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An Analysis of the Relationship between Fish Harvesting and Processing Sectors in New England

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Abstract *Using annual data from 1981 to 2002, the relationship between harvesting and processing of fish and the effects of imports on processing in New England were analyzed. Additionally, cause and effect relationships between harvesting and processing and between processing and imports were examined using Granger causality tests. Output from the fish processing sector is jointly driven by local fish landings and fish imports and unidirectional causalities exist from local landings to processing and from processing to imports. Generally, processors optimize business operations over multiple species and multiple supply sources. Rebuilding the groundfish stock would not lead to a dramatic and immediate increase in the processing industry. Instead, the actual growth in the processing sector would be relatively smaller than that in the harvesting sector.*

Key words Fish processing, fish harvesting, fish imports, causality.

JEL Classification Codes Q2, Q22, L66.

Introduction

The commercial fisheries of the Gulf of Maine and Georges Bank are among the most important in the nation. New Bedford, Portland, Point Judith, and Gloucester rank among the top-grossing fishing ports in the United States, and more than $692 million worth of fresh and partially processed fish was landed in New England in 2002. However, commercial landings of finfish and shellfish in New England have declined over the last fifty years from over one billion pounds in 1950 to 575 million pounds in 2002. Commercial landings of the traditional mainstay species of Atlantic cod, haddock, and yellowtail flounder have declined much more substantially, as these stocks have been overfished for much of the time.

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The fish-harvesting sector is linked tightly to an intricate network of onshore wholesaling, processing, and retail trade businesses. Together, the commercial fish harvesting and processing sectors in New England employ more than 16,000 people, and the annual total output value from these sectors exceeds $1.5 billion.[1] An economic input-output analysis indicates that every $1 million increase in the sales of fish harvests leads to $1.4 million in economic impacts capturing direct, indirect, and induced effects in economic sectors that both supply the fishing industry and purchase its products (MIG 2000; Marine Policy Center 2000).

The objective of this study was to develop a characterization of the relationship between fish harvesting and processing in New England. The characterization should enable improved assessment of the economic growth in the processing sector due to the rebuilding of groundfish stocks. The hypothesis that economic output from the New England processing sector is not related to changes in the supply of fish from local harvests is the focus of the study. If this hypothesis is rejected, then the economic ramifications of low resource levels may have been and continue to be deeper and more widespread than is currently appreciated. Further, the relationship between the output from the fish processing sector and fish imports is examined.

Most existing theoretical analyses involving the fish processing sector are based on single stock models (Clark and Munro 1980; Matulich, Mittelhammer, and Greenberg 1995; Matulich, Mittelhammer, and Reberte 1996; Weninger 1999). The processing sector is typically examined in a standard bioeconomic framework in connection with a harvesting sector. The processing sector is assumed to obtain raw fish supply only from local harvesters, and *vice versa*. If the processing sector has monopsonistic power, it can, in theory, indirectly regulate harvest, which may, in turn, lead to stock conservation. For this reason, shaping the market structure of the processing industry was once considered a possible tool for managing open-access fisheries (Crutchfield and Pontecorvo 1969; Clark and Munro 1980). In practice, the processing and harvesting sectors are usually not jointly managed. Industrial organization may depend on location and species.[2]

In an analysis of groundfish processing in New England, Hogan and Georgianna (1989) demonstrated that the quantity of raw fish imports was an important factor influencing processing sector output.[3] In fact, diversification of a portfolio of raw fish suppliers has been the strategy of processors in coping with input uncertainty in different parts of the world (Ottesen and Gronhaug 2003).

The remainder of this paper is organized as follows. The next section discusses the linkage between fish harvesting and processing. The third section describes the data on fish processing, landings, and imports by state in New England. Results of model estimations and statistical tests are summarized in the fourth section. The final section presents the conclusions.

[1] Estimates are based on IMPLAN 1997 data (MIG 2000).
[2] For example, Matulich, Mittelhammer, and Greenberg (1995) reported that the Alaska king crab industry may have exhibited bilateral monopoly in which fishers behaved as monopolists through bargaining associations, while processors behaved as countervailing monopsonists. In most cases, however, a competitive harvesting sector and an oligopsonistic processing sector are assumed in theoretical analyses (Matulich, Mittelhammer, and Greenberg 1995; Weninger 1999).
[3] Specifically, they developed empirical estimates of supply and demand systems for imports from Canada of cod, haddock, and flounder, using two-stage least square regressions. Their results indicated that in coping with declining local supply, the processing sector increased its demand for imports or other substitutes (see also Dirlam and Georgianna 1994).

Linkage between Harvesting and Processing

Clark and Munro (1980) examined the theoretical linkage between harvesting and processing in a bioeconomic framework. In their analysis, local landings are the only source of raw fish supply to the processing sector in the region. The processing sector (or firm) is modeled to maximize:

$$\pi(h) = \alpha ph - ch - p_e h, \tag{1}$$

where $\alpha \leq 1$ is a "recovery factor" (*i.e.*, weight of processed fish product resulting from one unit of raw fish), h is the harvest from local fisheries, p is the price of processed fish, p_e is the price of raw fish,[4] and c is the unit processing cost. Thus, the output of the processing sector at a specific location is driven by local harvest (h), which is regulated by the stock size of the local fishery. If the stock declines, the processing sector contracts over time.[5]

When the processing sector has both local landings and imports of different species (j) as input sources and assuming that all prices are exogenous, equation (1) may be modified:

$$\pi(h, m) = \sum_j [p_j Q_j - c_j(h_j + m_j) - p_{ej} h_j - p_{ij} m_j] \tag{2}$$

$$Q_j = \alpha_j(h_j + m_j) \quad j, \tag{3}$$

where m_j is the import quantity of species j, p_{ij} is the import price of species j, and Q_j is the total quantity of species j processed. With imports, Q_j may be driven by either h_j or m_j. Thus, the relationship between the size of processing sector, ΣQ_j, and local harvest, h_j, is weakened in that Q_j is "caused" entirely by h_j only when m_j is constant. Furthermore, the processing sector may substitute one species with another (Dirlam and Georgianna 1994).[6] With the possibility of multiple substitutions, it is unclear whether causality exists between local landings of a specific species (h_j) and the processed quantity of the same species (Q_j). The issue of causality is the focus in this study.

We examine the interaction between fish processing, landings, and imports through two empirical analyses. First, we model the processing output as a linear function of landings and imports using time series data:

$$Q = \beta_h h + \beta_m m + u, \tag{4}$$

where β_h and β_m are coefficients and u is an error term. The results will be used to compute the elasticities of processing with respect to landings and imports. We estimate the model for quantity and value separately. While the quantity model is essentially equation (3) aggregated across a set of species, the value (revenue) model describes a more complex relationship affected by both quantities and prices (p, p_e, and p_i), which are, in turn, affected by other supply and demand factors (*e.g.*, processing and harvesting capacities).

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[4] It could be an ex-vessel price or a wholesale price, depending on whether the harvesting and processing sectors are vertically integrated.

[5] The path of contraction may vary, depending on the characteristics of the relevant species (*e.g.*, a schooling fishery vs. a search fishery).

[6] In addition to substitution in inputs, processors may also optimize their output product mix to maximize profits. For a discussion of output product substitution, see Gordon, Hannesson, and Bibb (1993).

A characterization of the revenue relationship is of interest, since the interaction between fish processing, landings, and imports may be driven by relevant revenues. For example, sustained growth in processing revenues may lead to investment in that sector. In a dynamic context, processing capacity at time t may be determined by capital investments in previous periods (*i.e.*, t–1, t–2, …). In theory, these investments are made according to revenue projections based on historical data.

In the second part of our study, we analyze the associations between harvesting and processing using a Granger causality test. The test examines whether or not a kind of statistical feedback exists between two time series (Q and h). The variable Q is *Granger-caused* by variable h if information about the past and present h improves the forecasts of the Q variable. Q is Granger-caused by h if it can be predicted more efficiently when information about both the past and present h is taken into account in addition to all other relevant information (Granger 1969).[7]

When previous realizations of h affect the current realization of Q, but previous realizations of Q do not affect the current realization of h, then causality is said to be unidirectional. The case of bi-directional causality and absence of causality can be defined accordingly. An interesting question in an empirical analysis of the relationship between fish landings and processing is identifying the direction of causality between the two sectors. Landings are expected to cause processing, because a greater quantity of landings provides more raw fish input to the processing sector. Alternatively, a scenario in which the harvesting sector is driven by the processing sector is also possible. For example, an increased fish demand by consumers may enable processors to offer higher ex-vessel prices, which, in turn, prompts fishers to work harder to land more fish.

Data

Data for fish landings and processing were obtained from the National Marine Fisheries Service (NMFS) in two separate data sets: one included all commercially harvested species (*e.g.*, finfish and shellfish) from 1981 to 2000 and the other included only whitefish species[8] from 1981 to 2002. Data for fish imports were obtained from the US Census Bureau.[9]

We focus on regional aggregate data due to movements of unprocessed landings and imports. Figure 1 depicts the trends in quantity (in millions of kg) and value (in millions of 2002 dollars) of New England processing, landings, and imports of all fish species. Annual changes in these time series are shown in table 1.[10] From 1981 to 2000, the processing quantity and value declined, on average, 2.8% and 4.2%, respectively. The average rate of contraction was greater in the 1990s than in the earlier decade. Landings also decreased during the study period at an average annual rate of 1.1% in quantity and 0.2% in value. Imports fluctuated in the two decades with a relative steady growth in the 1990s.

Similar information for whitefish is illustrated in figure 2 and table 2. There

[7] The Granger causality test is based on the assumption that the concerned time series (Q and h) are stationary. If they are not, appropriate differencing of the original time series is needed (Coondoo and Dinda 2002).

[8] Whitefish species included in the analysis: Atlantic cod, haddock, pollock, American plaice (dab), Atlantic halibut, summer flounder, windowpane flounder (sand flounder), winter flounder (lemon sole), witch flounder (gray sole), yellowtail flounder, red hake, silver hake (whiting), white hake, and ocean perch (redfish or Acadian redfish).

[9] Quantities of landings are in live weight. Quantities of processing and imports are in product weight.

[10] In our data, the quantity of fish processed does not equal the sum of landings and imports due to the "recovery factor" [$\alpha \leq 1$ in equation (3)] and the fact that not all imports and landings are processed in the local processing facilities.

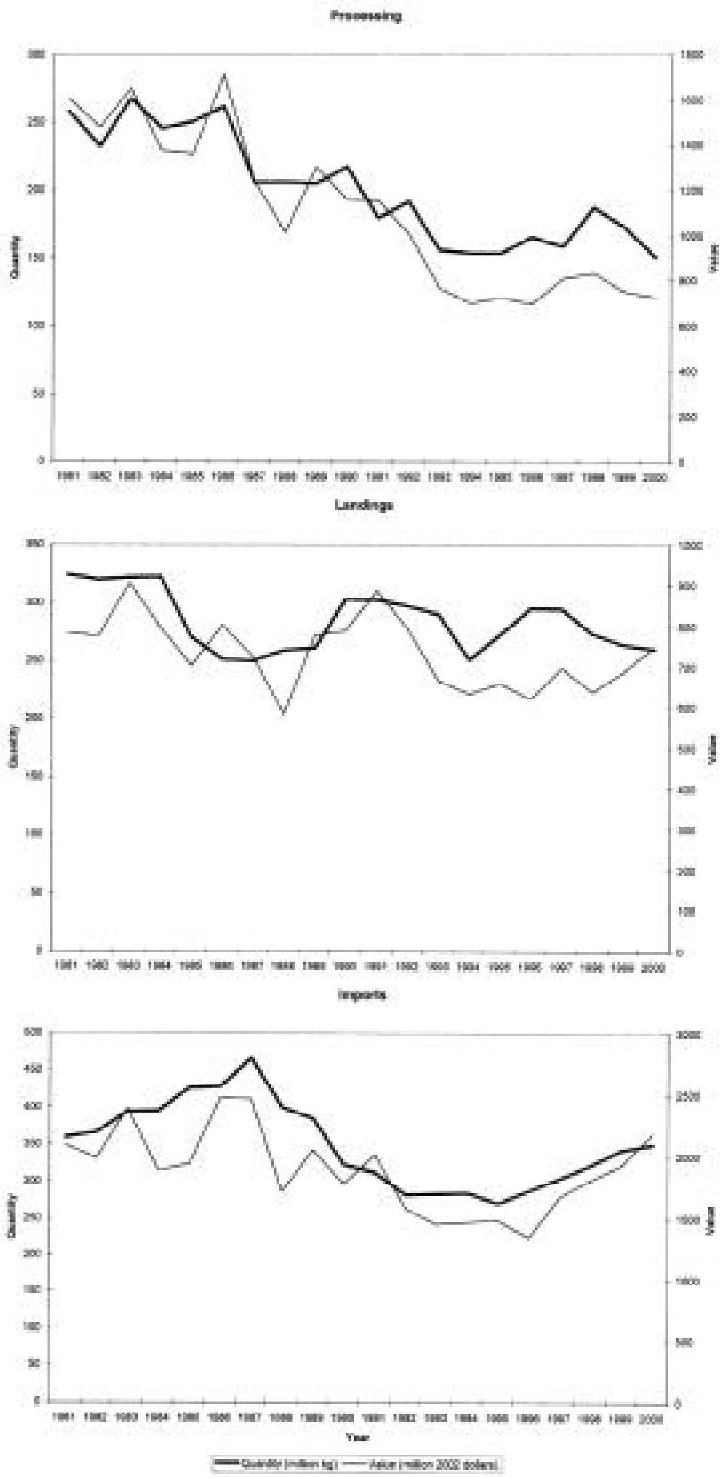

Figure 1. New England Fish Processing, Landings, and Imports (All Species) 1981–2000

Table 1
Annual Changes in Processing, Landings, and Imports (All Species)

	Quantity			Value		
Year	Processing	Landings	Imports	Processing	Landings	Imports
1982	–0.105	–0.013	0.019	–0.084	–0.009	–0.053
1983	0.143	0.006	0.075	0.113	0.153	0.184
1984	–0.088	0.002	0.002	–0.185	–0.127	–0.235
1985	0.020	–0.174	0.075	–0.011	–0.126	0.028
1986	0.044	–0.074	0.005	0.231	0.133	0.245
1987	–0.243	–0.005	0.085	–0.324	–0.103	–0.006
1988	0.001	0.035	–0.153	–0.200	–0.217	–0.360
1989	–0.004	0.008	–0.038	0.248	0.289	0.178
1990	0.058	0.149	–0.176	–0.115	0.014	–0.142
1991	–0.190	–0.001	–0.033	–0.004	0.115	0.123
1992	0.065	–0.019	–0.102	–0.134	–0.111	–0.242
1993	–0.206	–0.024	0.005	–0.272	–0.175	–0.085
1994	–0.015	–0.145	0.005	–0.093	–0.049	0.013
1995	0.000	0.084	–0.050	0.036	0.039	0.009
1996	0.075	0.078	0.059	–0.040	–0.060	–0.098
1997	–0.043	–0.002	0.058	0.148	0.118	0.217
1998	0.166	–0.074	0.056	0.029	–0.090	0.080
1999	–0.077	–0.035	0.061	–0.101	0.077	0.062
2000	–0.141	–0.015	0.021	–0.036	0.083	0.122
Mean 81–00	–0.028	–0.011	–0.001	–0.042	–0.002	0.002
Mean 81–90	–0.019	–0.007	–0.012	–0.036	0.001	–0.018
Mean 91–00	–0.037	–0.015	0.008	–0.047	–0.005	0.020

were more significant drops in whitefish processing and landings than in the all-species case. From 1981 to 2002, average reductions in the quantity and value of processing were 3.8% and 3.9%, respectively. The decline in whitefish landings was 5.4% per year in quantity and 4.3 % per year in value. The reduction in whitefish landings was offset by rising imports, especially during the early 1980s. Over the entire study period, imports grew over 2% in both quantity and value.

Table 3 reports the average annual quantity and value of processing, landings, and imports of all species for the six New England states from 1981 to 2000. In terms of fish processing, Massachusetts was dominant, with an average quantity of 139.12 million kg valued at $793.97 million per year. Maine also had a significant processing sector, although much smaller than that in Massachusetts. The processing sectors were relatively small in New Hampshire, Rhode Island, and Connecticut. In terms of fish harvesting, Massachusetts was also the leading state, although not as dominant as it was in processing. The sum of landings in Maine (92.90 million kg) and Rhode Island (55.10 million kg) accounted for more than half of the total landings in New England. Due to its proximity to Canada, Maine was the leading state for imported fish, followed by Massachusetts.

Average annual quantity and value of processing, landings, and imports of whitefish from 1981 to 2002 are presented in table 4. The overall pattern of processing, landings, and imports in table 4 mirrors that in table 3. Massachusetts was dominant in whitefish processing. Both Maine and Rhode Island had small processing sectors relative to their harvesting sectors, and both trucked whole fish to Massachusetts for processing. In addition, Rhode Island shipped some of its landings to New York for processing (Dirlam and Georgianna 1994).

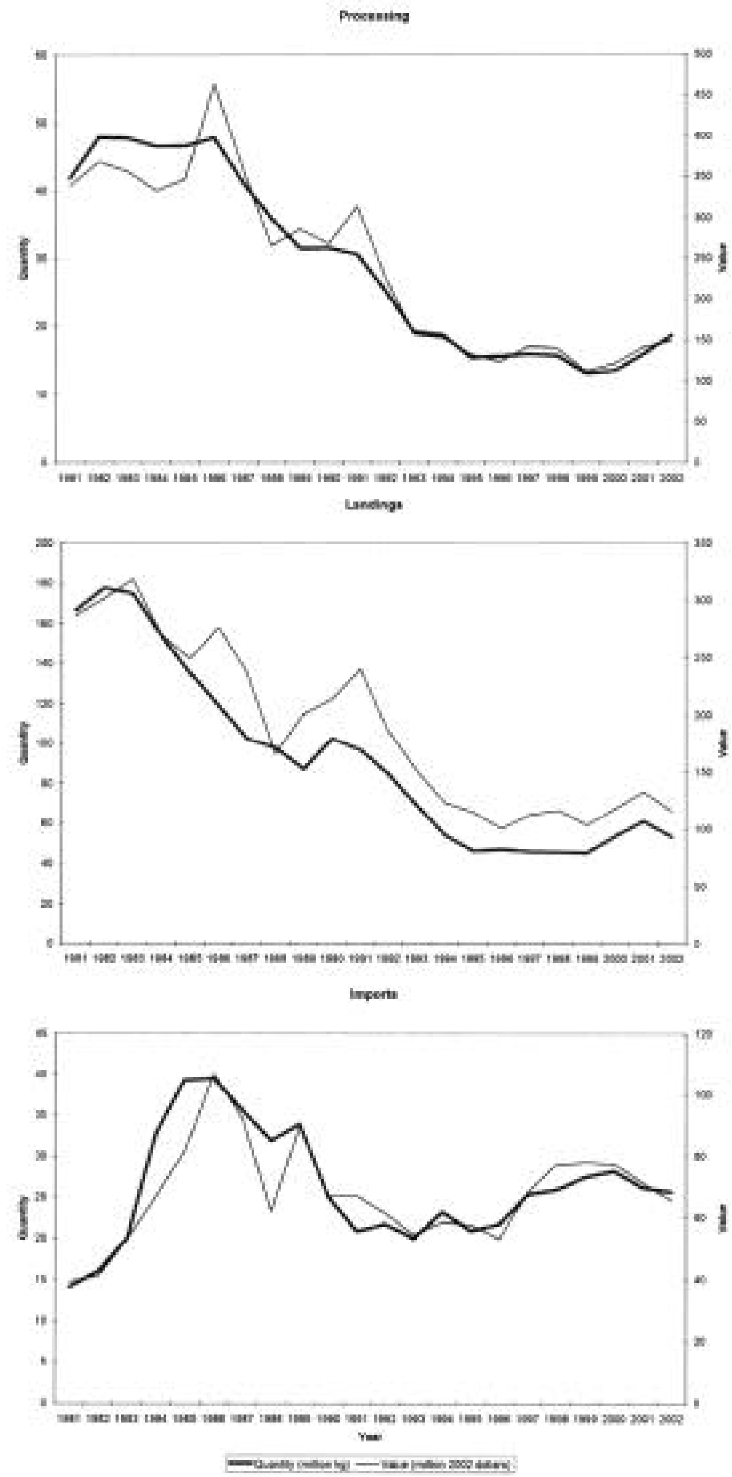

Figure 2. New England Processing, Landings, and Imports (Whitefish Species) 1981–2002

Table 2
Annual Changes in Processing, Landings, and Imports (Whitefish Species)

	Quantity			Value		
Year	Processing	Landings	Imports	Processing	Landings	Imports
1982	0.135	0.064	0.127	0.084	0.050	0.045
1983	–0.002	–0.016	0.221	–0.032	0.054	0.250
1984	–0.026	–0.126	0.494	–0.069	–0.163	0.232
1985	0.001	–0.131	0.180	0.042	–0.081	0.197
1986	0.025	–0.127	0.005	0.290	0.105	0.272
1987	–0.149	–0.152	–0.103	–0.252	–0.156	–0.149
1988	–0.135	–0.044	–0.108	–0.308	–0.357	–0.394
1989	–0.135	–0.114	0.060	0.076	0.193	0.366
1990	0.002	0.160	–0.304	–0.067	0.064	–0.288
1991	–0.032	–0.057	–0.183	0.160	0.112	–0.001
1992	–0.187	–0.129	0.041	–0.326	–0.255	–0.088
1993	–0.279	–0.204	–0.083	–0.365	–0.203	–0.120
1994	–0.019	–0.246	0.149	–0.030	–0.208	0.071
1995	–0.196	–0.158	–0.105	–0.138	–0.069	–0.014
1996	0.013	0.015	0.039	–0.073	–0.134	–0.083
1997	0.021	–0.021	0.154	0.141	0.111	0.251
1998	–0.013	–0.005	0.022	–0.015	0.036	0.124
1999	–0.184	–0.008	0.058	–0.223	–0.117	0.009
2000	0.028	0.167	0.025	0.079	0.129	–0.007
2001	0.168	0.132	–0.074	0.152	0.120	–0.083
2002	0.158	–0.139	–0.019	0.055	–0.139	–0.085
Mean 81–02	–0.038	–0.054	0.028	–0.039	–0.043	0.024
Mean 81–90	–0.031	–0.054	0.063	–0.026	–0.033	0.059
Mean 91–02	–0.043	–0.055	0.002	–0.049	–0.051	–0.002

Table 3
Average Annual Quantity and Value (All Species) 1981–2000

	Mean					
Variable	CT	MA	ME	NH	RI	VT
Quantity (million kg)						
Processing	0.46[a]	139.12	34.91	17.44	9.13	—
Landings	6.65[a]	125.50	92.90	4.90	55.10	—
Imports	0.03[b]	148.91	195.90	—	0.13	4.45
Value (million 2002 dollars)						
Processing	3.35[a]	793.97	204.08	59.05	43.69	—
Landings	42.63[a]	359.19	220.47	13.46	102.63	—
Imports	0.13[b]	727.18	1,132.50	—	0.87	28.71

[a] Based on data from 1983 to 2000.
[b] Based on data from 1983 to 1986.

Table 4
Average Annual Quantity and Value (Whitefish Species) 1981–2002

	Mean					
Variable	CT	MA	ME	NH	RI	VT
Quantity (million kg)						
Processing	—	25.15	2.58	—	1.27[a]	—
Landings	1.79	56.67	18.05	2.55	12.77	—
Imports[b]	—	3.30	22.68	—	—	0.16
Value (million 2002 dollars)						
Processing	—	211.25	19.82	—	10.51[a]	—
Landings	3.11	122.87	34.57	4.88	22.58	—
Imports[b]	—	11.59	55.74	—	—	0.41

[a] Based on data from 1982 to 2002.
[b] Fresh and frozen whole fish.

Results

Interaction between Fish Processing, Landings, and Imports

To examine the interaction between fish processing, landings, and imports, processing output was first modeled as a linear function of landings and imports using New England regional data aggregated across all species [equation (4)]. A time trend was included to capture the variation in intercept over the study period. The same model specification was used to estimate quantity and value, respectively. Results of Yule-Walker Estimates[11] are summarized in table 5.

Results of the quantity and value models are consistent. Most independent variables in both models were statistically significant at the 5% or 1% level. The quantity (or value) of fish processed was positively related to both landings and imports, because processors utilize either local harvests or imports as their inputs. The data indicate a downward trend in the processing sector 1981 to 2000, as depicted in figure 1.

Using the model coefficients in table 5, we calculate the elasticities of the processing quantity with respect to the quantities of landings and imports, respectively (columns 2 and 3 in table 6). A similar set of elasticities based on the value model is also included in columns 4 and 5 of table 6. Processing is inelastic with respect to both landings and imports. Based on the quantity model, the mean elasticity from 1981 to 2000 was slightly higher for landings (0.763) than that for imports (0.704). By contrast, the mean elasticity was lower for landings (0.416) than that for imports (0.595) according to the value model. In all cases, the mean elasticities were greater in the 1990s than in the 1980s.

Next, similar models were estimated for whitefish, using the second data set. The results are provided in table 7. Again, New England aggregate quantities and values were used in the estimation due to interstate shipments. For example, a substantial amount of whitefish landings and imports in Maine were shipped to

[11] Estimates of an autoregressive error model corrected for 2nd order autocorrelation.

Table 5
New England Fish Processing: All-species Models (Yule-Walker Estimates)

Variable	Quantity	Value
	Coefficient (t-value)	
Intercept	5,039	78,749
	(2.68)**	(11.15)***
Landings	0.5228	0.5827
	(3.03)***	(2.13)*
Imports	0.3988	0.3283
	(4.71)***	(5.10)***
Year	–2.5749	–39.5336
	(–2.82)***	(–11.36)***
Observations	20	20
R^2	0.8764	0.9544
DW	2.4413	2.1666

Notes: *, **, and *** against the reported coefficients denote significance at 10, 5, 1% levels, respectively.

Table 6
Elasticities of Processing with Respect to Landings and Imports (All Species)

	Quantity		Value	
Year	Landings	Imports	Landings	Imports
1981	0.656	0.555	0.284	0.428
1982	0.719	0.628	0.306	0.442
1983	0.627	0.587	0.319	0.474
1984	0.685	0.642	0.338	0.451
1985	0.565	0.678	0.301	0.469
1986	0.502	0.652	0.273	0.475
1987	0.637	0.905	0.341	0.653
1988	0.659	0.776	0.335	0.556
1989	0.667	0.750	0.349	0.519
1990	0.730	0.593	0.397	0.505
1991	0.882	0.694	0.448	0.573
1992	0.811	0.587	0.458	0.515
1993	0.974	0.725	0.505	0.621
1994	0.855	0.740	0.528	0.691
1995	0.930	0.704	0.529	0.673
1996	0.932	0.693	0.519	0.635
1997	0.972	0.766	0.503	0.680
1998	0.765	0.687	0.447	0.716
1999	0.798	0.788	0.533	0.843
2000	0.904	0.927	0.601	0.987
Mean 81–00	0.763	0.704	0.416	0.595
Mean 81–90	0.645	0.677	0.324	0.497
Mean 91–00	0.882	0.731	0.507	0.693

Massachusetts for processing (Dirlam and Georgianna 1994). All independent variables in both quantity and value models were statistically significant at the 1% or 5% level (table 7). An increase in either landings or imports leads to growth in the processing sector. As in the all-species case, there was a declining trend in processing of whitefish between 1981 and 2002.

Again, we calculate elasticities using model coefficients in table 7. As shown in table 8, a key feature in the whitefish model is that the elasticity of processing with respect to imports was notably higher in the late 1990s than in previous years. For example, in 1999 and 2000, both processing quantity and value were elastic with respect to imports (> 1). From 1991 to 2002, the mean elasticity of imports was greater than that of landings in both quantity and value models (see the last row in table 8). By contrast, the opposite was true in the 1980s.

The results suggest that the processed value and quantity do not change at the same rate as landings or imports. In addition, processing is generally inelastic with respect to landings. Output from processing is jointly determined by local landings and imports. The results hold at both the aggregate (all-species) and disaggregate (whitefish species) levels. Although this confirms that an increase in landings leads to an increase in processing, *ceteris paribus,* it may not yet be said that landings cause processing.

Table 7
New England Whitefish Processing (Yule-Walker Estimates)

	Quantity	Value
Variable	Coefficient (t-value)	
Intercept	1,517	11,920
	(5.23)***	(2.81)**
Landings	0.1772	0.8972
	(8.63)***	(4.83)***
Imports	0.5443	1.8511
	(10.46)***	(5.68)***
Year	–0.7627	–6.0120
	(–5.28)***	(–2.84)**
Observations	22	22
R^2	0.9871	0.9641
DW	1.7985	1.9660

Notes: *, **, and *** against the reported coefficients denote significance at 10, 5, 1% levels, respectively.

Causality between Fish Landings and Processing

The existence and direction of causality between fish landings (h) and processing (Q) was examined using a Granger causality test.[12] Separate tests were conducted at the state level and at the regional level, where all species were included. In all tests, landings and processing data were differenced to make the series stationary. The re-

[12] h_t is said to fail to Granger cause Q_t if the forecast of Q_t conditional upon $Q_{t-1}, Q_{t-2}, \ldots, h_{t-1}, h_{t-2}, \ldots$ is no better than the forecast of Q_t conditional upon $Q_{t-1}, Q_{t-2}, \ldots$ alone. In this case, testing for causality involves testing the hypothesis that the coefficients of VAR of lags p are significantly different from zero using Wald statistics.

Table 8
Elasticities of Processing with Respect to Landings and Imports (Whitefish Species)

	Quantity		Value	
Year	Landings	Imports	Landings	Imports
1981	0.706	0.184	0.760	0.215
1982	0.657	0.182	0.734	0.207
1983	0.648	0.228	0.800	0.275
1984	0.587	0.384	0.728	0.371
1985	0.514	0.459	0.644	0.434
1986	0.441	0.449	0.535	0.426
1987	0.440	0.470	0.589	0.473
1988	0.482	0.483	0.561	0.434
1989	0.492	0.587	0.631	0.580
1990	0.576	0.432	0.718	0.465
1991	0.561	0.371	0.685	0.396
1992	0.594	0.467	0.735	0.502
1993	0.641	0.568	0.864	0.641
1994	0.511	0.672	0.723	0.709
1995	0.530	0.735	0.774	0.803
1996	0.531	0.755	0.729	0.795
1997	0.509	0.862	0.708	0.888
1998	0.513	0.893	0.745	1.020
1999	0.612	1.137	0.828	1.287
2000	0.703	1.134	0.871	1.182
2001	0.678	0.890	0.843	0.934
2002	0.504	0.746	0.694	0.813
Mean 81–02	0.565	0.595	0.723	0.629
Mean 81–90	0.554	0.386	0.670	0.388
Mean 91–02	0.574	0.769	0.767	0.831

sults are summarized in table 9. Hypothesis 1 relates to the test of landings to processing causality and Hypothesis 2 relates to the test of processing to landings causality. Both sets of null hypotheses are based on non-causality and were tested using Wald statistics. For example, the first null hypothesis for the Granger causality test is "h does not Granger-cause Q." A rejection of this hypothesis is consistent with a finding of causality between h and Q.[13]

Hypothesis 1 was rejected at the 1% level for Massachusetts (quantity), Maine (value), and Rhode Island (value), and rejected at the 10% level in the case of Massachusetts, Maine, and New Hampshire combined (quantity). Rejecting Hypothesis 1 indicates that landings Granger-cause processing in these cases. As noted, Massachusetts was dominant in both landings and processing. There was a cause and effect relationship between the two sectors in this important state, in spite of the substitution effect of imports. Combining Massachusetts, New Hampshire, and Maine into a subregion, the test result indicates that the harvesting-processing causal relationship holds in the subregion. When Rhode Island is added to the analy-

[13] The optimal number of lags is also a critical issue in Granger causality test. We used a group of information criteria including the Akaike Information Criterion (AIC), the Schwarz Bayesian criterion (SBC), and the Akaike final prediction error criterion (FPE), and we selected the appropriate lag for each test based on the information criteria and model coefficients (the second column of table 9).

Table 9
Granger Causality Test for Fish Landings and Processing (All Species)

		Null Hypothesis 1 Fish Landings $\nrightarrow$ Processing				Null Hypothesis 2 Processing $\nrightarrow$ Fish Landings			
		Quantity		Value		Quantity		Value	
State(s)	Lag	χ^2	Prob. > χ^2	χ^2	Prob. > χ^2	χ^2	Prob. > χ^2	χ^2	Prob. > χ^2
Massachusetts	2	9.32	0.0095***	0.21	0.9006	0.41	0.8138	0.56	0.7569
Maine	3	3.09	0.3778	11.90	0.0077***	2.58	0.4616	1.17	0.7592
New Hampshire	3	0.26	0.9668	0.61	0.8936	4.26	0.2346	4.87	0.1814
Rhode Island	3	0.89	0.8274	12.86	0.0050***	0.37	0.9458	4.67	0.1976
MA, ME, and NH	2	5.00	0.0820*	0.81	0.6662	0.97	0.6146	1.37	0.5036
MA, ME, NH, and RI	2	4.48	0.1066	0.99	0.6096	2.16	0.3399	1.70	0.4283

Notes: *, **, and *** against the reported coefficients denote significance at 10, 5, 1% levels, respectively.

sis, we cannot reject Hypothesis 1 ($p = 0.107$ in the last row of table 9), implying a weakened relationship. This result is not surprising, as Rhode Island's harvest sector is linked closely to the processing sector in New York (Dirlam and Georgianna 1994). As expected, Hypothesis 2 cannot be rejected in any of the tests, suggesting that processing does not Granger-cause landings.

Causality between Fish Imports and Processing

The existence and direction of causality between changes in fish imports (m) and processing (Q) was also explored. No significant cause and effect relationship between the two series was found at the individual state level. Because of significant inter-state shipments, the New England region may be viewed as one market. Therefore, the Granger causality test was formulated at the aggregate level, and the results are included in table 10.[14] Hypothesis 1 relates to the test of imports to processing causality, and Hypothesis 2 relates to the test of processing to imports causality. Based on the test results, the second hypothesis was rejected, suggesting that, at the regional level, processing Granger-causes imports. That is, an increase in demand for fish may lead to more fish processing, which, in turn, leads to more fish imports. Another explanation is that both the hoarding of skilled labor and the desire to maintain specific retail customers prompts processors to attempt to maintain output by importing more fish when local landings decline (Hogan and Georgianna 1989). For these reasons, it is not surprising to see that imports do not Granger-cause processing (Hypothesis 1 cannot be rejected).

Finally, the same set of Granger causality tests listed in tables 9 and 10 were repeated for whitefish. The null hypothesis could not be rejected in any of these cases. Generally, the cause-effect relationships between landings and processing and between processing and imports do not hold for whitefish alone, probably due to substitution effects with other species.

Conclusions

The study results suggest that processing output does not change at the same rate as landings or imports. Also, processing is generally inelastic with respect to landings. In the case of whitefish, import elasticity was greater than that of landings. Apparently, output from the fish processing sector is jointly determined by local fish landings and fish imports. The level of imports is an important factor in the management of fish processors. Local landings were found to Granger-cause processing in several cases, implying that past resource conditions indeed affected present processing output at the *aggregate* (all-species) level. In contrast, no significant causality was found between processing and landings.

A unidirectional causality was also found from processing to imports at the all-species level, which is consistent with results of Hogan and Georgianna (1989): processors import more fish when local landings decline. It is important to note that all identified Granger causalities in the study existed only at aggregate (all-species) level and the cause and effect relationship did not hold for whitefish alone. This is due to inter-species substitution as well as substitution among different raw fish suppliers (*e.g.*, local landings versus imports).

The study findings imply that the impact of low groundfish resource stock on

[14] Connecticut was excluded due to missing values and its proximity to New York City.

Table 10
Granger Causality Test for Fish Imports and Processing (All Species)

States	Null Hypothesis 1 Imports $\nrightarrow$ Processing				Null Hypothesis 2 Processing $\nrightarrow$ Imports			
	Quantity		Value		Quantity		Value	
	χ^2	Prob. > χ^2	χ^2	Prob. > χ^2	χ^2	Prob. > χ^2	χ^2	Prob. > χ^2
MA, ME, NH, and RI	1.24	0.5380	1.81	0.4037	8.51	0.0142***	2.52	0.2838

Notes: *, **, and *** against the reported coefficients denote significance at 10, 5, 1% levels, respectively.
Lag = 2.

the regional economy does not seem to be more widespread than previously thought. Rebuilding the stock would not lead to a dramatic and immediate increase in the processing industry. Instead, actual growth in the processing sector could be relatively smaller than that in the harvesting sector. Our results indicate that firms in the fish processing sector optimize their business operations over multiple species and multiple supply sources. Although an increase in local fish landings generally leads to an expanded seafood processing sector, the interaction may be complex due to various substitution effects. A clearer understanding of these substitution effects will improve assessment of the economic gains accruing from rebuilding fisheries in New England.

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