INDUSTRY ANALYSIS OF GULF AREA FROZEN PROCESSED SHRIMP AND AN ESTIMATION OF ITS ECONOMIC ADAPTABILITY TO RADIATION PROCESSING

by

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Industry Analysis Of Gulf Area Frozen Processed Shrimp And An Estimation Of Its Economic Adaptability To Radiation Processing

by

Morton M. Miller, Darrel A. Nash
and Francis M. Schuler

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ABSTRACT

Perishability is a cost-increasing factor common in the marketing of seafood products. Modern preservation techniques, particularly the various modes of freezing, have been highly effective extenders of storage life and have paved the way for universal distribution of the products of many fisheries. Nonetheless, problems of quality maintenance persist in the seafood industry and there is ample justification for continued efforts to improve preservation methods. This is especially true for the shrimp industry which yearly is confronted by a proportionately small but costly spoilage problem.

Irradiation preservation is one of the new methods under study that appears especially suitable for seafood products. As a follow-up to technological research, this study explores the commercial feasibility of using irradiation as a preservation technique for processed shrimp products in the Gulf and South Atlantic States Region.

The study finds that the loss rate due to spoilage among processed shrimp products may be as high as 6 percent of total production. This represents at minimum an annual economic loss to distributors in the neighborhood of $16 million. Consumers are heavy losers too, inasmuch as shrimp lost through spoilage reduce supplies and set the stage for higher prices.

Assuming that irradiation processing could eliminate at least one-half the spoilage problem, commercial investments in shrimp irradiation processing appear highly attractive. The investment, from a social point of view, would likewise be attractive, as ample public benefits would be generated by a relatively modest public expenditure for research and development of the process.

It is also pointed out in the study that there is no certainty at present that shrimp irradiation processing will perform, technologically, in strict accordance with the assumptions made in this economic feasibility analysis. However, the analysis serves a useful purpose in emphasizing, generally, the economic wisdom of even modest expenditures and efforts to improve the quality of high-valued high-volume seafood products.

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Status of the Shrimp Industry

The shrimp industry, by far, is the most important fishing industry in the United States. The domestic catch in 1968 was 292 million pounds (live weight), and brought U. S. fishermen a record $113 million--an all-time high for any single United States fishery. By way of comparison, the salmon and tuna catches, which follow shrimp in importance, were sold for $55 and $47 million respectively (tables 1 and 2, and figures 1 and 2).

Shrimp is a high-value product and its status as the top revenue producing U. S. fishery reflects a strong consumer demand. The 265 million pounds of processed shrimp manufactured in the United States, in 1967, for example, were sold at an average of $1.00 per pound, f.o.b. plant. Salmon production that same year was 129 million pounds, and was valued, f.o.b. plant, at $0.88 per pound. Tuna production--389 million pounds--had an average wholesale value of $0.67 per pound. There are other shellfish products that are higher priced than shrimp, but their volume is only a fraction of shrimp production. Cooked crab meat, for example, sold for $1.40 per pound, f.o.b. plant, but total produced was only 16.1 million pounds (table 3).

Table 1. Leading species of fish and shellfish in U. S. catch, by value, 1967, 1968

Species	Rank 1968	Rank 1967	Value 1968[1/] ($000)	Value 1967 ($000)	Percent of Total U. S. Catch 1968	Percent of Total U. S. Catch 1967
Shrimp	1	1	113,300	103,468	24.0	23.5
Salmon	2	2	54,900	48,533	11.6	11.0
Tuna	3	3	47,305	44,183	10.0	10.1
Crabs	4	5	44,500	30,227	9.4	6.9
Oysters	5	4	29,800	32,241	6.3	7.3
Lobsters, Northern	6	6	25,200	22,389	5.3	5.1
Clams	7	7	20,100	20,129	4.3	4.6
Menhaden	8	8	18,700	14,391	4.0	3.3
Flounder (Atl. & Gulf)	9	9	13,900	13,658	2.9	3.1
Haddock	10	10	9,300	11,094	2.0	2.5

1/ Preliminary

Source: Fisheries of the United States...1967, United States Department of the Interior, Bureau of Commercial Fisheries

Table 2. Relative volume and value of shrimp landed in the U. S., 1958-1968

Year	Shrimp (Thou. lbs.) 1/	All Species (Thou. lbs.)	Percent of total (Percent)	Rank	Shrimp (Thou. dollars)	All Species (Thou. dollars)	Percent of total (Percent)	Rank
1958	213,842	4,735,845	4.5	6	72,930	370,679	19.7	1
1959	240,182	5,121,953	4.7	4	58,133	345,051	16.8	1
1960	249,452	4,942,229	5.0	3	66,932	353,565	18.9	1
1961	174,530	5,186,709	3.4	5	51,688	362,210	14.2	2
1962	191,106	5,354,185	3.6	7	73,236	396,428	18.5	1
1963	240,478	4,847,109	5.0	5	70,004	377,162	18.6	1
1964	211,821	4,540,622	4.7	6	70,076	389,498	18.1	1
1965	243,645	4,776,013	5.1	6	82,409	445,498	18.5	1
1966	239,046	4,364,106	5.5	5	96,296	472,238	20.4	1
1967	307,787	4,054,557	7.6	4	103,468	439,579	23.5	1
1968 2/	291,600	4,116,100	7.1	4	113,300	471,500	24.0	1

1/ Live weight

2/ Preliminary

Source: Fisheries of the United States, United States Department of the Interior, Bureau of Commercial Fisheries 1959-1968.

Figure 1. United States total shrimp consumption, 1958-1968

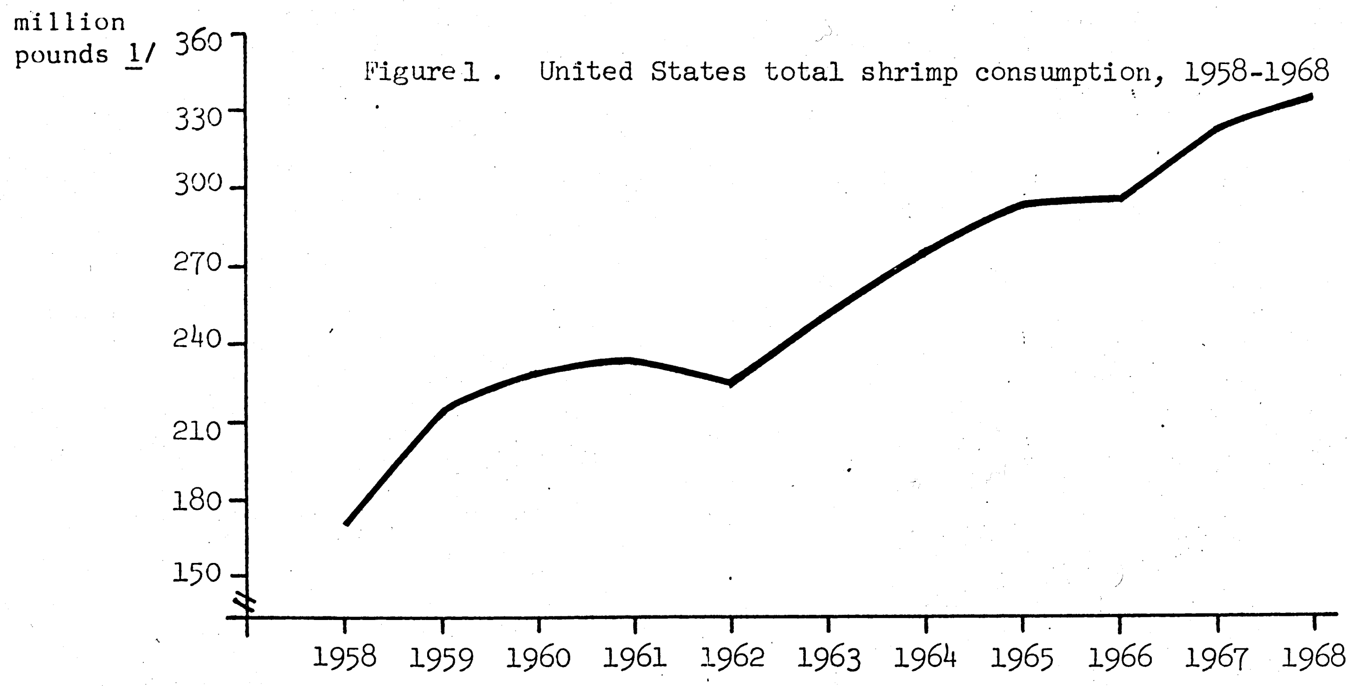
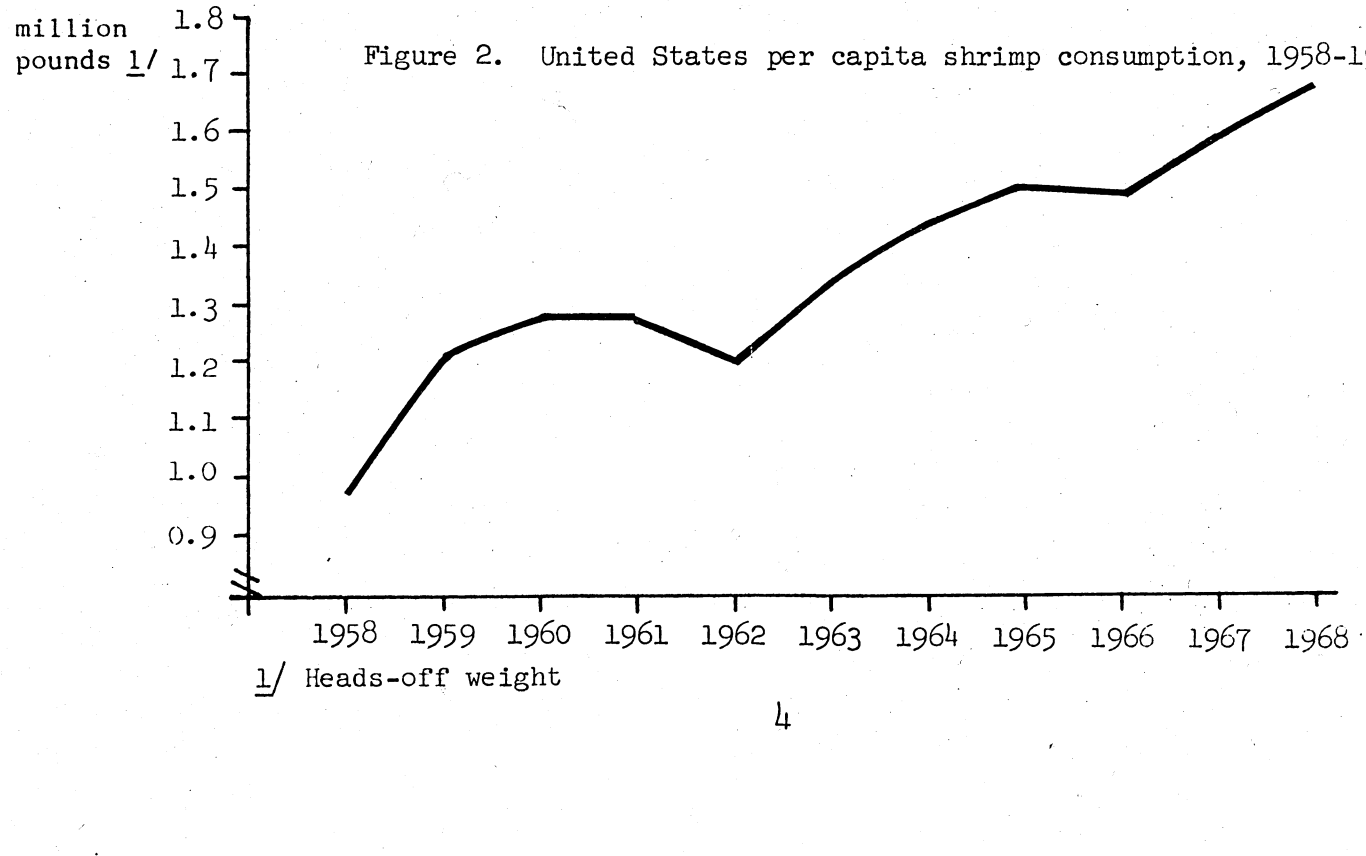


Figure 2. United States per capita shrimp consumption, 1958-1968



1/ Heads-off weight

Table 3. U. S. production of processed shrimp, salmon, tuna, blue crabs, lobsters, and eastern oysters, 1966, 1967

	Quantity		Value 1/		Average Value	
	1966	1967	1966	1967	1966	1967
	(million lbs)		(million $)		(cents per lb)	
Shrimp (all prod.)	222.3	264.9	227.8	264.9	102.5	100.0
Salmon (all prod.)	233.1	129.3	166.3	113.3	71.3	87.6
Tuna (all prod.)	394.3	389.4	270.2	262.0	68.5	67.2
Blue Crabs (Cooked meat)	17.5	16.1	20.8	22.5	118.9	139.8
Lobsters (Cooked meat)	1.03	.97	4.25	4.36	413.5	449.5
Oysters (all prod.)	59.8	62.4	44.9	50.9	75.1	81.6

1/ f.o.b. plant

Source: Fishery Statistics of the United States, United States Department of the Interior, Bureau of Commercial Fisheries

Description of the Resource

Various species of shrimp are found in waters along the Atlantic, Gulf and Pacific Coasts of the United States. Large commercial stocks, however, primarily exist in the Gulf of Mexico, and ports along the Gulf Coast of the United States account for over two-thirds of the total U. S. catch. There has been a surge, in recent years, in catches off New England, and off the northern Pacific Coast, but these are small-sized, "cold water" varieties of shrimp particularly suited to canning or packaging as a specialty product. Shrimp caught off the U. S. South Atlantic Coast are of the same type found in the Gulf (tables 4 and 5).

Within the Gulf and South Atlantic Region, the areas of heaviest concentration are located in Texas and Louisiana--ports in the two states handle 72 percent of total area landings (table 6). It should be noted, however, that a large percentage of the Louisiana catch is made up of small subadult shrimp--68 or more per pound--that are used in canning. In 1967, for example, approximately 44 percent of Louisiana shrimp landings consisted of this variety.[1/]

There are three major species of shrimp caught by U. S. fleets: brown (Penaeus aztecus); pink (Penaeus duorarum); and white (Penaeus setiferus). These species are similar in appearance, and habits. Differences involve variations in the locations of the spawning

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1/ U. S. Department of the Interior, Bureau of Commercial Fisheries, Shrimp Landings, 1967

Table 4. U. S. Landings of shrimp, by region, 1958-1968 1/

Year	New England	Mid-Atlantic	Chesapeake	South Atlantic	Gulf	Pacific	Total
1958	5	8	--	22,584	173,354	17,891	213,842
1959	17	4	--	26,006	193,503	20,652	240,182
1960	90	5	--	31,214	205,725	12,418	249,452
1961	68	6	--	19,749	133,795	20,912	174,530
1962	388	7	--	26,078	141,726	22,906	191,105
1963	561	7	--	15,529	203,116	21,260	240,478
1964	932	2	--	17,341	179,032	14,497	211,821
1965	2,093	6	--	26,191	195,237	20,091	243,645
1966	3,894	--	--	21,475	179,230	34,438	239,046
1967	6,996	--	--	20,598	225,731	54,462	307,787
1968 2/	14,400	--	--	24,300	200,700	52,200	291,600

1/ Heads-on weight

2/ Preliminary

Source: Fisheries of The United States, United States Department of the Interior, Bureau of Commercial Fisheries, 1958-1968.

Table 5. Percentage distribution of U. S. landings[2], by region, 1958-1968

Year	New England	Mid-Atlantic	Chesapeake	South Atlantic	Gulf	Pacific	Total[1]
1958	---	---	---	10.6	81.1	8.4	100.0
1959	---	---	---	10.8	80.6	8.6	100.0
1960	---	---	---	12.5	82.5	5.0	100.0
1961	---	---	---	11.3	76.7	12.0	100.0
1962	0.2	---	---	13.6	74.2	12.0	100.0
1963	0.2	---	---	6.4	84.5	8.8	100.0
1964	0.4	---	---	8.2	84.5	6.8	100.0
1965	0.8	---	---	10.7	80.1	8.2	100.0
1966	1.6	---	---	9.0	75.0	14.4	100.0
1967	2.3	---	---	6.7	73.3	17.7	100.0
1968	4.9	---	---	8.3	68.8	17.9	100.0

1/ May not add to 100.0 due to rounding

2/ Heads-on weight

Source: Fishery Statistics of the United States, United States Department of the Interior, Bureau of Commercial Fisheries

Table 6. Gulf and South Atlantic shrimp landings, by state, 1967

	Catch 1/ (thou. lbs.)	Value (thou. $)	Price/lb. (cents)
Texas	64,191	46,355	72.2
Louisiana	47,499	24,573	51.7
Florida, West Coast	14,664	10,475	71.4
Alabama	9,027	6,048	67.0
Mississippi	6,004	3,121	52.0
Georgia	4,270	3,022	70.8
North Carolina	3,067	1,809	59.0
Florida, East Coast	3,175	2,500	78.7
South Carolina	2,588	1,678	65.0
Total	154,485	99,581	64.45

1/ Heads-off weight

Source: U. S. Shrimp Landings, 1967, United States Department of the Interior, Bureau of Commercial Fisheries areas, and in the timing of migrations to and from nursery areas. All spawn offshore; the post-larvae migrate to inshore areas where they grow to subadulthood; and the adolescent shrimp return to offshore waters where they become adults and spawn. This basic life cycle is annual, but not necessarily within a calendar year.[2]

Species are interchangeable, but the shrimp catch is graded by size and expressed in terms of number of shrimp per pound (table 7). Because adult shrimp migrations are seaward, the older (and larger) shrimp are taken in farther offshore waters. The larger shrimp (under 30 count), which bring higher prices than the smaller, generally undergo a minimum of processing and they are marketed mostly as shell-on, frozen raw headless. Medium sized shrimp are used largely in the processing of frozen breaded products. The smallest sizes are used by the canneries, or in the preparation of frozen specialties.[3]

Supply Trends

Domestic landings of shrimp have shown a slightly rising trend over the past decade. However, landings in 1968 decreased 6 percent from

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2/ Shrimp Biological Research Committee, The Shrimp Fishery of the Gulf of Mexico (Rio Grande River to Key West, Florida), October, 1966

3/ U. S. Department of the Interior, Survey of the United States Shrimp Industry, Vol. I, Fish and Wildlife Service, Special Scientific Report--Fisheries No. 277, November, 1958.

Table 7. South Atlantic and Gulf Area shrimp landings, by size count, 1967

Size Count	Brown	White	Pink	Royal Red	Sea Bobs	Total
			(thousand pounds)			
Under 15	1,559	864	295	---	---	2,718
15 - 20	8,524	4,804	982	---	---	14,310
21 - 25	14,032	5,169	1,505	24	---	20,730
26 - 30	13,979	4,621	2,072	10	---	20,682
31 - 40	26,668	5,912	4,556	29	---	37,165
41 - 50	10,170	3,048	3,264	30	---	16,512
51 - 67	10,242	3,189	2,779	21	---	16,231
68 and over	20,685	4,433	807	---	214	26,139
Total	105,859	32,040	16,261	114	214	154,488

Source: Shrimp Landings, 1957, United States Department of the Interior, Bureau of Commercial Fisheries the previous year. The quantity of shrimp demanded, however, has climbed sharply, and increasing quantities of shrimp are being imported. The volume of U. S. landings in 1968 was 1.4 times the 1958 total, whereas imports increased 2.4 times over the same period (table 8). Imports now make up over half the U. S. supply of shrimp (tables 8 and 9; figures 3 and 4), compared with about 40 percent in 1958. More than 70 countries shipped 186 million pounds (product weight) of shrimp to the United States in 1967, although three countries--Mexico, India, and Panama--accounted for more than half the volume. Among the three, Mexico was the leader with 70.4 million pounds (table 10).

It is highly likely that imports will continue to increse in proportion to domestic landings. Past experience indicates that increased fishing effort on the traditional grounds fished by the United States fleets would not produce material gains in production.[4/] Added effort by U. S. fleets would thus have to be concentrated in distant waters. However, this would require a general shift toward larger vessels that are equipped to preserve the catch for periods longer than the four to seven days that is the present norm for most vessels. Presently, some fleets include larger vessels equipped for on-board freezing, but these are relatively few in number. In some cases, it is the practice for larger off-shore vessels to transfer

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[4/] Longnecker, Oscar M., The Place of the Shrimping Industry in the United States Fishery, Presented at the Conference on the Future of the U. S. Fishing Industry, University of Washington, Seattle, Washington, March 24-27, 1968.

Table 8. U. S. landings and imports of shrimp, 1958-1968

	U. S. Landings	U. S. Imports	Index Landings	Index Imports
	(thou. lbs.) 1/		(Base 1958 = 100)	
1958	127,287	85,394	100	100
1959	142,965	111,704	112	131
1960	148,483	119,139	117	140
1961	103,865	134,564	82	158
1962	119,154	152,504	94	179
1963	150,737	167,344	118	196
1964	133,113	169,510	105	198
1965	152,346	178,955	120	210
1966	148,255	194,946	116	228
1967	189,500	202,000	149	237
1968 2/	178,600	209,500	140	245

1/ Heads-off weight

2/ Preliminary

Source: Shellfish Situation and Outlook, March, 1969, United States Department of the Interior, Bureau of Commercial Fisheries

Table 9. U. S. landings, imports for consumption, domestic exports, and new supply for domestic consumption, thousands of pounds, 1958-1968, heads-off weight

Year	U. S. landings	Imports	Domestic exports[1/]	New supply[2/] for consumption	Ratio of imports to: Landings (%)	Ratio of imports to: Supply (%)
1958	127,287	85,394	6,641	206,040	67	41
1959	142,965	111,704	8,806	245,863	78	45
1960	148,483	119,139	11,144	256,478	80	46
1961	103,865	134,564	10,750	227,679	130	59
1962	119,154	152,504	9,445	262,213	128	58
1963	150,737	167,344	15,482	302,599	111	55
1964	133,113	169,510	16,693	285,930	127	59
1965	152,346	178,955	16,759	314,542	117	57
1966	148,255	194,946	14,781	328,420	131	59
1967	189,500	202,000	19,673	371,827	107	54
1968	178,600	209,500	21,974	366,126	117	57

1/ Includes: (1) The quantity of fresh and frozen shrimp as reported.
(2) The quantity of canned shrimp multiplied by 2.20.
(3) The quantity of dried shrimp multiplied by 4.58.

2/ Landings plus imports minus exports; excludes carryover.

Source: Fisheries of the United States, United States Department of the Interior, Bureau of Commercial Fisheries

Figure 3. United States shrimp landings, 1958-1968

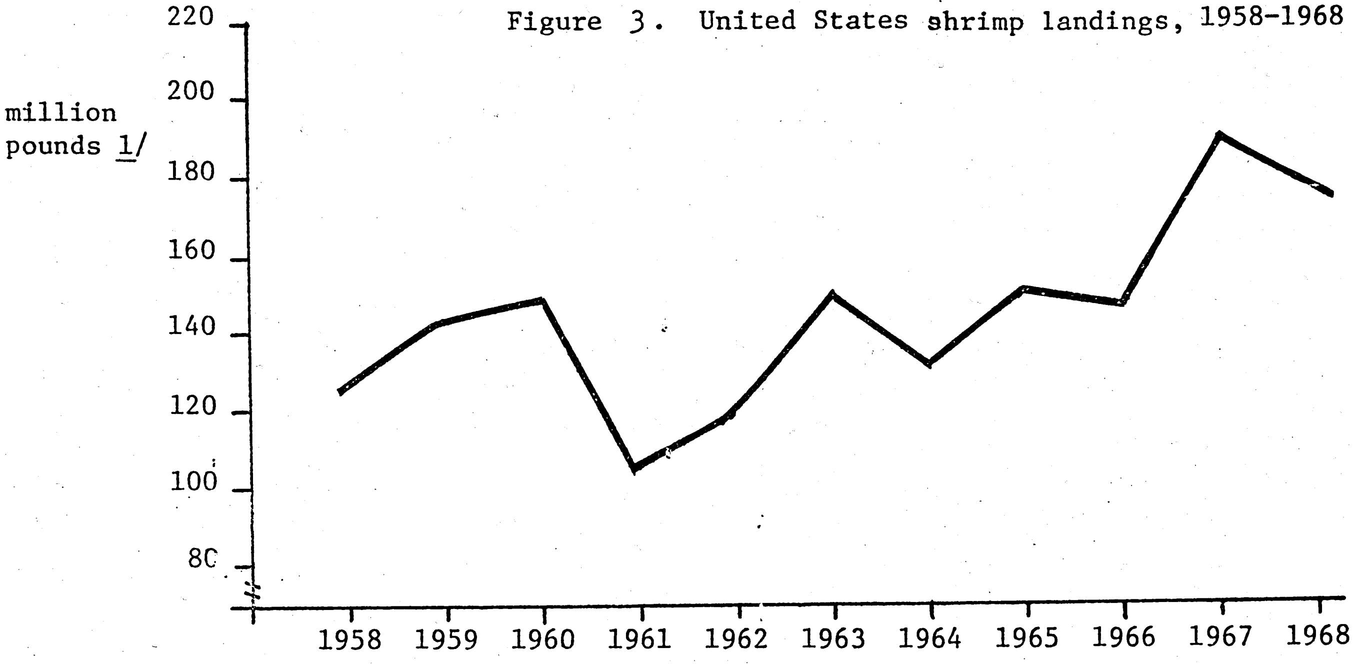
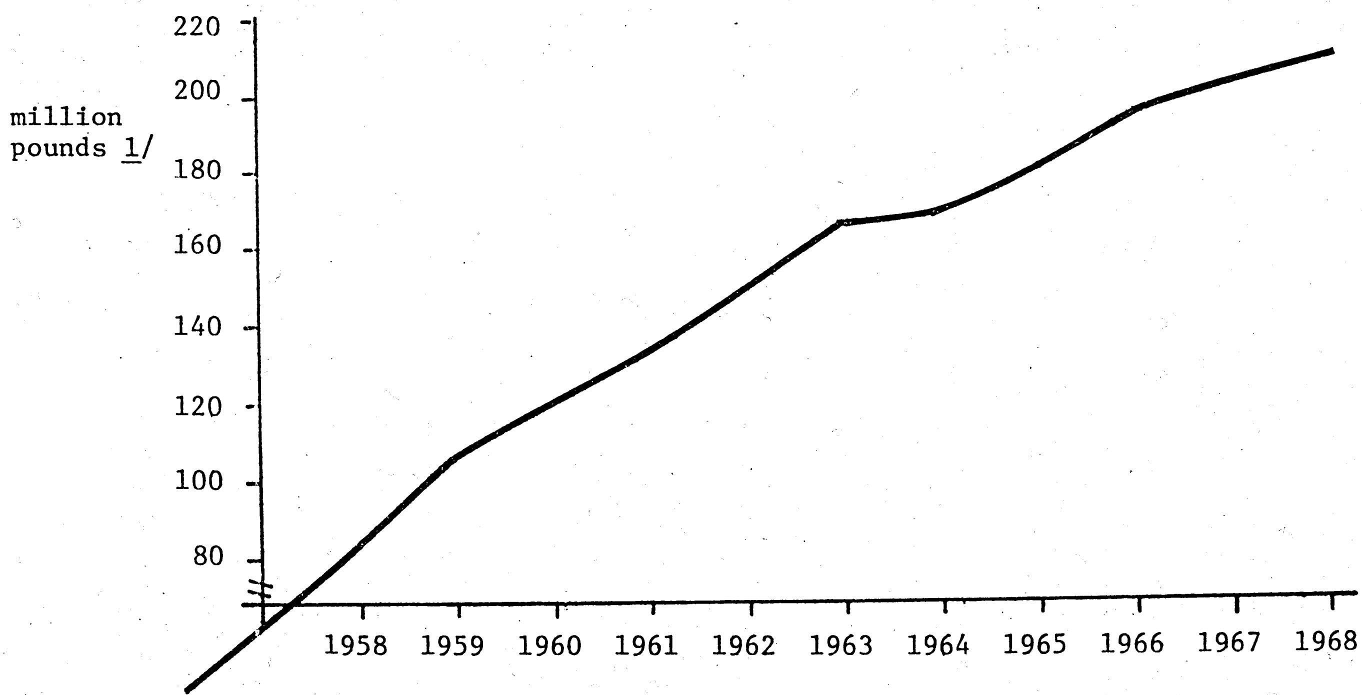


Figure 4. United States shrimp imports, 1958-1968



1/ Heads-off weight

Table 10. United States imports of shrimp, by leading countries, 1959-1967

Country	1959	1960	1961	1962	1963	1964	1965	1966	1967
					(thousands of pounds) (product weight)				
Barbados	--	--	--	--	246	1,472	1,830	1,934	2,225
British Guiana	967	3,568	3,506	4,129	5,509	5,502	7,972	8,780	9,452
Columbia	1,898	2,174	1,873	2,207	1,870	1,774	1,796	2,212	2,726
Costa Rica	1,157	461	1,321	1,671	1,508	1,976	1,753	1,779	1,679
Ecuador	4,712	4,192	4,684	5,121	5,631	5,759	5,667	5,239	5,986
El Salvador	1,836	6,697	8,093	7,156	6,667	6,296	5,376	6,955	6,724
French Guiana	--	--	--	--	2,789	2,961	3,960	4,668	6,717
Guatemala	182	257	743	2,298	1,943	2,207	1,515	2,481	1,924
Honduras	314	361	227	379	835	698	1,632	2,107	1,922
India	2,866	2,891	3,221	5,616	9,951	10,232	14,301	16,499	18,436
Iran	739	1,226	1,953	724	87	682	6,801	9,106	1,674
Japan	7,227	2,947	1,823	3,922	4,084	2,891	2,506	2,642	935
Kuwait	--	146	194	415	3,728	5,358	5,818	5,744	8,053
Pakistan	640	1,018	1,686	3,156	3,685	4,812	6,541	8,191	7,457
Mexico	68,654	73,583	79,181	77,665	76,512	72,122	59,937	68,715	70,395
Nicaragua	213	266	803	1,971	1,611	2,520	3,153	3,914	5,053
Panama	8,805	8,422	9,892	10,117	10,258	12,122	10,264	9,733	11,126
Republic of Korea	170	93	171	1,756	2,151	1,294	939	989	487
Saudia Arabia	--	77	--	--	100	430	1,201	1,622	2,427
Surinan	289	381	447	1,036	1,205	1,323	1,409	2,080	2,129
Thailand	53	40	35	250	888	573	954	1,787	2,559
Venezuela	370	344	2,469	6,341	5,790	7,904	12,719	2,881	4,773
All Other	5,463	4,274	3,946	5,253	4,482	3,669	4,897	8,491	11,214
TOTAL	106,555	113,418	126,268	141,183	151,530	154,577	162,942	178,549	186,073

Source: 1950-65: Charles H. Lyles, Historical Statistics (Shrimp Fishery), United States Department of the Interior, Bureau of Commercial Fisheries, Washington, D. C. May 1967

1960-67: Fisheries of the United States . . . 1967, United States Department of the Interior, Bureau of Commercial their catches to carier vessels for shipment to U. S. ports. In other cases, U. S. vessels operating in distant waters unload at a foreign processing facility and the shrimp eventually enter the U. S. as imports. In any event, increased effort in shrimp fishing on a world-wide basis appears to assure the U. S. a continuous supply flow.

Seasonal Factors

Shrimp are landed at Gulf and South Atlantic ports year-round although there are well defined seasonal cycles identified with individual species and with shrimp sizes. Brown shrimp, for example, reach marketable size in late spring, and landings are heaviest during the summer months. White shrimp landings peak in late summer and autumn, and pink shrimp are in abundance from November through March (table 11).

The seasonal cycles of the three dominant shrimp species are complementary. However, the overall seasonality (all species) is heavily influenced by the preponderance of brown shrimp in the catch. Total domestic landings, therefore, peak in midsummer. Catches continue heavy through the fall months, buttressed by the heavy seasonal concentration of white shrimp during October and November.

Table 11. Seasonal index of South Atlantic and Gulf shrimp landings, by species

Month	Brown	White	Pink	Total
Jan	22.0	55.4	115.5	45.6
Feb	15.9	26.0	120.4	36.9
Mar	20.7	23.9	124.4	31.4
Apr	27.3	19.3	112.4	40.8
May	75.4	65.6	113.9	83.5
Jun	203.5	57.6	88.5	132.9
Jul	291.3	25.3	68.6	168.1
Aug	226.1	86.0	39.7	151.2
Sep	139.9	151.6	45.2	139.6
Oct	88.4	290.4	104.0	153.1
Nov	58.3	248.3	152.2	124.6
Dec	31.6	153.0	116.2	86.0

As might be expected, imports offset, to an extent, the seasonal low in landings, thereby reducing the amplitude of the seasonal changes in total supplies. The seasonal index for total supplies ranges from 84 in April to 118 in November (table 12).

The seasonal pattern of the various species is especially reflected in the seasonal landings cycles of individual areas. This is due to species concentrations. For example, brown shrimp are found mostly off the Texas Coast and account for more than 85 percent of the State's total shrimp landings. Therefore, the seasonal landings cycle at Texas ports is a replica of the brown shrimp seasonal index--that is, a summer peak and winter trough. Similarly, Florida landings follow the pattern for pink shrimp--low summer, high fall and winter (tables 13, 14, and 15).

Price Structure - Ex-vessel

The average price received by fishermen for all shrimp landed at Gulf and South Atlantic ports in 1967 was $0.645 per pound. Prices vary considerably, however, according to size count and there is also some variance between species. Invariably there is a near perfect positive correlation between size and price, that is, the larger the size the higher the price. For example, the ex-vessel price for "jumbo" shrimp--less than 15 per pound--was $1.16 per pound, compared with $1.04 per pound for shrimp that

Table 12. Seasonal index of supplies of shrimp

Month	Landings	Imports	Supply
Jan	45.6	113.8	106.5
Feb	36.9	85.4	96.4
Mar	37.4	97.2	91.1
Apr	40.8	86.2	84.2
May	83.5	89.5	88.6
Jun	132.9	90.7	98.1
Jul	168.1	84.6	97.1
Aug	151.2	70.5	94.9
Sep	139.6	89.7	96.5
Oct	153.1	137.5	114.0
Nov	124.6	135.9	117.8
Dec	86.0	118.2	114.0

Table 13. Seasonal index of Gulf shrimp landings, by State

Month	Florida (West)	Alabama	Mississippi	Louisiana	Texas
Jan	113.1	40.9	13.5	36.3	39.3
Feb	99.6	20.2	6.2	20.6	38.8
Mar	108.5	20.6	5.3	15.1	40.3
Apr	110.1	20.2	7.0	27.6	39.8
May	105.3	39.1	11.3	117.7	49.9
Jun	79.0	204.4	341.3	218.8	73.5
Jul	61.5	243.4	353.6	135.4	191.4
Aug	52.1	197.6	173.3	113.9	199.7
Sep	60.5	128.2	71.8	112.3	194.1
Oct	127.9	104.1	79.7	160.9	157.2
Nov	161.0	99.9	82.4	146.2	103.7
Dec	121.4	80.8	53.8	96.0	66.8

Table 14. Seasonal index of South Atlantic shrimp landings, by State

Month	N. Carolina	S. Carolina	Georgia	Florida (East)
Jan	0.6	0.8	18.3	98.3
Feb	0.4	0.5	3.2	29.0
Mar	0.4	0.5	8.9	18.6
Apr	0.6	0.5	4.7	12.1
May	29.1	2.9	21.8	20.7
Jun	140.0	72.8	61.7	58.5
Jul	271.6	289.0	156.2	111.7
Aug	260.1	227.8	138.8	111.6
Sep	257.0	202.8	251.2	105.8
Oct	193.9	285.0	242.3	174.8
Nov	40.7	88.4	162.1	276.7
Dec	5.7	30.8	130.3	179.2

Table 15. Seasonal index of South Atlantic and Gulf shrimp landings, by size count

Month	25 and under	26-50	51 and over	Total
Jan	69.3	43.1	36.8	45.6
Feb	61.5	30.4	26.1	36.9
Mar	61.4	33.6	24.3	37.4
Apr	63.3	39.5	23.0	40.8
May	91.0	51.8	102.0	83.5
Jun	93.9	74.6	317.4	132.9
Jul	52.7	211.3	161.6	168.1
Aug	72.8	219.2	96.9	151.2
Sep	156.6	176.0	55.6	139.6
Oct	235.0	133.5	117.9	153.1
Nov	139.4	108.7	135.1	124.6
Dec	95.9	76.8	105.4	86.0

measured 15-20 to the pound, and $0.87 for 21-25 count shrimp. The differences reflect both smaller supplies and stronger consumer preference for the larger sizes (table 16).

Consumer type and process type also are important factors in the demand for various shrimp sizes. Jumbo shrimp, for example, are preferred by the luxury restaurant trade for preparation of shrimp cocktails or other popular (and expensive) appetizer or entree items. Medium size shrimp (which sell for less than the larger sizes), on the other hand, are well suited for manufacturing into breaded products and are purchased largely by manufacturing plants who operate under tighter constraints of end-product pricing. Moreover, there is a greater availability of these middle sizes, than of the large sizes.

The chief determinant of price differences as between species appears to be quantities landed. The average ex-vessel price for brown shrimp in 1967 was 60.1 cents per pound, compared with 74.4 cents for whites. The total quantity of brown shrimp landed that year was more than three times the quantity of white.

Processing

The processing of the shrimp catch begins, generally, at sea, where shrimp brought aboard the vessel are headed and washed, and stored

Table 16. Average prices received by fishermen for shrimp, Gulf and South Atlantic, by count size, 1967

Size Count	Brown	White	Pink	Royal Red	Sea Bobs	All Species Average
			(cents per pound)			
Under 15	117.9	113.4	109.2	---	---	115.5
15 - 20	101.2	108.3	103.8	---	---	103.8
21 - 25	83.2	95.7	97.3	92.0	---	87.3
26 - 30	71.4	82.0	90.0	93.4	---	75.7
31 - 40	60.8	67.5	77.9	82.4	---	64.0
41 - 50	52.1	60.5	63.4	69.0	---	55.9
51 - 67	43.6	47.9	53.6	65.3	---	46.2
68 and over	26.7	32.7	38.1	38.8	21.3	28.0
All Sizes Aver.	60.1	74.4	74.1	78.7	21.3	64.5

Source: Shrimp Landings, 1967, U. S. Department of the Interior, Bureau of Commercial Fisheries in iced holds. On vessels with freezer equipment, shrimp may be frozen and placed in 5 pound cartons for direct marketing, or frozen in blocks for thawing and further processing ashore. The large majority of shrimp taken by the domestic fleet, however, is preserved at sea on ice for periods ranging up to seven days. (Vessels remaining at sea a greater length of time transfer their catch to returning vessels.)

Once ashore, most of the domestic catch is sold to manufacturing plants as a raw material for further processing. The channel may not be direct, as fish are often purchased from the vessels by a "packing house," and assembled quantities are resold to the processors.

Probably about 80 percent of the U. S. catch of shrimp is processed as a frozen product; most of the remainder is canned or dried (table 17). The quantity of shrimp processed by plants as a non-frozen product is practically nil, although relatively small quantities of "fresh" shrimp (i.e., non-frozen) move directly from the packing (or assembly) houses to selected wholesale markets (table 18). These include New Orleans, New York and Chicago. New York's Fulton Fish Market, for example, received about 1.7 million pounds of fresh shrimp in 1966, along with 9.5 million pounds of frozen.

Table 17. Production of processed shrimp, Gulf and South Atlantic States, by preservation method, 1966 1/

	Quantity (thous. lbs.) 2/	Value (thous. dollars)	Average price 3/ (cents/lb.)
Fresh	220	277	125.9
Frozen	177,442	175,751	99.0
Canned	13,061	20,814	159.4
Cured (dried)	426	1,374	322.5
Total	191,149	198,216	103.7

1/ Represents output of 148 plants in the following states: Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas.

2/ Product weight.

3/ F.o.b. plant.

Source: United States Department of the Interior, Bureau of Commercial Fisheries.

Table 18. U. S. production and imports of processed shrimp, by product type, 1967

Shrimp product type	U. S. processed 1/ Quantity: Product weight (thous. pounds)	U. S. processed 1/ Quantity: Live weight equivalent (thous. pounds)	U. S. processed 1/ Value (thous. dollars)	U. S. imports 1/ Quantity: Product weight (thous. pounds)	U. S. imports 1/ Quantity: Live weight equivalent (thous. pounds)	U. S. imports 1/ Value (thous. dollars)
Raw headless 2/	101,090	159,143	88,487	131,927	209,764	105,813
Peeled 2/						
Raw	32,239	65,768	42,874	38,959	79,476	31,875
Cooked	7,102	22,229	12,389	1,797	5,625	1,450
Breaded 2/	94,230	94,330	85,319	830	830	1,029
Specialties 2/	12,057	20,980	10,478	---	---	---
Canned	17,864	57,183	24,728	2,224	7,139	2,070
Cured	352	2,707	582	336	2,584	255
Unclassified	---	---	---	9,999	17,398	8,285
Total	264,884	422,340	264,857	186,072	322,816	150,877

1/ A substantial quantity of U. S. processed shrimp is manufactured from imported raw headless shrimp, hence U. S. processed totals duplicate part of the import total.

2/ Mostly frozen.

Source: U. S. Department of the Interior, Bureau of Commercial Fisheries

There are three major frozen product forms, which, in order of importance, are: raw headless, breaded, and peeled and deveined. On a product weight basis, raw headless shrimp account for slightly more than one-third the total output of frozen shrimp products. Breaded shrimp make up about 36 percent of total production and peeled and deveined about 15 percent. A small percentage of the production total is comprised of frozen specialty items such as shrimp cocktail, dinners, and spreads.

Production trends indicate that breaded shrimp are likely to gain an increasing share of total U. S. production of frozen shrimp products. Similarly, peeled and deveined shrimp will account for a growing share of total production. Since 1955, there have been year-to-year fluctuations in the production of raw headless shrimp with no discernible trend. The quantity of raw headless shrimp produced in U. S. plants in 1967 was about 46 percent below the 1955 average level. The output of breaded and peeled shrimp has been gaining steadily. Production totals for 1966 for breaded and for peeled were up 2.4 and 4.6 times, respectively, from 1955. By 1985, breaded shrimp will likely comprise about 60 percent of total frozen shrimp output, and most of the remainder will be shared equally by raw headless, and peeled (table 19).

Table 19. Trends in U. S. production of frozen shrimp products, 1955-1967

Year	Raw Headless	Breaded	Peeled	Raw Headless	Breaded	Peeled
	(thous. pounds)			(Index, 1955 = 100)		
1955	69,122	38,991	8,503	100	100	100
1956	61,355	50,888	9,749	89	131	115
1957	58,269	51,085	10,819	84	131	127
1958	63,276	60,865	9,702	92	156	114
1959	61,598	69,764	12,987	89	179	153
1960	78,071	70,348	22,158	113	180	261
1961	46,417	73,795	19,828	67	189	233
1962	51,177	76,803	21,268	74	197	250
1963	66,441	76,216	24,477	96	195	288
1964	64,537	91,333	26,693	93	234	314
1965	64,449	98,144	27,640	93	252	325
1966	62,210	104,926	30,130	90	269	354
1967	101,090	94,230	39,341	146	242	463

Source: United States Department of the Interior, Bureau of Commercial Fisheries, Fishery Statistics of the United States

The sharply rising trends in U. S. production of breaded and of peeled and deveined shrimp are consistent with a growing demand for convenience food items. The trends probably also reflect this competitive position of U. S. producers vis-a-vis imports. All foreign shrimp products are duty free, yet foreign imports of breaded shrimp are insignificant. Over 90 percent of imported shrimp are raw headless, or peeled and deveined, and the total quantity in each category imported, exceeds domestic production of like products. It should be noted, however, that in the case of raw headless shrimp, a substantial percentage of imports (over 30 percent) is used as raw material for further processing in U. S. plants. More than one-third of shrimp used in breading is of foreign origin, and canners also use imports. Nonetheless, substantial quantities of foreign-packed raw-headless shrimp are marketed in direct competition with U. S. producers.

The geographic distribution of shrimp processing plants follows, generally, the distribution of landings. Texas, Louisiana and the West Coast of Florida are the top three areas for landings and for processed shrimp products. There is an outstanding exception to this pattern, however, in the case of Georgia, which is a major shrimp processing State but a minor State in regard to landings. None of the leading major processed production areas, in fact, are self sufficient in raw material. As shown in table 20, all apparently supplement area landings with substantial imports of raw shrimp from other States or from foreign sources. In Texas, for example, the quantity of shrimp landed equals less than three-fourths the quantity processed. Georgia shrimp landings probably fill little more than 20 percent of the processing plant requirements, and a similar situation prevails on the Florida East Coast. Alabama is the single State producing a measurable quantity of processed shrimp that has an apparent surplus of raw material(table 20).

Shrimp processing plants are located in coastal counties throughout the South Atlantic and Gulf region. Most areas produce two or more product types of frozen shrimp, although canning is heavily concentrated in Louisiana. Within some of the producing area, there is a notable degree of product specialization. On the East Coast of Florida, for example, breaded products account for 80 percent of total frozen shrimp produced and manufactured by area plants. Similarly, plants in Georgia specialize heavily in breaded shrimp as do plants on the Florida West Coast and Texas, to a lesser degree. Plants in Louisiana, Mississippi, and Alabama, on the other hand, concentrate production in raw headless shrimp (tables 21 and 22).

Table 20. Gulf and South Atlantic shrimp landings and processing plant throughput, by State, 1966

	Landings	Quantity Processed	Net Apparent Imports 1/	Ratio: Imports to Landings
	(thous. lbs, live wt. equivalent)			
North Carolina	5697	34	(5663)	(.994)
South Carolina	4262	155	(4107)	(.964)
Georgia	6475	30151	23676	3.657
Florida				
East Coast	5038	16898	11860	2.354
West Coast	28877	55929	27052	.937
Total	33915	72827	38912	1.147
Alabama	10607	7434	(3173)	(.299)
Mississippi	7559	13186	5627	.744
Louisiana	62078	66573	4495	.072
Texas	69907	96358	26451	.378

( ) indicates negative

1/ From other States, or other countries

Source: U. S. Department of the Interior, Bureau of Commercial Fisheries

Table 21. Processed shrimp plants and production, by State and County, 1966

State,	County	Number of plants processing shrimp	Fresh processed	Frozen processed	Canned	Cured	Total shrimp processed
			(thous. pounds)				
Georgia							
	Glynn	4					
	Chatham	2					
State total		6	---	25,087	---	---	25,087
Florida East Coast							
	St. Johns	1					
	Lake	1					
	Duval	1					
	Dade	6					
	Palm Beach	2					
State total		11	60	14,802	---	---	14,862
Florida West Coast							
	Bay	1					
	Okaloosa	1					
	Franklin	1					
	Escambia	3					
	Hillsborough	9					
	Pinellas	1					
State total		16	14	42,089	---	---	42,103
Alabama							
	Baldwin	4					
	Mobile	4					
State total		8	---	4,544	---	---	4,544
Mississippi							
	Harrison	10					
	Jackson	1					
State total		11	---	2,878	2,678	---	5,556

(continued)

Table 21 (continued). Processed shrimp plants and production, by State and County, 1966

State,	County	Number of plants processing shrimp	Fresh processed	Frozen processed	Canned	Cured	Total shrimp processed
			(thous. pounds)				
Louisiana							
	St. Mary	5					
	Vermilion	4					
	Cameron	2					
	Lafayette	1					
	Terrebonne	24					
	Assumption	1					
	LaFourche	4					
	Jefferson	12					
	Orleans	6					
	St. Bernard	2					
State total		61	146	19,516	10,120	340	30,122
Texas							
	Galveston	7					
	Hidalgo	2					
	Aransas	1					
	Calhoun	4					
	Matagorda	2					
	Brazoria	2					
	Jefferson	3					
	Cameron	12					
	Nueces	1					
State total		34	---	68,526	263	86	68,875
Grand total		147	220	177,442	13,061	426	191,149

Source: U. S. Department of the Interior, Bureau of Commercial Fisheries

Table 22. Frozen shrimp production in South Atlantic and Gulf plants, by product type, 1966

State,	County	Raw headless	Peeled and deveined	Breaded	Specialties	Total frozen products
			(thous. pounds)			
Georgia						
	Glynn					
	Chatham					
State total		1,269	2,982	19,196	1,640	25,087
Florida East Coast						
	St. Johns					
	Lake					
	Duval					
	Dade					
	Palm Beach					
State total		2,193	564	11,883	162	14,802
Florida West Coast						
	Bay					
	Okaloosa					
	Franklin					
	Escambia					
	Hillsborough					
	Pinellas					
State total		7,410	9,082	25,596	1	42,089
Alabama						
	Baldwin					
	Mobile					
State total		3,902	376	---	266	4,544
Mississippi						
	Harrison					
	Jackson					
State total		2,848	30	---	---	2,878

(continued)

Table 22 (continued). Frozen shrimp production in South Atlantic and Gulf plants, by product type, 1966

State,	County	Raw headless	Peeled and deveined	Breaded	Specialties	Total frozen products
			(thous. pounds)			
Louisiana						
	St. Mary					
	Vermilion					
	Cameron					
	Terrebonne					
	Assumption					
	LaFourche					
	Jefferson					
	Orleans					
	St. Bernard					
State total		15,458	2,211	1,503	344	19,516
Texas						
	Galveston					
	Hidalgo					
	Aransas					
	Calhoun					
	Matagorda					
	Brazoria					
	Jefferson					
	Cameron					
	Nueces					
State total		26,614	9,976	31,599	337	68,526
Total Gulf and South Atlantic States		59,694	25,221	89,777	2,750	177,442

Processing Costs

Raw materials comprise the largest component of shrimp processing costs. This is especially true of packaged raw headless (shell on) shrimp, which undergo a minimum of processing. For example, the total cost of producing one pound of raw headless shrimp in the Gulf area in early summer 1968 was just under $0.95. About 90 percent of this cost was the price paid for raw shrimp delivered to the plant. The breading operations have a somewhat different cost structure. The raw material that goes into one pound of breaded shrimp amounts to less than 80 percent of the total cost, inasmuch as the product undergoes more processing than the raw headless, and the value per pound of raw material is diluted to the extent that bread makes up the total weight of the product. (Standard breading is up to 50 percent of product weight.) 5/ Typical processing costs are given in table 23.

Because processing costs are highly dependent on the cost of raw materials, they have a considerable seasonal variation, in accordance with seasonal price movements. Shrimp prices, at the ex-vessel level, respond sharply to changes in quantities landed. Recent price elasticity estimates indicate that a given percentage change in quantities landed will be accompanied by an even larger percentage change in prices.

5/ U. S. Department of the Interior, Bureau of Commercial Fisheries, United States Standards for grades of Frozen Raw Breaded Shrimp

Table 23. Processing costs, Gulf shrimp plants, early summer, 1968

(Based on 26-30 count shrimp)

	Raw Headless	Peeled and Deveined (IF)	Machine Breaded	Hand Breaded
	(dollars per pound)			
Raw Material				
Shrimp	.850	1.050	.600	.600
Breading & other	---	---	.04	.040
	.850	1.050	.640	.640
Labor				
Grading/Handling/ Peeling	.015	.115	.045	.075
Breading/Cooking	---	---	.040	.165
Other	.010	.050	.010	.025
Packaging	.010	.010	.010	.010
Freezing	.0125	.040	.0125	.0125
Overhead	.050	.050	.050	.050
Total	.9475	1.315	.8075	.9775

Wholesale processed shrimp prices reflect changes in prices at the vessel level, but the amplitude of seasonal change is relatively small. Processors' margins, therefore, are subject to change seasonally with the changes in raw material costs. (Comparative seasonal indices of ex-vessel and wholesale prices, and wholesale prices in effect during 1967 are shown in tables 24 and 25 and in Figure 5.)

Demand

There is a strong demand for shrimp in the United States. It is indicated that per capita consumption of shrimp rose to 1.68 pounds in 1968, in a steady advance from 0.96 pounds in 1957. The trend represents a 5.2 percent increase per year, and it has been in effect in a period when shrimp prices were increasing faster than most wholesale or consumer prices. The wholesale price for shrimp for 1967, was 46 percentage points above the base year (1960). A comparable measure of the wholesale price for all commodities for the period shows a gain of between 5 and 6 points. The change in the consumer price index between 1960 and 1967 was close to 14 percent.

As may be seen in table 26, shrimp is no exception to the general rule that the demand for an economic good is inversely related to its price, all other things the same. As econometric studies have invariably found, the coefficients of the price variables in equations describing consumption of shrimp are negative. That

Table 24. Seasonal index of shrimp prices

	Ex-vessel All Gulf & South Atlantic	Wholesale Chicago Raw Headless Frozen	Wholesale Chicago Breaded
		Index	
Jan	101.1	98.4	99.9
Feb	110.2	99.9	98.9
Mar	114.3	100.5	100.9
Apr	118.6	103.0	101.1
May	96.7	103.5	100.9
June	77.4	101.2	100.4
July	85.4	100.3	99.6
Aug	90.3	98.4	99.5
Sep	107.6	95.8	99.4
Oct	99.1	97.1	99.2
Nov	96.4	101.7	99.7
Dec.	94.8	99.7	99.8

Table 25. Wholesale prices of processed shrimp products, Chicago, 1967

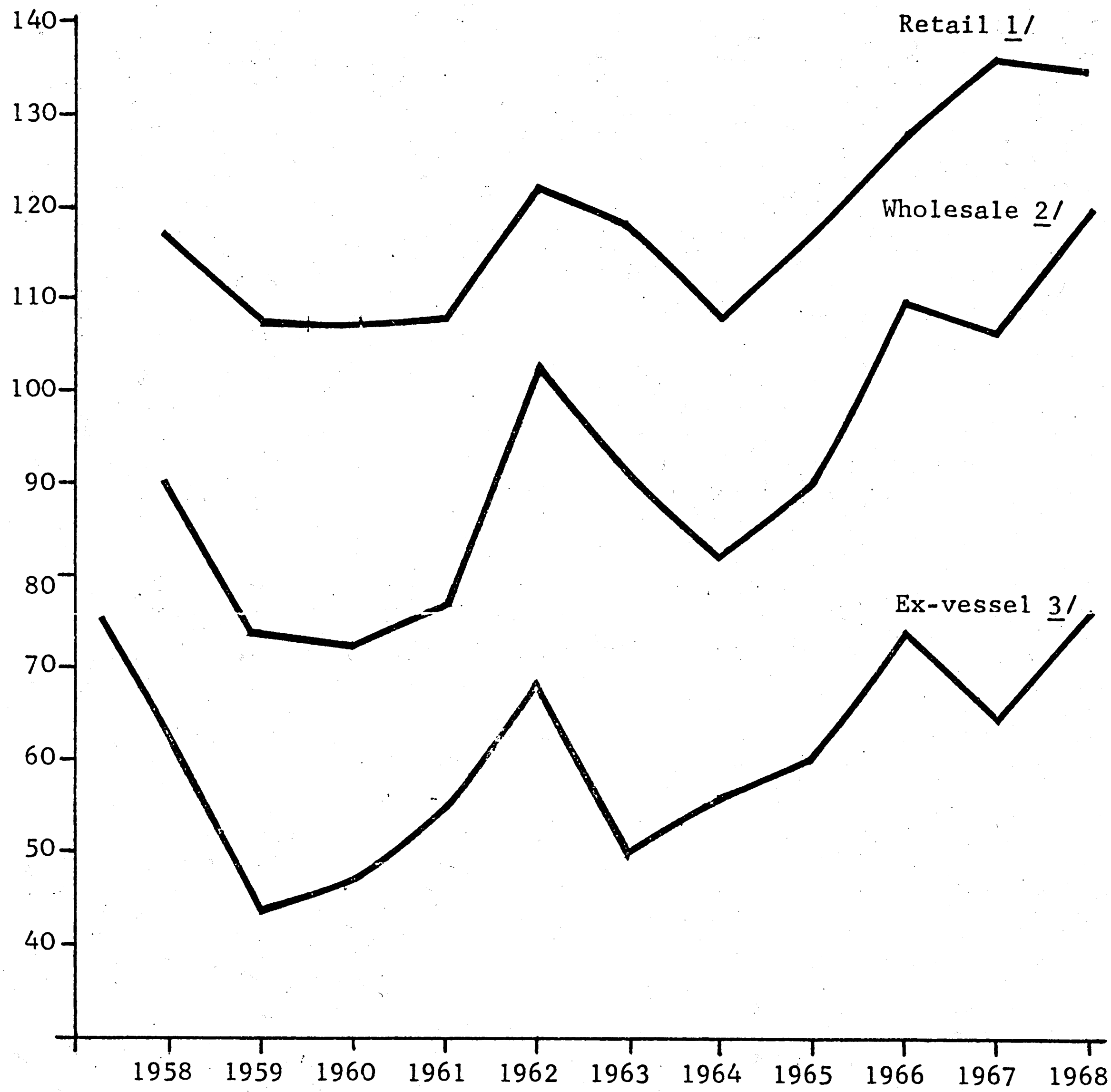
Month	Raw Headless 1/	Breaded 2/	Peeled Deveined 3/
	(dollars per pound)		
Jan	1.11	.99	1.63
Feb	1.16	1.00	1.64
Mar	1.17	1.00	1.68
Apr	1.18	1.00	1.68
May	1.20	1.00	1.71
Jun	1.22	1.00	1.72
Jul	1.03	.94	1.63
Aug	.85	.83	1.52
Sep	.88	.83	1.48
Oct	.94	.84	1.52
Nov	1.01	.84	1.54
Dec	1.04	.88	1.58

1/ 26-30 count, Gulf browns

2/ 26-30 count, 2-4 pound

3/ 26-30 count, 3 pound

Figure 5. United States shrimp prices, 1958-1968



1/ Retail price - BLS 41-city average, frozen
2/ Wholesale price - Chicago, 26-30 count, raw headless
3/ Ex-vessel price - Gulf and South Atlantic States

Table 26. Regression equations[1/] relating per capita consumption of shrimp to prices and per capita income

Equation Number	Equation	R^2	R	d [2/]	Elasticity of Demand Price	Elasticity of Demand Income
1	$\log(q) = -0.58 - 0.37 \log(P_{E-V}) + 1.93 \log(i)$	0.92	0.96	0.81	-0.37	1.93
	(-3.28) (12.3)					
2	$\log(q) = -0.53 - 0.46 \log(P_W) + 1.98 \log(i)$	0.93	0.96	0.73	-0.46	1.98
	(-3.52) (12.4)					
3	$\log(q) = -0.42 - 0.46 \log(P_R) + 1.77 \log(i)$	0.89	0.94	0.79	-0.46	1.77
	(-1.70) (10.0)					

1/ Least squares fit of annual data 1950-1968, total United States
2/ Durbin-Watson statistic
3/ Numbers in parentheses are student's t statistic
4/ Variables

- q - per capita consumption of shrimp
- P_{E-V} - ex-vessel price
- P_W - wholesale price
- P_R - retail price
- i - deflated per capita personal disposable income

is, less shrimp will be consumed at higher prices.[6/]

Additionally, these studies generally agree that a rise in shrimp prices is associated with a less than proportionate decline in per capita consumption. For example, in equation number 3 (table 26) the retail price elasticity of demand is -.46. This means that a 10 percent rise in the retail price of shrimp is associated with only a 4.6 percent decline in per capita consumption. The demand for shrimp, then, is said to be inelastic with respect to price. This condition gives shrimp marketers considerable leeway in raising prices, for although the quantity sold may be less, revenue from sales will increase.

Income is another factor influencing the demand for shrimp. The three equations in table 26 show a direct relation between per capita consumption and deflated per capita disposable income. (This is indicated by the positive income coefficients.) An increase in the quantity of shrimp consumed is associated with an increase in purchasing power. The equations indicate that a 10 percent increase in income is associated with an increase in per capita consumption of between 18 and 20 percent. This income-elastic demand, as it is called, supports the contention that

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6/ Nash, Darrel A. and Frederick W. Bell. An Inventory of Demand Equations for Fishery Products, U. S. Department of the Interior, Bureau of Commercial Fisheries. (The results reported in table 25 are similar to those reported by Richard Suttor, David Elkin, John Doll, and Donald Cleary at a demand for fishery products workshop.)

shrimp may be classified as a "luxury" food item, or one whose prominence is born of affluence.

Population growth is another important determinant of the total quantity of shrimp demanded. The population effect, however, will vary with the changing composition of the population. Hence it is not likely that population growth and the increase in total consumption of shrimp (or other seafoods) occur in equal ratio. During the period 1957-1968 population increased an average of 1.5 percent a year, while total shrimp consumption was increasing at a 6.7 percent annual rate. However, to attribute 1.5 percent of the total shrimp consumption increase per year to population is to oversimplify. As noted in a recent cross-sectional study of the demand for fish and shellfish,[7] the population mix is important. If the mix (distribution by age, sex, race, etc.) changes, the population effect will not be evenly distributed. The study found that the net effect of a unit change in the number of persons in each of five page classifications was considerably different. For example, a unit change in the number of persons 2-5 years old had a significant positive effect on expenditures for frozen shrimp and total shrimp. A unit change in the 11-18 year old range, however, had a negative effect on shrimp expenditures. With this in mind, we can say that increasing total shrimp consumption is associated with increasing population. But the degree of the association is left unanswered.

7/ Purcell, J. C. and Robert Raunikar. Analysis of Demand for Fish and Shellfish, University of Georgia, Experiment, Georgia.

Marketing

Shrimp are distributed from plants in the Gulf to market centers throughout the Nation. The markets have similar characteristics in regard to product types consumed, and in regard to point of origin of manufactured shrimp products. Thus Texas plants serve the same markets as Louisiana or Florida plants. There is a minor exception to this homogeneity, however. New York appears to be the only major market outside the Gulf Area that markets "fresh" (non-frozen) shrimp. About 15 percent of the shrimp that flows through the Fulton wholesale market is sold as "fresh", and these are shrimp that have been shipped from points on the Atlantic Coast, namely the Carolinas, Georgia, and East Coast Florida. The Fulton Market apparently receives no "fresh" shrimp from the Gulf Ports (tables 27 and 28).

The mobility of shrimp supplies contributes to a uniformity of retail prices in various parts of the country, with differences traceable in large part to transportation costs. Prices in California, for example, are about 15 percent higher than in the Eastern United States. A representative price, published by the Bureau of Labor Statistics, indicates that in 1967 packaged raw headless shrimp sold for between $1.30 and $1.60 per pound, throughout the country (table 29).

Table 27. Receipts of raw headless shrimp at New York's Fulton Fish Market, by State and County

Point of Origin	Fresh 1965	Fresh 1966	Frozen 1965	Frozen 1966	Total 1965	Total 1966
	(thousand pounds)					
Alabama	--	0.2	448.5	514.4	448.5	514.6
Florida	826.7	730.8	1511.5	1295.8	2338.2	2026.6
Georgia	227.7	196.5	44.5	1.2	272.2	197.7
Maine	9.5	5.9	--	--	9.5	5.9
Massachusetts	25.9	37.3	--	--	25.9	37.3
North Carolina	261.0	330.8	--	31.9	261.0	362.7
South Carolina	615.7	366.9	--	--	615.7	366.9
Louisiana	--	--	1048.5	845.9	1048.5	845.9
Mississippi	--	--	277.5	70.0	277.5	70.0
Texas	--	--	3004.0	2260.0	3004.0	2260.0
Virginia	--	--	--	72.0	--	72.0
Total U.S.	1966.5	1668.4	6334.5	5091.2	8301.0	6759.6
Mexico	--	--	3178.0	3609.8	3178.0	3609.8
El Salvador	--	--	--	67.5	--	67.5
Guyana	--	--	--	20.0	--	20.0
Panama	--	--	6.5	218.0	6.5	218.0
Venezuela	--	--	--	57.8	--	57.8
Guatemala	--	--	381.5	380.9	381.5	380.9
Nicaragua	--	--	--	52.0	--	52.0
Total Foreign	--	--	3566.0	4406.0	3566.0	4406.0
Grand Total	1966.5	1668.4	9900.5	9497.2	11867.0	11165.6

Source: U. S. Department of the Interior, Bureau of Commercial Fisheries, Market News Service

Table 28. Receipts of fresh and frozen shrimp and shrimp products at Chicago wholesale fish market

Point of shipment	Raw headless fresh		Raw headless frozen		Breaded frozen		Peeled frozen		Misc. frozen		Total	
	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
					(thous. pounds)							
Florida	---	0.1	583.5	662.1	943.7	1,065.8	172.1	214.2	3.1	---	1,702.4	1,942.2
Louisiana	6.5	6.3	605.3	704.4	11.4	22.7	16.1	29.1	---	---	639.3	762.5
Alabama	---	---	148.2	198.4	6.1	23.2	3.0	---	---	---	157.3	221.6
Arizona	---	---	591.1	118.7	13.6	---	26.2	---	---	---	630.9	118.7
California	---	---	115.5	101.8	7.2	14.4	11.3	---	---	---	134.0	116.2
Georgia	---	---	24.7	21.7	13.8	16.2	0.9	15.9	1.2	---	40.6	53.8
Massachusetts	---	---	10.1	22.5	19.3	3.0	1.9	11.9	7.2	3.8	38.5	41.2
Michigan	---	---	2.8	---	---	---	---	---	1.2	1.6	4.0	1.6
Mississippi	---	---	25.0	3.8	---	---	---	---	---	---	25.0	3.8
New Jersey	---	---	---	0.4	---	---	---	---	---	0.8	---	1.2
New York	---	---	384.3	489.8	33.1	20.3	145.4	166.9	4.9	5.2	567.7	682.2
Pennsylvania	---	---	6.2	9.1	---	---	6.4	---	---	---	12.6	9.1
Texas	---	---	2,423.8	2,476.8	1,941.5	1,751.1	1,099.7	1,131.5	6.5	9.2	5,471.5	5,368.6
Washington	---	---	4.8	---	68.3	1.1	---	0.8	---	---	73.1	1.9
Wisconsin	---	---	---	0.5	---	0.2	---	---	---	---	---	0.7
Ohio	---	---	---	---	---	---	---	---	2.1	---	2.1	---
Total all States	6.5	6.4	4,925.3	4,810.0	3,058.0	2,918.0	1,483.0	1,570.3	26.2	20.6	9,499.0	9,325.3

Source: U. S. Department of the Interior, Bureau of Commercial Fisheries, Market News Service

Table 29. Retail price for frozen shrimp in selected cities, midmonth of each quarter, 1966-1967 1/

City	February	May	August	November
	(dollars per pound)			
1966				
Baltimore	1.21	1.31	1.29	1.31
Chicago	1.13	1.19	1.19	1.32
Cleveland	1.16	1.27	1.33	1.44
Detroit	1.22	1.28	1.32	1.39
Los Angeles	1.31	1.34	1.38	1.42
Pittsburgh	1.27	1.30	1.37	1.34
St. Louis	1.18	1.19	1.24	1.32
San Francisco	1.40	1.43	1.46	1.55
Washington, D.C.	1.16	1.24	1.29	1.37
New York	1.96	2.13	2.14	2.18
Philadelphia	1.92	2.17	2.13	2.15
1967				
Baltimore	1.34	1.30	1.30	1.31
Chicago	1.35	1.30	1.26	1.21
Cleveland	1.36	1.40	1.31	1.33
Detroit	1.41	1.40	1.41	1.35
Los Angeles	1.45	1.50	1.53	1.49
Pittsburgh	1.38	1.38	1.39	1.31
St. Louis	1.34	1.37	1.39	1.33
San Francisco	1.56	1.61	1.61	1.52
Washington, D.C.	1.30	1.33	1.45	1.28
New York	2.19	2.18	2.23	2.21
Philadelphia	2.17	2.23	2.19	2.02

1/ Prices are for frozen, raw headless shrimp in 10-oz. packages except for New York and Philadelphia which are 7-oz. packages of peeled and deveined shrimp. Package prices are converted to dollars per pound.

Source: Bureau of Labor Statistics.

Spoilage Losses

Continual seizures of in-transit frozen shrimp products by the Food and Drug Administration, for violations of health and safety standards, justifies a belief that substantial losses are being incurred by processors and distributors as a result of spoilage. FDA inspectors, it has been reported, sample products in about one-third of the Nation's fish processing plants, and find violations in about one-third of the lots of shellfish products sampled.[8/] Thus, perhaps as much as one-third of the output of shellfish plants may be subject to a shortened shelf life, and at least part of this output may have to be destroyed somewhere in the distribution chain.

Data are not available to support precise estimates of the shrimp industry's annual losses from product spoilage. The wholesale value of shrimp products seized by the FDA averaged about $100,000 annually over the period 1962-1967, which is a tiny fraction of the total value of processed shrimp production in the U. S.[9/] Not known is the value of the lots inspected by the FDA; therefore, there is no way to calculate a representative spoilage loss ratio.

8/ U. S. Congress, Hearings on S. 1472

9/ Notices of Judgment Under Federal Food, Drug and Cosmetic Act, HEW, FDA

We do know, however, that violations may be present in as many as one out of three lots inspected, and from this we can formulate a reasonable spoilage loss estimate (although an uncomfortably large degree of this formulation is grounded in judgment alone).

First we can reject as unreasonable an assumption that because one-third of the inspected lots are in violation of FDA standards, one-third of the shrimp product must be discarded. FDA violations pertain to economic factors (weight, label, etc.) that may be correctable, as well as health factors. Also, lots are not inspected under a probability sample design, which raises the liklihood of sample bias. As a judgment than, we estimate that approximately one-third of the lots found in violation are beyond recovery and must be counted as a loss. If the samplings were strictly representative, we could then estimate a spoilage loss rate of approximately one-ninth (1/3 x 1/3), or about eleven percent. As noted above, however, we recognize the possibility of sample bias. Therefore, we have settled for a spoilage loss rate estimate of 6 percent, which is the basic figure used later in this report for assessing the benefits of radiation processing.

It should be understood that the spoilage loss is not borne by a particular sector of the industry. Rather, these losses occur throughout the distribution chain. In a fairly recent study of the impact of radiation processing on the marketing of fishery products, it was shown that spoilage losses in fishery products were experienced at the processing level, and also by wholesalers and retailers.[10]

The figures for weight losses in shrinkage and spoilage of fishery products, experienced throughout the U. S. given in the report are as follows:

	Winter	Summer	100 lbs.
Producers	1.3%	1.8%	98.2
Processors	1.3	1.8	96.4
Distributors	1.7	2.6	93.9
Wholesalers	2.4	3.2	90.4
Retailers	3.7	4.8	86.5

The data above reflect the experience of all U. S. fishery product producers and distributors for all products handled. There is no way to isolate shrimp from this total. Nonetheless, the data allow some perspective of the scope of the spoilage problem, and affirm the reasonableness of estimating the spoilage loss rate for shrimp at 6 percent. On the basis of the above data, for example, the spoilage shrinkage loss throughout the distribution chain, in summer would be close to 15 percent. Thus, starting with 100 pounds of product and deducting the losses at each stop in the chain, the result would be 86.5 pounds at the retail end (100 x .982 x .964. . ., etc.).

[10] Snead, Larry L. Research Study Concerning Potential Effects of Radiation Processing on Market Supplies and Structures of the Domestic Fishing Industry, U.S. Department of the Interior, Bureau of Commercial Fisheries, January 1966.

Role of Radiation Processing

Applicability to Shrimp Products

Ionizing radiation can effectively eliminate spoilage organisms, as well as bacterial pathogens and animal parasites, in what promises to be a relatively low cost technique, without compromising the taste and textural quality of the subject food.[11] In laboratory tests, low dosage irradiation has added about 11 days to the 14-day expected shelf life of iced raw shrimp, demonstrating that irradiation can arrest quality deterioration in marketing raw iced shrimp, and will allow surface shipments of greater distance.[12] Most shrimp products, however, are sold in a frozen form and shipping distance is no particular marketing obstacle. Nonetheless, it is not uncommon for the frozen product to be thawed and stored, on ice or under refrigeration, prior to final sale or use. In these instances, an irradiated product could possibly keep its quality longer in a thawed or thawing state, and spoilage loss would thereby be reduced.[13]

11/ Desrosier, Norman W., The Technology of Food Preservation, Westport, Connecticut: The AVI Publishing Co., Inc., 1963.

12/ Steinberg, Maynard A., The Atom Preserves Seafoods, Reprint from Proceedings of the Gulf and Caribbean Fisheries Institute, Eighteenth Annual Session, November 1965.

13/ The extent of the practice of thawing frozen shrimp prior to final sale is not known, nor is the amount of spoilage loss (if any) at the distribution level. However, extended keeping qualities, in any case, would be of benefit to the consumer who "uses up" shelf life in transporting the product from market to home (under non-refrigerated conditions), and is likely to keep the shrimp under refrigeration for a period before cooking. Research is needed to define precisely the effects of irradiation on the post-frozen shelf life.

Irradiation, in conjunction with freezing, is also a possible technique for reducing the quantity of bacteriologically unacceptable frozen shrimp products in the market place. Yearly, significant quantities of frozen shrimp products are detained by federal and state regulatory agencies who find evidence of spoilage and/or pathogens. Researchers, for example, have found that "pasteurizing" doses of radiation will destroy about 95 percent of any coliform organisms present.[14/]

Assuming that radiation processing would be an effective means of controlling bacterial count and reducing the likelihood of spoilage, the question remains as to what point in the production system would be most suitable to the process. Visits to shrimp processing plants and interviews with plant managers turned up no evidence of spoilage problems with raw shrimp products prior to further processing. It was found that raw shrimp received at processing plants are of good quality, and that the holding time prior to processing was minimal. It is likely that these factors reflect, in part, good management practices, and that sub-standard shrimp have been culled from the lot prior to shipment to plant. Nonetheless, the only documented evidence of spoilage loss we were able to uncover concerned processed shrimp products and we could

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14/ Novak, Arthur F. and Joseph A. Liuzzo, "Radiation-Pasteurization of Gulf Shellfish," Final Summary Report for U. S. Atomic Energy Commission under contract Number AT-(40-1)-2951.

only assume that the suitable point of control was at the plant level. Hence, this analysis considers that only the processed products would be irradiated, either prior to, or subsequent to freezing.

Plant Location

The geographical distribution of shrimp processing plants indicates adequate throughput for six irradiation facilities, located in the geo-center of production in each of six designated areas on the Gulf and South Atlantic Coasts from Texas to Georgia.

We have assumed that all frozen product types will be candidates for irradiation, and have constructed a forecast of production, based on time series trends, by product type, through 1985. As may be seen in table 30, total production for the six areas will reach 391 million pounds in 1985, ranging by area from 11 million pounds to 140 million pounds. The product mix, over time, will change with faster gains in the production of breaded and peeled products which sell at somewhat lower prices per pound than frozen raw headless. With the change in mix, there will, therefore, be an alteration of the average value per product pound and the forecast, which holds prices constant at the 1966 level, takes these changes into account (table 31).

Table 30. Production of frozen processed shrimp products in the Gulf and South Atlantic Region, by producing area, 1966 actual, and projected 1967-1985

	Area Number 1/						
	thousand pounds						
	I	II	III	IV	V	VI	Total
1966	48,863	19,334	19,188	7,531	56,055	23,531	174,502
1967	51,631	19,789	19,574	7,616	59,529	25,161	183,603
1968	54,529	20,244	19,960	7,696	63,166	26,868	192,463
1969	57,508	20,708	20,329	7,770	66,938	28,669	201,922
1970	60,745	21,204	20,719	7,847	71,042	30,634	212,191
1971	64,039	21,880	21,371	8,029	75,057	32,427	222,803
1972	67,498	22,574	22,038	8,214	79,278	34,319	233,921
1973	71,139	23,307	22,740	8,407	83,727	36,315	245,635
1974	74,969	24,064	23,464	8,604	88,408	38,416	257,925
1975	78,959	24,866	24,207	8,811	93,315	40,653	270,812
1976	82,467	25,522	24,866	8,979	97,576	42,527	261,926
1977	85,909	26,169	25,492	9,140	101,786	44,410	274,087
1978	89,600	26,855	26,168	9,312	106,288	46,410	307,633
1979	94,434	27,560	26,864	9,487	110,969	48,492	317,806
1980	97,430	28,269	27,529	9,649	115,893	50,724	329,496
1981	101,026	28,979	28,215	9,835	120,283	52,687	341,025
1982	104,749	29,707	28,917	10,023	124,832	54,724	352,957
1983	108,602	30,467	29,648	10,221	129,538	56,832	365,308
1984	112,553	31,214	30,272	10,388	134,490	59,275	378,192
1985	116,752	31,988	31,081	10,590	139,559	61,370	391,340

1/ These areas cover the Gulf and S. Atlantic coasts from Southern Texas to South Carolina. The areas were formed by assuming location of an irradiation facility at 6 points of concentrated production. The boundaries of each are the practical distance limits for transporting processed products to ten facilities for radiation preservation. Locations of Areas are as follows:

I Southern Texas
II Central and Northern Texas
III Louisiana
IV Mississippi, Louisiana
V Florida
VI Georgia, South Carolina

Table 31. Production of fresh and frozen processed shrimp products, by product type by area 1/, 1966, and projected 1970, 1975, 1980, 1985

	Raw	Peeled	Breaded	Total	Weighted Average Price
	----------------	thousand lbs.	----------------		$ per lb.
Area I					
1966	11,914	8,765	28,184	48,863	1.030
1970	12,264	11,086	37,395	60,745	1.028
1975	13,493	16,036	49,430	78,954	1.035
1980	14,447	21,805	61,178	97,430	1.043
1985	15,599	27,261	73,892	116,752	1.047
Area II					
1966	14,700	1,213	3,421	19,334	.916
1970	15,131	1,534	4,539	21,204	.915
1975	16,647	2,219	6,000	24,866	.916
1980	17,825	3,018	7,426	28,269	.918
1985	19,246	3,773	8,969	31,988	.919
Area III					
1966	15,471	2,212	1,505	19,188	1.062
1970	15,925	2,798	1,996	20,719	1.073
1975	17,521	4,047	2,639	24,207	1.095
1980	18,760	5,503	3,266	27,529	1.117
1985	20,256	6,880	3,945	31,081	1.132
Area IV					
1966	7,126	405	---	7,531	.969
1970	7,335	512	---	7,847	.973
1975	8,070	741	---	8,811	.980
1980	8,641	1,008	---	9,649	.988
1985	9,330	1,260	---	10,590	.993
Area V					
1966	9,212	9,587	37,256	56,055	1.007
1970	9,483	12,127	49,432	71,042	1.005
1975	10,433	17,541	65,341	93,315	1.013
1980	11,170	23,852	80,871	115,893	1.022
1985	12,061	29,820	97,678	139,559	1.025
Area VI					
1966	1,357	2,982	19,192	23,531	.922
1970	1,397	3,772	25,465	30,634	.919
1975	1,537	5,456	33,660	40,653	.924
1980	1,645	7,419	41,660	50,724	.929
1985	1,777	9,275	50,318	61,370	.931

1/ See footnote to table 30.

Feasibility of Radiation Processing

The construction and operation of irradiation facilities require considerable capital. The investment required for a plant capable of handling 70 million pounds of product annually, to cite an example, would be nearly $1.5 million. Operating expenses annually for this plant would amount to another half million dollars.

To evaluate the economic merit of radiation processing for shrimp products it is therefore necessary to calculate, with some precision, how productive the required capital investment would be. If the investment in irradiation facilities yields a low return relative to other investment opportunities, it is not likely to attract capital. Additionally, it is contemplated that research and development costs will be borne for the most part by the Federal Government. The feasibility of these public expenditures must therefore be scrutinized in light of their worth to society.

There are, then, two facets of a feasibility analysis in regard to radiation processing of shrimp products. The first considers the feasibility of private (as opposed to government) investments in implementing processing operations. The second considers the social worth of research and development expenditures for the process.

We will first discuss the merits of private investment in irradiation facilities, or more specifically, the commercial feasibility of radiation processing. As noted above, we contemplate six irradiation plant sites located to serve the shrimp production centers in the Gulf and South Atlantic States. These plants would be operated as service facilities, separate from the normal processing operation. The charges for this service, we have assumed, would reflect the average unit cost for the radiation process, inclusive of an allowance for return on investment. Processors, additionally, would bear the costs incurred in transporting the product to and from the irradiation facility and for any additional handling required. We have also assumed that processors would submit their entire output for processing.

The mechanism for our analysis was a discounted cash flow model from which we determined the internal rate of return on private investments in shrimp irradiation facilities. The internal rate of return is the interest rate that discounts the annual net cash flow (over the life of the investment) to an amount in the base period that is equal to the investment. Put another way, it is the rate of compound interest at which the present value of the project investment would have to be invested at the current time to yield the earnings of the project investment over its life. The net cash flow in the model is the algebraic summation of investments, operating expenses, and dollar returns (not including depreciation or income taxes).

It was assumed that the initial investment in the plant would be made in 1975 and that the plant would become operational in 1976. Capital outlays will be required annually for increasing the radiation source (cobalt) to handle additional output and to replenish the used up source. Allowances for plant enlargement after five years of operation were built into the model and operating expenses were calculated for each year of project life.

The dollar returns for each year represent the savings that will result from reduced spoilage loss. These savings are considered to be the value of 6 percent of total annual production in each area.[15/] Thus, the net cash flow in each year was (a) savings from reduced spoilage loss; minus (b) investments; minus (c) operating expenses.

The investment and operating costs for irradiation plants were calculated in accordance with the method described in a Department of Commerce research report.[16/] Because of the high fixed investment relative to variable costs, the average cost per unit of output drops noticeably with increased output at a given plant capacity. Efficiency is also enhanced by increased plant utilization. Thus,

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15/ In estimating the value, appropriate adjustments were made for the price effect of increase in supplies that follow the elimination of spoilage loss. The 6 percent increase in supply would be accompanied by approximately a 12 percent drop in prices, at wholesale.

16/ U. S. Department of Commerce, The Commercial Prospects for Selected Irradiated Foods, U. S. Government Printing Office, 1968.

with a given output requirement, unit costs can be minimized by achieving the desired output through multi-shift operations, rather than through a single shift operation with a larger plant capacity. Table 32 gives a typical cost breakdown of the type used in this analysis.

Using the forecast production of processed shrimp products for each of the six designated areas, the estimated cost per pound for irradiation processing ranged from about 1/2 cent to 3 cents, depending on size of annual output and hours of annual plant operation. These estimates are given in table 33. As will be noted, the analysis proceeds under assumptions in regard to hours of plant operation, ranging from full use, seven days per week--three shifts, to six days per week--one shift. Figure 6 illustrates relationships between cost per pound, and plant capacity and throughput.

Results of Analysis

The high value of shrimp products in combination with the low irradiation processing costs made possible by high throughput volume, produce a favorable economic environment for the new process. The indicated payoff on investment in the process is quite large in all areas under consideration, assuming that the new process will eliminate spoilage equal to an estimated 6 percent of the total domestic output. The strongest areas are in Southern Texas and in Florida where the annual rate of returns on investment in radiation

Table 32 Estimated radiation processing costs for single plant in each of six shrimp producing areas - at forecast 1975 production levels and full utilization

	Area I	Area II	Area III	Area IV	Area V	Area VI	Explanatory Notes
Annual throughput (1,000 lbs.)	78,959	24,866	24,207	8,811	93,315	40,653	(1)
Plant capacity (lbs./hr.)	10,444	3,289	3,202	1,165	12,343	5,377	(2)
Investment requirement ($)							
Source	166,456	52,421	51,032	18,575	196,721	85,702	(3)
Plant	882,186	518,053	511,681	321,206	952,763	649,727	(4)
Total	1,048,642	570,474	562,713	339,781	1,149,484	735,429	
Operating expenses ($)							
Labor	96,314	77,497	77,106	63,755	99,389	85,006	(5)
Operating supplies	4,411	2,590	2,558	1,606	4,764	3,249	(6)
Maintenance	44,109	25,903	25,584	16,060	47,638	32,486	(7)
Source replenishment	23,304	7,339	7,144	2,600	27,541	11,998	(8)
Depreciation - Source	16,646	5,242	5,103	1,857	19,672	8,570	(9)
Depreciation - Plant	102,921	60,439	59,696	37,474	111,156	75,801	(10)
Utilities	8,822	5,181	5,117	3,212	9,528	6,497	(11)
Taxes and insurance	17,644	10,361	10,234	6,424	19,055	12,995	(12)
Third party liability	44.109	25,903	25,584	16,060	47,638	32,486	(13)
Total	358,280	220,455	218,127	149,050	386,380	269,089	
Allowance for return on investment @ 12% ($)	125,837	68,457	67,526	40,774	137,938	88,251	
Total expense return allowance ($)	484,117	288,912	285,653	189,824	524,318	357,340	
Irradiation cost per lb. ($)	.0061	.0116	.0118	.0215	.0056	.0088	

EXPLANATORY NOTES for Table 32.

(1) Based on the assumed number of hours plant will operate annually.

(2) Hours of plant operation are the product of assumed operating days per week and hours operated per day, assuming annual operations for 50 weeks and 10 percent downtime.

(3) Based on relationship between size of source and plant cost per curie of source size, as developed in: U. S. Department of Commerce, The Commercial Prospects for Selected Irradiated Foods, TID-24058, March, 1968, p. 20.

(4) Computed according to procedure outlined in study cited in note 3, pp. 11-21. Briefly the steps are:

   (a) Determine desired throughput in terms of pounds per hour capacity.

   (b) Determine desired rads dosage.

   (c) Multiply throughput times dose to get rad pounds per hour.

   (d) Multiply rad pounds per hour by the conversion factor 0.000085 to obtain the required source size in curies. This yields the number of required curies at 100 percent efficiency level.

   (e) Determine percent efficiency level of the facility and divide into figure yielded in step (d). This will be the actual number of curies required.

   (f) Multiply actual number of required curies by assumed cost per curie, for source cost.

(5) Direct labor (production) costed at $2.50 per hour, indirect labor costs include supervisory and support labor, and assumed to be 100 percent of direct labor. Op. cit., p. 10.

(6) At 1/2 percent per year of plant costs. Ibid., p. 11.

(7) At 5 percent per year of plant cost. Ibid.

(8) At rate of 14 percent per year. Ibid., p. 10.

(9) At 10 percent per year. Ibid.

EXPLANATORY NOTES for Table 32 (continued)

(10) At 10 percent per year for 75 percent of plant cost, and 16.6 percent per year for remainder. Ibid.

(11) At 1 percent per year of plant cost. Ibid., p. 11.

(12) At 2 percent per year of plant cost. Ibid.

(13) At 5 percent per year of plant cost.

Table 33. Estimated cost per pound for low dosage radiation processing (125 K rads) of shrimp products, at various forecast annual throughput levels, assuming four levels of per hour plant capacity (as indicated by number of hours plant will operate annually)

Annual throughput (thous. lbs.)	Area ident.	Forecast year	Irradiation cost per pound, by plant capacity in terms of required annual hours of plant operation: 1/ A. (2,160 hrs.)	B. (4,320 hrs.)	C. (6,480 hrs.)	D. (7,560 hrs.)
7,847	IV	1970	.0363	.0279	.0243	.0231
8,811	IV	1975	.0340	.0261	.0227	.0215
9,649	IV	1980	.0324	.0247	.0215	.0204
10,590	IV	1985	.0307	.0234	.0203	.0193
20,719	III	1970	.0215	.0160	.0137	.0129
21,204	II	1970	.0212	.0158	.0135	.0127
24,207	III	1975	.0198	.0147	.0125	.0118
24,866	II	1975	.0196	.0145	.0123	.0116
27,529	III	1980	.0186	.0137	.0116	.0110
28,269	II	1980	.0183	.0135	.0115	.0108
30,634	VI	1970	.0176	.0129	.0109	.0103
31,081	III	1985	.0175	.0128	.0109	.0102
31,988	II	1985	.0172	.0126	.0107	.0101
40,653	VI	1975	.0153	.0111	.0094	.0088
50,724	VI	1980	.0138	.0099	.0083	.0078
60,745	I	1970	.0127	.0090	.0075	.0071
61,370	VI	1985	.0126	.0090	.0075	.0070
71,042	V	1970	.0118	.0083	.0069	.0065
78,959	I	1970	.0113	.0079	.0066	.0061
93,315	V	1975	.0105	.0073	.0060	.0056
97,430	I	1980	.0103	.0072	.0059	.0055
115,893	V	1980	.0096	.0066	.0054	.0050
116,752	I	1985	.0095	.0066	.0054	.0050
139,559	V	1985	.0089	.0060	.0049	.0046

1/ Hours of annual operation represent various shift schedule options. These are:

A. 2,160 hours = 6 days/week 1 8 hour shift(s)
B. 4,320 hours = 6 days/week 2 8 hour shift(s)
C. 6,480 hours = 6 days/week 3 8 hour shift(s)
D. 7,560 hours = 7 days/week 3 8 hour shift(s)

Required per hour plant capacity is the quotient of annual throughput divided by number of hours of operation of plant, with allowances for down time.

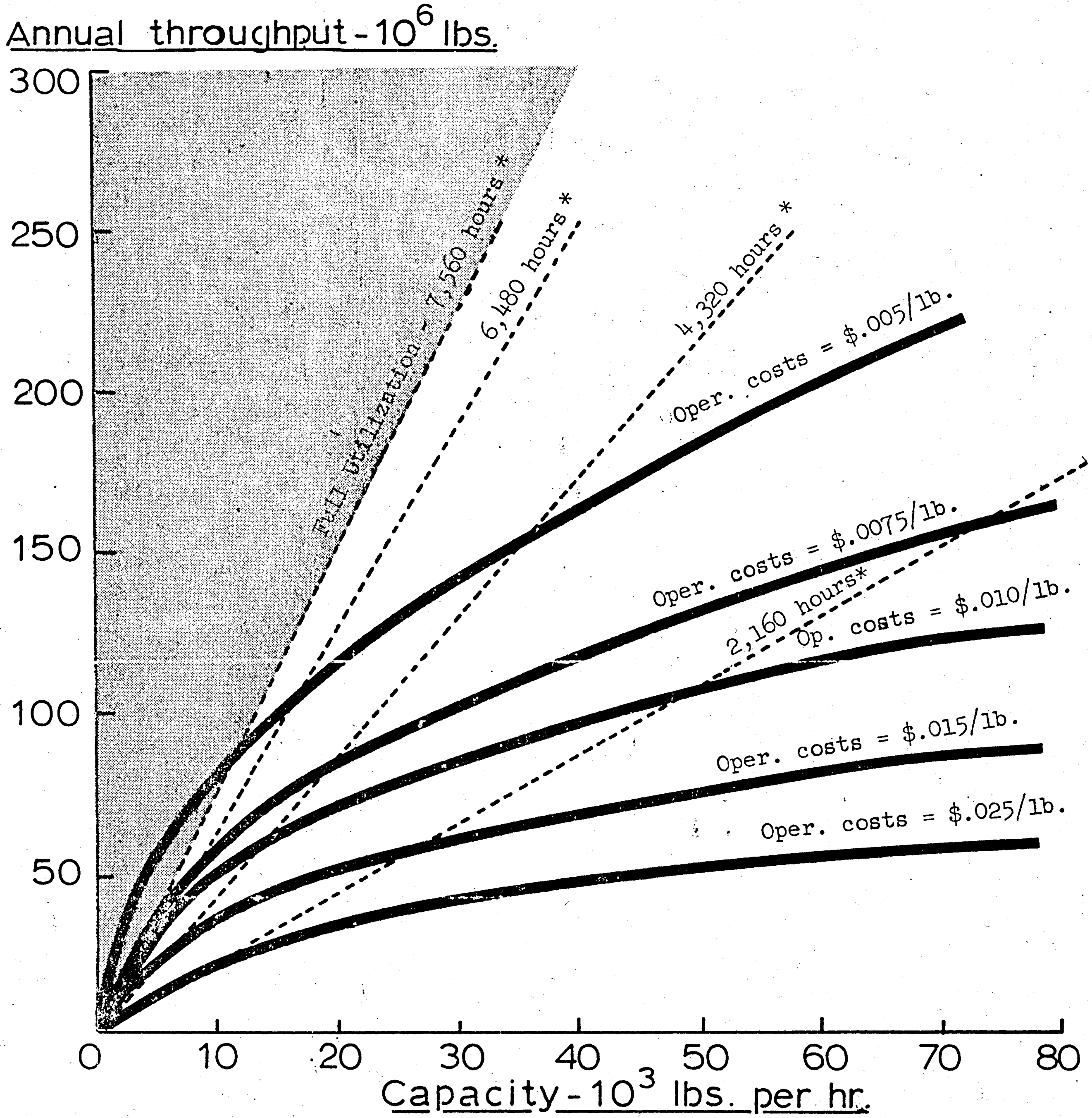

Figure 6. Relationship of radiation processing costs per pound to annual plant throughput and per hour plant capacity, at 125,000 rads dosage, $.45 per curie and 30% efficiency.

* Shift equivalents:

7,560 hrs. =	7 days/wk.,	3 shifts	(incl. allowance for down time)
6,480 hrs. =	6 days/wk.,	"	"
4,320 hrs. =	"	2 shifts	"
2,160 hrs. =	"	1 shift	"

facilities would exceed 200 percent. The ratio of benefits to costs for undertaking irradiation processing in these areas was calculated to be 16:1, at an assumed interest discount rate of 12 percent. The least payoff would occur in the Louisiana/ Mississippi area where the rate of return was calculated to be 47 percent. The benefit cost ratio here was 3:1. (The cash flow models for each area are given in Appendices 5 through 10.)

The rates of return are based solely on the net cash returns resulting from reduced spoilage loss, which we estimated at 6 percent of the value of output. It is possible that these figures are high. We therefore calculated the rates of return at smaller savings levels. As may be seen in table 34, the returns on investment (and benefit/cost ratios) were also high for all areas where the assumption was made that spoilage loss elimination would be equal to 5 percent of total output. At a 4 percent savings assumption, the feasibility of investing in irradiation facilities would become questionable in the Mississippi/Eastern Louisiana area, and at 3 percent, irradiation processing would be clearly feasible in only three of the six areas: Southern Texas, Western Louisiana and Florida. If spoilage loss savings were valued as low as 2 percent of the value of total production as a result of irradiation processing, the process fails the feasibility test in all areas.

Table 34. Returns on industry investments in shrimp irradiation facilities in six Gulf and South Atlantic areas assuming 6 percent and under spoilage loss savings

	Savings in Spoilage Loss @				
	6%	5%	4%	3%	2%
Internal Rate of Return (percent)					
Area I	239	179	120	60	negative
Area II	97	68	38	2	negative
Area III	129	95	61	25	negative
Area IV	47	28	6	negative	negative
Area V	235	173	113	53	negative
Area VI	124	88	52	14	negative
All Areas	170	125	80	34	negative
Benefit/Cost Ratios - discounted at 12 percent annual rate of interest					
Area I	15.5	11.6	7.4	3.8	less than 1
Area II	5.9	4.2	2.4	less than 1	less than 1
Area III	8.1	5.9	3.8	1.7	less than 1
Area IV	2.9	1.9	less than 1	less than 1	less than 1
Area V	16.3	12.1	7.9	3.7	less than 1
Area VI	8.4	6.0	3.6	1.1	less than 1
All Areas	11.2	8.3	5.3	2.3	less than 1

To summarize, investment in irradiation processing facilities for shrimp products would be highly attractive in all areas if spoilage losses equal to 4 percent or more of total output could be eliminated. If the process would permit spoilage loss savings of less than 4 percent (but more than 2 percent), investment in plants would be commercially attractive in only three areas of highest output. At spoilage loss savings of 2 percent or below, returns on investment would be negative for all areas.

The Social Value of Irradiation Processing

The first phase of this analysis was confined to the purely commercial aspects of making investment decisions regarding irradiation facilities for shrimp products. In this second phase, we broaden the analysis to include a consideration of social benefits and costs generated by investments in irradiation processing.

The social costs (or investment) in developing a commercially feasible irradiation technique for shrimp products are considered as the summation of government and private development and investment expenditures. Society, in effect, bears the costs regardless of how they are channeled. Government expenditures are made possible by society diverting spendings from consumer goods to taxes; and industry expenditures are made possible through foregoing private consumption spendings for investment in an irradiator.

In total, the "social investment" in six shrimp irradiation plants would amount to $9.9 million over the time span 1970-1985. The major share of this investment, 91%, will be borne by private industry for plant facilities and cobalt radiation source. Federal funding for research and development will amount to less than $900,000.

The clearest social benefit from irradiation processed shrimp products would develop from the elimination of losses due to spoilage. Our investigations led us to an assumption that irradiation processing would eliminate spoilage losses, among shrimp products, equal to 6 percent of total annual domestic output. This, in effect, represents a reduction in processing costs that will be reflected in lower prices. A measure of society's benefit, then, is the amount saved (and thus freed for other use) from shrimp purchases under lower price schedules. These savings can be looked upon as a "bonus" to consumers in an amount equal to the price differential times the quantity that would have been purchased at the old, higher price.[17/]

[17/] This "bonus" in the context of economic theory is an addition to "consumer surplus," the latter being defined by Stigler as "the amount over and above the price actually paid, that a man would be willing to pay, rather than go without it." The exchange price of a good is set at the value of the last unit sold. In most cases quantities of the good would have been sold at higher prices indicating that units preceding the last unit of sale are worth more to consumers. The gap, then, between what worth the various units have to consumers and the actual price paid (based on the last unit sold) is in effect a welfare "surplus."

Our analysis assumes an average retail price of $1.40 per pound, the price in effect in 1966. It is further assumed that annual shifts in supply and demand will be compensatory and prices will be stable (aside from inflationary effects), throughout the project life. Irradiation, through elimination of spoilage loss, will increase the quantity of shrimp available for marketing, which will depress the price. How much, depends upon the sensitivity of the shrimp market to changes in supplies. For purposes of the analysis, we have assumed that the elasticity of demand for shrimp at retail was unitary, that is, each 1 percent increase in supplies would be accompanied by a proportionate drop in prices. Statistical analysis failed to yield significant estimates of retail price elasticity so we adopted this assumption, which we considered reasonable in light of the estimated elasticity at wholesale (-.46). At a savings in spoilage equal to 6 percent of output, the adjusted price would be $1.40 x 0.94, or $1.316 per pound, which represents a savings of $0.084 per pound. Consumers are thus benefited by the saving realized per pound ($0.084) times the quantity that would have been purchased, in any event, at the old price. These, we considered, were the gross benefits to society from which the costs of irradiation processing were deducted to arrive at net benefits. (Irradiation costs, we assume, represent a reduction in marketing margins. If these costs were added to the retail price, consumer surplus would be cut back, accordingly.)

Similar to the commercial feasibility analysis, we evaluated the public benefits of shrimp irradiation in terms of the rate of return these benefits would product from the investment in research and development of the process and the construction and operation of plants. The procedure used was a discounted cash-flow rate of return analysis (already discussed). We also related the discounted present value of benefits to the present value of investments, using various rates.

Our analysis indicated there is a high social value in investments in irradiation processing of shrimp products, assuming that the new process effectively eliminates spoilage loss. If, in fact, the process can "save" 6 percent of the annual production of processed shrimp, society's investment would net an annual return of 97 percent during a 15 year project period. This is the same as saying that the investment in irradiation processing would be self-liquidating in 15 years, even if the cost of money was as high as 97 percent. We also calculated the earnings on the investment in terms of benefit cost ratios. Assuming an interest rate of 12 percent for discounting costs and earnings to present value (1970) earnings were 12 times the expenditures.

The returns on investment in irradiation processing were also high under assumptions that recovered spoilage losses were equal to less than 6 percent of the total output. At 5 percent savings, for example, the computed rate of return was 87 percent. It will be recalled that under conditions where the elimination of spoilage losses would be equal to 4 percent or less of total output, fewer than 6 irradiation plants would be commercially feasible. Taking this into account, we calculated the social rate of return to be 76 percent under the 4 percent spoilage assumption (5 operating plants); and 54 percent under the 3 percent assumption (3 operating plants).

The rates of return, and benefit cost ratios under varying assumptions are shown in table 35.

Observations in Regard to the Social R.O.I.

As the reader has observed, the social worth of irradiation processing for shrimp products is extremely high, even if it is assumed that only 3 percent of the output is lost through spoilage and is recoverable through irradiation. Whether irradiation processing can, technologically, accomplish its assumed task under production conditions, is not a certainty. Nonetheless, we urge careful consideration of this analysis in its larger context, which is the elimination of spoilage of high value fishery products, in general. Means are available, other than irradiation processing, to minimize spoilage: for example, plant modernization, and improved handling practices. Our analysis, we hope, has pointed out, the potential worth to society of even small investments in improving the quality of high valued fishery products.

Table 35. Social rates of return and benefit-cost ratios from public investment in shrimp irradiation development

	Assumptions in regard to spoilage loss elimination			
	A 1/	B 2/	C 3/	D 4/
Social rate of return on project investment (%)	97.2	87.5	76.3	53.6
Benefit-cost ratios at discount rate of:				
6%	15.5	12.3	9.4	5.6
12%	12.0	9.5	7.3	4.3
18%	9.5	7.5	5.8	3.4
27%	6.8	5.4	4.2	2.4

1/ Elimination of spoilage loss equal to 6% of domestic production.

2/ Elimination of spoilage loss equal to 5% of domestic production.

3/ Elimination of spoilage loss equal to 4% of domestic production.

4/ Elimination of spoilage loss equal to 3% of domestic production.

Appendix 1. United States shrimp landings, value and price, by area, 1950-1968--heads-on weight

Year	Landings			Value			Average price		
	Gulf & S. Atlantic	Others	Total	Gulf & S. Atlantic	Others	Total	Gulf & S. Atlantic	Others	Total
	----Thousands of pounds 1/--			----Thousands of dollars----			------Cents per pound-----		
1950	188,234	3,240	191,474	43,144	308	43,452	22.9	9.3	22.7
1951	221,422	2,894	224,316	51,518	344	51,862	23.3	11.9	23.1
1952	223,939	3,282	227,221	54,755	348	55,103	24.5	10.6	24.2
1953	257,436	2,921	260,357	76,267	374	76,641	29.6	12.8	29.4
1954	265,799	2,535	268,334	60,535	296	60,831	22.8	11.7	22.7
1955	240,941	3,394	244,335	61,404	378	61,782	25.5	11.1	25.3
1956	219,139	5,034	224,173	70,305	589	70,894	32.1	11.7	31.6
1957	197,043	6,839	203,882	72,438	707	73,145	36.8	10.3	35.9
1958	195,938	17,904	213,842	71,829	1,101	72,930	36.7	6.1	34.1
1959	219,509	20,673	240,182	56,875	1,258	58,133	25.9	6.1	24.2
1960	236,939	12,513	249,452	66,143	789	66,932	27.9	6.3	26.8
1961	153,544	20,986	174,530	50,589	1,099	51,688	32.9	5.2	29.6
1962	167,804	23,301	191,105	71,832	1,404	73,236	42.8	6.0	38.3
1963	218,645	21,833	240,478	68,785	1,259	70,044	31.5	5.8	29.1
1964	196,373	15,448	211,821	69,328	1,048	70,376	35.3	6.8	33.2
1965	221,428	22,217	243,645	81,067	1,342	82,409	36.6	6.0	33.8
1966	200,883	38,163	239,046	93,785	2,511	96,296	46.7	6.6	40.3
1967	246,300	65,900	312,200	99,000	4,100	103,100	40.2	6.2	33.0
1968 2/	225,000	66,600	291,600	108,600	4,700	113,300	48.3	7.1	38.9

1/ Heads-on weight. To convert to heads-off weight divide Gulf and South Atlantic landings by 1.59 and all other landings by 1.75.

2/ Preliminary.

Source: United States Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Fishery Statistics of the United States

Appendix 2. South Atlantic shrimp landings, value, and price, by states, 1950-67 1/

Year	North Carolina			South Carolina		
	Landings	Value	Average Price	Landings	Value	Average Price
	1000 lbs.	1000 $	¢ per lb.	1000 lbs.	1000 $	¢ per lb.
1950	4,948	1,999	40.4	4,610	2,169	47.0
1951	4,881	1,950	40.0	2,220	1,043	47.0
1952	5,187	1,905	36.7	2,423	940	38.8
1953	8,718	3,623	41.6	3,027	1,482	49.0
1954	5,466	1,836	33.6	3,954	1,661	42.0
1955	6,146	2,369	38.5	4,117	1,591	38.6
1956	3,716	1,594	42.9	3,326	1,393	41.9
1957	4,722	2,262	47.9	3,982	1,750	44.0
1958	1,501	719	47.9	3,461	2,091	60.4
1959	3,796	1,414	37.2	4,473	1,917	42.9
1960	3,565	1,607	45.1	4,780	2,166	45.3
1961	1,795	830	46.2	2,325	1,301	56.0
1962	3,616	2,239	61.9	4,102	2,613	63.7
1963	2,098	1,065	50.8	1,375	643	46.8
1964	2,666	1,503	56.4	1,665	861	51.7
1965	3,395	1,719	50.6	4,341	2,635	60.7
1966	3,552	2,563	72.2	2,671	2,181	81.6
1967	3,450	1,890	54.8	2,561	1,679	65.6

(Continued)

Appendix 2. (Continued)--South Atlantic shrimp landings, value, and price, by states, 1950-67 1/

Year	Georgia			Florida, East Coast		
	Landings	Value	Average Price	Landings	Value	Average Price
	1000 lbs.	1000 $	¢ per lb.	1000 lbs.	1000 $	¢ per lb.
1950	6,633	3,177	47.9	5,516	2,687	48.7
1951	4,523	2,133	47.2	4,900	2,256	46.0
1952	3,562	1,677	47.1	4,104	2,063	50.3
1953	4,480	2,616	58.4	3,373	2,210	65.5
1954	4,602	2,013	43.7	3,022	1,373	45.4
1955	4,157	1,862	43.7	2,462	1,117	45.4
1956	4,751	2,662	56.0	3,390	2,157	63.6
1957	5,203	2,971	57.1	3,083	2,149	69.7
1958	5,206	2,939	56.4	3,276	2,209	67.4
1959	4,525	1,837	40.6	2,685	1,360	50.6
1960	6,192	2,575	41.6	4,043	2,163	53.5
1961	4,054	2,371	58.5	3,581	2,437	68.0
1962	5,494	3,880	70.6	3,325	2,543	76.5
1963	3,478	1,802	51.8	2,898	1,736	59.9
1964	3,795	2,298	60.6	2,876	1,971	68.5
1965	5,520	3,418	61.9	3,473	2,388	68.8
1966	4,142	3,341	80.7	3,223	2,725	84.6
1967	4,950	3,024	61.1	3,244	2,727	84.1

1/ Landings are heads-off weight. Data for years prior to 1957 are found by dividing landings in heads-on weight by the following conversion factors: North Carolina - 1.6798; South Carolina - 1.6804; Georgia - 1.6821; Florida, East Coast - 1.6801.

Source: U.S. Department of the Interior, Bureau of Commercial Fisheries, Fishery Statistics of the United States

Appendix 3. Gulf shrimp landings, value, and price, by states, 1950-67 1/

Year	Florida, West Coast			Alabama			Mississippi		
	Landings	Value	Average Price	Landings	Value	Average Price	Landings	Value	Average Price
	1000 lbs.	1000 $	¢ per lb.	1000 lbs.	1000 $	¢ per lb.	1000 lbs.	1000 $	¢ per lb.
1950	8,117	3,962	45.5	2,982	1,107	37.1	6,244	2,071	33.2
1951	17,707	8,010	45.2	3,785	1,268	33.5	4,934	1,470	29.8
1952	22,096	11,812	53.4	3,697	1,521	41.1	4,488	1,611	35.9
1953	31,424	19,009	60.5	3,457	1,800	52.1	5,621	2,301	40.9
1954	27,256	13,164	48.3	3,708	1,039	28.0	5,452	1,534	28.1
1955	28,861	14,324	49.6	3,976	1,349	33.9	8.987	2,504	27.9
1956	29,235	17,571	60.1	4,580	2,197	48.0	8,652	3,670	42.5
1957	24,953	16,460	66.0	3,593	1,871	52.1	6,985	3,186	45.6
1958	27,147	16,312	60.1	3,160	1,984	62.8	4,589	2,826	61.6
1959	19,198	9,751	50.8	4,772	1,991	41.7	7,521	2,345	31.1
1960	26,467	12,155	45.9	4,267	2,090	49.0	6,566	2,899	44.1
1961	21,469	11,094	51.7	2,098	1,154	55.0	2,624	1,281	48.8
1962	20,108	14,556	72.4	2,349	1,647	70.1	3,837	2,220	57.9
1963	21,865	12,256	56.0	4,877	2,419	49.6	5,910	2,484	42.0
1964	25,028	13,322	53.2	4,552	2,630	57.8	4,034	1,805	44.7
1965	23,633	13,905	58.8	6,028	3,654	60.6	5,157	2,523	48.9
1966	18,063	12,427	68.8	6,623	4,921	74.3	4,731	2,751	58.2
1967	14,560	10,465	71.8	9,280	6,039	65.1	5,951	3,130	52.6

(Continued)

Appendix 3. (Continued)--Gulf shrimp landings, value, and price, by states, 1950-67 1/

Year	Louisiana			Texas		
	Landings	Value	Average Price	Landings	Value	Average Price
	1000 lbs.	1000 $	¢ per lb.	1000 lbs.	1000 $	¢ per lb.
1950	46,125	16,338	35.4	27,038	9,904	36.6
1951	50,796	19,022	37.4	37,977	14,366	37.8
1952	49,247	17,440	35.4	38,378	15,785	41.1
1953	51,521	17,872	34.7	41,571	25,354	61.0
1954	49,546	16,513	33.3	55,041	21,402	38.9
1955	42,664	14,317	33.6	42,209	21,971	52.0
1956	30,084	13,614	45.2	36,891	22,507	61.0
1957	18,027	9,205	51.1	45,691	32,093	70.2
1958	23,635	13,049	55.2	44,577	29,646	66.5
1959	33,355	13,067	38.4	50,334	23,193	45.9
1960	36,760	15,881	43.2	48,395	24,606	50.8
1961	18,468	8,913	48.3	34,980	21,208	60.6
1962	27,778	14,985	54.0	35,230	27,149	77.1
1963	51,702	19,787	38.3	44,052	26,519	60.2
1964	38,095	18,790	49.3	41,574	26,144	62.9
1965	39,818	19,581	49.2	48,278	31,241	64.7
1966	39,564	24,387	61.6	43,774	38,485	87.9
1967	47,548	24,361	51.3	NA	NA	NA

1/ Landings are heads-off weight. Data for years prior to 1956 are found by dividing landings in heads-on weight by the following factors: Florida, West Coast - 1.6804; Alabama - 1.6793; Mississippi - 1.5151; Louisiana - 1.6875; Texas - 1.6943.

Source: U. S. Department of the Interior, Bureau of Commercial Fisheries, Fishery Statistics of the United States

Appendix 4. Shrimp landings in South Atlantic and Gulf, by species, by size, 1958, 1962, and 1966

		1958			1962			1966		
		Quantity	Value	Average Price	Quantity	Value	Average Price	Quantity	Value	Average Price
		1000 lbs.	1000 $	¢ per lb.	1000 lbs.	1000 $	¢ per lb.	1000 lbs.	1000 $	¢ per lb.
Brown:	Under 15	2,104	1,847	87.8	1,809	1,745	96.5	1,898	2,128	112.1
	15 - 20	7,314	6,029	82.4	5,823	5,502	94.5	6,957	7,143	102.7
	21 - 25	9,239	6,954	75.3	5,572	5,167	92.7	10,811	10,549	97.6
	26 - 30	9,138	6,331	69.3	4,461	3,840	86.1	8,065	7,588	94.1
	31 - 40	14,334	8,866	61.9	9,647	7,173	74.4	15,341	12,734	83.0
	41 - 50	6,461	3,401	52.6	6,766	4,122	60.9	6,618	4,790	72.4
	51 - 67	4,436	2,011	45.3	4,501	2,239	49.7	6,546	3,973	60.7
	68 & over	3,934	1,576	40.1	10,002	3,959	39.6	14,490	5,169	34.6
	Total	56,960	37,014	65.0	48,480	33,747	69.5	71,177	54,074	76.0
Pink:	Under 15	20	18	89.0	76	71	93.4	185	202	109.2
	15 - 20	1,447	1,187	82.0	2,168	1,925	88.8	918	893	97.3
	21 - 25	4,618	3,578	77.5	2,660	2,279	85.7	1,909	1,713	89.7
	26 - 30	3,996	2,901	72.6	3,912	3,263	83.4	2,300	1,943	84.5
	31 - 40	4,804	3,084	64.2	7,098	5,408	76.2	4,824	3,701	76.7
	41 - 50	3,515	1,882	53.5	3,959	2,539	64.1	3,421	2,243	65.6
	51 - 67	3,765	1,598	42.4	2,258	1,172	51.9	3,552	1,945	54.8
	68 & over	3,366	1,043	31.0	1,358	508	37.4	1,594	647	40.6
	Total	25,531	15,289	59.9	23,489	17,166	73.1	18,704	13,286	71.0
White:	Under 15	76	66	87.7	94	90	95.7	774	865	111.8
	15 - 20	2,570	2,123	82.6	2,144	2,060	96.1	3,960	4,136	104.4
	21 - 25	4,857	3,583	73.8	2,996	2,816	94.0	4,487	4,340	96.7
	26 - 30	5,135	3,511	68.4	3,718	3,245	87.3	3,371	3,033	90.0
	31 - 40	7,551	4,577	60.4	6,088	4,558	74.9	6,015	4,788	79.6
	41 - 50	4,394	2,244	51.1	4,185	2,570	61.4	3,382	2,343	69.3
	51 - 67	3,900	1,677	43.0	5,832	2,815	48.3	7,239	3,976	54.9
	68 & over	4,460	1,487	33.3	5,988	2,203	36.8	6,638	2,734	41.2
	Total	32,943	19,269	58.5	31,044	20,358	65.6	35,866	26,215	73.1
Royal Red (all sizes)		--	--	--	96	76	79.2	123	99	80.5
Sea bobs (all sizes)		1,118	196	17.5	2,629	483	18.4	473	110	23.3
	Grand Total	116,552	71,769	61.6	105,839	71,830	67.9	126,342	93,785	74.2

Source: United States Department of the Interior, Bureau of Commercial Fisheries, Shrimp Landings

Appendix 5. Shrimp irradiation facilities cash flow rate of return analysis[1]

Area I

	Annual Throughput	Investment:			Oper. Exp.	Oper. Rev.	Net Cash Flow
		Plant	Source Cost	Source Repl.			
	(thous. lbs.)			(thousand dollars)			
1975		-1,257					-1,257
1976	82,467		-304	-43	-1,161	4,464	2,956
1977	85,909		-13	-44	-1,542	4,660	3,061
1978	89,600		-14	-46	-1,594	4,869	3,215
1979	94,434		-17	-49	-1,682	5,136	3,388
1980	97,430	-110	-11	-50	-1,724	5,304	3,409
1981	101,026		-14	-52	-1,783	5,500	3,651
1982	104,749		-13	-54	-1,844	5,708	3,797
1983	108,602		-15	-56	-1,907	5,924	3,946
1984	112,553		-15	-58	-1,971	6,146	4,102
1985	116,752		-16	-60	-2,040	6,381	4,265

Marginal Efficiency of Capital (Rate of Return) = 239%

[1] Assumptions:

(a) Source cost @ $.45/curie
(b) 0.3 Efficiency
(c) 125 K Rads Dosage
(d) Plant and source size geared to operations of 4,320 hours annually, which in shift equivalents, is 6 days per week, 2 shifts, 50 weeks per year, with 10% downtime.
(e) Eliminates spoilage loss equal to 6% of total output.

Appendix 6. Shrimp irradiation facilities cash flow rate of return analysis[1]

Area II

	Annual Throughput	Investment: Plant	Investment: Source Cost	Investment: Source Repl.	Oper. Exp.	Oper. Rev.	Net Cash Flow
	(thous. lbs.)			(thousand dollars)			
1975		-711					-711
1976	25,522		-94	-13	-443	1,221	671
1977	26,169		-2	-14	-546	1,251	689
1978	26,855		-3	-14	-558	1,286	711
1979	27,560		-2	-14	-571	1,319	732
1980	28,269	-42	-3	-15	-582	1,355	713
1981	28,979		-3	-15	-592	1,389	779
1982	29,707		-3	-15	-606	1,423	799
1983	30,467		-2	-16	-618	1,462	826
1984	31,214		-3	-16	-630	1,497	848
1985	31,988		-3	-17	-642	1,500	838

Marginal Efficiency of Capital (Rate of Return) = 97%

[1] Assumptions:

(a) Source cost @ $.45/curie
(b) 0.3 Efficiency
(c) 125 K Rads Dosage
(d) Plant and source size geared to operations of 4,320 hours annually, which in shift equivalents, is 6 days per week, 2 shifts, 50 weeks per year, with 10% downtime.
(e) Eliminates spoilage loss equal to 6% of total output.

Appendix 7. Shrimp irradiation facilities cash flow rate of return analysis[1]

Area III

	Annual Throughput	Investment: Plant	Investment: Source Cost	Investment: Source Repl.	Oper. Exp.	Oper. Rev.	Net Cash Flow
	(thous. lbs.)			(thousand dollars)			
1975		-703					-703
1976	24,866		-92	-13	-435	1,427	887
1977	25,492		-2	-13	-551	1,469	903
1978	26,168		-3	-14	-555	1,514	942
1979	26,864		-2	-14	-561	1,561	984
1980	27,529	-40	-3	-14	-570	1,605	978
1981	28,215		-2	-15	-580	1,650	1,053
1982	28,917		-3	-15	-592	1,695	1,085
1983	29,648		-2	-15	-606	1,743	1,120
1984	30,272		-3	-16	-614	1,784	1,151
1985	31,081		-3	-16	-628	1,837	1,190

Marginal Efficiency of Capital (Rate of Return) = 129%

Assumptions:

(a) Source cost @ $.45/curie
(b) 0.3 Efficiency
(c) 125 K Rads Dosage
(d) Plant and source size geared to operations of 4,320 hours annually, which in shift equivalents, is 6 days per week, 2 shifts, 50 weeks per year, with 10% downtime.
(e) Eliminates spoilage loss equal to 6% of total output.

Appendix 8. Shrimp irradiation facilities cash flow rate of return analysis[1]

Area IV

	Annual Throughput	Investment: Plant	Investment: Source Cost	Investment: Source Repl.	Oper. Exp.	Oper. Rev.	Net Cash Flow
	(thous. lbs.)			(thousand dollars)			
1975		-433			-232		-433
1976	8,979		-33	-5	-252	460	170
1977	9,140		-1	-5	-257	470	202
1978	9,312		-	-5	-259	479	217
1979	9,487		-1	-5	-260	489	223
1980	9,649	-19	-1	-5	-261	498	212
1981	9,835		-	-5	-265	508	238
1982	10,023		-1	-5	-268	518	244
1983	10,221		-1	-5	-272	529	251
1984	10,388		-	-5	-277	538	256
1985	10,590		-1	-5	-279	549	264

Marginal Efficiency of Capital (Rate of Return) = 47%

[1] Assumptions:

(a) Source cost @ $.45/curie
(b) 0.3 Efficiency
(c) 125 K Rads Dosage
(d) Plant and source size geared to operations of 4,320 hours annually, which in shift equivalents, is 6 days per week, 2 shifts, 50 weeks per year, with 10% downtime.
(e) Eliminates spoilage loss equal to 6% of total output.

Appendix 9. Shrimp irradiation facilities cash flow rate of return analysis[1]

Area V

	Annual Throughput	Investment: Plant	Investment: Source Cost	Investment: Source Repl.	Oper. Exp.	Oper. Rev.	Net Cash Flow
	(thous. lbs.)			(thousand dollars)			
1975		-1,362					-1,362
1976	97,576		-360	-50	-1,727	5,170	3,033
1977	101,786		-16	-53	-1,795	5,404	3,540
1978	106,288		-16	-55	-1,868	5,653	3,714
1979	110,969		-17	-57	-1,946	5,914	3,894
1980	115,893	-122	-18	-60	-2,062	6,183	3,921
1981	120,283		-17	-62	-2,088	6,417	4,250
1982	124,832		-17	-64	-2,163	6,666	4,422
1983	129,538		-18	-67	-2,239	6,917	4,593
1984	134,490		-18	-69	-2,320	7,189	4,782
1985	139,554		-19	-72	-2,473	7,467	4,903

Marginal Efficiency of Capital (Rate of Return) = 235%

[1] Assumptions:

(a) Source cost @ $.45/curie
(b) 0.3 Efficiency
(c) 125 K Rads Dosage
(d) Plant and source size geared to operations of 4,320 hours annually, which in shift equivalents, is 6 days per week, 2 shifts, 50 weeks per year, with 10% downtime.
(e) Eliminates spoilage loss equal to 6% of total output.

Appendix 10. Shrimp irradiation facilities cash flow rate of return analysis[1]

Area VI

	Annual Throughput	Investment: Plant	Source Cost	Source Repl.	Oper. Exp.	Oper. Rev.	Net Cash Flow
	(thous. lbs.)			(thousand dollars)			
1975		-931					-931
1976	42,527		-157	-22	-836	2,053	1,038
1977	44,410		-7	-23	-868	2,146	1,218
1978	46,410		-7	-24	-902	2,245	1,312
1979	48,492		-8	-25	-937	2,349	1,379
1980	50,724	-86	-8	-26	-970	2,459	1,369
1981	52,687		-8	-27	-1,004	2,555	1,516
1982	54,724		-8	-28	-1,039	2,657	1,582
1983	56,832		-8	-29	-1,074	2,759	1,648
1984	59,275		-9	-31	-1,113	2,881	1,728
1985	61,370		-8	-32	-1,148	2,982	1,794

Marginal Efficiency of Capital (Rate of Return) = 170%

[1] Assumptions:

(a) Source cost @ $.45/curie
(b) 0.3 Efficiency
(c) 125 K Rads Dosage
(d) Plant and source size geared to operations of 4,320 hours annually, which in shift equivalents, is 6 days per week, 2 shifts, 50 weeks per year, with 10% downtime.
(e) Eliminates spoilage loss equal to 6% of total output

Appendix 11.

Social rate of return analysis for shrimp 1/
irradiation development project Assumption "A"

	SOCIAL COST			SOCIAL BENEFITS			
	Research and Development	Plant and Source	Total Social Cost	Gross Benefits	Plant Operation costs	Net Social Benefits	Net Cash Flow
	----------		thousand dollars	----------			
1970	-170		-170				-170
1971	-180		-180				-180
1972	-365		-365				-365
1973	-100		-100				-100
1974	-75		-75				-75
1975	-5,397		-5,397				-5,397
1976	-1,186		-1,186	20,681	-4,854	15,827	14,641
1977	-193		-193	21,647	-5,559	16,088	15,895
1978	-201		-201	24,284	-5,736	18,548	18,347
1979	-211		-211	25,091	-5,957	19,134	18,923
1980	-633		-633	26,015	-6,169	19,846	19,213
1981	-220		-220	26,922	-6,312	20,610	20,390
1982	-226		-226	27,880	-6,512	21,368	21,142
1983	-234		-234	28,846	-6,716	22,130	21,896
1984	-243		-243	29,862	-6,925	22,937	22,694
1985	-252		-252	30,895	-7,210	23,685	23,433

Marginal efficiency of capital (rate of return) = 97.2%

1/ Benefits derived from spoilage loss elimination equal to 6% of total domestic output of processed shrimp.

Appendix 12.

Social rate of return analysis for shrimp irradiation development project Assumption "B" 1/

	SOCIAL COST			SOCIAL BENEFITS			
	Research and Development	Plant and Source	Total Social Cost	Gross Benefits	Plant Operation costs	Net Social Benefits	Net Cash Flow
	----thousand dollars----						
1970	-170		-170				-170
1971	-180		-180				-180
1972	-365		-365				-365
1973	-100		-100				-100
1974	-75		-75				-75
1975	-5,397		-5,397				-5,397
1976	-1,186		-1,186	17,416	-4,854	12,562	11,376
1977	-193		-193	18,228	-5,559	12,669	12,476
1978	-201		-201	20,454	-5,736	14,718	14,517
1979	-211		-211	21,133	-5,957	15,176	14,965
1980	-633		-633	21,910	-6,169	15,741	15,108
1981	-220		-220	22,680	-6,312	16,368	16,148
1982	-226		-226	23,478	-6,512	16,966	16,740
1983	-234		-234	24,290	-6,716	17,574	17,340
1984	-243		-243	25,151	-6,925	18,226	17,983
1985	-252		-252	26,019	-7,210	18,809	18,557

Marginal efficiency of capital (rate of return) = 87.5%

1/ Benefits derived from spoilage loss elimination equal to 5% of total domestic output of processed shrimp.

Appendix 13.

Social rate of return analysis for shrimp irradiation development project Assumption "C" 1/

	SOCIAL COST			SOCIAL BENEFITS			
	Research and Development	Plant and Source	Total Social Cost	Gross Benefits	Plant Operation Costs	Net Social Benefits	Net Cash Flow
	----------	----------	----------	thousand dollars	----------	----------	----------
1970	-170		-170				-170
1971	-180		-180				-180
1972	-365		-365				-365
1973	-100		-100				-100
1974	-75		-75				-75
1975	-4,964		-4,964				-4,964
1976	-1,148		-1,148	13,597	-4,530	9,427	8,279
1977	-187		-187	14,246	-5,247	8,999	8,981
1978	-196		-196	16,038	-5,420	10,618	10,492
1979	-205		-205	16,576	-5,638	10,938	10,733
1980	-608		-608	17,192	-5,845	11,347	10,739
1981	-215		-215	17,808	-5,984	11,824	11,609
1982	-220		-220	18,435	-6,180	12,255	12,035
1983	-227		-227	19,090	-6,380	12,710	12,483
1984	-238		-238	19,774	-6,585	13,189	12,951
1985	-246		-246	20,474	-6,867	13,607	13,361

Marginal efficiency of capital (rate of return) = 76.3%

1/ Benefits derived from spoilage loss elimination equal to 4% of total domestic output of processed shrimp.

Appendix 14.

Social rate of return analysis for shrimp irradiation development project Assumption "D" 1/

	SOCIAL COST			SOCIAL BENEFITS			
	Research and Development	Plant and Source	Total Social Cost	Gross Benefits	Plant Operation Costs	Net Social Benefits	Net Cash Flow
	------------------------thousand dollars------------------------						
1970	-170		-170				-170
1971	-180		-180				-180
1972	-365		-365				-365
1973	-100		-100				-100
1974	-75		-75				-75
1975	-3,322		-3,322				-3,322
1976	-862		-862	8,350	-4,252	4,098	3,236
1977	-141		-141	8,686	-4,380	4,306	4,165
1978	-148		-148	9,009	-4,501	4,508	4,360
1979	-156		-156	9,463	-4,680	4,783	4,627
1980	-428		-428	9,815	-4,891	4,924	4,496
1981	-162		-162	10,160	-4,992	5,168	5,006
1982	-166		-166	10,530	-5,141	5,389	5,223
1983	-170		-170	10,910	-5,293	5,617	5,447
1984	-179		-179	11,300	-5,448	5,852	5,673
1985	-186		-186	11,710	-5,684	6,026	5,840

Marginal efficiency of capital (rate of return) = 53.6%

1/ Benefits derived from spoilage loss elimination equal to 3% of total domestic output of processed shrimp.

Appendix 15.

Benefit-cost ratio analysis for shrimp irradiation development project Assumption "A" 1/

Interest Rate %	1970 - Present Value ($) Benefits ($000)	Costs ($000)	B/C Ratio
0	200,173	9,886	20.2
3	145,722	8,243	17.7
6	107,781	6,960	15.5
9	80,908	5,943	13.6
12	61,578	5,123	12.0
15	47,472	4,455	10.7
18	37,035	3,904	9.5
21	29,213	3,446	8.5
24	23,281	3,061	7.6
27	18,731	2,735	6.8

1/ Benefits derived from spoilage loss elimination equal to 6% of total domestic output of processed shrimp.

Appendix 16.

Benefit-cost ratio analysis for shrimp irradiation development project Assumption "B" 1/

Interest Rate %	1970 - Present Value ($) Benefits ($000)	Costs ($000)	B/C Ratio
0	158,809	9,886	16.1
3	115,598	8,243	14.0
6	85,491	6,960	12.3
9	64,169	5,943	10.8
12	48,834	5,123	9.5
15	37,643	4,455	8.4
18	29,364	3,904	7.5
21	23,161	3,446	6.7
24	18,456	3,061	6.0
27	14,848	2,735	5.4

1/ Benefits derived from spoilage loss elimination equal to 5% of total domestic output of processed shrimp.

Appendix 17.

Benefit-cost ratio analysis for shrimp irradiation development project Assumption "C" 1/

Interest Rate %	1970 - Present Value ($) Benefits ($000)	Costs ($000)	B/C Ratio
0	114,914	9,344	12.3
3	83,666	7,786	10.7
6	61,892	6,572	9.4
9	46,469	5,610	8.3
12	35,375	4,836	7.3
15	27,278	4,206	6.5
18	21,286	3,688	5.8
21	16,796	3,257	5.1
24	13,389	2,895	4.6
27	10,776	2,589	4.2

1/ Benefits derived from spoilage loss elimination equal to 4% of total domestic output of processed shrimp.

Appendix 18.

Benefit-cost ratio analysis for shrimp irradiation development project Assumption "D" 1/

Interest Rate %	1970 - Present Value ($) Benefits ($000)	Costs ($000)	B/C Ratio
0	49,871	6,810	7.3
3	36,367	5,691	6.4
6	26,945	4,820	5.6
9	20,261	4,132	4.9
12	15,446	3,579	4.3
15	11,926	3,129	3.8
18	9,319	2,758	3.4
21	7,362	2,450	3.0
24	5,875	2,191	2.7
27	4,734	1,972	2.4

1/ Benefits derived from spoilage loss elimination equal to 3% of total domestic output of processed shrimp.

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FIGURES

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14. A Price Incentive Plan for Distressed Fisheries by A. A. Sokoloski and E. W. Carlson.

15. Demand and Prices for Shrimp by D. Cleary.

16. Industry Analysis of Gulf Area Frozen Processed Shrimp and an Estimation of Its Economic Adaptability to Radiation Processing by D. Nash and M. Miller.

17. An Economic Evaluation of Columbia River Anadromous Fish Programs by J. A. Richards.

18. Economic Projections of the World Demand and Supply of Tuna, 1970 - 90 by F. Bell.

19. Economic Feasibility of a Seafood Processing Operation in the Inner City of Milwaukee by D. Cleary.

20. The 1969 Fishing Fleet Improvement Act: Some Advantages of its Passage by the Division of Economic Research.

21. An Economic Analysis of Policy Alternatives for Managing the Georges Bank Haddock Fishery by L. W. Van Meir.

22. Some Analyses of Fish Prices by F. Waugh and V. Norton.

23. Some Economic Characteristics of Pond-Raised Catfish Enterprises by J. E. Greenfield

24. Elements Crucial to the Future of Alaska Commercial Fisheries by D. Nash, A. Sokoloski, and D. Cleary.

25. Effects on the Shrimp Processing Industry of Meeting the Requirements of Wholesome Fishery Products Legislation by D. Nash and M. Miller.

26. Benefit Cost Analysis of a Proposed Trawl Systems Program by M. Miller.

27. An Economic Analysis of Future Problems in Developing the World Tuna Resource: Recommendations for the Future Direction of the BCF Tuna Program by F. Bell.

28. Economic Efficiency in Common Property Natural Resource Use: A Case Study of the Ocean Fishery by D. W. Bromley

29. Costs, Earnings and Borrowing Capacity for Selected U. S. Fisheries, by A. Sokoloski, E. Carlson, and B. Noetzel.

30. Fish Cycles: A harmonic analysis by F. Waugh and M. Miller.

31. Benefit-Cost Analysis as Applied to Commercial Fisheries Programs, by F. Bell.

32. Economic Study of San Pedro Wetfish Boats by W. F. Perrin and B. Noetzel.

33. A Survey of Fish Purchases by Socio-Economic Characteristics - First Quarterly Report - February, May, April, 1969 by Darrel A. Nash.

34. A Survey of Fish Purchases by Socio-Economic Characteristics, Second Quarterly Report - May June July by D. Nash.

35. A Simplified Guide to Benefit-Cost Analysis for BCF Programs by F. Bell .

36. Estimation of the Optimal Number of Vessels in a Fishery: Theoretical and Empirical Basis for Fishery Management by F. Bell .

37. Major Economic Trends in Selected U.S. Master Plan Fisheries: A Graphical Survey by Richard K. Kinoshita and Frederick W. Bell

38. Market Potential for the San Pedro Wetfish Fishery by D. Nash

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