries solvent extraction process. Most are still in the experimental stage.

In the wet rendering process, shown on Figure 10, (page 29) the fish or fish waste is removed from the boat, weighed and cooked by steam. This material is then pressed to give a solid press cake and liquid press liquor. Processing of press liquor is described in the "Fish Oil" section (page 79).

The press cake is dehydrated in one of several different types of dryers to a meal containing about 8 percent moisture (69). The dried meal is then sold directly or further ground and powdered prior to marketing.

In the dry rendering process, the fish are first dried in large steam-heated dryers. The dried product is then pressed to release the oil and the press cake sold as a fish meal.

The solvent and digestion processes are used to obtain a fish protein concentrate with a protein concentration exceeding that of the normal fish meal value (i.e., 40-50 percent).

Equipment

Packaged fish meal plants. Packaged fish meal plants are designed to be used on board ship or in small operations. Several companies make units of varying sizes and capacities up to 60 tons per day (86, 87). Auxiliary equipment can be purchased to recover oils and stickwater.

Mexico has been a forerunner in developing on-board fish meal plants. de Sollano (88) reported on a dry-rendering process to produce fish meal with a high protein concentration. The weight of the fish is reduced by 80 percent, significantly reducing transportation costs. Lopez (89) noted several uses of these plants on shrimp trawlers to utilize the fish caught in the shrimp nets. The machines cost approximately $14,000 and process about 1,000 pounds of fish per day.

Two Scandanavian firms are constructing special fish meal plants for both large and small boats. The units have capacities of from 10 to 60 tons per day for trawlers and 150 to 600 tons per day for factory ships (90).

One Danish firm markets (especially for research purposes) a fish meal plant with a capacity of 55 pounds per hour (91).

Driers. A variety of drier types can be used in fish meal processing. Peruvian factories use fire gases, but this method has proven to be uneconomical and non-uniform (92). Air pollution is excessive.

Beatty (93) stated that small operations usually use vacuum drying ovens. Larger operations use vacuum belt-driers, vacuum propeller-driers, and vacuum cylinder-driers. One corporation makes rotary coil evaporating equipment to reduce the load on the hot air driers (94).

In the menhaden reduction industry, the press cake is fed to large rotary, direct-flame or steam dryers (95). The resulting material has a moisture level of about 6 to 10 percent.

Dyer (96) stated that the driers are the major source of odor in fish reduction plants. In some plants, the air is recycled after passing through a cyclone and a water scrubber. Venturi scrubbers also are used in some plants on all odor sources.

Characteristics of Fish Meals

Shellfish. Brown (97) listed the protein concentration of shrimp meal as approximately 50 percent; oil, 14 percent; and ash, 20 percent. Thurston and MacMaster listed the calcium carbonate and ash contents of shrimp meal as shown on Table 49. Peniston, et al. (99) concluded that shellfish waste meals have limited markets due to the high concentrations of minerals and chitin. These concentrations limit the amount that can be fed to animals.

Table 49. Shrimp Meal Proximate Analyses (98).

Raw Material	$CaCO_3$ (%)	Ash (%)
Peeler waste	9.4-23.2	19.0-20.3
Shells	24.8-27.1	27.5-29.9
Whole shrimp	5.3	17.7

Khandker (100) studied the possibility of making shrimp meal from fresh or soiled shrimp heads. Proximate analyses are listed on Table 50. The protein concentrations were lowered by enzymatic and bacterial action during spoilage. The meals from the spoiled heads had an offensive odor.

Table 50. Analyses of Shrimp Meal Made from Fresh and Spoiled Heads (100).

Raw Material	Total Protein (%)	Protein from Chitin (%)	Crude Protein (%)	Moisture (%)	Ash (%)
Fresh heads	47.95	3.60	44.35	4.75	20.90
Spoiled heads					
24 hours*	42.68	3.45	39.23	7.75	20.61
48 hours*	42.51	3.00	39.51	6.75	21.72
72 hours*	41.49	3.30	38.19	7.04	23.10

*The lapse of time between removal from ice and beheading at the packing plant.

Vilbrandt and Abernathy (51) stated that steam cooking at atmospheric pressures is not adequate to preserve shrimp wastes. They recommended a water, acid, or brine cook which yielded a meal with protein concentrations exceeding 40 percent (dry weight basis). These processes would generate strong liquid wastes.

Anchovies, Herring, Menhaden, Sardines, and Mackerel. Thurston and MacMaster listed the proximate analyses of various oily fish meals as shown on Table 51. These calcium carbonate values are significantly less than those of the shellfish meals and would not limit the allowable quantities in animal feeds.

Table 51. Average Proximate Analyses of Some Oily Fish Meals (98).

Species	$CaCO_3$ (%)	Ash (%)
Anchovy	1.53	21.9
Herring	0.45	9.7
Mackerel	1.30	23.2
Menhaden	0.85	18.9
Sardines	1.05	17.8

Karrick, Clegg, and Stansby listed the composition of sardine and mackerel meals and press cake as shown on Table 52. The meals made from canning scraps were quite similar in oil and moisture content to the whole fish meals.

Table 52. Composition of Press Cake and of the Corresponding Meals in Different Dryer Types (101, 102).

Dryer Type	Raw Material	Processed Material	Moisture (%)	Oil (%)
Direct flame dryer	Pilchard and mackerel canning scrap	Press cake	56.5	5.55
		Meal	8.4	8.57
Indirect flame dryer (250°F.)	Whole pilchard	Press cake	53.6	4.80
		Meal	7.5	7.85
Air-lift dryer (175°F)	Pilchard scrap	Press Cake	49.5	4.11
		Meal	13.3	6.96

Grau and associates (103) found that menhaden meal is capable of being stored at room temperature up to six months without onset of rancidity.

Tuna. Tuna meals are a highly nutritional animal feed (104). However, they can be quite variable in quality because of the use of various waste portions for other products. For example, the diversion of dark meat for pet foods alters the composition of the tuna meal.

Thurston and MacMaster (99) listed calcium carbonate contents of 1.45 percent for albacore and 0.98 percent for skipjack, similar to oily fish meals. Tuna meals are high in mineral content and contain approximately 60 percent protein (105).

Visceral meals. The Fisheries Research Board of Canada (106) determined that visceral meals are high in protein and contain all the essential amino acids and vitamins necessary for good nutrition. Rapid enzymatic and bacterial decomposition were noted. The meal tasted like bouillon, but was not considered suitable for human consumption.

Olley, Ford and Williams (107) stated that viscera are difficult to process due to autolysis. The viscera were difficult to handle in screw conveyors. Visceral meals were found to be similar in composition to whole herring meals and were judged rich in soluble nitrogen. The authors concluded that, given efficient processing, fish viscera could provide fair quality meals.

A continuous pulp press is commercially available that will produce (from fish waste) a press cake of 45 to 55 percent moisture and remove 40 to 70 percent of the oil (108).

Meal and oil have been produced from catfish wastes (23). The dried meal contained 47 percent protein at a yield of 21 percent, as shown on Table 53.

Table 53. Composition of Catfish Wastes, Scrap and Meal (23).

Material	Moisture (%)	Total Solids (%)	Fat (%)	Ash (%)	Protein (%)
Wet waste	64	36	---	---	---
Dried scrap	3.4	96.6	40	15.3	35.6
Meal	6.2	93.8	20.1	23.2	46.8

Lantz (109) reported a fish meal made from a 1:1 mixture of offal and whole trash fish that contained 66 percent protein, 13 percent oil and 7 percent moisture. A solvent extraction process was used to remove the oil.

Finch (110) stated that large tuna canneries process ground entrails, cooker water, and scrap to give meal, oil and fish solubles. The tuna meal he analyzed contained 55 to 62 percent crude protein and approximately 22 percent ash. The ash consisted mainly of calcium and phosphorus from the bones.

Carpenter and Olley (111) studied various methods of offal preservation for meal processing. A dipping method in a solution of 1 percent formaldehyde and 1 percent nitrite was found to be satisfactory, although loss of protein was reported. (It should be noted that nitrite has been found by some investigators to be carcinogenic).

Kawada and associates (112) studied the nutritional value of viscera from cottlefish, octopus, mackerel and pollock. They reported a relatively uniform distribution of amino acids, high B-vitamin levels, and a higher methionine content than in muscle protein.

The amino acid content of viscera meals is comparable to whole fish meals, as shown on Table 54. The viscera meals would therefore probably be competitive as an animal feed, because their initial cost is lower.

Table 54. Amino Acid Content of Various Fish Meals, g/16g N (113).

	Raw Material		
Amino Acid	Herring	Eviscerated Cod Offal	Shrimp Offal
Alanine	6.35	5.86	5.42
Arginine	6.25	5.68	5.98
Aspartic acid	9.22	7.48	8.50
Available lysine	7.04	5.40	5.30
Cystine	1.03	0.66	0.88
Glutamic acid	12.73	11.10	11.65
Glycine	6.26	10.97	8.18
Histidine	2.13	1.56	2.04
Isoleucine	4.40	2.87	3.57
Leucine	7.15	4.97	5.62
Lysine	7.59	5.44	5.64
Methionine	2.98	2.41	3.52
Phenylalanine	3.83	2.63	5.50
Proline	4.09	5.93	4.83
Serine	3.88	4.38	3.94
Threonine	4.29	3.25	2.37
Tyrosine	3.18	2.01	5.29
Valine	5.35	3.36	4.05

Fish Oils

Fish oils are the most valuable of the fish rendering products. Fish oils in food products are currently prohibited by the Food, Drug and Cosmetics Act of 1938 (114). They are considered non-edible because the raw material from which the oil is extracted is not completely edible. Fineberg and Johanson (114) estimated that 75 percent of the fish oils produced outside the U.S. are used for human consumption.

The major oil-producing species are menhaden and anchovies. In 1968, 73 plants produced 173 million pounds of oil with a value of $7 million (37). The largest production takes place on the Atlantic Coast.

Sanford and Lee (84) listed three characteristics of fish oils which distinguish them from vegetable oils: (1) they contain a high degree of unsaturation, with (2) longer fatty acid molecules and (3) are typified by increased chemical reactivity. Considerable research has been devoted to methods of fractionating the various oils (115).

Methods of Manufacture

Fish oils are obtained from the press water in the wet reduction process (described in the "Fish Meal" section) as shown on Figure 10 (page 29). The press water is screened to remove any solids and then passed through a gravity separator or a centrifuge. The sludge from this process is returned to the press cake and the clarified press liquor is passed to an oil centrifuge. The oil centrifuge yields two products; the fish oil and the stickwater. The oil is marketable in the centrate form.

In the dry-rendering process, the liquid from the presses is fish oil; no recovery steps are necessary.

The press liquor yield and composition vary; an average yield is 5 to 10 pounds of oil per 100 pounds of press liquor (9).

Anderson (116) described an alkaline digestion method of manufacturing commercial oil from salmon wastes. The wastes are ground and added to a 3.5 percent sodium hydroxide solution. The mixture is then stirred and heated to 180° to 200°F for 30 minutes. Next, the solution is diluted with twice the original volume of hot water. The oil and one-quarter of the water are then drawn off and centrifuged.

Eyck, Magnusson and Bjork (117) studied this method further. They found an optimum combination of process variables at 1.5 parts of sodium hydroxide per 100 parts of waste, a digestion temperature of 200°F and a digestion time of from 35 to 40 minutes. The production was found to yield approximately 6 pounds of oil per 100 pounds of pink salmon wastes.

Butler and Miyauchi (118) determined that the alkaline digestion process was adaptable to produce oils bearing vitamin A from total salmon cannery wastes.

Presently, oil is manufactured from ground heads and in some cases, ground offal in some Alaskan salmon canneries (42). The recovered oil is added back to the low oil content sockeye salmon pack when necessary. Only fresh heads and wastes are used and the quality of the oil is carefully monitored. The method of manufacture is as follows (42):

a. "Vertical retort-type pressure cookers are 3/4 filled with ground salmon heads. This takes about 25 minutes with good quality sockeye from one iron chink (Model K).
b. One scoop of salt is added (3-4 lbs).
c. The lid is closed and steam admitted with the main vent open.
d. Steam is allowed to flow until the internal temperature of the cooker reaches 212°F (15 minutes) at which time the vent is closed and the pressure raised to 12 psig and the temperature to 242°F (15 minutes).
e. The heads are cooked at 12 psig for 40 minutes at which time the steam is shut off and the pressure allowed to drop to 5 psig before opening the vent (15 to 20 minutes).
f. When ambient pressure is reached, the cooker is opened and the contents allowed to settle for 5 minutes.
g. Cold water is added from the bottom of the cooker to float the oil up to the decanting spout from which it flows to the heated settling tank where it is allowed to settle for 15 to 20 minutes.
h. The oil is then centrifuged. The oil may be either bulk stored or held in smaller containers."

Brocklesby and Denstedt (119) stated that due to the freshness criterion, the recovery of oil from waste is not feasible if the waste must be transported. For small, isolated plants which cannot afford their own rendering equipment, the travel time will result in the oil becoming partly decomposed.

Ehlert (120) holds a U.S. patent on an enzyme degradation method of producing fish oil and meal. No large-scale enzyme recovery operations were noted in the literature.

Characteristics of Fish Oils

Butler and Miyauchi (118) stated that of the salmon viscera oils, the Vitamin A concentration was highest in that from chum salmon, as shown on Table 55.

Table 55. Vitamin A Concentration in Salmon Oils (USP units per gram), (118).

Species	Heads	Heads and Viscera (less gonads)	Total Viscera
Chum	175	7,319	66,820
Coho	540	2,126	6,079
King	270	14,960	20,182
Pink	257	2,515	2,844
Red	335	5,218	13,907

The viscera of various bottom fish contain large amounts of Vitamin A, but small amounts of oil (121). An alkaline digestion or solvent extraction process is generally used. The stomachs, liver, milt and roe are removed before processing.

Fineberg and Johanson (114) listed several chemical characteristics of the oil from anchovies, herring, sardines and menhaden, shown on Table 56.

Hannewijk (122) stated that tuna oils are of a somewhat low quality. This is caused by the poor condition of the waste materials at the time of rendering.

Table 56. Fish Oil Characteristics (114).

Constant	Menhaden	Herring	Sardine	Anchovy
Iodine value	190	150	194	198.5
Saponification value	190	195	195	193.5
Free fatty acid (%)	3	5.0	13	0.2
Moisture and insolubles (%)	1	1		0.5
Unsaponifiables (%)	0.6-1.6	2-3	0.5-2	3

Use of Fish Oils

The methods of refinement of fish oil to give various products are fully described in Fishery Leaflet 528 (123). Approximately one-half of the fish oil used in the U.S. is manufactured into drying oil uses: paints, varnishes, lacquers, resins, caulks, sealants, inks and putties (114). The *Commercial Fisheries Review* (124) noted that menhaden oil could be used as a plasticizer suitable for blending into resins.

A high percentage of the fish oils consumed in the United States is used in animal feeds. Advantages include growth-promoting effects, low cost, and high vitamin A and D contents (125). Oxidized fish oils with high peroxide values should not be fed because peroxides are toxic. Disadvantages include increased vitamin E requirements for most animals when fish oils are added to their diets and fishy flavors in animal meat.

Fish oils have excellent coherence characteristics for the emulsion application of insecticides. The Commercial Fisheries Review (126) noted the effectiveness of fish oils to control nematodes. Lee (127) reported that the advantage of fish oils as fungicides was their lack of human toxicity. Fungicides prepared from fish oil are relatively expensive.

Mattei and Roddy (128) noted that leather could be fatliquored with perch, herring, salmon, menhaden and cod oils. The oil produces an internal lubrication which gives leather the familiar soft texture.

Stansby (129) and Olden (130) reported that fish oil can be highly effective as an ore flotation agent. No commercial application was reported in the literature, however.

Hannewijk (122) described in detail the processing required to produce fish oil for use in margarine and shortening. Federal laws prohibit this use in the United States (114).

Condensed Fish Solubles

Condensed fish solubles are the by-products produced from the stick-water generated in fish meal and oil plants. In 1968, 32 plants yielded over 143 million pounds of solubles with a value of approximately 4 million dollars (37).

Methods of Manufacture

Fish solubles contain mainly water-soluble substances from stickwater. The stickwater is transferred from the holding tanks to an evaporator (see Figure 10-page 29). The evaporator reduces the water content from 95 percent to 50 percent (131). Solubles are produced in the form of a brown, somewhat viscous liquid with a mild, fishy odor. They may be sold in the feed trade, but normally are dried as press cake for meal.

Characteristics of Fish Solubles

Lassen listed the proximate composition of fish solubles as shown on Table 57. The protein level is high, for a material which is 50 percent water; fish solubles therefore make an excellent animal feed.

Table 57. Typical Analysis of Condensed Fish Solubles (131).

Parameter	Value
Total solids	50.43%
Ash	8.86%
Fat	4.8 %
Crude protein (N X 6.25)	33.85%
Sp. gr. at 20°C	1.20
pH	4.5

Stickwater

The stickwater from the centrifuge contains from 0.5 to 0.9 percent oil (131). This oil is highly dispersed and intimately tied to the proteinaceous material and thus is not removed in the centrifuge. Prior to 1938, stickwater was discharged to local watercourses after the removal of the oil. Serious pollution problems resulted in many cases, leading to the institution of solubles-recovery techniques.

The volume of stickwater generated can vary from 150 to 220 gallons per ton of fish (131). Kempe, et al. (69) estimated a flow of 120 gallons per ton of anchovies. Paessler and Davis (38) reported the BOD_5 of sardine stickwater to be 47,000 mg/l. Lüneburg (132) described stickwater as containing large quantities of suspended and dissolved organic and inorganic materials.

Pretreatment of Stickwater. Stickwater can be stabilized by proper pH adjustment (131). In this stabilization, small amounts of coagulable proteins are precipitated and a change in the collodial properties of the remaining solids results. After this change, the stickwater can be centrifuged to yield additional oil, resulting in better solubles-drying characteristics.

Stickwater Evaporation. There are several evaporation processes that are used to concentrate stickwater. These include multiple effect evaporation, submerged combustion, submerged evaporation, Vincent evaporation and drum drying (69).

Multiple effect evaporators are steam heated and operate under vacuum. More than a pound of waste can be handled per pound of steam applied. They are best used in high volume plants because of the high capital costs, the need for trained operators and the necessity for continuous operation. Gallagher (133) described in detail a plant using multiple effect evaporators. With proper operation the pure condensate is returned to the feed water circuit, eliminating the need for discharge (92). Nachenius (134) stated that three of the most common problems encountered in the process are scale formation, corrosiveness of the product, and unstable product quality due to poor operation.

Submerged combustion and submerged evaporation systems and Vincent evaporators are direct fired; that is, the heat present in the combustion gases is used directly to evaporate the water. Submerged evaporators and submerged combustion systems have been used in several cases to evaporate stickwater (69). Gray and black particles develop in the solubles from the submerged combustion method, but the necessary equipment is simple and inexpensive. Several other disadvantages include the production of noxious odors, lower heat exchange efficiencies than multiple effect evaporators, maximum soluble solids concentrations of 30 to 35 percent and the possibility of foaming.

Drum driers are simple and reliable to use. However, the heat exchange efficiency is low and the steam pressure required is quite high.

Other Stickwater Concentration Methods. A number of other chemical and/or physical processes could be used to concentrate stickwater. At present, however, evaporation has proved to be the most practical.

Gunther and Sair (135) hold a U.S. Patent on a process by which the gel point of the stickwater is reduced by addition of enzymes. The water is then driven off until the concentrate contains 70 percent solids.

Tschekalin (136) reported on a simple method of gravity separation to produce a raw product to be made into an adhesive.

Several firms make equipment that operates on the ultrafiltration and reverse osmosis principles (137, 138, 139). Ultrafiltration is the term applied to separation of high molecular weight solutes and colloids; whereas, reverse osmosis is applied to low molecular weight, high osmotic pressure solvents (140). These units have been designed to concentrate whey, but could possibly be economically used for stickwater concentration.

One Danish firm makes pilot plant scale stickwater concentrators for research use (91).

Fish Protein Concentrate

The development of fish protein concentrate (FPC) has led to claims of the discovery of the answer to the world's shortage of animal protein. FPC is an inexpensive, stable, highly nutritive, quality product prepared from fresh fish or fish wastes.

FPC has not been fully exploited in the U.S. because of 1) incomplete experimental data, 2) the lack of a ready market and 3) governmental restrictions. In several foreign countries the process has been studied and exploited (141).

Advantages of this product include its high protein content and reportedly low cost. Several possible disadvantages exist which may limit its ultimate use. These include rapid spoilage if the oil content is high, adverse consumer reaction to strong fishy tastes, and the large weight loss of the fish during processing (approximately 80 percent) (141). The cost would be approximately $0.40 per pound (142).

The composition of FPC is strictly defined by Federal regulations (143). These regulations require the product to be not less than 75 percent protein, less than 10 percent moisture and less than 0.5 percent fat. The material shall have no more than a faint, characteristic fishy odor and taste. No allowance is made for utilizing fish offal; only whole fish may be used.

Although this product is sometimes called fish flour, it does not exhibit the hydrative, adhesive, and gel-forming properties of starch flours (144).

Research has conclusively demonstrated that FPC can make an acceptable and nutritious product for human consumption. Presently the economics of fortifying food are unknown, although no insurmountable problems are forecast (145).

Methods of Manufacture

FPC is manufactured by three general types of methods; chemical, biological and physical. These are briefly described by Knobl (146) and Bertullo (147) and are summarized on Table 58.

Table 58. Methods of Preparation of Fish Protein Concentrates (147).

Raw Material Used	Method	Solvent or Biological Agent Used
Anchovies	Chemical	Hexane
Cod	Chemical	Polyphosphoric acid and isopropanol
Commercial fish meal		
Fresh fish	Chemical	Ethanol or acetone plus NaOH, KOH, HCl
Fresh fish	Chemical	Ethylene dichloride
Fresh fish	Biological	Enzymes
Fresh fish or fish meal	Chemical	Secondary or n-butanol, isopropanol
Fresh haddock	Physical	---
Hake, pilchard	Chemical	Ethanol
Herring	Physical	---
Jack mackerel	Biological	Enzymes
Red hake	Chemical	Isopropanol
Red hake	Biological	Enzymes
Sardines and fatty fishes	Chemical	Mixture of hexane, ethyl acetate, and isopropanol
Whiting	Biological	Yeast
Whiting	Chemical	Hexane and hexane plus ethanol

Knobl (146) stated that chemical methods remove the water, lipids, and odor-causing compounds without dissolving the proteins. Biological methods result in a mixture of protein breakdown products and thus facilitate physical removal of water and lipids through filtration and centrifugation. Biological methods are relatively simple and give a more flavorful product than chemical extraction methods.

Liston, et al. (148) reported on a chemical process using an acidified brine solvent to extract the protein from whole fish. Much lower production costs were predicted using this method.

Peniston and associates (99) have developed a rendering process for shellfish wastes. The protein is extracted with a dilute sodium hydroxide solution. The liquid sodium proteinate extract can be refined by any of several methods. Possible by-products from the solid residue include chitin, lime, and a soil conditioner.

Kornberg (149) discussed the economics of a 50-ton per day isopropanol extraction process. The plant would cost under $1 million and could produce 7.5 tons of FPC per day at a cost under $0.20 per pound.

Characteristics of FPC

The isopropanol extraction method for red hake yields FPC of the following approximate composition: protein, 80 percent; volatiles, 7 percent; ash, 13 percent; and lipids, 0.20 percent (150).

Guttmann and Vandenheuvel (151) reported on the production of FPC from cod and haddock offal. The yield of FPC was 10 percent by weight and the approximate composition was 2-3 percent moisture, 2-5 percent ash, negligible lipids, and 94-98 percent protein. The process included an acid treatment of the offal followed by an isopropanol extraction of the press cake.

Power (152) reported on FPC produced from whole codfish, beheaded and eviscerated codfish, cod trimmings (fillet wastes), cod trimmings press cake, and whole herring. The procedure used was the same as that of Guttmann and Vendenheuvel. All protein concentrates made were judged to be satisfactory except the one from whole hake. The protein level in the concentrate from cod trimmings was 87 percent; from cod trimming press cake cooked by indirect heat, 77 percent; and from cod trimming cake cooked in live steam, 71 percent. All the proteins were relatively high in lysine.

Present and Future FPC Production

Russo reported that two future FPC plants are planned in the U.S. (153). The Cape Flattery Co. will have an FPC plant completed by the fall, 1970 in Seattle, Washington. The Bureau of Commercial Fisheries has just dedicated a pilot plant operation in Aberdeen, Washington which will process whole hake.

Cardinal Proteins, Ltd. of Canso, Nova Scotia will have a plant completed in 1970. The capacity is expected to be 200 tons of fresh fish per day with an output of 30 tons of FPC per day (154). The estimated cost is $5 million (155).

The Viobin Company built the first U.S. FPC plant in New Bedford, Massachusetts and it is now operated by Alpine Marine Protein Industries (156). A floating FPC factory, owned by Marine Protein Concentrates Ltd. of Canada, was operated out of Neah Bay, Washington during 1968 and 1969 (157). The ship, named Cape Flattery I, uses the Viobin process and has a production capability of 40 tons of FPC per day (200 tons of fish). Two other ships have been purchased for conversion to FPC plants.

Olden (141) reported on the successful production and marketing of fish protein concentrate in South Africa. The FPC is used as an essential animal amino acid source in foods such as bread, biscuits, ice cream, mayonnaise, and pharmaceuticals.

Animal Feed

The use of whole fish and fish scraps for animal feed has been studied thoroughly. The fresh wastes or whole fish are usually processed into fish meal, fish oil, or cooked and canned pet food. In addition to meal and oil, the Bureau of Commercial Fisheries (37) listed, for the U.S. in 1968, 10 plants producing crushed shells for poultry feed, 4 plants producing miscellaneous animal feeds, and 2 plants producing pelletized fish hatchery feed; all using fish wastes and whole fish.

Jones (158) discussed the possible species and wastes that could be used for pet food in several geographic areas of the United States. He concluded that now-discarded fish and fish wastes will be needed in the future to meet expanded raw material demands. Several species of presently non-utilized fish were listed.

Fish Meal

Fish meals with high protein content can be manufactured from most commercial species. Fish meals produced from some wastes are as high in protein as those from whole fish (159). However, meals from other wastes may be of considerably lower quality and protein levels because of higher bone protein and non-protein nitrogen contents.

Fish meals can be an excellent protein and amino acid source, being especially rich in lysine and methionine (160). Fish products are also rich in phosphorus, calcium, manganese, iodine, vitamin B_{12}, riboflavin, niacin and choline.

Grau and associates (103) found that the excellent growth characteristics of fish meal were absent in spoiled, cooked fish, but that room-temperature storage of the meal did not affect these characteristics.

An article in Feedstuffs (161) described broiler rations containing up to 10 percent fish meal. Fish meals were described as a desirable supplement because of higher coefficients of digestibility, higher levels of amino acids (especially lysine and methionine) and the presence of an unidentified "growth factor", when compared to less expensive protein supplements, such as soybean meal.

Research has shown that the percentage of fish meal that can be used in the total feed varies from 2.5 to 5 percent during the finishing periods to 10 percent during growth periods for chickens, turkeys and swine. Greater usages during finishing may result in off-flavors in the pork or poultry (160). Baelum (162) reported that the addition of fish meals to poultry diets resulted in higher egg production and increased growth rates. Braude (163) stated that swine have been successfully fed fish wastes and fish meal as protein, mineral and vitamin supplements.

Substantial amounts of fish and fish wastes have been used for years in mink food. In general, the response of the mink has been good. Variability in composition and nutritive value of the feeds (a function of the seasonal nature of the catch) has resulted in differences in feeding results. Sanford (164) reported on a now-defunct fish waste mink feed operation in northern Oregon. In Astoria and Newport, Oregon, the wastes were ground, placed into paper bags, and frozen. Not all fish and fish wastes can be used for feeding mink; wastes that are spoiled, contain thiaminase, or are highly oily can cause several diseases (164).

Condensed Fish Solubles

Winchester (165) added condensed fish solubles to the list of excellent animal feeds from fish. Condensed solubles contain B-vitamins and are a source of the fish growth factor. This factor increased growth by 6 percent in chickens. A combination of meal and solubles seemed to optimize this effect. The fish meal counteracted the methionine and lysine deficit of corn-soybean oil meal.

A note in Commercial Fisheries Review (166) also listed the nutritional value of condensed fish solubles and added that increased "hatchability" of eggs was evidenced when the solubles were added to the diets of laying hens.

Fish Oils

Fish oils contain a broad spectrum of fatty acids that are utilized by animals. When used properly, fish oils enhance growth rates, contribute to significant increases in metabolizable energy and increase digestibility. Oxidized fish oils with high peroxide values should not be used for animal feeds, however (125). The vitamin E requirements for most animals are increased when fish oils are added to their diets.

Fish Silage

Fish and fish wastes used for animal feed are preserved as a fish silage in several foreign countries. Hansen (167) described the process used in Denmark. Offal with a protein content of about 15 percent is treated with sulfuric and/or formic acid. Acidification causes a gradual breakdown of the tissues and forms a slurry. A solid silage mixture is made by adding dried vegetable feedstuffs. A pH of 3.5 to 4.0 is common for the final product.

Prater and Montgomery (168) described a process used in Wales. The process involves first acidifying the fish with 95 to 97 percent sulfuric acid, then grinding the fish or fish offal and adding fresh water at the rate of 1-1/2 to 2 gallons per 100 pounds of pulp. Next sulfuric acid is added to reduce the pH to approximately 2. This mixture is stirred, the oils removed and then it is stored in cooled, air-tight containers. Before the ensilage is fed, limestone is added to raise the pH to approximately 4.

Freeman and Hoogland (169) prepared a fish silage from cod and haddock offal in the above manner. The proximate composition ranged from 20 to 26 percent dry matter and 13 to 15 percent protein when preserved at a pH of 1.9 to 2.5.

Krishnaswamy, Kadkol, Revankar (170) described a fermentation procedure used to produce a fish silage. The final product contained 7 percent moisture, 72 percent protein, 4 percent ash and included several essential vitamins.

A variety of acids is used in a process described by Majewski (171). The fish material is treated with hydrochloric acid to pH 6.5, sulfuric acid to pH 5, and formic acid to pH 4. After 24 to 48 hours, formic acid is added to bring the total acid concentration to approximately 2 percent. This liquid feed is stable for periods as long as one year.

Animal Feeds by Species

Bottom Fish. In one research project, rats were used to test the digestibility and protein quality of dried portions of cod and haddock viscera. The digestibility was judged to be good, but the metabolic utilization of nitrogen was judged to be poor (172).

Freeman and Hoogland (169) stated that chickens grew well on a 20 to 25 percent addition of cod and haddock acid silage to their diet. Hogs fed a 50 percent addition to their diets of this fish silage (as the only source of animal protein) also grew well. A fishy taste in the meat was noted if the ration was not discontinued at least three weeks before butchering.

Anderson, Wisutharom and Warnick (173) reported on nutrition tests using hake meal fed to chickens. The meal proved to have a balanced amino acid content. However, the growth characteristics of the chickens fed meals of hake, herring, anchovy and tuna varied widely.

Snyder and Nilson (174) found that rats could use pollock fish scales as a protein source.

Jorgensen (175) concluded that 20, 40, or 60 percent additions of cod trimmings to a mink ration gave a satisfactory diet.

Catfish. The Bureau of Commercial Fisheries (22) listed two methods of catfish waste disposal: (1) processing for pet food, and (2) cooking and feeding the wastes to catfish. Deyoe (176) presently is conducting research in this area. A process is being developed that will convert catfish wastes to a supplement for animal diets. Results to date have shown the wastes to have a high nutritional value.

Herring and Anchovies. Thurston, Ousterhout, and MacMaster (177) determined the composition of herring meal. The meal averaged approximately 80 percent protein and 10 percent ash. Chickens fed this meal averaged 6 percent weight gain per day with 96 percent digestibility of protein.

Breirem, *et al.* (178) reported that herring meals gave higher weight gains in young cattle than oilseed meals. The high contents of minerals and vitamin D in the herring meal were thought to be responsible. Anderson, *et al.* (173) also reported on chicken nutrition tests using herring and anchovy meals. The growth characteristics varied widely between the various meals.

Fladmark (179) holds a U.S. patent for a process to make a cattle feed containing 50 to 70 percent solids from herring-oil factory waste-waters. The water is evaporated under pressure to concentrate the solids.

Menhaden. Crude menhaden oil fed at a 5 percent level gave superior growth performances in Berkshire pigs, one investigating team noted (180). A fishy taste, however, was detectable in the meat.

Leong and associates (181) found that for chickens, a 5 percent diet of menhaden oil was equal in nutritive value to the same level of corn oil. A fishy flavor in the poultry was reported.

Salmon. Landgraf, Miyauchi and Stansby (182) reported on the feasibility of the use of Alaskan salmon trimmings for animal feed in the state of Washington. In their study the wastes were packed in plastic bags in Alaska and frozen for shipping to Washington. The process proved, in the opinion of the investigators, to be economically feasible in 1950. Fins and heads were excluded. The viscera were marketed mostly as hatchery feed. Kyte (183) cited research by the Bureau of Commercial Fisheries indicating that salmon viscera produced a growth in hatchery fish superior to any meat product tested.

Leekley, *et al.* (184) stated that mink can use frozen salmon offal as a major portion of their diet.

Wigutoff (185) examined the economics of transporting Alaskan salmon wastes to hatcheries and fur-farms in the contiguous states of the U.S. The prospect was determined to not be profitable in 1952 due to high transportation costs and low costs of competing feeds. The same shipping methods described by Landgraf, *et al.* (182) were assumed for this study.

Burrows and Karrick (186) determined the nutritional value of salmon wastes for hatchery feed. Their general conclusion was that salmon viscera would make an excellent feed. They concluded that neither dehydration nor freezing had detrimental effects on nutritional value.

Shellfish. Meiske and Goodrich (187) reported on research using oyster shells as a replacement for alfalfa-breme hay in the finishing rations for cattle. The use of shells in the feeds proved feasible, but considering the rate of weight gain and feed costs, the diet with a 7.5 percent ground alfalfa-breme hay supplement was superior.

Marvin and Anderson (188) described a method to convert clam wastes to an animal food. A 2 percent solution of pectin was made from the clam wastes by heating to 160°F. The thick liquid was then canned.

Tomiyama and associates (189), studying shellfish wastes, found that autolyzed shellfish viscera could supplement a vegetable protein diet in chicks; the adsorbate from the autolyzed viscera on activated charcoal promoted growth in chicks, while the non-adsorbed portion did not promote growth. The autolyzed viscera also promoted egg production.

Peniston and associates (99) stated that shellfish meals have equal or superior nutritional value to soya protein. These meals were judged to be readily usable in pet food, other animal feed and possibly for making protein concentrate for human consumption. Jensen (27) stated that shrimp waste would be a desirable hatchery feed because the natural pigment would result in more brightly colored fish. Rousseau (190) also noted this possible advantage of shrimp wastes.

Tuna. Thurston, Ousterhout, and MacMaster (177) reported a proximate analysis of tuna meal as 6 percent moisture, 60 percent protein, and 22 percent ash. The pepsin digestibility exceeded 90 percent and chick growth averaged approximately 5 percent per day.

Anderson, et al. (173) studied the relative nutritional values of tuna, herring, anchovy and hake meals. No definite conclusions were reached due to a high variability of the data.

Stansby (104) stated that tuna wastes used for animal feeds can cause nutritional problems such as steatitis. Tuna meals were considered a premium poultry feed.

Miscellaneous Fishery Products

Extensive research has been undertaken to develop new and useful products from whole fish and fish waste. However, it is the opinion of the authors that most of the methods developed thereby would not solve the problems of solid wastes disposal. These methods usually consume only a small part of the waste and the new waste generated in the process (in many cases) is more noxious and less biodegradable than the original waste. If any of these methods could be developed into profitable processes, the revenues realized from these operations could conceivably be used to at least partially defray the expense of disposing of the remaining wastes.

Protein Hydrolysates

Protein hydrolysates are a combination of proteins that have been chemically degraded to smaller molecules by hydrolysis. Digestion with acid, alkali or enzymes is the normal procedure. Peptones, amino acids, proteases, and polypeptides are four of the major product groups (45).

Several authors noted the amino acid content of fish and fish wastes. Seagran (191), and Seagran, Morey and Dassow (192) listed the essential amino acid content of the roe of each of the five major salmon species. The relative distributions were found to be uniform. Pottinger and Baldwin (193) listed the arginine, histidine, lysine, tryptophan and cystine contents of the edible portions of 26 species of fish and 4 species of shellfish. The values compared favorably with those of casein, beef and egg albumin. Jones and Carrigan (45) concluded that utilization of salmon wastes for preparation of protein hydrolysates is possible, but that the economic potential is questionable. Various enzymatic digestion methods have been investigated (45, 194, 195).

The various protein hydrolysates have several uses which include bacteriological culture media, antibiotics, food flavoring and various treatment and diet supplements for hospital patients. Entry into these markets seems unlikely due to the economics of the situation (45).

Fats and Lipids

Fats and lipids are a group of organic compounds classified by their solubility in organic solvents and insolubility in water. This class includes oils, but fish oils are considered elsewhere in this report (page 79).

Specific fats are used in a variety of industries including food processing, cosmetic and soap production, and chemical production. Fats, lipids, and cholesterol are recovered from a wide variety of animal and vegetable tissues.

Jones and Carrigan (45) concluded that salmon cannery wastes could be economically used for speciality fat and lipid production. Jones, Carrigan and Dassow (196), after further studies, concluded that salmon eggs could be utilized for their lipid and phospholipid fractions, but the extraction of cholesterol did not appear feasible.

Enzymes

Enzymes are complicated organic catalysts produced by living organisms. Commercial uses include incorporation into pharmaceuticals, leather treatments, and food preparations. At present, animal rendering constitutes the largest source of commercial enzymes. Jones and Carrigan (45) reported on the possible recovery of pyloric ceca, a digestion enzyme, from salmon wastes. The enzyme has several industrial applications, such as meat tenderizers or leather conditioners.

Hormones

Hormones are substances secreted by the endocrine glands which control various bodily functions. The most important industrial hormonal process is the isolation of insulin.

Cooke and Carter (197) stated that the Halifax Experimental Station has produced a very pure insulin from fish and some has been manufactured commercially on the Canadian east coast. Jones and Carrigan (45) concluded that it would be difficult to recover the salmon pancreas to isolate insulin, considering the mechanical processing methods now being used.

Vitamins

Vitamins are organic compounds essential to living organisms. They play essential roles in metabolism, usually in enzyme systems. A commercial market exists for vitamin supplements and vitamin additives for foods.

Fish oils have been used extensively for their vitamin content, the most common example being cod liver oil. Pottinger and associates (198) found that haddock liver oil contains fewer vitamins than cod liver oil. Also in many cases the iodine number of the haddock liver oil exceeded the maximum U.S.P. recommended values.

Harrison and associates (199) examined the vitamin contents of fish oils obtained from salmon waste. Oil was removed from the various parts of the waste and assayed (see Table 59). These tests showed the oils of chinook to be the best source of vitamin A, but poorest in vitamin D. Pink and chum salmon were high in vitamin D, but low in vitamin A. Sockeye and silver salmon were good sources of both vitamins.

Stansby (35) listed the vitamin A content of fish oils extracted from the liver and viscera of 8 species of fish as shown on Table 60. Fish liver oils were judged to be the best commercial source of vitamin A and in the case of tuna, for vitamin D. Fish flesh was a good source of both thiamine and riboflavin.

Table 59. Summary of Vitamin A and D Assays of Fish Wastes (199).

Raw Material	Estimated Vitamin A Potency (units/gram)	Estimated Vitamin D Potency (units/gram)
Chinook backbones and collars	Much less than 500	More than 150
Chinook eggs	Much less than 4500	Less than 150
Chinook heads	Much less than 4500	Less than 150
Chinook livers	4,000-8,000	150-400
Chinook total wastes	About 500	150-200
Chinook viscera less livers and eggs	1,300-2,000	200
Chum total waste	Much less than 500	300
Pink total waste	Less than 400	Over 300
Silver total waste	500	Over 300
Sockeye total waste	About 400	300
Steelhead viscera	About 500	Very low

Table 60. Vitamin A Content of Fish Oils (35).

Raw Material	Vitamin A Content (units/gram of oil)
Halibut, viscera	70,000-700,000
Herring, whole	50-300
Ling cod, viscera	10,000-175,000
Menhaden, whole	500
Rockfish, viscera	15,000-125,000
Sablefish, viscera	90,000-250,000
Sardine, whole	50-300
Swordfish, viscera	2,000-30,000

Shell Products

The Bureau of Commercial Fisheries (37) listed several commercial shell products including marine pearl shell buttons, colored chips, mussel shells and crab shells for deviled crab meat. Marine pearl buttons produced in 1968 had a value of over $1 million.

Chitin and Glucosamine

Prawn shells and wastes have been used to produce chitin and glucosamine (200). An acetone extraction and acid digestion were used to yield 27 percent chitin and 10 percent glucosamine from the waste. Peniston and associates (99) reported on an extraction method to yield chitin from shellfish wastes. Crab waste ranged from 30.0 to 42.5 percent chitin and shrimp wastes ranged from 42.3 to 51.5 percent chitin.

Meinhold and Thomas (201) reported on a commercial process of producing chitosan from shrimp wastes. Chitosan is produced from chitin by hydrolysis. Chitosan is a highly polymeric, free, primary amine similar to cellulose except that amino groups replace the hydroxyl groups. Possible commercial applications for chitosan include the manufacture of paper products, animal feeds, and photographic materials.

Fertilizers

Shrimp wastes make valuable fertilizers since the calcium carbonate which is a major constituent of shrimp wastes is similar to agricultural lime and the chitin contains about 7 percent nitrogen which would be slowly released by soil organisms (99). Idler and Schmidt (202) described a process to produce these fertilizers. Enzyme digestion was utilized and urea, phosphoric acid, potassium hydroxide and water were added to produce a final product with a $N:P_2O_5:K_2O$ ratio of 10:5:5. A California firm makes a crab waste fertilizer (sacked in 100 pound bags) that sells for approximately 30 to 35 dollars per ton (203).

Lime and Limestone

Lime is produced from various shellfish wastes by combustion of the calcium carbonate residue. In 1963, 55,000 tons of lime were made from oyster shells, having a value of $468,000 (38). The lime is used in various chemical processes including cement manufacture (204) and animal feed supplementation (205).

The limestone residue from shellfish wastes, approximately 95 percent of the total weight, can be used to treat acid wastes (204). Cronan (206) reported on a Texas firm that neutralized a 0.6 percent acid waste stream to pH 5.6 by passing the waste through a clam-shell-filled pit.

Nelson, Rains and Norris (207) found that clam shells could be used to produce reagent grade limestone.

Glue

Excellent adhesive materials can be made from fish waste. Canadian researchers have developed a superior product with little or no odor using cod skins (208). The Commercial Fisheries Review (209) reported that the menhaden skull might be used for glue production.

Fish Roe and Caviar

The roe (eggs) of fish are the most valuable of the miscellaneous fish products. If large enough, almost any species can be used. Presently, several species of fish roe are cured and canned, including that from alewives, bottom fish, shad, sturgeon, whitefish and salmon (210). In a broad sense, all canned roe is caviar, but the commonly accepted caviar is made from sturgeon eggs.

A variety of curing methods are used. Sturgeon and salmon eggs are salted in brine. Others are salted and air dried, salted in brine or dry salted. Each commercial packer has his unique process which he believes to give the eggs superior quality (211).

The greatest interest in caviar production has been evidenced in Alaska, where salmon eggs are used. Until about 1960 salmon roe was considered worthless and discarded with the offal. Since then, salmon eggs have been utilized for bait and for a red caviar developed by Japanese firms. In 1964, 1.5 million pounds with a value of $300,000 were used for bait and 350,000 pounds were used for caviar at a value of $750,000 (212).

A large volume of salmon eggs is available from salmon processing each year. Magnusson and Hagevig (43) listed the egg content of the total "waste" for the five species of salmon. These values ranged from 8 to 17 million pounds annually, if all salmon roe were recovered.

Alaskan caviar production takes place under Japanese technical supervision (212). The eggs from the waste flow are washed in salt water. The skeins are next agitated in a saturated salt solution for 20 minutes. The skeins then are graded and packed in salt for shipment to Japan.

Miscellaneous Roe Products

Calson (213) reported on a smoked salmon egg spread. The spread was stable at room temperature.

Kyte (214) stated that oil and protein contained in salmon eggs are valuable if they can be separated. Certain enzyme preparations partially separate these two constituents. About one-third of the oil is in a free-oil droplet form, the other two-thirds is closely associated with the protein (183).

Jones, Carrigan and Dassow (196) concluded that protein, fat, and lecithin could possibly be recovered from salmon eggs. Cholesterol concentrations were judged to be average. Kyte (183) judged the amino acid distribution of salmon egg protein to be capable of supplementing plant protein diets.

WASTEWATER STRENGTHS AND VOLUMES

Fish processing wastes come from a variety of sources. Thus, the pollutional strengths of these wastes vary over a wide range. In the literature this topic has been only lightly covered. Therefore, the task of describing fish processing waste strengths is difficult.

The Washington State Water Pollution Control Commission (8) characterized in general terms fish processing wastewaters as shown on Table 61. The listed biochemical oxygen demands (BOD_5) and solids concentrations are very high compared to domestic sewage. These values can be considered only crude estimates at best, since neither the products, processes or plant sizes are listed.

Table 61. Fish Processing Wastewater Characteristics (8).

Parameter	Unit	Value
Volume	gal/ton fish	465-9,100
BOD_5	mg/l	2700-3,440
BOD_5	lbs/1000 gal effluent	2.6-29
BOD_5	lbs/ton fish	8-120
BOD_5	lbs/ton product	21-24
Suspended solids (S.S.)	mg/l	2,200-3,020
Total solids (T.S.)	mg/l	4,198-21,820
Population equivalent (P.E.)*	BOD based/ton fish	47-706

*Assuming 1 P.E. = 0.17 lbs BOD_5/capita-day

A thorough waste survey of German fish processing was reported by Limprich (215). The parameters measured for the city of Cuxhaver, which has plants canning herring, processing and freezing red perch, and producing fish meal, are listed on Table 62. These values are within the range listed on Table 61.

Table 62. German Fish Processing Wastewater Characteristics (215).

Parameter	Unit	Value
Volume (including cooling water)	gal/ton fish	7,200
Volume (excluding cooling water)	gal/ton fish	5,800
BOD_5	lbs/ton fish	82
BOD_5	mg/l	2,658
Ammonia N	mg/l	6.0
Nitrate N	mg/l	0
Total N	mg/l	710

The total nitrogen level exceeded 700 mg/l and thus nitrification could contribute significantly to the oxygen demand in the BOD test. Buczowska and Dabaska (216) stated that nitrification begins in fish processing wastewaters sooner than in normal sewage, and is likely to be significant in the 5-day BOD test.

Untreated effluents from fish processing contain large bacterial populations. The major contribution comes from the washing of the fish before processing. Keil and Randow (217) found the "bacterial count" from a German fish processing plant to be from 260,000 to 850,000 per ml.

Bottom Fish

The wastewater flows from bottom fish processing (outlined on Figure 3, page 11) include large volumes of wash water which contains blood and small pieces of flesh, the body portion of the fish after filleting and the skins.

Claggett and Wong (218) listed the wastewater flow from a bottom fish plant as 450 gpm with 750 mg/l total solids. A report by the firm of Stevens, Thompson, Runyan and Ries, Inc. (219) listed wastewater flows from a bottom fish processing plant as 0.46 to 0.59 mgd. This process included water transport of the fish to the filleting tables. The BOD_5 concentration varied from 192 to 640 mg/l and the BOD_5 per hundred pounds of product averaged 3.7 pounds. The organic loading ranged from 298 to 1,100 pounds of BOD_5 per day.

In 1969 the firm of Cornell, Howland, Hayes and Merryfield (220) measured the waste loadings from this same fish processor after the fish flume had been replaced by a conveyor belt. The flow had decreased to 0.15 mgd; the average BOD_5 concentration was 640 mg/l and the suspended solids, 300 mg/l (see Table 63). The average waste loadings were 800 lbs BOD_5/day and 375 lbs suspended solids/day. The fish scaling operation produced significant quantities of wastewater. The wastewater flow from the scaler was 0.23 mgd with average concentrations of 400 mg/l BOD_5 and 290 mg/l suspended solids (220); however, the scaler was only operated for approximately 2 hours per average processing day.

Limprich (215) reported on the waste flows from a bottom fish processing plant at Cuxhaven, Germany. The average discharge was 132 gpm with a BOD_5 concentration of 1,726 mg/l. This waste was clarified and the sludges were centrifuged and then processed for fish meal.

Table 63. Bottomfish Processing Wastewater Characteristics.

Parameter	Unit	Value	Reference
Flow	gpm	450	(215)
	gpm	320-410	(219)
	gpm	105	(220)
	gpm	132	(215)
BOD_5	mg/l	192-640	(219)
	mg/l	640	(220)
	mg/l	1,726	(215)
	lbs/ton of product	74	(219)
Suspended solids	mg/l	300	(220)

Herring, Menhaden and Anchovies

Limprich described in detail the wastes from a German fish meal plant using approximately 450 tons of raw material per day. The resultant flows and strengths are summarized on Table 64.

Table 64. Fish Meal Processing Wastewater Characteristics (215).

Parameter	Cooling Waters	Other Wastewaters
Discharge	1440 gpm 240-480 gal/ton fish	680 gpm 510-1020 gal/ton fish
BOD_5	621 mg/l	1005 mg/l

The wastewaters from the production of fish meal, solubles, and oil (diagrammed on Figure 10, page 29) from herring, menhaden and anchovies can be divided into two categories: high volume, low strength wastes and low volume, high strength wastes.

The high volume, low strength wastes consist of the water used for unloading, fluming, transporting, and handling the fish plus the wash-down water. Davis (221) estimated the fluming flow to be 2000 gallons per ton of fish with a suspended solids content of 5000 mg/l. The solids consist of blood, flesh, oil, and fats. Claggett and Wong (218) listed a herring pump water flow of 250 gpm with a total solids concentration of 30,000 mg/l and oil concentration of 4,500 mg/l. Pump water is used to transport the fish from the holds of the boats to the processing plant.

The bilge water in the boats was estimated at 400 gallons per ton of fish with a suspended solids content of 10,000 mg/l (221). Other wastes come from leakage from holding tanks, wash-up, evaporators and the drier air scrubbers. Paessler and Davis (38) described in detail these wastes and process modifications that can be used to reduce the waste loads.

Jordan (222) discussed the wastewaters from a fish meal operation. The drainage and rinsing waters from the storage bunkers are usually thick, slimy, highly colored, and strongly malodorous. These wastes have large amounts of insoluble and soluble solids with high nitrogen and phosphate levels. Active decomposition begins rapidly, resulting in the production of hydrogen sulfide. Limprich (215) listed this waste volume as 36 to 48 gal/ton of fish.

Other wastewaters include the condensate from the cooking operation and the cooling water from the condensers. The volumes are large, but the organic loads are small. These wastes contain small amounts of soluble and insoluble solids, including fats. The chemical oxygen demand is usually about 300 mg/l and the wastes are not readily putrefiable (222). Tanzler (223) recommended that this wastewater be first passed through a separator before discharge and the water draining from the fish be passed through a vacuum thickener. Condensate from the thickener would still contain suspended matter which should be removed before discharge to a stream. The final wastewaters generated in the process come from the drying of the fish meal. These wastes are similar to the condensate wastes.

The strongest segment of the fish meal wastes is the stickwater. In most instances stickwater is now evaporated to produce condensed fish solubles but in previous years it was discharged untreated. The volume was estimated by Kempe, _et_. _al_. (69) and Davis (221) to be about 120 gallons per ton of fish processed. Paessler and Davis (38) reported stickwater strengths from 56,000 to 112,000 mg BOD_5/l and grease concentrations from 4,200 to 24,400 mg/l for menhaden. California rendering plants using sardine scrap produced an average BOD_5 of 42,000 mg/l. Jordan (222) stated that stickwater decomposes rapidly, evolving hydrogen sulfide, and leads to nuisance conditions if discharged to waterways or sewage treatment plants. Davis (221) estimated stickwater to be 6 percent solids, consisting almost entirely of protein, with very little oil.

The Biological Board of Canada studied the total waste flow from a sardine rendering plant in British Columbia. The effluent contained approximately 80,000 mg/l total solids (224), 0.57 percent oil, 1.91 percent suspended solids and 2.96 percent dissolved protein (225). Flow was approximately 1900 gal/hr during the 600-hour processing season. Hart, Marshall, and Beall stated that the water was "not affected" beyond a 700-foot radius from the outfall (226).

Knowlton (227) and Tetsch (228) agreed that separation of fats, greases, oils, and protein emulsions should take place at the fish processing plant before discharge to municipal sewers.

Salmon

The wastes from the salmon canning process (illustrated on Figure 12, page 35) include butchering water, viscera, wash water, retort water, and cooling water. Also included is cooking water when oil recovery from the heads is practiced.

Claggett and Wong (218) listed the flow from a salmon canning line as 300 gpm with a total solids concentration of 5000 mg/l and oil concentration of 250 mg/l. The firm of Stevens, Thompson, Runyan and Ries, Inc. reported on the effluents from several salmon processors (219). Later studies of the same firms were reported by Foess (220). The wastewater characteristics are listed on Table 65. The values for all parameters are quite variable; the strengths depend on the efficiency of solids removal. The BOD_5 concentrations range from 200 to 4000 mg/l; suspended solids, 40-5000 mg/l; total solids, 80-8000 mg/l; and volatile solids, 60-7000 mg/l. Mild curing was reported to produce considerably weaker wastes than canning operations.

Caviar production results in extremely strong wastes, but waste volumes are small. These wastes should be recovered and not discharged to the waterways or sewage treatment plants.

Table 65. Salmon Processing Wastewater Characteristics.

Process	Flow (mgd)	COD (mgd)	BOD_5 (mg/l)	BOD_5/raw product (lbs/ton)	Suspended Solids (mg/l)	Total Solids (mg/l)	Volatile Solids (mg/l)	Reference
Canning	0.043-0.046	5,920	3660-3900	6.5-178	508-4780	1188-7444	1048-7278	(219)
Canning	0.33	--	3,860	---	2,470	---	---	(220)
Caviar	---	--	270,000	---	92,600	386,000	292,000	(219)
Mild curing	0.018-0.066	--	173-1320	10-80	44-456	258-2712	98-2508	(219)
Mild curing and fresh	0.011-0.036	--	206-2218	3.2-36	112-820	484-2940	184-1756	(219)
Mild curing or freezing	0.014-0.046	--	397-3082	3.8-19	40-1824	88-3422	67-2866	(219)

Sardines

The National Canners Association has completed a one-week study of the wastes from four Maine sardine packers. These wastes were divided into four categories: pump water, flume water, hold water and processing wastes flume water. Ranges are listed on Table 66.

Table 66. Sardine Packing Wastewater Characteristics (229)

Source	COD (mg/l)	BOD_5 (mg/l)	Suspended Solids (mg/l)	Oil and Grease (mg/l)	Flow (gpm)
Flume water	500-1,400	200-1,150	400	300-360	130-300
Hold water	800	370	---	---	---
Pump water	170-340	10-45	---	---	800-1,000
Waste flume water	240-1,700	100-2,200	100-2,100	60-1,340	40-180

The pump waters transferred the fish from the shipboard holds to a screen separator in the plant. These wastes were lightly polluted, as shown by a BOD_5 of under 50 mg/l, but comprised the largest flow. The flume water conveyed the fish through the plant and became heavily polluted. The hold water resulted from the storage of fish in the boats. The small volumes made this wastewater of lesser consequence. The processing wastewaters were used to transfer the solid wastes to a truck for disposal. This waste flow could easily be eliminated through the use of dry capture techniques. All the liquid wastes were discharged untreated. The water usages for each plant are listed on Table 67. The volumes for salt water seem excessive and probably reflect its ready availability and the lack of effluent treatment requirements.

Table 67. Sardine Packing Plant Water Usages (229).

Plant	Annual Pack (cases)	Fresh Water Usage		Salt Water Usage	
		(mg/yr)	(gal/case)	(mg/yr)	(gal/case)
A	130,917	8.	62	120	900
B	36,188	2.2	60	120	3,300
C	86,173	13.0	150	96	1,100
D	130,407	3.3	25	120	920

Shellfish

Shellfish processing wastes include large volumes of processing wash waters, solid wastes, canning waters, and plant clean-up waters (see Figures 14 and 15, pages 44 and 45. Crawford (26) reported that the mechanical shrimp peeler effluents he studied averaged 29,000 mg/l total solids and 6.4 percent (dry weight basis) total nitrogen.

Tuna

Tuna processing wastes (listed on Figure 16, page 49) include water from butchering, cooking, canning, retorting and cooling and the eviscerated solid wastes. The Kennedy Engineers (230) reported on tuna cannery wastes in American Samoa. The waste concentrations averaged 5,100 mg/l BOD_5, 5,890 mg/l grease and 1,730 mg/l suspended solids, of which 85 percent was volatile.

Chun, et al., (105) studied in detail the wastes from a tuna canning and rendering plant in Hawaii. The study was conducted for only a 5-day period; however, the investigators stated that total solids averaged 17,900 mg/l, of which 37 percent was organic. The average BOD_5 for each day ranged from 500 to 1550 mg/l and the average COD for each day ranged from 1300 to 3250 mg/l. The waste was claimed to be toxic, so these BOD_5 values are questionable. The average waste flow was 6800 gallons per ton of fish (see Table 68). An excess of phosphorus and nitrogen was present in the waste. Treatability studies showed the waste to be toxic in the opinion of the researchers.

Table 68. Tuna Wastewater Characteristics (105).

Parameter	Concentration mg/l	Concentration lb/ton of fish
COD	2,273	129
BOD_5	895	48
Total solids	17,900	950
Suspended solids	1,091	58
Grease	287	15

However, considering the literature studied, the high BOD values, and the organic nature of fish wastes the conclusion of toxicity seems unjustified.

The 5-day BOD was only approximately 40 percent of the COD value. Due to the high nitrogen levels and high proportion of particulate matter in the waste, a considerable BOD would be expected to be exerted after five days. In this case at 22 days the BOD exerted was 3525 mg/l and still increasing. It is important to realize that the waste will exert a considerable nitrogenous BOD in excess of the 5-day value.

STANDARD WASTE TREATMENT METHODS

The liquid wastes resulting from fish processing are most commonly discharged to adjoining waters. This practice has been restricted in many areas in recent years as plants have consolidated and enforcement of water pollution control regulations has intensified. The resultant action in many cases has been to discharge the wastes to the municipal sewers. Only one case was mentioned in the United States literature that had on-site treatment of fish processing wastes before discharge to a water body (231).

The specific difficulties encountered in the treatment of fish processing wastes are attributable in large part, to the characteristics of the wastes. These are usually: high flows, medium to high BOD_5 and suspended solids, and high grease and protein levels (when compared to domestic sewage). The high grease and protein levels probably produce the most serious treatment problems due to the difficulty of removal. The frequently short processing seasons, high peak loadings and rapid biodegradability of the wastes are also important considerations.

Screens

Claggett and Wong (232) studied the effectiveness of screening salmon canning wastewaters. Two specific types were tested as, shown on Figures 17 and 18: rotary and tangential screens. A 34-mesh rotary screen made of stainless steel was investigated. The 4-foot long barrel section was rated at 100 gpm. Solids were removed with a screw conveyor and blinding was prevented through the use of high pressure nozzles.

The tangential screen employed two screening surfaces, each one square foot in area, sized at 20 and 40 mesh. The resulting operating capacities were 35 and 20 gpm, respectively.

Both screen types were judged to be successful on salmon canning wastes (232). The results, shown on Table 69, indicate that with the low capital and operating costs associated with screening, a processor could expect removal of over one-half of the total solids in his waste stream.

Table 69. Solids Removal (g/l) from Salmon Wastewater by Screening (232).

Screen	Mesh Size	Raw Waste	Underflow	Overflow
Rotary	34	4.2	2.4	105.1
Tangential	40	4.5	2.5	164

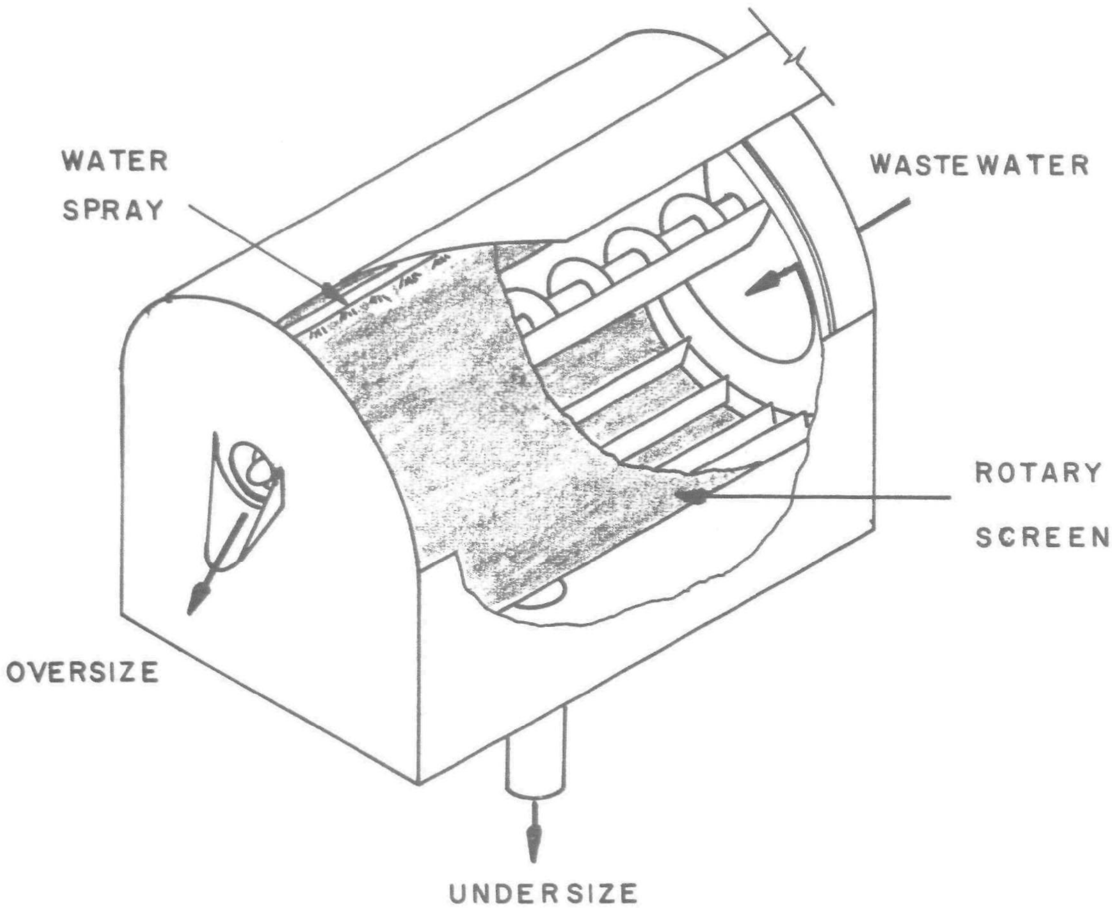

FIGURE 17. ROTARY SCREEN (232).

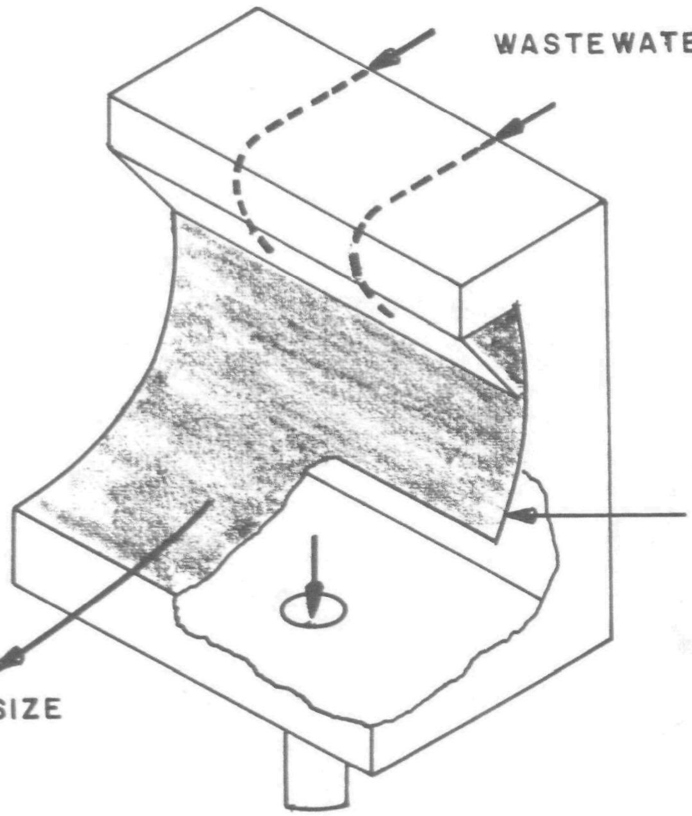

FIGURE 18. TANGENTIAL SCREEN (232).

Centrifuges

Jaegers and Haschke (233) stated that centrifuges can be effectively used to remove fish pulp from waste streams. Fats and proteins can also be recovered by this method (234). However, centrifuging entire waste streams is very expensive when compared to other methods, due mainly to high capital costs.

Clarifiers, Gravity

Large quantities of fats and greases are present in the wastewaters from the processing of oily fishes (sardines, herring, etc.). Knowlton (227) reported the fats and grease content of sardine canning wastewaters to be from 1,000 to 30,000 mg/l compared to 50 to 200 mg/l in domestic sewage. These organics are present as flotables or as emulsions. When the untreated wastes are discharged, serious problems can result if the emulsified grease coalesces and rises to the surface of the receiving water (235).

The greases can be removed by two methods in clarifiers: flotation and sedimentation. Flotation will be described in the following section. Sedimentation of the fats and greases is enhanced by various coagulants. Limprich (215) reported that the application of 2.5 g clay plus 2.5 g lime and 100 mg of ferric chloride per liter gave an optimal precipitation, with a BOD_5 decrease of 75 percent. A similar procedure was described by Schulz (236) using 2.5 g/l of Al_2O_3, 2.5 g/l of lime, and 100 mg/l of $FeCl_3$. Griffen (237) also mentioned that the high fat and protein wastes can be treated with lime. Chlorination before sedimentation is recommended to prevent serious odor problems from rapid degradation (228, 236, 237). It should be noted that the coagulant dosages recommended above would lead to sludge volumes of at least an order of magnitude greater than those normally encountered in wastewater treatment practices. Thus, in many cases, these dosages would prove impractical.

Buczowska and Dabaska (216) listed sedimentation results for fish processing wastewaters. In two hours of quiescent settling, 32 percent of the suspended solids were removed with 25 percent of BOD_5. About 58 percent of the organic matter in the wastewaters was in solution or colloidal suspension. Limprich (215) stated that 58 percent of the suspended matter settled out in 2 hours for "fish wastes". The resulting sludge was described as being "very voluminous". Corresponding values for sewage after 2 hours of settling would be approximately 70 percent suspended solids and 40 percent BOD_5 removals (238).

A partially successful gravity clarification system was developed using large quantities of a commercial coagulant called F-FLOK (232). F-FLOK is marketed by the Georgia Pacific Corporation and is derived from lignosulfonic acid. The floc formed slowly, but after formation, sedimentation rates of 4 feet per hour could be achieved. The summary for a large scale test on salmon wastewaters (Table 70) shows a maximum solids removal of about 70 percent. The underflow was judged to be quite dilute.

Table 70. Gravity Clarification Using F-FLOK Coagulant (232).

Coagulant Concentration (mg/l)	Total Solids Recovery (%)	Protein Recovery (%)
5020	68	92
4710	60	80
2390	47	69

Claggett (240) mentioned that normal detention times in gravity clarifiers may lead to strong odors due to rapid microbial action.

Drangsholt (239) described a method to chemically treat stickwater for discharge. The waters are first aerated and skimmed to remove fats and colloids; the pH is then raised and coagulants are added to precipitate the proteins. The final effluent is neutralized and passed through sand and activated carbon filters.

Clarifiers, Flotation

The flotation technique relies on the entrainment of minute air bubbles which float particles to the water surface. The resulting sludge blanket is continuously skimmed from the surface. Two methods are used to entrain the air bubbles in the flow, each method having definite advantages over the other.

The first method uses mechanical aerators to "whip" the air bubbles into solution. Dreosti (241) reported that good laboratory results were obtained using fish wastes with suspended solids levels of up to 8,000 mg/l. Higher suspended solids concentrations led to sludges that did not consolidate well on the surface.

For optimum results, Dreosti (241) recommended a small quantity of air for flotation and agitation times of only 1 or 2 seconds. Centrifugal pumps could be used if air were bled into the pump chambers. Coagulants improved the removal efficiency; however, no mention was made of types or quantities used. The minimum detention time was estimated to be 5 minutes.

Hopkins and Einarsson (231) reported a fish waste treatment installation using a "whip-type" air flotation unit. A flow of 0.065 mgd was passed through tanks with an "Air-O-Mix" aeration unit. The resulting sludge, including 15.5 pounds per day of grease and 35 pounds per day of fish solids, was flash incinerated.

The second method involves flow pressurization. The total influent flow or a part of the flow is pressurized and then passed into the flotation unit, which is at ambient pressure. The now supersaturated solution begins to release air, forming many tiny bubbles. These bubbles then float the suspended solids to the surface. This method requires pressure pumps and containers. However, greater efficiency is usually obtained than with the "whipping" method.

Claggett (240), and Claggett and Wong (232)(218) described in detail pilot scale tests of the flow pressurization method of solids removal from fish processing wastes. Water was pressurized by a centrifugal pump to about 40 psig. Air was added at the rate of about 2 percent by volume. The pressurization tank had a one-minute detention time. The recovered sludge was heated and the protein and oil fractions removed by centrifuges.

All tests were conducted using a coagulant aid. These aids act by breaking the oil-water emulsions, coagulating small particles and reducing the solubility of protein fractions. The specific aids tested were alum, ferric chloride, F-FLOK, aluminum hydroxide, Zetol A (trade name for an animal glue), and lime.

In the first tests on salmon processing wastewaters, alum, ferric chloride and F-FLOK were compared. The partial results on Table 71 show that alum and ferric chloride performed well as coagulants, but large dosages of F-FLOK were necessary to achieve comparable results. Ferric chloride-treated and recovered solids showed signs of extreme oxidation in the oils. In all cases a significant carry-over of the floc was noticed in the effluent.

In the second test on salmon processing wastewaters, precipitated aluminum hydroxide, lime, Zetol A and F-FLOK were compared. The results shown on Table 72 show that precipitated aluminum hydroxide was only partially effective. The F-FLOK gave similar results, but dosages over 2,000 mg/l were used, leading to large sludge volumes.

Table 71. Effects of Flotation with Coagulant Aids on Salmon Processing Wastewaters (218).

Coagulant Aid	Dosage (ppm)	pH	Influent Total Solids (ppm)	Effluent Total Solids (ppm)	Solids Removal Efficiency (%)	Dry Solids Recovered at 50 gpm (lbs/hr)
Alum	47	6.1	5,400	1,560	71	11.5
Alum	47	6.0	2,290	1,200	48	8.5
Ferric Chloride	60	5.5	5,580	2,400	57	11.0
Ferric Chloride	60	5.5	2,860	950	67	15.0
Ferric Chloride	133	4.1	1,800	1,180	34	10.5
F-FLOK	1000	4.0	5,900	1,200	63	--

Table 72. Effects of Flotation with Coagulant Aids on Salmon Processing Wastewaters (232).

Coagulant Aids	Influent			Effluent			Removal Efficiencies		
	T.S. (mg/l)	S.S. (mg/l)	BOD_5 (mg/l)	T.S. (mg/l)	S.S. (mg/l)	BOD_5 (mg/l)	T.S. (%)	S.S. (%)	BOD_5 (%)
75 mg/l aluminum hydroxide	2,685	640	1,775	1,505	1,305	475	44	51	26
1 mg/l Zetol A	2,441	697	1,275	1,625	200	381	33	71	70
375 mg/l aluminum sulfate plus 75 mg/l lime	4,268	1993	2,833	2,162	397	633	49	80	78

Claggett and Wong (218) concluded that flotation cells could be used effectively on fish processing wastes. Alum treatment was judged the most promising of the methods used. Feeding tests showed that alum could be included in the recovered solids up to the 1 percent level without altering the growth rate of chickens.

A method has been developed to remove fish oils down to the 0.008 percent level (80 mg/l) by acidification of the waste stream followed by flotation (242). This method would require neutralization after treatment. Specially-coated treatment equipment would be needed to avoid corrosion.

Aerobic Biological Treatment

Buczowska and Dabaska (216) concluded that the carbon:nitrogen ratio of fish processing wastewaters indicates that biological treatment should be successful. The biochemical oxidation rate was said to be similar to sewage, but nitrification begins sooner and is more significant. Assuming primary stage removal of reasonable levels of solids, grease and oils, no special problems should be encountered, the authors said.

Without this pretreatment several problems can develop. Matusky, Lawler, Quirk and Genetelli (243) mentioned that oil and grease can interfere with oxygen transfer in an activated sludge system. Czapik (244) reported on a trickling filter that clogged due to high solids and oil levels in the wastewaters from a fish processing plant.

A Japanese activated sludge plant has been especially designed for fish wastes (245). The wastewater flow is approximately 0.41 cfs (0.27 MGD) and the BOD_5 concentration ranges from 1,000 to 1,900 mg/l (see Table 73). Pilot plant studies were conducted using a 10-hour separation time and the organic and hydraulic loadings listed on Table 74. The results showed adequate treatment using conventional biological waste treatment. Bulking occurred when the organic loading rate exceeded 0.31 lb/ft^3/day.

Table 73. Wastewater Characteristics of a Japanese Fish Sausage Plant (245).

Parameter	Units	Value
pH		6.9-7.1
Total solids	mg/l	1,560-2,450
Volatile solids	mg/l	1,120-1,900
Suspended solids	mg/l	320- 695
BOD_5	mg/l	1,000-1,900
Total nitrogen	mg/l	70- 311

Table 74. Activated Sludge Pilot Plant Results (245).

Parameter	Raw Waste	Effluent Characteristics: BOD loading ($lb/ft^3/day$) 0.075	0.14	0.21	0.26
pH	6.9	5.5	6.0	6.0	6.2
S.S. (mg/l)	320	---	---	12	70
BOD_5 (mg/l)	1,000	5	10	13	27
(% removal)		99.5	99.0	98.7	97.3
Total N (mg/l)	70	---	---	35	51

Anaerobic Biological Treatment

Fish wastes were judged to present no unusual problems in digester operations, assuming that large waste solids are first removed at the processing plant (8). Matusky, et al, (243), stated that fish solids and oil digested readily and the resultant sludge dewatered easily. The digester loading rates varied from 0.1 to 0.36 lbs v.s./ft^3/day.

In the system described by Hopkins and Einarsson (231), the clarified wastewater was effectively treated in a series of septic tanks.

ON-GOING RESEARCH

A variety of research projects on subjects relating to fish processing wastes are presently on-going or have been recently completed. These projects are briefly summarized below to describe the general trends in current research efforts and to indicate specific individuals who can provide recently developed data.

Harvesting and Processing Modifications

The Oregon State University Seafoods Laboratory (246) is presently studying the efficiency of the Yanagiya Flesh Separator. The device consists of a revolving stainless steel drum perforated with numerous 1/16" diameter holes. A continuous belt is forced against a portion of the drum. Whole fish or filleted fish bodies are placed between the revolving drum and the belt and the soft flesh portions are continuously pressed through the drum and extracted. Present data show excellent recovery of the flesh portions from the bone structures of the fish. A larger model of this device is presently being used by one Oregon processor to remove cooked tuna flesh from bone scraps. The recovered flesh is processed as pet food.

Richardson and Amundson (247) have undertaken a 5-year study of rendering of Great Lake alewives. Microbial activity is used to separate the oil and scrap. Proposed as possible uses are fish protein concentrates, fish oil and various oil-based products.

The College of Fisheries of the University of Washington (248) has concluded research on the enzyme digestion of shrimp wastes. An effort was made to develop an active digestive system that could operate at high temperatures.

Law (249) currently holds a U.S.D.A. grant to study the utilization of marine waste products and latent fisheries.

A new, rapid method of ship-board fish meal production has been developed by a Mexican firm (89). Fresh fish are ground and dried simultaneously in a 240°C gas stream. The meal is then cooled and packaged. The complete process takes from 6 to 8 seconds as compared to 22 minutes in an alcohol extraction process. One ton of fish meal is recovered from five tons of fish. No reference was made to the applicability of this method to fish wastes, but there appears to be no obvious reason to discount it as a possibility.

A packaged on-board freezer has been recently marketed by a Pennsylvania firm (250). This unit freezes up to 300 pounds of shrimp per hour and maintains freezing temperatures in the storage hold. Utilization of this apparatus could eliminate the use of ice and its resultant wastewater.

Two new American ocean vessels have recently been active in the harvesting and processing of fishery products (251). Named the "Seafreeze Atlantic" and "Seafreeze Pacific", these two ships cost over $5 million each, and each can handle 50 tons of fish per day. Processing is so complete that "...only the skins are wasted." If this venture proves successful, terrestial accumulation of fish processing wastes could be substantially reduced in the future.

The Bureau of Commercial Fisheries (252) has developed a trap to harvest the sable fish population off the Pacific Coast. The trap has been judged to be moderately successful and further development is planned.

Waste Strengths and Volumes

The National Canners Association (253) is presently conducting research on wastewater characteristics from sardine, shrimp. salmon, and tuna processing plants. The wastewater parameters to be measured are COD, BOD_5, total solids, dissolved solids, suspended solids, oil, grease, nitrogen and chlorides. A study on Maine sardine plants has been completed (253).

Waste Treatment

A Northern California firm (62) has developed a direct-fired gas drier to economically dry fish meal. The drier jet exhausts upward with an adequate velocity to "fluidize" the drying bed of meal. High heat transfer efficiencies have been obtained with this machine (i.e., greater than 95 percent recovery).

Kempe (254) has proposed research on the efficiency of spray-evaporation of stickwater. This method is considered to be superior to other evaporation methods due to its lower cost, simplicity of operation and faster start-up. These factors are especially important to the smaller rendering plants with limited capital.

Johnson and Hayes (255) have proposed a pilot plant study on the utilization of king crab wastes for chitin. Mathews (60), of the University of Alaska, is presently studying the utilization of king crab wastes.

Deyoe (256), at Kansas State University, has proposed research on the nutritive value and economic utilization of catfish processing wastes. Meals produced by various methods would be chemically analyzed and animal feeding tests performed.

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This report is of value only insofar as it truthfully represents the "state of the art"; therefore its degree of success can be measured by the level of industrial, governmental, and university cooperation achieved.

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PUBLICATIONS

The following publications were generated as a direct result of this project:

1. Soderquist, M. 1969. Water Pollution in the Seafoods Industry In: Pollution and the Fisheries. National Fisheries Institute, Washington, D.C. Pp. 16-19.

2. Soderquist, M.R., K.J. Williamson and G.I. Blanton, Jr. 1970. Seafoods Processing: Pollution Problems and Guidelines for Improvement. In: Proceedings of the National Symposium on Food Processing Wastes, Portland, Oregon, April 6-8, 1970. Pacific Northwest Water Laboratory, Federal Water Quality Administration, Corvallis, Oregon. Pp. 189-225.

APPENDIX I

Summary of Water Quality Standards for The States with Seafoods Processing Industries

The following report was summarized from the October 29, 1969 issue of Chemical Week.

State	pH Range	Allowable Deviation	Dissolved oxygen (minimum mg/l or % saturation)
Alabama	6.0-8.5	1.0	2.0 at 5 ft. or middepth if less than 10 ft.

Other Requirements: Solids. Free from waste materials that cause unsightly or putrescent conditions or interfere directly or indirectly with industrial use.

Alaska	7.0-8.0	0.5	5.0

Other Requirements: Color. True color less than 50 color units. Solids. No dissolved solids above natural conditions causing corrosion or scaling problems. No visible evidence of other floating solids or sludge deposits. No imposed sediment load that would interfere with established treatment levels.*

Arizona	6.5-8.6	0.5	---

Other Requirements: Turbidity. 50 JCU (streams); 25 JCU (lakes). Color. Free from waste materials in amounts sufficient to change existing color enough to interfere with industrial use or to create a nuisance. Solids. Free from wastes that would be unsightly, putrescent, odorous, or in amounts that would interfere with industrial use.

Arkansas	6.0-9.0	1.0 (24 hours)	4.0 (average for any cross section)

Other Requirements: Taste and Odor. Must not cause offensive odors or otherwise interfere with industrial use. Solids. No distinctly visible persistent solids, bottom deposits or sludge banks due to wastes.

California	6.5-8.6 7.0-8.6 (Coastal waters)	---	6.0 Coastal water: 5.0; (unless naturally lower)

Other Requirements: Turbidity. Free from wastes that could alter water's existing turbidity. Color. Free from substances attributable

State	pH Range	Allowable Deviation	Dissolved oxygen (minimum mg/l or % saturation)

to wastes that produce detrimental color. Taste and Odor. No substances that impart foreign taste or odor. Solids. Dissolved solids in fresh water must not exceed 300 mg/l at anytime; annual mean: 175 mg/l. Settleable solids must not be able to change nature of stream bottom or harm aquatic environment.

Connecticut	6.0-9.0	---	2.0

Other Requirements: Turbidity, Color, Taste and Odor. None in such quantities that would impair industrial use. Solids. Limited to small amounts that may result from discharge of appropriately treated wastes.

Delaware	6.5-8.5	---	50%* or 4.0

Other Requirements: Solids. Free from unsightly and malodorous nuisances due to floating solids or sludge deposits. Toxic Substances. None in concentrations harmful (synergistically or otherwise) to humans, fish, shellfish, wildlife, or aquatic life.

Florida	6.0-8.5	1.0	4.0

Other Requirements: Turbidity. 50 JCU. Color. Must not render water unfit for industrial-cooling or process-water supply purposes. Solids. Dissolved solids must not exceed 1,000 mg/l; monthly average: 500 mg/l. Must be free from floating wastes that are unsightly or deleterious or other wastes that settle to form putrescent or objectionable sludge deposits.

Georgia	6.0-8.5	---	2.5 3.0 (daily average)

Other Requirements: Solids. Free from wastes that are unsightly, putrescent or otherwise objectionable or would interfere with industrial use. Toxic Substances. No wastes in concentrations that would prevent fish survival or interfere with industrial use.

Hawaii	6.5-8.5	---	4.5

Other Requirements: Taste and Odor. Wastes, after dilution and mixture must not interfere with industrial use.

State	pH Range	Allowable Deviation	Dissolved oxygen (minimum mg/l or % saturation)
Idaho	6.5-9.0	0.5	75% (at seasonal low)

Other Requirements: Turbidity. No objectionable turbidity that can be traced to a point source. Solids. No floating or submerged matter; no sludge deposits that could adversely affect industrial use.

Illinois	5.0-9.0	---	2.0 3.0 (for 16 hrs. in any 24 hr. period)

Other Requirements: Color, Taste, and Odor. Free from wastes that produce color, odor, or taste, in such a degree as to create a nuisance. Solids. Free from floating wastes that settle and form unsightly, deleterious or putrescent deposits.

Indiana	5.0-9.0	---	1.0 2.0 (daily average)

Other Requirements: Solids. Dissolved solids must not exceed 1,000 mg/l; monthly average: 750 mg/l. Must be free from unsightly, putrescent, deleterious or otherwise objectionable wastes.

Iowa	---	---	---

Other Requirements: Solids. Free from floating wastes in amounts that would be unsightly or deleterious or other wastes that settle to form putrescent or objectionable sludge deposits.

Kansas	6.5-9.0	---	4.0*

Other Requirements: Taste and Odor. Concentrations limited to those that would not result in noticeable offensive odors or otherwise interfere with industrial use. Solids. Free from floating debris or material in amounts that would be unsightly or detrimental to industrial uses.

Kentucky	5.0-9.0	---	---

Other Requirements: Solids. Dissolved solids must not exceed 1,000 mg/l; monthly average: 750 mg/l. No floating wastes in unsightly or deleterious amounts; no other wastes that settle to form putrescent or objectionable sludges.

State	pH Range	Allowable Deviation	Dissolved oxygen (minimum mg/l or % saturation)
Louisiana	6.0-9.0	---	50%

Other Requirements: Solids. None that would produce floating masses, sludge banks or beds on bottom, either organic or inorganic.

Maine	6.0-9.0*	0.5*	2.0*

Other Requirements: Turbidity, Color, Taste, and Odor. Free from wastes that impart turbidity, color, taste, or odor or impair industrial use. Solids. Free from sludge deposits, solid refuse and floating solids.

Maryland	5.0-9.0 (unless natural)	---	4.0 (unless naturally lower)

Other Requirements: Color, Taste, and Odor. Free from waste materials that change existing color or produce taste and odor to such a degree as to create a nuisance or interfere with industrial use. Solids. Free from wastes that float, settle to form deposits, create a nuisance or interfere with industrial use and are unsightly, putrescent or odorous.

Massachusetts	6.0-9.0	---	2.0

Other Requirements: Solids. None allowed except that which may result from the discharge from waste-treatment facilities providing appropriate treatment.

Michigan	6.5-8.8	0.5	Enough to prevent nuisance

Other Requirements: Turbidity, Color. No objectionable unnatural turbidity or color in quantities sufficient to interfere with industrial use. Taste and Odor. Below levels that are or may become injurious to industrial use. Solids. Dissolved solids must not exceed 750 mg/l; monthly average: 500 mg/l. No floating solids or objectionable deposits in quantities that would interfere with industrial use.

Minnesota	6.0-9.0	---	---

Other Requirements: Color, Taste and Odor, Solids. Free from wastes that cause nuisance conditions, such as material discoloration, obnoxious odors, significant floating solids, excessive suspended

State	pH Range	Allowable Deviation	Dissolved oxygen (minimum mg/l or % saturation)

solids or sludge deposits.

Mississippi	6.0-8.5	1.0	3.0

Other Requirements: Solids. Dissolved solids must not exceed 1,500 mg/l; monthly average: 750 mg/l. Must be free from floating wastes that settle to form unsightly deleterious, objectionable or putrescent deposits.

Missouri	6.5-9.0	---	4.0*

Other Requirements: Solids. No noticeable organic or inorganic deposits or floating materials in unsightly or deleterious amounts.

Montana	6.5-9.5	0.5	---

Other Requirements: Solids. No floating solids and sludge deposits in amounts deleterious to industrial use; no sediments or settleable solids that affect treatment levels.

Nebraska	6.5-9.0	1.0	5.0

Other Requirements: Turbidity. No more than 10% increase above normal level. Solids. Dissolved solids must not exceed 1,500 mg/l. No more than 20% increase (limit: 100 mg/l) from any point source. No waste solids that permit deposition or are deleterious to industrial use.

New Hampshire	6.0-8.5 (unless natural)	---	5.0

Other Requirements: Solids. No floating solids or sludge deposits in objectionable amounts.

New Jersey	6.5-8.5 (unless natural)	---	4.0*

Other Requirements: Turbidity, Solids. None noticeable in water or deposited along shore. Color, Taste and Odor. None that are offensive to humans or detrimental to aquatic biota.

State	pH Range	Allowable Deviation	Dissolved oxygen (minimum mg/l or % saturation)
New York	6.0-9.5	---	3.0

Other Requirements: Color. No colored wastes that alone or in combinations make water unsuitable for industrial use. Solids. No floating or settleable solids or sludge deposits that are readily visible and attributable to wastes.

North Carolina	6.0-8.5 4.3 (swamps)	---	3.0

Other requirements: Color. Must not render water unfit for industrial cooling. Solids. Must not, after dilution and mixture, make water unfit for industrial cooling.

Oregon	6.5-9.0	---	5.0

Other Requirements: Turbidity. 5 JCU above natural. Solids. No floating solids, organic or inorganic deposits injurious to industry.

Pennsylvania	6.0-9.0	---	4.0 5.0 (daily average)

Other Requirements: Solids. Dissolved solids must not exceed 750 mg/l; monthly average: 500 mg/l. No floating wastes or substances that settle to form sludge in amounts harmful to industrial use.

Rhode Island	6.0-8.5	---	3.0* 5.0* (16 hrs./day)

Other Requirements: Solids. No solid refuse, floating solids or sludge deposits.

South Carolina	6.0-8.5 5.0-8.5 (swamps)	---	3.0* 2.5*

Other Requirements: Solids. None from waste sources in amounts that are unsightly, putrescent, odorous or that cause a nuisance or interfere with industrial use.

State	pH Range	Allowable Deviation	Dissolved oxygen (minimum mg/l or % saturation)
South Dakota	6.0-9.5	1.0	---

Other Requirements: Solids. Dissolved solids must not exceed 2,000 mg/l. No wastes producing floating solids, sludge deposits or other offensive effects.

Tennessee	6.0-9.0	1.0 (24 hrs)	Enough to prevent offensive conditions

Other Requirements: Solids. Dissolved solids must not exceed 500 mg/l. No distinctly visible solids, bottom deposits or sludge banks that could be detrimental to industrial use.

Texas	5.0-8.5 5.0-9.0 (cooling water)	---	4.0

Other Requirements: Solids. Dissolved solids must not exceed 1,000 mg/l. unless water used only for cooling water. Must be essentially free from floating or settleable suspended solids that would adversely affect industrial use.

Utah	6.5-9.0	---	---

Other Requirements: Solids. No floating wastes that are unsightly or that interfere with industrial use; no wastes that settle to form unsightly or odorous sludge or bottom deposits.

Virginia	5.0-9.0 (swamps as low 4.3)	---	1.0* 2.0* (daily average)

Other Requirements: Solids. No floating wastes that are unsightly or create a nuisance or other wastes that settle to form unsightly, putrescent or odorous deposits.

Washington	6.5-8.5	0.5	6.5 or 70%

Other Requirements: Turbidity. Less than 10 JCU over natural conditions. Color, Taste and Odor, Solids. Dissolved, suspended, floating or submerged matter shall not reduce esthetic values so as to affect industrial use.

State	pH Range	Allowable Deviation	Dissolved oxygen (minimum mg/1 or % saturation)
Wisconsin	6.0-9.0	0.5	1.0 2.0 (daily average)

Other Requirements: Solids. Dissolved solids must not exceed 1,000 mg/1; daily average: 750 mg/1. No floating or submerged debris or waste substances that would cause objectionable deposits in amount to create a nuisance.

*Standard reserved from Federal Water Quality Administration approval.
Abbreviations: JCU - Jackson Candle Units.

Note: Specific limits for coliforms, biochemical oxygen demand (BOD_5), oil, grease, etc. are not included. Some states set standards for each stream reach or river basin; in such cases, table shows the least stringent requirements.

APPENDIX II

Synopsis of Charges to Industries Served by Municipal Treatment Systems

Charges for municipal treatment of industrial wastewaters are commonly computed by formulas of the type shown below.

$$\text{Daily Sewage Charge} = (Q \times A) + (Q \times S.S. \times B) + (Q \times BOD_5 \times C)$$

Where: Q = Flow (mgd)

A = \$/million gals

$S.S.$ = lbs of suspended solids/million gals

B = \$/lb of S.S.

BOD_5 = lbs of BOD_5/million gals

C = \$/lb of BOD

The three basic parameters monitored are flow, 5-day biochemical oxygen demand, and suspended solids. Other parameters are included in the treatment charges if the industrial waste poses unusual treatment problems.

Ranges of presently-used values for parameters A, B, and C in several Pacific Northwest municipalities are listed below.

Table 75. Treatment Charge Parameters (258).

Parameter	Unit	Range	Average
A	$/million gals	$4.58 -$26.95	$20.09
B	$/lb of S.S.	0.0025- 0.0056	0.0039
C	$/lb of BOD	0.0017- 0.0041	0.0028

APPENDIX III

Tabulation of On-Site Seafood Processing Center Survey Results

Location	Species	Processing Season	Wastewater Disposal			Solid Waste Disposal				
			Untreated Discharge	On-site Treatment	Municipal Treatment	Viscera Disposal At Sea	Rendering Plant	Animal Feed	Adjoining Water	Municipal Disposal
1. Kodiak, Alaska	Dungeness crab	8/15-2/15	X						X	
	Tanner crab	Year around	X						X	
	Dungeness crab	7/1-9/1	X						X	
2. Kodiak, Alaska	King crab	8/1-1/15	X						X	
	Dungeness crab	5/1-10/1	X						X	
	Tanner crab	9/1-7/1	X						X	
	Salmon	7/1-9/10	X						X	
	Scallops	Year around	X						X	
	Shrimp	Year around	X						X	
	Herring roe	4/1-5/1	X						X	
3. Kodiak, Alaska	Dungeness crab	3/1-10/1	X						X	
	King crab	8/15-1/15	X						X	
	Tanner crab	9/1-7/1	X						X	
4. Juneau, Alaska	Salmon	7/1-9/15	X					X		
	King crab	8/15-2/15	X						X	
	Scallops	----	X						X	
	Halibut	5/7-10/15	X						X	
5. Kena, Alaska	Salmon	6/20-8/5	X						X	
6. Anchorage, Alaska	Salmon	6/25-8/10	X						X	

Location	Species	Processing Season	Wastewater Disposal			Solid Waste Disposal				
			Untreated Discharge	On-site Treatment	Municipal Treatment	Viscera Disposal At Sea	Rendering Plant	Animal Feed	Adjoining Water	Municipal Disposal
7. North Naknek, Alaska	Salmon	---	X						X	
8. North Naknek, Alaska	Salmon	---	X						X	
9. North Naknek, Alaska	Sockeye Salmon	6/20-7/20	X						X	
10. South Naknek, Alaska	Red Salmon	6/20-7/15	X						X	
11. Terminal Island, California	Tuna	Year around	X	Solids Removal			X	X		
	Tuna meal	Year around								
	Pet Foods	Year around								
	Solubles	Year around								
12. Eureka, California	Sole	Year around	X					X		
	Lingcod	Year around	X					X		
	Rockfish	Year around	X					X		
	Sablefish	Year around	X					X		
	Salmon	3/1-9/1								

Location	Species	Processing Season	Wastewater Disposal			Solid Waste Disposal				
			Untreated Discharge	On-site Treatment	Municipal Treatment	Viscera Disposal At Sea	Rendering Plant	Animal Feed	Adjoining Water	Municipal Disposal
	Tuna	Year around	X					X		
	Dungeness crab	12/1-5/1	X				X			
	Shrimp	---	X				X			
13. Eureka, California	Salmon	3/1-9/1	X					X		
	Sole	Year around	X					X		
	Lingcod	Year around	X					X		
	Rockfish	Year around	X					X		
	Sablefish	Year around	X					X		
	Tuna	---	X					X		
14. Astoria, Oregon	Fish	2/1-3/1, 5/1-11/1	X						X	
15. Astoria, Oregon	Salmon	6/1-11/1	X					X		
	Tuna	7/1-4/1	X					X		
16. Astoria, Oregon	Fish	Year around	X					X		
17. Warrenton, Oregon	Shrimp	3/1-11/1	X					X		
18. Hammond, Oregon	Fish	5/1-2/1	X					X		

Location	Species	Processing Season	Wastewater Disposal			Solid Waste Disposal				
			Untreated Discharge	On-site Treatment	Municipal Treatment	Viscera Disposal At Sea	Rendering Plant	Animal Feed	Adjoining Water	Municipal Disposal
19. Astoria, Oregon	Fish	Year around	X					X		
20. South Boston, Massachusetts	Haddock	---	X			X		X		
	Cod	---	X			X		X		
	Pollock	---	X			X		X		
21. Gloucester, Massachusetts	Lobster	4/1-1/1	X							x
22. Gloucester, Massachusetts	Herring	Year around	X					X		
	Fish oil	Year around								
	Fish meal	Year around								
	Fish solubles	Year around								
23. South Boston, Massachusetts	Haddock	---	X			X		X		
	Perch	---	X			X		X		
24. Westwego, Louisiana	Shrimp	5/1-1/1	X				X			
	Oysters	1/1-5/1	X				X			

INDEX

A

B

C

G

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P

Q

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1 Accession Number	2 Subject Field & Group	
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5 *Organization*

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CURRENT PRACTICE IN SEAFOODS PROCESSING WASTE TREATMENT,

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27 *Abstract*

This report contains discussions of the processing of the major United States seafoods species, the resultant wastewater strengths and flows, solid wastes magnitudes, current treatment and by-product recovery methods, and current and recommended research in water pollution abatement. The geographic distribution of fish and shellfish landings and products is described. The report is based on a comprehensive literature review and extensive on-site investigations of current research, processing and treatment activities in the major seafoods centers of the United States.

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