Special Report 395
September 1973

OSU SEA GRANT MARINE ADVISORY PROGRAM

Oregon State University Extension
MARINE ADVISORY PROGRAM

Seafood Solid Waste in Oregon: Disposal or Recovery?

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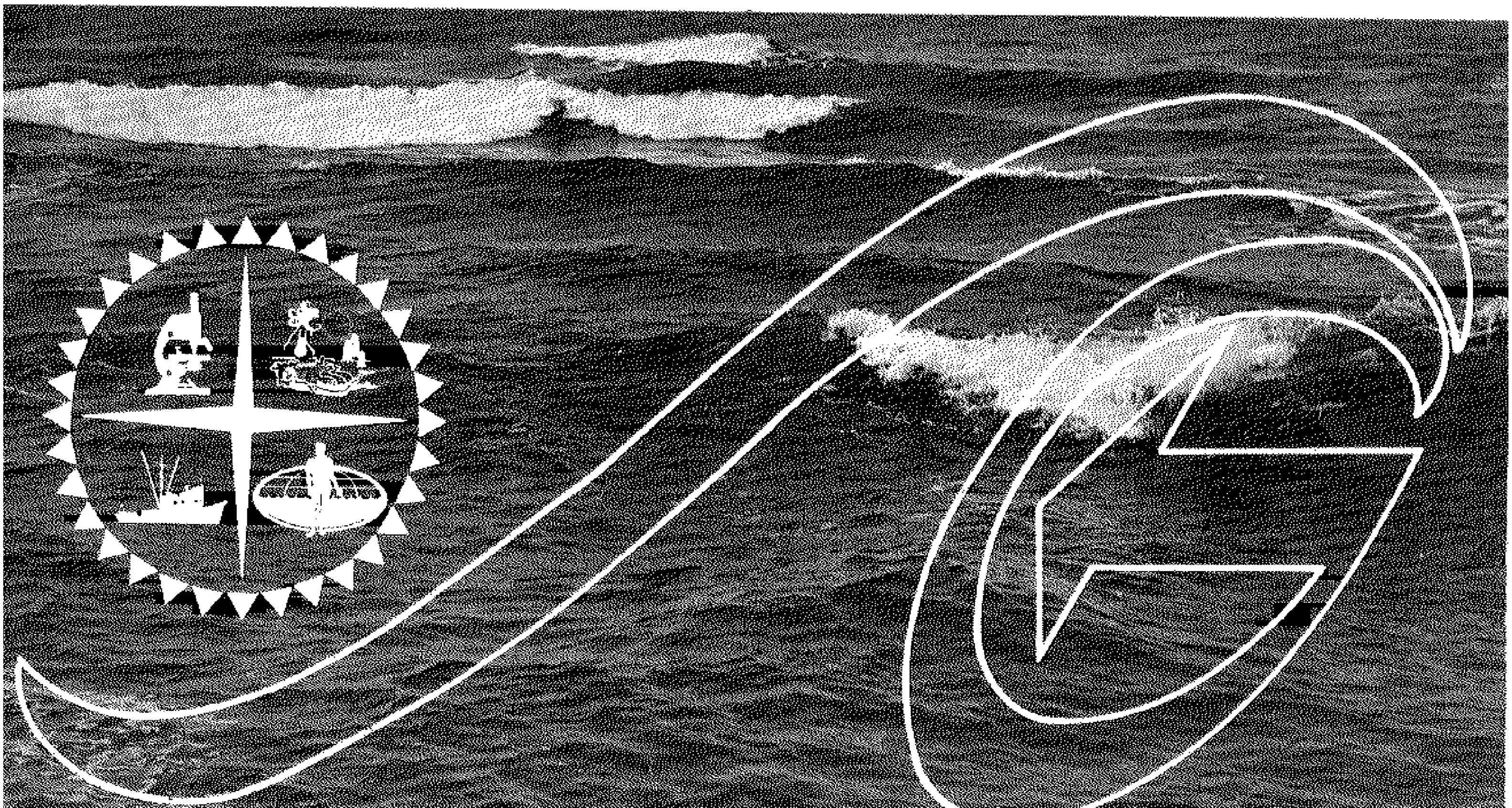


One of a series of publications reporting Extension work in agriculture, home economics, 4-H clubs, and the Sea Grant Marine Advisory Program, Lee Kolmer, director, Oregon State University, Oregon counties, and the U. S. Department of Agriculture cooperating. Printed and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914.

This information is published by Oregon State University as part of the Department of Commerce National Oceanic and Atmospheric Administration Sea Grant Program.

SEAFOOD SOLID WASTE IN OREGON: DISPOSAL OR RECOVERY?

Oregon Department of Environmental Quality (DEQ) permits for discharging seafood-processing wastes into adjacent estuarine waters expire July 31, 1974. Beyond this date, Oregon's seafood processors must adopt one or a combination of three options: curtailment of waste production, disposal outside of estuaries, or conversion of waste to some other product.

This bulletin describes the quantity and nature of seafood waste from processing operations in Newport, Winchester Bay, Charleston, Bandon, Port Orford, and Brookings; and it discusses ten alternatives to discharge directly into estuaries. Other port areas were not included because of lack of funds and staff time, and because the disposal problem is less severe in those ports.

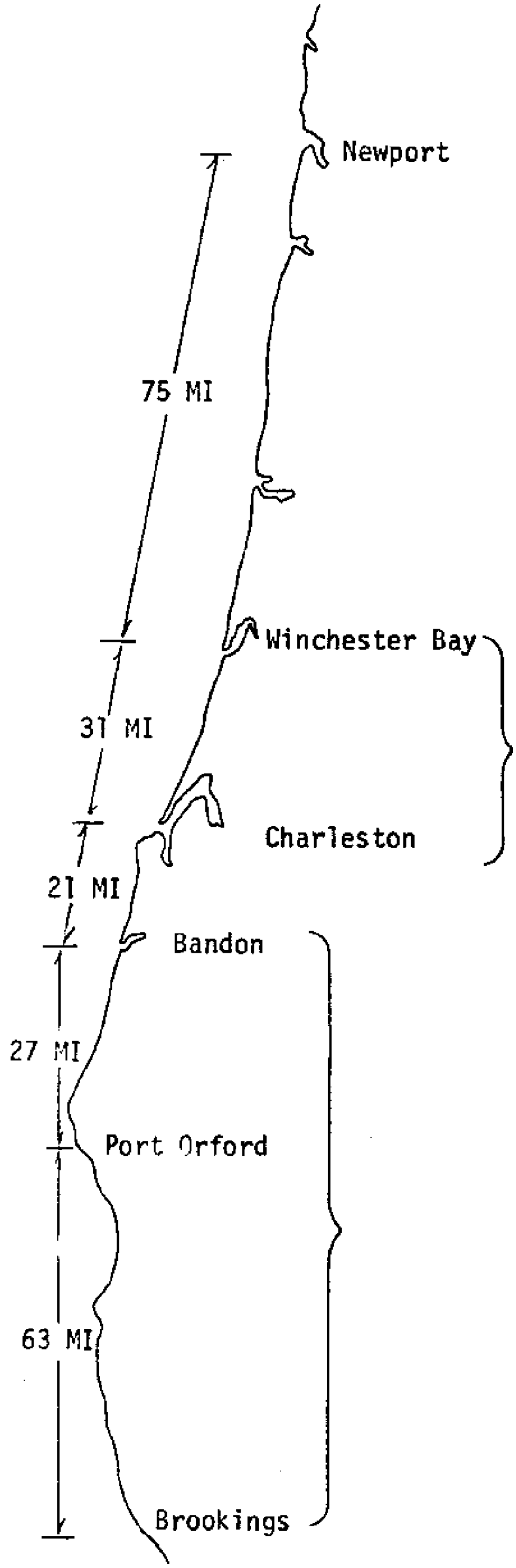
Quality and Nature of Seafood Waste

In most cases, seafood waste production was reported for groundfish, salmon, shrimp, and crab, over a period of five years (1968 to 1972). Tunafish processing generates insignificant waste in the study area and was therefore not considered. Figure 1 shows the location of the reporting areas in the study and provides a summary of the wastes generated by each fishery.

Groundfish (sole, lingcod, rockfish, flounder, etc.) are processed by skinning the fish and cutting a fillet from each side. The remainder, called the frame, is discharged into the estuary, sold for mink food, or sold for crab bait. Waste ranges from 68 to 75 percent of the round weight (weight of the whole fish), depending on the species (1). It is low in oil content, and the frames from different species of groundfish may be handled as a unit for most recovery purposes.

Salmon heads are the only solid wastes from salmon in the study area. The salmon are caught by trollers, who remove the entrails at sea. The heads constitute 7 to 8 percent of the round weight; they have a high oil content. A large portion of the salmon is iced and shipped to market without being headed first; each processor accounted for this in estimating the percentage of waste from salmon. The salmon waste quantities at Newport are low because nearly all salmon are shipped from Newport with the heads on.

This study was begun at the request of Oregon's seafood processors, and it was made possible by their continuing cooperation. The processors organized themselves into two steering committees, one centered at Charleston and the other at Newport. These committees provided overall guidance for the study, and they continue to function. Steering committee members, as well as cooperating processors and other cooperating firms, are listed in the appendix (p. 21).



	Groundfish	Salmon	Shrimp	Crab
Newport	1,310	22	1,735	1,224
Winchester Bay / Charleston	4,978	366	2,506	1,320
Bandon / Port Orford / Brookings	724	75	556	371

Figure 1—1968-1972 average solid seafood waste available by coastal region (in thousands of pounds).

Shrimp and crab waste is characterized by high percentages of chitin and calcium carbonate, and a relatively low percentage of protein. Chitin is a major component of the shell; it is similar to cellulose and does not break down readily. The solid waste portions of shrimp are the heads and the tail shell. Shrimp may be picked by hand or peeled by machine. Waste will be 76 to 78 percent of the round weight by either method (1). Processors generally estimate 75 percent waste, as some shrimp are sold in the shell.

Crab is processed in a number of ways in the study area. It is sold live, in the shell, in leg sections, or as fresh, frozen, smoked, or canned meat. Dungeness crab is the only species fished for off Oregon up to this year. About 75 percent of the round weight is waste when the crab is picked. Increasing quantities of Tanner crabs are being processed in the study area; their waste fraction is 80 percent of round weight. Processors may sell up to 60 percent of their Dungeness crabs whole. As with salmon, each processor estimated the waste generated from crab processing.

Cooperating processors furnished monthly quantities of solid wastes for 1968-1972. In some cases company records (and therefore data) were incomplete. Port landings data from the Fish Commission of Oregon were used to supplement the data from the processors.

Waste quantities for Coos Bay and Winchester Bay are combined throughout the study because of the proximity of the two and the need to make use of some combined port landings for annual totals in 1968-1971.

Table 1 lists the 1968-1972 waste generated in the three coastal regions (Newport, Coos Bay-Winchester Bay, Brookings-Port Orford-Bandon) and the total for the coast from Newport to Brookings.

The month-by-month distribution of waste quantities is different for groundfish, salmon, shrimp, and crab. Some of the major factors affecting distribution are the legal seasons, fishing effort, fish availability, and weather conditions. The monthly distribution of waste will not be identical from year to year. Table 2 shows the average and range of month-by-month distribution by coastal region and fishery. The average salmon, groundfish, and crab waste distributions are used to project their future distribution. The shrimp season has been changed this year, so the projected pattern for shrimp waste has also been changed. Figures 2, 3, 4, and 5 summarize these monthly distributions for each fishery.

Seafood Waste Projections for 1974

Groundfish may be caught commercially year round. Normally the catches from November through April are lower; catches from May through October are higher. Some processors in each coastal area are planning expansion of fish-filleting lines by 1974. The increase in groundfish waste may be as much as one third of the 1972 quantity.

Salmon wastes are significant at Coos Bay and Brookings because they represent a large portion of the fin fish waste quantity during June, July,

Table 1—Seafood solid waste quantities from three Oregon coastal regions (in thousands of pounds)

		Newport	Coos Bay-Winchester Bay	Brookings-Port Orford-Bandon	Total (Newport to Brookings)
Groundfish	1968	1,300	2,825	456	4,581
	1969	972	4,659	768	6,399
	1970	1,208	4,228	952	6,388
	1971	1,454	5,990	801	8,245
	1972	1,618	7,188	644	9,450
Salmon	1968	12	456	69	540
	1969	16	301	53	365
	1970	33	588	84	703
	1971	35	226	138	399
	1972	14	263	29	308
Shrimp	1968	819	1,937	710	3,466
	1969	593	2,468	75	3,136
	1970	1,413	2,116	690	4,219
	1971	1,695	1,759	304	3,758
	1972	4,154	4,249	1,002	9,405
Crab*	1968	873	766	343	1,982
	1969	1,082	1,044	514	2,640
	1970	1,425	1,662	506	3,593
	1971	1,879	1,930	136	3,945
	1972	859	1,196	355	2,410

*Dungeness crab season runs from December of preceding year through August for reporting year

Table 2—Seasonal distribution of seafood wastes by coastal region based on two to five seasons of monthly records (number in parentheses indicates number of seasons used for each category)

			Percent of Total Seasonal Waste By Month												
			Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Groundfish															
Newport	(4)	AVG		5	4	2	5	11	14	15	18	14	8	2	2
		RANGE		3- 8	2- 7	1- 3	2- 8	10-14	10-17	12-21	14-21	7-19	3-12	0- 4	0- 4
Coos Bay-Winchester Bay	(5)	AVG		6	5	5	7	9	13	13	13	10	10	5	4
		RANGE		1-10	4- 8	3- 7	4-10	5-13	12-16	10-15	10-17	9-14	7-11	2- 6	0- 6
Brookings-Port Orford-Bandon	(4)	AVG		4	8	9	6	7	10	19	12	10	8	5	2
		RANGE		3- 5	7- 9	7-11	3- 7	4-10	7-13	15-21	11-14	7-14	8- 9	4- 6	1- 2
Salmon															
Coast	(5)	AVG						1	29	48	19	2	1		
		RANGE						0- 2	13-37	36-61	8-42	0- 5	0- 2		
Shrimp															
Newport	(3)	AVG				3	8	15	19	14	16	12	13		
		RANGE				0- 7	3-12	13-18	15-22	11-15	13-18	10-16	10-17		
Coos Bay-Winchester Bay	(5)	AVG				10	15	12	13	12	16	16	6		
		RANGE				4-15	5-20	8-17	5-17	9-17	12-23	9-26	0-11		
Brookings-Port Orford-Bandon	(2)	AVG				1	8	16	21	16	21	13	4		
		RANGE*													
Crab (Dungeness primarily)															
Newport	(5)	AVG	17	28	24	19	8	2	1	+	+	+	+	+	
		RANGE	11-24	24=33	16-30	13-22	0-14	0- 4	0- 3	0- 1	0- 1	0- 1	0- 1	0- 1	
Coos Bay-Winchester Bay	(5)	AVG	16	22	19	16	10	9	4	4	+	+	+	+	
		RANGE	9-22	13-27	14-23	13-20	8-12	4-13	2- 8	0-11	0- 1	0- 1	0- 1	0- 1	
Brookings-Port Orford-Bandon	(5)	AVG	20	22	22	16	12	6	2						
		RANGE	0-52	15-26	14-30	11-20	4-20	0-10	0- 3						

* No range is given because only 2 years were available

\+ Indicates less than 0.5 percent.

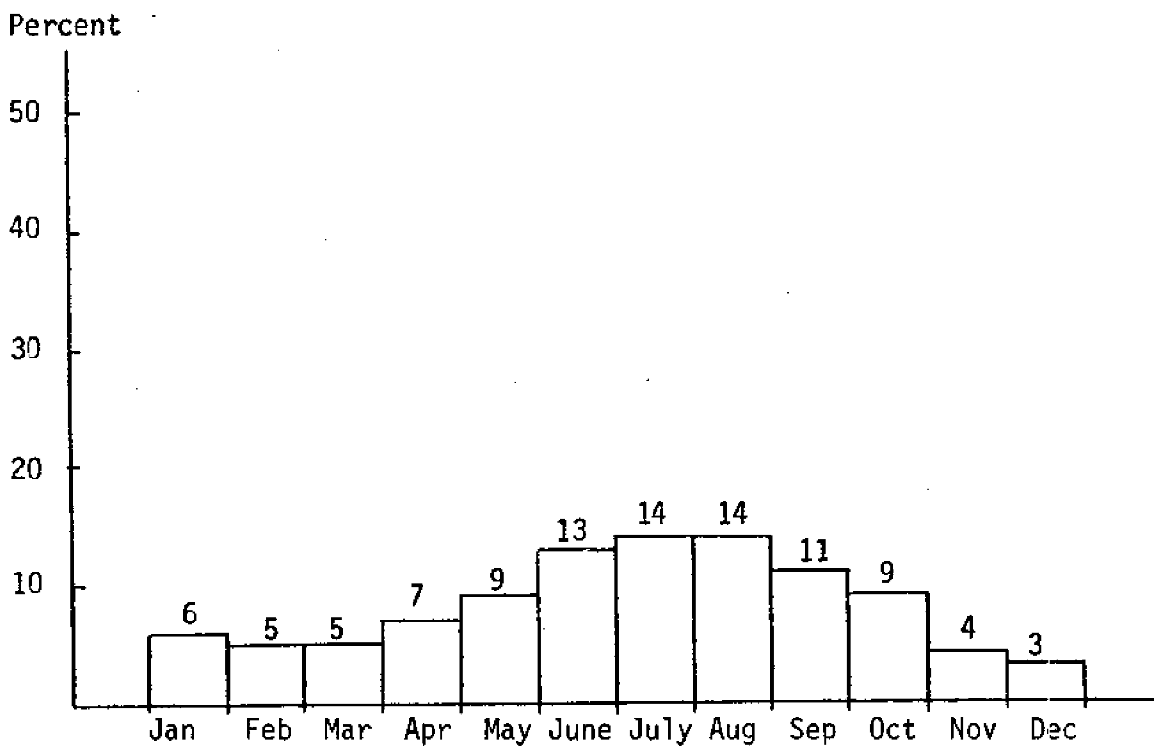


Figure 2—Percent of total annual solid groundfish waste generated by month, 1968-1972 average, Newport to Brookings combined

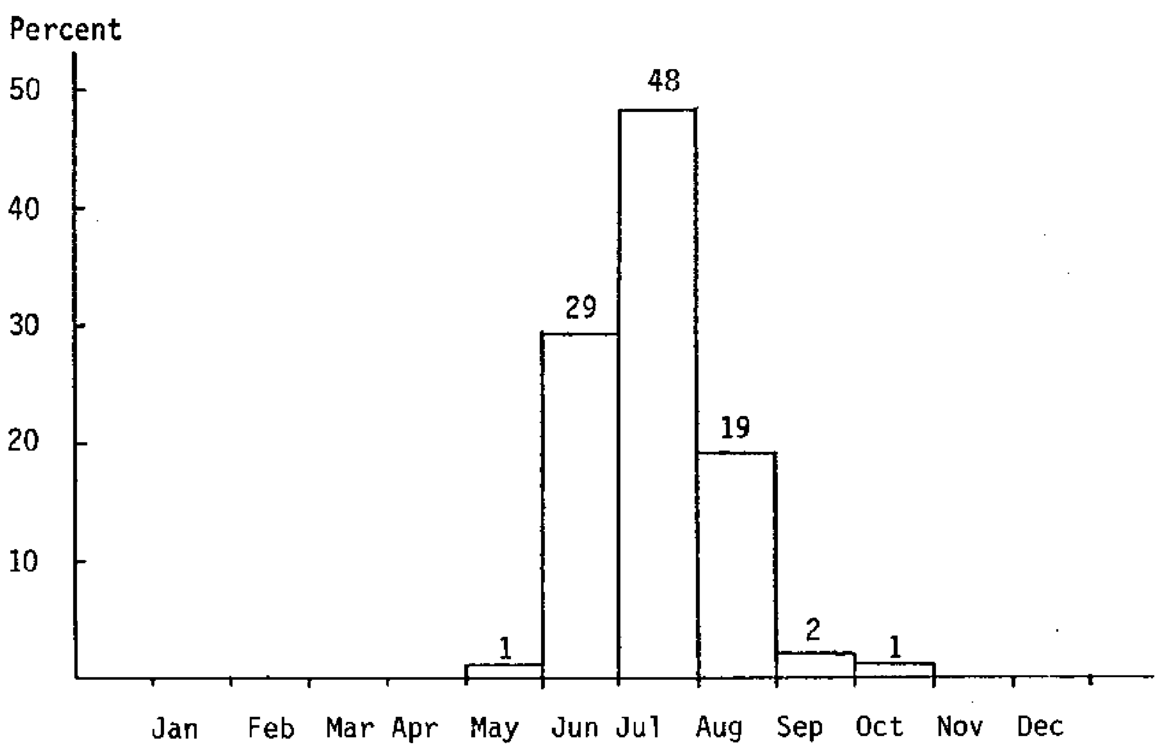


Figure 3—Percent of total annual solid salmon waste generated by month, 1968-1972 average, Newport to Brookings combined

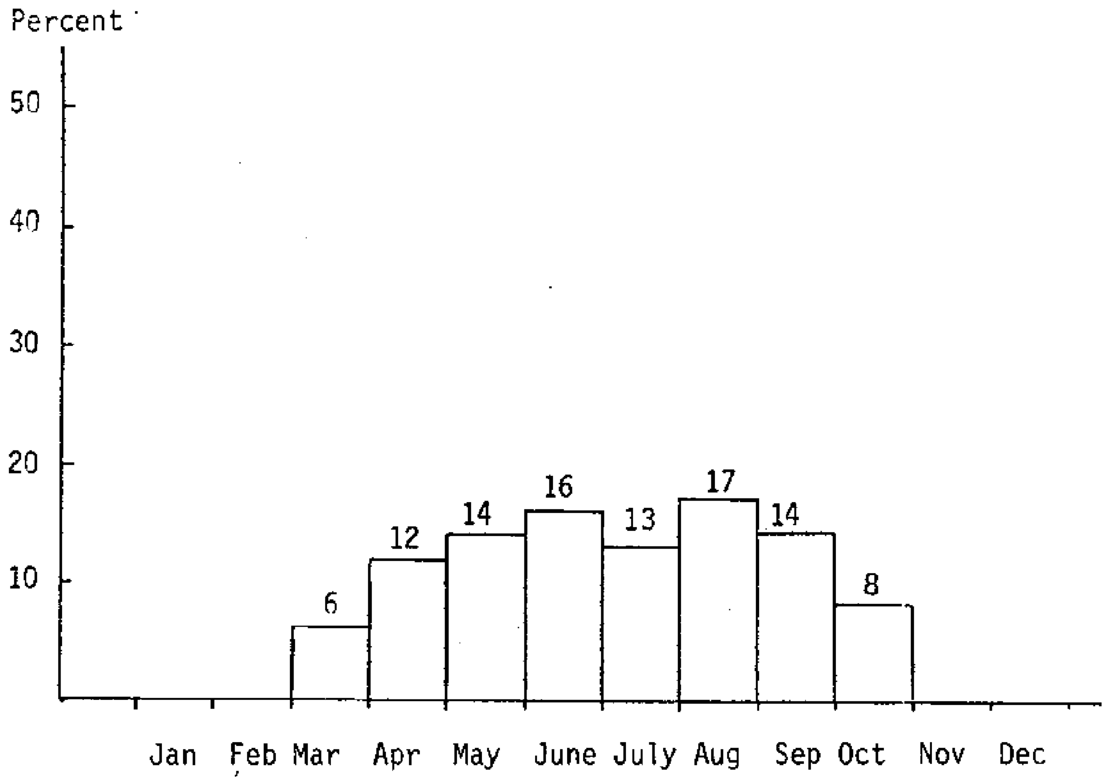


Figure 4—Percent of total annual solid shrimp waste generated by month, 1968-1972 average, Newport to Brookings combined

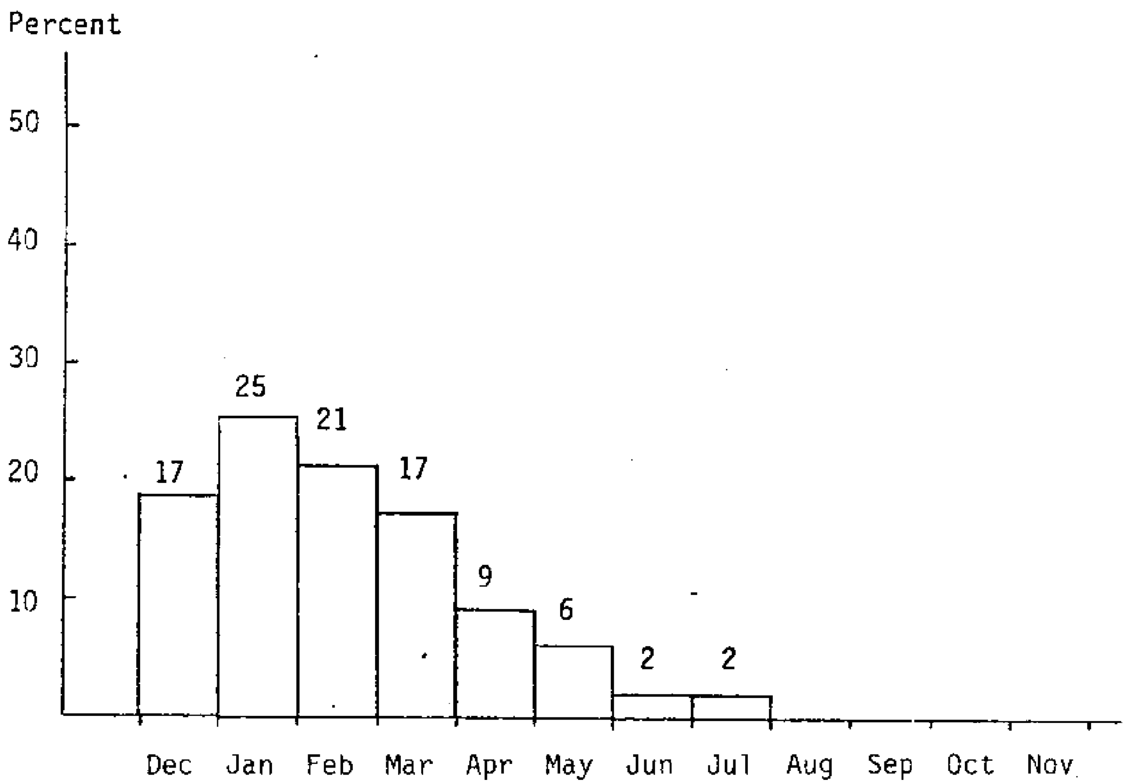


Figure 5—Percent of total annual solid crab waste generated by month, 1968-1972 average, Newport to Brookings combined

and August. Table 3 shows the percent of fin fish waste from salmon during the summer at Coos Bay. Such large portions of oily fish could not be combined with fillet waste for dry reduction to fishmeal.

Table 3.—Salmon waste as a percent of monthly fin fish waste at Coos Bay

	June	July	August
1968	12	23	9
1969	8	12	3
1970	8	17	21
1971	6	7	5
1972	11	15	2

More coastal processors are bidding on state hatchery salmon. Not all of these salmon are sold for human consumption, and quantities of waste could be generated from them. The waste from troll-caught salmon is likely to remain in the present range for several years.

The opening of the shrimp season has been changed this year from March to April. It is quite likely that the closing will also be changed from October to November by 1974. The catch of shrimp is well distributed throughout the season. If the distribution were uniform, 12.5 percent of the shrimp would be processed each month. However, the first and last months of the season usually represent less than 12.5 percent of the total season. Fishing effort for shrimp is increasing dramatically. Processors have also greatly increased their capacity for picking shrimp by using shrimp-peeling machines, and the expansion of shrimp facilities continues. Despite the change in the season, processors hope to process one and one-third to two times more shrimp during 1973 compared to 1972. The Fish Commission of Oregon believes shrimp to be underfished but has not determined how far present catches are from the maximum sustainable yield.

Dungeness has been the major crab species processed in Oregon. Its season is normally from December 1 through August; most crab are caught and processed between December and March. The catch of Dungeness during 1972-1973 has been lower than for the 1971-1972 season, concentrated in December and January. According to the Fish Commission, the low Dungeness crab population this year was caused by natural fluctuation; it is expected to return to previous levels.

Several processors have begun buying Tanner crabs from Alaska. Oregon fisherman are attempting to develop a Tanner crab fishery off Oregon. A Tanner fishery may at least partly supplant the Dungeness catch rather than add to it, as many fishermen would change from fishing one species to the other, depending upon availability. Such an occurrence would greatly alter the distribution of crab waste throughout the year.

No major expansion of crab-processing facilities is anticipated over the next two years, but if Oregon fishermen develop a Tanner crab fishery, the total crab waste could be increased without the expansion of processing facilities. Crab fishing could continue throughout the year, at least until a season for Tanner crabs is established. Tanner crabs also have higher associated waste quantities because the waste fraction from picking is higher, and the greater portion is picked.

The projected range and distribution of seafood wastes is given in Tables 4 through 7. The total projections are based on past trends and projections from processors; the wide range between maximum and minimum predicted totals for groundfish at Coos Bay, and for shrimp at Coos Bay and Newport, is caused by the difficulty of predicting precise levels for an expanding industry. The projected distributions are based mainly on the average monthly distributions listed in Table 2. They are intended only to indicate a typical pattern. Table 2 may be used to indicate probable deviations from the average distribution.

The maximum expected daily quantity of solid waste for 1974 was also estimated for Coos Bay-Winchester Bay and Newport (Table 8). These figures may be useful in determining the scale of alternatives.

Table 8—Maximum expected solid waste quantity for a single day, 1974 (in thousands of pounds)

	Coos Bay-Winchester Bay	Newport
Groundfish	70	40
Salmon	12	3
Crab	35	90
Shrimp	90	65

Alternatives to Discharge Into Estuaries

Solid waste from seafood processing can either be disposed of directly or recovered for another use. Disposal alternatives are those in which the waste does not become a market good. Recovery alternatives aim to create a market good from the solid waste. The preferred solutions would involve a combination of recovery and disposal. An ideal solid waste management system would have the flexibility to meet varying volumes, would minimize cost, and/or would generate additional profit for the processor.

Although economics are the processor's main criteria for evaluating alternatives, the decision process must also include legal, technical, and social considerations. The following sections discuss three disposal alternatives and seven recovery alternatives.

Table 4—Monthly groundfish waste projections for 1974 by coastal region (in thousands of pounds)

		Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Newport	MAX	2,000	100	80	40	100	220	280	300	360	280	160	40	40
	MIN	1,000	50	40	20	50	110	140	150	180	140	80	20	20
Coos Bay-Winchester Bay	MAX	10,000	600	500	500	700	900	1300	1300	1300	1000	1000	500	400
	MIN	5,000	300	250	250	350	450	650	650	650	500	500	250	250
Brookings-Bandon	MAX	1,000	40	80	90	60	70	100	190	120	100	80	50	20
	MIN	500	20	40	45	30	35	50	95	60	50	40	25	10

Table 5—Monthly salmon waste projections for 1974 by coastal region (in thousands of pounds)

		Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Newport	MAX	50	-	-	-	-	+	14	24	10	1	+	-	-
	MIN	20	-	-	-	-	+	3	5	2	+	+	-	-
Coos Bay-Winchester Bay	MAX	600	-	-	-	-	6	174	288	114	12	6	-	-
	MIN	200	-	-	-	-	2	58	96	38	4	2	-	-
Brookings-Bandon	MAX	150	-	-	-	-	1	44	72	29	3	1	-	-
	MIN	20	-	-	-	-	+	6	10	4	+	+	-	-

+ Indicates less than 500 pounds.

Table 6—Monthly shrimp waste projections for 1974 by coastal region (in thousands of pounds)

		Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Newport	MAX	8,000	-	-	-	640	1200	1520	1120	1280	960	1040	240	-
	MIN	4,000	-	-	-	320	600	760	560	640	480	520	120	-
Coos Bay-Winchester Bay	MAX	10,000	-	-	-	1500	1200	1300	1200	1600	1600	1000	600	-
	MIN	5,000	-	-	-	750	600	650	600	800	800	500	300	-
Brookings-Bandon	MAX	1,000	-	-	-	80	160	210	160	210	130	40	10	-
	MIN	500	-	-	-	40	80	105	80	105	65	20	5	-

Table 7—Monthly Dungeness crab waste projections for 1974 by coastal region (in thousands of pounds)

		Total	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Newport	MAX	2,500	425	700	600	475	200	50	25	25	-	-	-	-
	MIN	700	119	196	168	133	56	14	7	7	-	-	-	-
Coos Bay-Winchester Bay	MAX	2,500	400	550	475	400	250	225	100	100	-	-	-	-
	MIN	700	112	154	133	112	70	63	28	28	-	-	-	-
Brookings-Bandon	MAX	700	140	154	154	112	84	42	14	-	-	-	-	-
	MIN	250	50	55	55	40	30	15	5	-	-	-	-	-

Disposal methods examined in this study were incineration, ocean dumping from a barge, and landfill. DEQ policy encourages recycling of wastes. It is likely that any proposed disposal plan would first be challenged on the basis of whether DEQ-defined higher uses have been adequately considered.

Incineration. The DEQ has determined incineration to be the lowest-value use of wastes. To obtain an incineration permit, processors would have to show that no practicable alternative was available. There are four incineration plants in Oregon that burn animal flesh; they have high operating costs (a 400- to 500-pound-per-hour plant burns the equivalent of 180 gallons of fuel oil per ton of waste). Heat could possibly be reconverted into electricity and used or sold to a public utility to defer some of the cost of operating.

Capital costs would include land, air pollution control equipment, and storage for wastes and fuel. Although the technology exists to burn seafood wastes, it would be strongly challenged by DEQ.

Barging. Ocean dumping presently requires a permit from the U. S. Environmental Protection Agency (EPA). Fish wastes are exempt from permit requirements, except in harbors or enclosed bays or other locations where health, environment, or ecological systems could be endangered. However, preliminary investigation has shown barging to be infeasible: there is a limited daily quantity of waste, and there is a need to barge frequently to prevent the development of an odor problem. The smallest available oceangoing barges have a capacity of 1,000 tons. One day of heavy production at the Coos Bay-Winchester Bay area could produce 50 to 75 tons of solid waste. A barge would cost about $300 per day. The tug for such a barge at Coos Bay would run $1,500 to $2,000 per trip. If all wastes were barged in the Coos Bay-Winchester Bay region, the average per-ton barging cost could be as low as $50; there would be an additional cost for docking, handling, and storage. Inclement weather could also prevent regular service and cause storage problems.

Landfill. Landfills may be operated publicly or privately, but they require a DEQ permit. Applications for such a landfill permit must include: a letter of recommendation from a local or state health agency, a letter of recommendation from the area's public authority for solid waste disposal, a detailed feasibility report of plans, a geological and hydrological description of the site, and an outline of procedures for using the sanitary landfill method (daily covering of wastes) (2).

DEQ is presently surveying coastal dumps; it has found many present sites inadequate because ground cover is not available and because heavy rain, clay soils, and ground slope cause drainage problems. Thus, this alternative requires that special attention be given to the selection of an adequate and publicly acceptable disposal site. Coos and Curry Counties are currently developing a joint solid waste management program; county officials have said that seafood wastes could be included in the plan. Solid waste intended for disposal in the Newport area could be handled by the private contractor responsible for the city waste disposal.

Private landfills, which build up the soil and increase soil fertility, may offer some advantages over public landfills (dumps). Seafood wastes in general contain significant amounts of nitrogen and trace elements; shellfish wastes contain in addition significant amounts of calcium carbonate, similar to agricultural lime. Seafood wastes make excellent fertilizers and soil builders. A processor who finds an appropriate 5 to 20 acres of marginal land and obtains a landfill permit could anticipate recovering some of his cost by upgrading the land for sale for agricultural or horticultural use when the landfill is complete. Feasibility would depend heavily on site cost and accessibility.

The cost of using a public landfill would be negotiated with the responsible public body. There would be additional costs for collection and transportation of wastes. A private landfill requires a capital investment for land and a loading-excavating machine (3). Other costs will be collection, transportation, planning, and overhead (4). Benefits could be estimated by subtracting the purchase value of the landfill from the value it would have locally if it were used for special agricultural or horticultural products. Benefits would be accrued in the future, but they could be determined on an annual basis, depending upon the number of years the landfill would be used.

Oregon State University soils experts are currently examining the possibility of combining seafood wastes with dredge spoil. The alkaline waste from shellfish would be particularly beneficial because of the acidity of the spoils. The experts anticipate conversion of previously marginal land along the Columbia River to horticultural use. Dredge spoils from coastal estuaries have a high salt content that inhibits most plant growth, so a similar practice along estuaries is unlikely to produce outstanding results.

A sanitary landfill has the advantage of being a final disposal system, compared with incineration and recovery methods that leave residues. In addition, a landfill can be constructed in a short period of time, and it can accept varied load sizes with little change in cost per ton. The use of a landfill in conjunction with certain recovery methods may prove to be the most reliable solid waste system.

Seafood Waste Recovery

Converting waste to a market good can be both socially and economically desirable. Recovery alternatives differ according to the type of seafood waste considered. This requires a physical separation of wastes into groundfish, salmon, and shellfish waste.

The waste must be handled quickly or preserved temporarily so that spoilage does not make it undesirable or unusable as a byproduct.

Recovery alternatives include flesh for human consumption, Fish Protein Concentrate, fishmeal, mink food, fish food, fertilizer, and chitosan.

Human food. Methods are being developed to increase the yield of flesh from fish and crab. Flesh-separating machines which use mechanical pressure to force flesh through rotating screens have been used on fillet frames (5,6). The total yield can be extended to 60 percent of the round weight, depending on the species of fish. U. S. food regulations require fish to be headed and eviscerated before being used in these machines. Flesh separators are being used successfully on whole fish, thus eliminating the filleting process.

Possible products from the separated fish are "fishburger" patties, fish sticks, premolded forms, and extenders for other food products. The meat itself has some drawbacks. Separation appears to release chemicals that taint the flavor and increase the rate of spoilage. Fish flavor can also be detected when the flesh is used as an extender, but that is not necessarily a drawback.

The purpose for using the flesh separator is to provide more protein for direct human consumption. U. S. regulations and technological drawbacks make this alternative infeasible at the present time. If flesh separators are considered in the future, processors must recognize that the solid wastes resulting from this process may be unusable as animal feed (there would be insufficient flesh remaining).

The National Marine Fisheries Service, in cooperation with Bird Machine Company, has developed a crab meat centrifuge which can increase yield up to 50 percent over hand picking (7). Crab is cut into pieces and put through a centrifuge. All shell is separated from the meat, and large pieces of high quality crab meat are recovered. Several of these centrifuges are currently going into operation. Crab processed this way would still have at least 62 percent solid waste, but the waste would retain potential for chitin or fertilizer products.

Fish Protein Concentrate. Fish Protein Concentrate (FPC) is a food additive product that often is over 90 percent protein (8,9). In Canada, FPC may be used in the manufacture of food. In Latin American countries it is hailed as an important source of inexpensive, complete protein.

For some years the U. S. Government has inhibited its production by prohibiting both the sale of quantities over one pound and the inclusion of FPC as a supplement in prepared food; recent changes in regulations now make it legal to market whole Fish Protein Concentrate (if manufactured from whole hake, menhaden, anchovy, or herring) in any quantity or to use it as a food additive, provided the food is so labeled. However, solid waste from Oregon seafood processors still would not meet the whole fish requirements of these regulations.

The commonest method of making FPC is isopropyl alcohol extraction. It produces a white, tasteless, odorless, nonspoiling substance -- but one which does not dissolve or interact with food ingredients the way flour does. Scientists are developing a biological method of extraction that would produce an FPC with more desirable properties as a food.

FPC production is usually done on a large scale, using whole fish; however, there are precedents for using fish waste and small scale plants. A plant in Nova Scotia, Canada, processes 200 tons per day, and a third of its raw material is from cod and haddock trimmings. A model plant in Aberdeen, Washington, was built to process 50 tons a day, but it is no longer operating.

If fillet frames, rather than whole fish, are used to make FPC, the product will have a lower protein content and a higher ash content unless the frames are deboned. Fish oil, fish solubles, and bone meal can be produced with FPC to make use of nearly all solids. The market for those products are well developed. If shellfish are used, FPC can be produced in conjunction with chitin extraction.

FPC does not presently appear to be a viable alternative for reducing solid waste. However, if an FPC plant used whole fish for the major portion of its raw material, it might also be able to accept fish wastes that are handled sanitarily. The incentive to produce FPC hinges on the lowering of severe U. S. restrictions on its use and the improvement of FPC's functional properties.

Fishmeal. Fishmeal is a concentrated, nutritious animal feed supplement. The technology for producing fishmeal is well developed. Several unit plants have been designed lately to produce fishmeal economically on a small scale (8,10). There are two main methods of producing fishmeal, dry reduction and wet reduction (11). Dry reduction is limited to lean fish; it is a batch process in which solid waste is ground, sometimes pressed to reduce oils, and cooked and dried in one machine. Wet reduction is usually a continuous process, involving steam-cooking the fish, pressing the liquid from them, and drying the remaining solids. The liquid contains fish oils and solubles. The oil is separated from the liquid and marketed. The remaining solubles are condensed and added back to the meal or sold as condensed fish solubles. The dry reduction process allows more flexibility in processing, but the wet reduction process yields a less oily product and can handle any fish regardless of oil content. Shrimp and crab wastes may also be processed by the wet reduction method.

The market for fishmeal has changed dramatically during the last year. The relatively low price of U. S. fishmeal during the 1960's was associated with large supplies of Peruvian anchoveta meal during that time. Last year the anchoveta fishery collapsed; at the same time, worldwide fishmeal prices soared. It is unlikely that fishmeal prices will again fall to the level of the 1960's because of the continually increasing demand for it as animal feed.

In order to sell fishmeal for animal feed, a guaranteed analysis of food value should be provided, including minimum percent of protein, and maximum percentages of fat, moisture, ash, fiber, calcium, and phosphorus. This analysis could be a problem, as processors will be mixing different kinds of fish. Poultry farmers may also require feeding trials before accepting a new meal. Oregon is a protein-poor region. Soybeans are not grown locally. The transportation of soybeans from Decatur, Illinois, to Portland, Oregon, costs $35 per ton. If fishmeal is competitively priced, Oregon poultry growers could feed poultry 5 percent fishmeal (in 1972 that would have amounted to 27 million pounds of fishmeal). It is important that a local market be found for fishmeal. A Coos Bay or Newport recovery plant would sacrifice some economies of size, but it would have the advantage of a local market.

Shrimp and crab meal have a more limited market as poultry or swine feed because of their high mineral and fiber content and low (20 to 50) percent of protein. The primary market for these meals is as fish food.

A fish reduction plant could be scaled to accept quantities of whole fish as well as solid waste. Fishermen presently discard quantities of fish for which there is no market. At a rate of three to five cents a pound, fishermen would be encouraged to use extra "on board" storage capacity for those fish. Most extra whole fish would be brought in from April through October from shrimp and groundfish vessels. There is no shrimp fishing from November through March, and groundfish are usually fished less intensively in the same period. Large quantities of whole fish would accompany the seasonally larger quantity of waste. The resulting fishmeal would be superior to meal from fish frames alone; it would have a higher protein value and a lower ash content. The extra fish may also allow a plant to benefit from economies of size.

There are several major questions to answer relating to the feasibility of a fish reduction plant.

1. Are processors willing to commit their solid wastes to a reduction plant in the face of existing competing markets?
2. Will dry reduction or wet reduction be used?
3. What products will be made (fishmeal, salmon meal, shrimp meal, crab meal, fertilizer, fish oil, fish solubles, salmon oil)?
4. Will whole fish be solicited? If so, what quantity can be expected?

Mink feed. The mink industry has been in a period of decline. Only a few years ago, mink farmers were able to buy nearly all the groundfish waste. Their demand decreased greatly in the last two years, partly because of a public reaction (associated with the ecology movement) against the use of animal fur for clothing and partly because of a decline in the U. S. per-capita disposable income. As a luxury item, mink fur is subject to great fluctuations of demand, depending on disposable income. The demand for mink is picking up again, as public attitudes change and disposable income increases.

Not all fish wastes can be used for mink food. A few species (a minor portion of the total seafood wastes) contain high levels of a detrimental enzyme, thiamase. In addition, the oil content of fish used must be lower than 8 percent, a requirement that excludes salmon heads. Mink raisers will probably continue to bid on fish waste; the quantity they demand may be variable and closely tied with national economic conditions. Although this alternative is lucrative, it also involves uncertainty as a method of solid waste reduction.

Fish food. Commercial aquaculture enterprises are being established in Oregon. One enterprise anticipates using 4 to 5 million pounds of fish and 2 million pounds of shrimp or crab for feed. Shrimp are preferred over crab because of a pigment they have that brightens the color of salmonid flesh. The solid waste data for Newport indicate that the demand for fish is higher than could be provided by fish wastes there, but more than enough shrimp and crab waste is produced annually to fulfill the demand.

Processors using this alternative will need to provide separate collection facilities, as in the other reduction alternatives. The use processors make of this market will depend in part on how reliable it appears to them. They must decide what will be done with remaining waste if not all is used. The remaining portion may be more difficult to market because of its reduced quantity.

The production of fish food could also take place at a fish reduction plant. The Oregon Moist Pellet, an excellent fish food product, presently has a limited national market because it requires frozen storage. Promotion would be needed to expand the market.

Fertilizer. There are two alternatives, processed and unprocessed fertilizer. Fish fertilizer is important for its organic nitrogen, calcium, phosphorus, and trace elements. Shrimp and crab fertilizers have especially significant quantities of calcium carbonate ($CaCO_3$), an alkaline compound similar to agricultural lime. The alkalinity is especially valuable in the Willamette Valley and western Oregon, where soils are too acid.

A farmer in Smith River, California (near the Oregon border), purchased a truck to haul shrimp and crab waste from Brookings to his pasture land. He is paid a small fee for hauling away the waste. He reports excellent results with this fertilizer; it has improved his sandy, acid soil substantially. He works the shellfish waste into the field as soon as it arrives from Brookings in order to minimize odor problems. Shellfish wastes for which no other market is found could be promoted as excellent, inexpensive organic fertilizers. Yet it may be difficult to find farmers who are willing to commit themselves to hauling them away regularly.

The other alternative for fertilizer is to process it so that it can be marketed as a garden fertilizer (12). Processing involves grinding, drying, and some treatment. Most equipment is the same as equipment used in making fishmeal. Wastes should be processed fresh in order to minimize odor problems, but they would not have to be separated. Fish fertilizers are an alternate product for a recovery plant to make. The decision to produce fertilizer or fish meal (for animal feed) would depend on the economies of each. Presently fish meal is much more valuable.

Chitin. Chitin and $CaCO_3$ are the main components that limit the use of shrimp and crab meal for animal feeds. The National Oceanic and Atmospheric Administration is supporting research on the use of chitin and its derivative, chitosan. Several special uses are being developed. Chitosan has been tested for use in paper, baby food, stomach antacids , textile finishes, and water base paint emulsions, and in the manufacture of film and specialty adhesives (13). A market is presently developing for the use of chitosan as a coagulant in water treatment and purification; although this is an important potential use, the demand for it is minimal when compared with the quantity of chitin that is available.

Food and Chemical Research Laboratories, Inc., of Seattle, Washington, have suggested several ways in which shellfish wastes might be processed to achieve complete use of solids (14). They recommend extraction of protein from the chitin and $CaCO_3$. The method they suggest produces a water-soluble FPC product that is about 90 percent protein and 6 to 8 percent ash; it has a shellfish odor. It is expected to be a valuable animal food supplement and could be produced for human consumption if U. S. regulations allowed it. The remaining chitin and $CaCO_3$ could be sold as fertilizer. Chitin contains 6.9 percent nitrogen, which would be released slowly. $CaCO_3$ could also be extracted from chitin and the products sold separately.

Chitosan may be a high value byproduct, for its limited market, but unless and until a wider market develops, it will not play a major role in waste reduction.

Summary

The 1974 termination of solid waste discharge permits makes it imperative that seafood processors analyze alternatives. The nature and quantity of waste is crucial in determining the feasibility of various alternatives.

Groundfish waste quantities for 1974 are predicted to be from 1 to 2 million pounds at Newport, 5 to 10 millions pounds at Coos Bay-Winchester Bay, and between 500,000 and 1 million pounds from Brookings-Port Orford-Bandon. More wastes are generated during the summer months, especially salmon wastes. July is typically the peak month for salmon.

Shrimp wastes at Coos Bay-Winchester Bay will range from 5 to 10 million pounds; 4 to 8 million pounds are expected at Newport, and 500,000 to 1 million pounds between Brookings and Bandon (Table 6). Shrimp wastes are distributed fairly evenly over the season from April to October.

Crab wastes from Dungeness and/or Tanner crabs are expected to be between 700,000 and 2.5 million pounds at Newport and Coos Bay-Winchester Bay; 250,000 to 700,000 pounds may be expected from Brookings to Bandon (Table 7). If the crabs are primarily Dungeness, waste will mostly occur between December and March, with almost none occurring between July and November.

Three methods of disposal were studied for these wastes: incineration, barging off shore and landfill. Landfill appears to be the least costly and the most promising disposal alternative because of the limited quantity of wastes involved. It is also suitable as a backup to a recovery alternative in order to achieve completely acceptable use of waste.

Seven alternatives were considered for recovery of wastes for a marketable product:

Increased flesh for human consumption does not appear practical for fish, but it may be worth considering for crab meat because of the quality of the product. Fish Protein Concentrate, a food additive, is not a promising alternative presently because of its functional properties and severe U. S. restrictions on its sales (if these factors should change in the future, FPC could be a profitable byproduct). Fishmeal is the primary industrial product from fish waste; its market conditions are very promising. A plant scaled to use only wastes from Oregon's coast may yield economies of size, but there is a high local demand for protein products as animal feed. An independent cooperative is presently contracting for groundfish wastes for mink feed; the demand for mink feed varies from year to year and may not be a dependable means of solid waste disposal. There is a new and expanding market for seafood wastes as fish food in commercial aquaculture; it could become a large and important market. Fish reduction plants that produce fish meal could also, with slight modifications in the operation, produce fish food. Fertilizer from fish, shrimp, and crab wastes is a marketable product; presently it is less lucrative than fishmeal, but it can provide diversification for a fishmeal plant because it is made by nearly the same process. Finally, there is presently a very limited market for new special products using chitin from shrimp and crab shells. The removal of chitin from crab and shrimp wastes would leave a more desirable product for animal feed; such a process might be warranted at the present time, as chitin may be marketable as a nitrogen fertilizer.

Future Considerations

Oregon seafood processors appear to have a number of potentially economical alternatives for management of their solid wastes. Several private companies have expressed an interest in using solid wastes. For an individual contract, a processor should consider the following:

1. What type and portion of solids is a buyer willing to take?
2. What is the cost or benefit to the processor?
3. What is the risk that the contract will not be fulfilled or extended?

A fish reduction plant may be built to make use of solid wastes. It could be owned and run privately, or owned by processors and operated as a utility. If it is owned privately, the same three questions apply. Processors may want assurance that nearly all waste will be used. If the plant is owned cooperatively, processors would have a direct tie with the economics of the waste management.

Transportation and collection will be a major cost factor for any seafood waste use. Further studies should examine alternative transportation and collection systems.

Landfill or raw fertilizer alternatives should be recruited as backup systems for recovery alternatives. A local cooperative effort may be warranted. By this means, processors could plan a total solid waste management system.

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APPENDIX:

Cooperators in the Study

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