NOAA Technical Memorandum NMFS-F/NEC-87

Evidence of Structural Change in Preferences for Seafood

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

January 1992

Recent issues in this series

53. **Contaminants in Hudson-Raritan Estuary Water and Influence of Cold Storage upon Its Chemical Composition.** By Anthony Calabrese, Lawrence J. Buckley, and J. Christopher Powell. May 1988. vii + 37 p., 10 figs., 11 tables. NTIS Access. No. PB88-225628/AS.

54. **Epizootic Ulcerative Syndromes in Coastal/Estuarine Fish.** By Carl J. Sindermann. June 1988. v + 37 p., 8 figs., 1 table. NTIS Access. No. PB89-110803/AS.

55. **A Plan for Study: Response of the Habitat and Biota of the Inner New York Bight to Abatement of Sewage Sludge Dumping.** By Environmental Processes Division, Northeast Fisheries Center. June 1988. iii + 34 p., 5 figs., 3 tables, 4 app. NTIS Access. No. PB89-100903/AS.

56. **Characterization of the Middle Atlantic Water Management Unit of the Northeast Regional Action Plan.** By Anthony L. Pacheco, ed. July 1988. v + 322 p., 136 figs., 21 tables. NTIS Access. No. PB89-145262/AS.

57. **An Analysis and Evaluation of Ichthyoplankton Survey Data from the Northeast Continental Shelf Ecosystem.** By Wallace G. Smith, ed. August 1988. xiii + 132 p., 53 figs., 12 tables, 1 app. NTIS Access. No. PB89-122501/AS.

58. **An Indexed Bibliography of Northeast Fisheries Center Publications and Reports for 1987.** By Jon A. Gibson. August 1988. iii + 20 p. NTIS Access. No. PB89-113013/AS.

59. **Surveys of Breeding Penguins and Other Seabirds in the South Shetland Islands, Antarctica, January-February 1987.** By W. David Shuford and Larry B. Spear. September 1988. vii + 27 p., 14 figs., 1 table. NTIS Access. No. PB89-141311/AS.

60. **Survey of Antarctic Fur Seals in the South Shetland Islands, Antarctica, during the 1986-1987 Austral Summer.** By John L. Bengtson, Lisa M. Ferm, Tero J. Harkonen, Everett G. Schaner, and Brent S. Stewart. September 1988. vii + 8 p., 1 fig., 3 tables. NTIS Access. No. PB89-141303/AS.

61. **Fish as Sentinels of Environmental Health.** By Robert A. Murchelano. September 1988. iii + 16 p., 4 figs. NTIS Access. No. PB89-139737/AS.

62. **The Effects of Density Dependent Population Mechanisms on Assessment Advice for the Northwest Atlantic Mackerel Stock.** By W. J. Overholtz, S.A. Murawski, W.L. Michaels, and L.M. Dery. October 1988. v + 49 p., 7 figs., 20 tables. NTIS Access. No. PB89-151948/AS.

63. **Status of the Fishery Resources Off the Northeastern United States for 1988.** By Conservation and Utilization Division. October 1988. iii + 135 p., 51 figs., 52 tables. NTIS Access. No. PB89-130819/AS.

64. **The Shell Disease Syndrome in Marine Crustaceans.** By Carl J. Sindermann. February 1989. v + 43 p., 5 figs., 2 tables. NTIS Access. No. PB89-162523/AS.

65. **Stock Assessment Information for Pollock, *Pollachius virens* (L.), in the Scotian Shelf, Georges Bank, and Gulf of Maine Regions.** By Ralph K. Mayo, Stephen H. Clark, and M. Christina Annand. April 1989. vi + 14 p., 6 figs., 14 tables. NTIS Access. No. PB90-120676/AS.

66. **Guidelines for Estimating Lengths at Age for 18 Northwest Atlantic Finfish and Shellfish Species.** By Judith A. Pentilla, Gary A. Nelson, and John M. Burnett, III. May 1989. iii + 39 p., 18 figs., 19 tables. NTIS Access. No., PB90-120675/AS.

67. **Response of the Habitat and Biota of the Inner New York Bight to Abatement of Sewage Sludge Dumping. Second Annual Progress Report -- 1988.** By Environmental Processes Division, Northeast Fisheries Center. July 1989. vii + 47 p., 39 figs., 11 tables, 3 app. NTIS Access. No. PB90-125444/AS.

(continued on inside back cover)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The results from graphical and regression analyses of time-series data on seafood consumption and prices suggest that preferences for seafood strengthened in response to medical evidence that seafood promotes nutrition and health. The graphical analysis reveals steady increases in *per capita* consumption of seafood since the 1960s despite concurrent increases in the relative prices of seafood. The two-phase regression analyses of *per capita* consumption of generic seafood products (*i.e.*, fresh or frozen seafood, canned seafood, and cured seafood) and of the relative price of seafood identify the mid-1960s and early 1980s as times of change. These results, which match those reported for red meats and poultry, have important implications for modeling ex-vessel demand, estimating economic welfare, managing fishing effort, and allocating fish stocks.

INTRODUCTION

Since discovering the relationships between fat intake and nutrition and health, the medical profession has urged dietary changes (Clancy 1986). In fact, since the early 1980s, eating seafood at least twice a week has been recommended in order for one to benefit from the ability of omega-3 fatty acids to reduce heart disease and certain other ailments such as arthritis and various metabolic and neurological disorders (Lees 1988). Yet, despite these admonitions and Jones and Weimer's (1981) survey results on the changing American diet, economists have mostly ignored consumer demand for seafood, focusing instead on apparent structural changes in preferences for red meats and poultry since the 1960s (Chavas 1983; Choi and Sosin 1990; Dahlgran 1987; Eales and Unnevehr 1988; Goodwin 1989; Moschini and Meilke 1989; Nyankori and Miller 1982; Purcell 1989; Thurman 1987)[1]. In this paper, I begin to fill this gap with evidence of structural changes in preferences for seafood.

In addition to the relatively small amount of money that consumers spend on seafood (about 10 percent of the total meat budget, but growing), consistently dubious results probably have caused researchers to omit seafood from focused study[2]. In particular, positive own-price coefficients and complementarity between seafood and red meats and poultry are common results when the demand for seafood is estimated as part of a structural system (Goodwin 1989; Huang 1988; Pope *et al.* 1980; Wohlgenant 1985). However, such "dubious" results could be due to structural shifts in preferences for seafood. Positive own-price coefficients would result from simultaneous-equations bias if demand "traced" a relatively stable supply. Also, negative cross-price coefficients, which at face value indicate a curious complementarity, would result from omitted-variable bias when structural changes in preferences are not modeled. That is, stronger preferences for seafood would lead to both higher seafood prices and reduced preferences for red meats.

Because of the failure of structural models such as the oft-used almost-ideal-demand system (AIDS) to generate credible estimates of seafood demand, I have chosen a different approach to analyze for structural changes in preferences for seafood. Part of my analysis follows Purcell's (1989) admonition to utilize graphical analyses when examining the evidence of structural changes in demands for foods[3]. Accordingly, in the Graphical Analysis section of this report, plots of time-series data of relative prices and per capita consumption have been inspected for signs of preference change. The trends suggest that preferences for seafood strengthened since 1960, particularly during the mid-1960s and then again during the early 1980s.

In addition, two-phase regression has been used in the Two-phase Regression section of this report to test and quantify the apparent trends. However, due to the above-mentioned poor performance of previous structural models, I have used reduced-form models. The regression results corroborate the conclusions drawn from the graphical analysis.

Finally, three implications of the results for economic research and fishery management are highlighted in the Implications section of this report. A Summary and Conclusions section completes this report.

GRAPHICAL ANALYSIS

The 50-percent increase in annual consumption of seafood from about 10 pounds per capita in 1935 to about 15 pounds in 1988--despite steady increases in the relative prices of seafood--constitutes important evidence that preferences for seafood have strengthened (Figure 1)[4]. The near doubling of consumption of fresh or frozen fish and shellfish since 1935 to about 10 pounds in 1988 comprised most of this increase. Consumption of canned fish and shellfish also rose, but only slightly to about five pounds per capita in 1988. In contrast, consumption of cured fish and shellfish (*e.g.*, smoked fish and salted fish) declined 50 percent between 1935 and 1988 to only 0.3 pounds.

On average, the U.S. population increased its consumption of seafood by 50 percent even though seafood steadily became more expensive than other meats and foods. This is apparent from the ratios of the consumer price index (CPI) for all fish and shellfish products (the only available national time series of retail prices[5]) to the CPIs for poultry, beef & veal, pork, and all foods (Figure 1b)[6]. Also, during the late 1940s, much of the 1970s, and the late 1980s, annual *per capita* consumption of seafood increased despite concurrent increases in the price of seafood relative to *per capita* income.

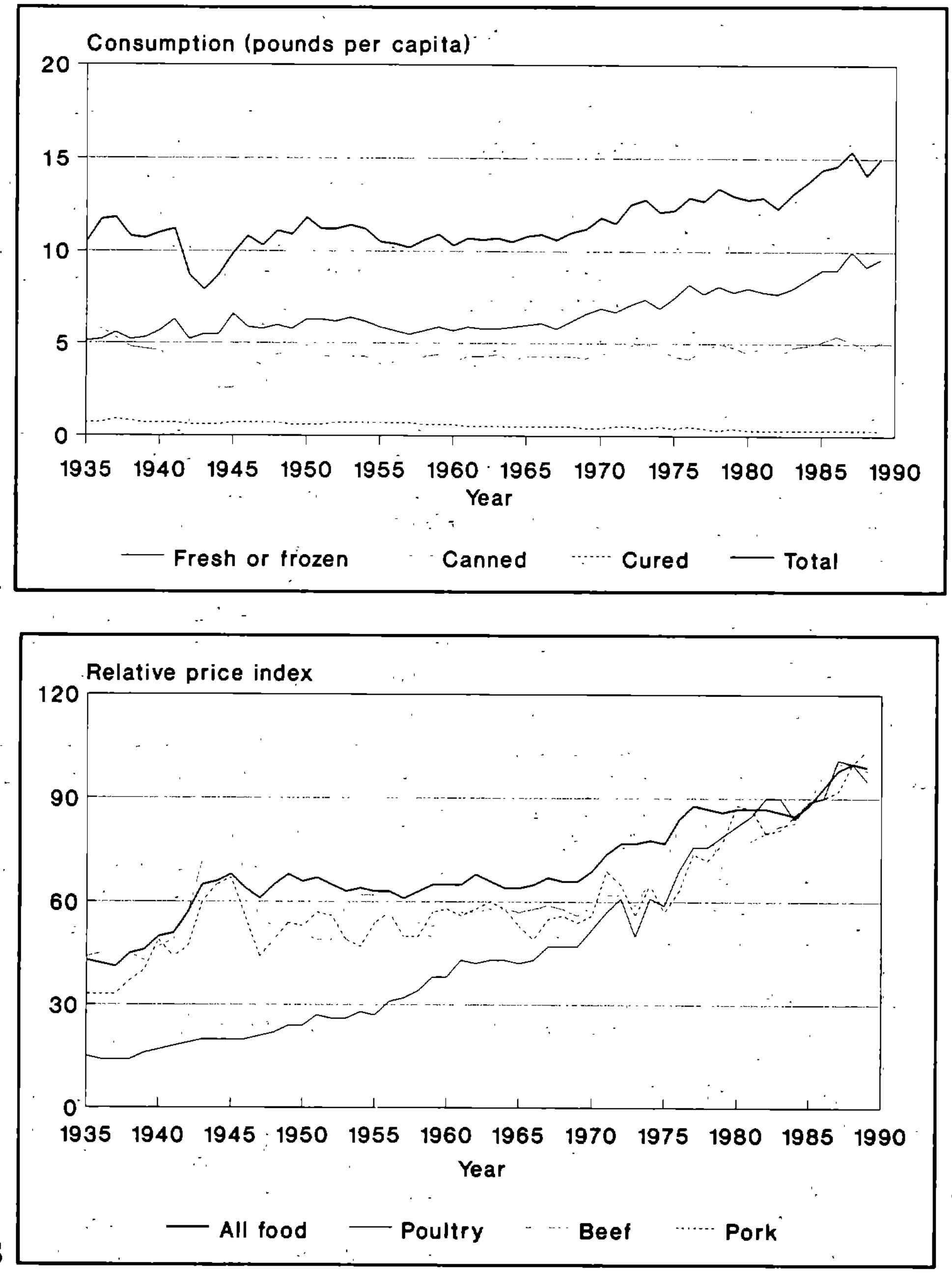

Figure 1. **Historical data on seafood demand:** (a) U.S. annual *per capita* consumption of commercial fish and shellfish (Fisheries Statistics Division, National Marine Fisheries Service 1989); and (b) relative prices (1988=100; Putnam 1989).

Graphs of the relative prices of seafood against total *per capita* consumption yield even more compelling insights into the possibility of preference change. In Figure 2, the jagged lines trace how seafood consumption and relative prices changed together over time. The last two digits of every fifth calendar year and the arrowheads mark the paths.

In Figure 2a, the price of seafood relative to *per capita* income is plotted against total annual *per capita* consumption. The influences of the Great Depression and World War II (WWII) are apparent from wide swings of *per capita* consumption during the late 1930s and the 1940s. Since the mid-1960s, however, *per capita* consumption generally increased, except during the late 1970s to early 1980s. Indeed, throughout the late 1960s, most of the 1970s, and the late 1980s, consumption increased despite increases in the price of seafood relative to income.

The mid-1960s and early 1980s also seemed to mark a change in the relationships between seafood consumption and the prices of seafood relative to other meats. In Figure 2b, the price of seafood relative to poultry is plotted against *per capita* consumption. During the 1950s and early 1960s consumption vacillated while the relative price of seafood increased, suggesting, perhaps, that consumers habitually ate seafood during particular days or holidays[7]. Subse-

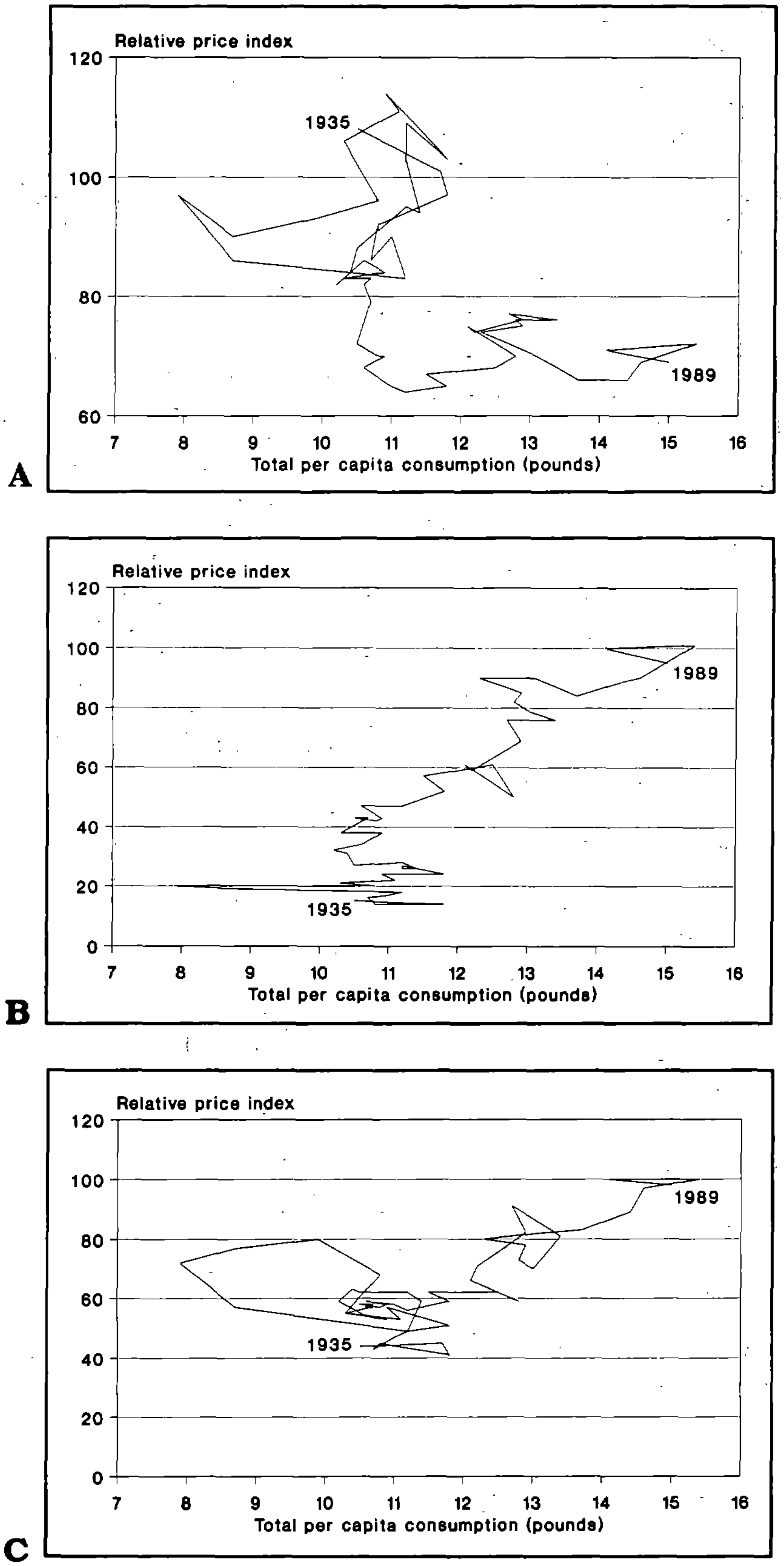

Figure 2. Historical relationships between annual *per capita* consumption of total seafood and the CPI of seafood relative to: (a) *per capita* income (x10,000); (b) the CPI of poultry (x100); and (c) the CPI of beef (x100).

quently, however, consumption increased despite continued increases in relative price, except between the late 1970s and early 1980s when consumption was somewhat stable.

The relationships between seafood consumption and the price of seafood relative to beef & veal (Figure 2c), to pork, and to "all foods" (available upon request) are similar to those for poultry.

TWO-PHASE REGRESSION

Although structural changes in preferences for seafood are apparent from Figure 2, additional insights can be gained by quantifying and testing for significance of the apparent trends. Accordingly, note that the trends in Figure 2 include upward-sloping portions that are punctuated by periods of relatively less change in annual *per capita* consumption prior to the mid-1960s and then again during the late 1970s to early 1980s. The functional form selected to test for evidence of structural changes in preferences for seafood should accommodate such "change-points."

I emphasized in the introduction that the consistently dubious estimates of the parameters of seafood demand models seem to preclude further use of structural models, such as the AIDS model, to test for evidence of structural changes in consumers' preferences for seafood when aggregate data are used. Consequently, I have chosen a reduced-form specification that can be understood in terms of the following conceptual model:

$$q_{d_t} = q_d(p_t, t, z_t)$$

$$q_{s_t} = q_s(p_t, t, w_t)$$

where q_{d_t} and q_{s_t} are *per capita* demand and supply, respectively, during time period t, and where p is price and z_t and w_t are exogenous determinants of demand and supply. The variables in this system could be partitioned to accommodate a system of substitutes (*e.g.*, seafood, poultry, beef). Also, Rausser *et al.* (1982) have already explained how the time period, t, can be specified to pick up changes in preferences over time[8].

In order for average *per capita* consumption to have any behavioral meaning, the conceptual model must be interpreted as aggregate demand and aggregate supply divided by population size[9]. Accordingly, the reduced-form models are:

$$q_t = q(t, z_t, w_t)$$

$$p_t = p(t, z_t, w_t).$$

Accordingly, neither own-price nor the prices of substitutes are part of the reduced-form specification of q_t.

A test of the significance of t is consistent with a test of possible structural changes in preferences for seafood. If preferences for seafood strengthened over time, then one should expect increases in t to be associated with increases in q_t and p_t in the reduced-form models (as well as in the elusive structural models)[10]. Thus, it has not been necessary to recover the underlying structural models to test for possible structural changes in preferences for seafood.

Based on this derivation (and the need for an alternative to structural models), the following general reduced-form specifications have been estimated:

$$q_{i,t} = q_{i,t}(t, z_t) \quad [i = 1,2,3] \tag{1a}$$

$$p_t = p_t(t, z_t) \tag{1b}$$

where $q_{i,t}$ is annual *per capita* consumption of the i[th] generic seafood product (*i.e.*, of fresh or frozen seafood, canned seafood, or cured seafood) in the U.S. during year t, p_t is the CPI of seafood relative to the CPI of all foods[11], and z_t is defined as above. Unfortunately, data on exogenous determinants of supply (*i.e.*, w_t) cannot be specified, but this is not unusual for economic studies of seafood markets[12]. For convenience, the subscript i has been omitted from the remainder of the report.

TWO-PHASE REGRESSION MODEL

Hinkley (1971) described a two-stage regression procedure that tests for the location of a structural change in a time-series process--*i.e.*, a change-point. When applied to this study, the empirical version of equations (1a) and (1b) become:

$$q_t = a_0 + a_1 t + a_2(t - d)D_{d(t)} + a_3 z_t + e_t \tag{2a}$$

$$p_t = b_0 + b_1 t + b_2(t - d)D_{d(t)} + b_3 z_t + n_t \tag{2b}$$

where a_j and b_k are parameters, e_t and n_t are residual processes, and d is a change-point in the relationships between t and q_t or between t and p_t, such that $D_{d(t)}$ equals 0 if t is less than or equal to d, and equals 1 if t is greater than d. The change may be either instantaneous or gradual, occurring over several years. If gradual, the model actually selects a point within the interval of change.

The nature of a change-point is clarified when equations (2a) and (2b) are decomposed into two phases:

$$q_t = \begin{cases} a_0 + a_1 t + a_3 z_t + e_t & [t = 1,\ldots,r] \quad (3a) \\ a_0' + a_1' t + a_3 z_t + e_t & [t = (r+1),\ldots,T] \quad (3a') \end{cases}$$

$$p_t = \begin{cases} b_0 + b_1 t + b_3 z_t + n_t & [t = 1,\ldots,r] \quad (3b) \\ b_0' + b_1' t + b_3 z_t + n_t & [t = (r+1),\ldots,T] \quad (3b') \end{cases}$$

where T is the terminal time period, and the change-point lies in the interval (r,r+1). Mathematically, the change-point is the time period when these lines intersect, *i.e.*, $d = (a_0 - a_0')/(a_1' - a_1)$ or $(b_0 - b_0')/(b_1' - b_1)$. In addition, $a_2 = a_1' - a_1$, and $b_2 = b_1' - b_1$.

A maximum likelihood procedure is used to search the interval (3,T-2) for the value of d which minimizes the model's residual sum of squares (see Solow 1987). Because the change-point is not selected a priori, "data dredging" is avoided[13].

For any value of the change-point, model (2) is a linear regression model with regressors t, $(t - d)D_{d(t)}$, and z_t. The parameters are estimated by fitting model (2) with the optimal value of d. Subsequently, a_1', a_0', b_1', and b_0' can be derived from these estimates.

The test of the null hypothesis of no change-point (against the two-sided alternative)--which is tantamount to testing whether there is no difference between the trend coefficients before and after the hypothesized change-point--uses the likelihood ratio statistic[14]:

$$U = [(S_0 - S)/3]/[S/(N - 4)]$$

where S_0 is the residual sum of squares from fitting the null models:

$$q_t = a_0 + a_1 t + a_3 z_t + e_t \qquad [t = 1,\ldots,T] \qquad (4a)$$

or

$$p_t = b_0 + b_1 t + b_3 z_t + n_t \qquad [t = 1,\ldots,T]. \qquad (4b)$$

Also, S is the residual sum of squares from fitting the alternative model at the optimal value of d, and N is the number of observations. When $U \geq F_{3,N-4,0.05(2)}$, the null hypothesis is rejected at the 95-percent level of significance. A significant change-point is consistent with a structural change in preferences for seafood.

Finally, the 95-percent confidence interval for the optimal change-point is the time period which satisfies

$$(S_a - S)/[S/(N - 4)] \leq F_{1,N-4,0.05(2)}$$

where S_a is the residual sum of squares from an alternative model with a non-optimal change-point. See Solow (1987) for a clear discussion of the two-phase regression model and its test statistics.

RESULTS

Model Specification and Data

Model (2) for the three generic types of seafood and the seafood CPI (relative to the CPI for all foods) has been estimated with the above two-phase regression procedure. In addition to t and $(t - d)D_{d(t)}$, each model has been specified as a function of real *per capita* income (nominal income divided by the CPI for all foods), M, which is representative of z in model (1)[15].

In addition, each model has been estimated from two ranges of the data. Range I encompasses the years 1935-88 (t = 1,...,54), including, therefore, the end of the Great Depression and WWII. Range II encompasses the years 1958-88 (t = 1,...,31). Range II has been selected because it corresponds to data bases used to model derived demand at the harvesting level (*e.g.*, Bell 1968; Felixson *et al.* 1987), and, therefore, should be most relevant to fishery economists.

As noted in Figure 1, data on *per capita* consumption of seafood have been reported by the Fisheries Statistics Division, National Marine Fisheries Service (1989). Also, *per capita* income and the CPIs for seafood and for all foods have been provided by the U.S. Bureau of Labor Statistics (Putnam 1989).

Regression Models

The regression results are reported in Table 1. SHAZAM's procedure to adjust automatically the covariance matrix for unknown sources of heteroskedasticity has been used to estimate these models (White 1987).

First consider the results from modeling *per capita* consumption of fresh or frozen seafood. Although the linear time trends are insignificant (95-percent level of confidence), the change-point results are positive and significantly different from zero in both ranges of data. The year 1967 corresponds to the change-point in both models.

The residual sum of squares from estimating the model for fresh or frozen seafood from data in range II is presented in Figure 3a. The 95-percent confidence interval around the optimal change-point is from 1962 to 1970. However, the local minimum corresponding to the year 1983 is also important because it is virtually identical to the "global" minimum. Also, it coincides with when the health benefits of omega-3 fatty acids from seafood began to be widely publicized by the popular press as well as by physicians[16].

Although the estimated coefficients on *per capita* income, M, are positive in both models of consumption of fresh or frozen seafood, the estimates are not robust. This appears to be due in large part to the high correlation (0.97) between t and M[17]. Nevertheless, the effect of income on consumption of seafood also is ambiguous. For example, both Bockstael (1976) and Crutchfield (1985) reported *per capita* income to be a significant determinant of the aggregate demand for **fresh** groundfish in retail markets, but it was not a significant determinant of the demand for **frozen** groundfish products in their studies. This result is important to my study because frozen seafood constitutes about 60-70 percent of total fresh or frozen seafood products. Cheng and Capps (1988) also reported mixed results of how income affected a household's expenditures on seafood. In their microeconomic study, household income was a significant determinant of expenditures on crabs, oysters, and total finfish (they used the 90-percent level of confidence). How-

Table 1. Regression results for *per capita* consumption of fresh or frozen seafood, canned seafood, and cured seafood, and for seafood price, over two ranges of years: 1935-88 and 1958-88

Range (N)	Coefficient Estimates (t-Statistic) R^2	Intercept	t	$(t\text{-}d)D_{d(t)}$	M	Change-Points Optimal (95% CI)	U	Local Minimum
				Fresh or Frozen Seafood				
1935-88 (54)	0.91	5.073 (12.85)	0.004 (0.25)	0.126 (10.04)	0.010 (1.04)	1967 (1963-69)	26.22[a]	-
1958-88 (31)	0.94	3.526 (3.53)	-0.047 (-1.00)	0.140 (4.53)	0.031 (2.13)	1966 (1962-70)	4.36[a]	1982
				Canned Seafood				
1935-88 (54)	0.61	7.307 (10.70)	-0.180 (-3.71)	0.277 (4.96)	-0.038 (-3.23)	1943 (1942-44)	16.74[a]	-
1958-88 (31)	0.61	2.425 (2.83)	-0.064 (-1.78)	0.052 (2.34)	0.026 (2.14)	1967 NS[b]	1.32	-
				Cured Seafood				
1935-88 (54)	0.87	0.832 (8.96)	-0.002 (-1.05)	-0.005 (-1.71)	-0.002 (-1.26)	1955 NS[b]	1.49	-
1958-88 (31)	0.82	0.477 (3.37)	-0.034 (-4.09)	0.020 (3.04)	0.002 (1.21)	1961 NS[b]	0.64	-
				Seafood Price				
1935-88 (54)	0.87	44.916 (7.06)	0.397 (1.77)	0.694 (3.57)	0.126 (0.91)	1969 (1963-76)	3.74[a]	1944
1958-88 (31)	0.94	72.933 (8.45)	0.462 (1.22)	1.183 (4.58)	-0.121 (-0.98)	1966 (1962-70)	3.60[a]	1985[c]

[a] Significant at the 95-percent level of confidence (*i.e.*, $U > F_{3,N-4,0.05(2)}$).
[b] NS - not significant.
[c] The residual sums of squares for the optimal and local minima were virtually identical.

ever, in the same study, income was not a significant determinant of expenditures on shrimp, total shellfish, and, curiously, any finfish product when examined separately (cod, flounder, haddock, perch, snapper).

The regression models for canned seafood are noticeably different from the models for fresh or frozen seafood. First, the coefficients on t are negative and significant in both ranges, although the high degree of collinearity between t and M should still be kept in mind. The positive and significant change-point within range I probably shows the impact of WWII on production and trade, not preferences. Finally, the change-point during range II is positive and identical to that for fresh or frozen seafood, but it is insignificant judging from the test on the likelihood ratio statistic, U[18].

Turning to consumption of cured seafood, a negative trend in consumption may have been picked up by the regression model; however, no significant change-point is apparent. These results are not surprising given the apparently linear, negative trend in *per capita* consumption of cured seafood (Figure 1a).

Finally, the qualitative results from modeling the relative price of seafood are very similar to the models for fresh or frozen seafood, as one would expect, because the majority of seafood is marketed in these forms. Once again, it is difficult to draw firm conclusions from the empirical estimates of the coefficients on t because of the collinearity with M. However, the optimal change-points are virtually the same as for consumption of fresh or frozen seafood (Figure 3b). In addition, a local minimum appears during WWII in

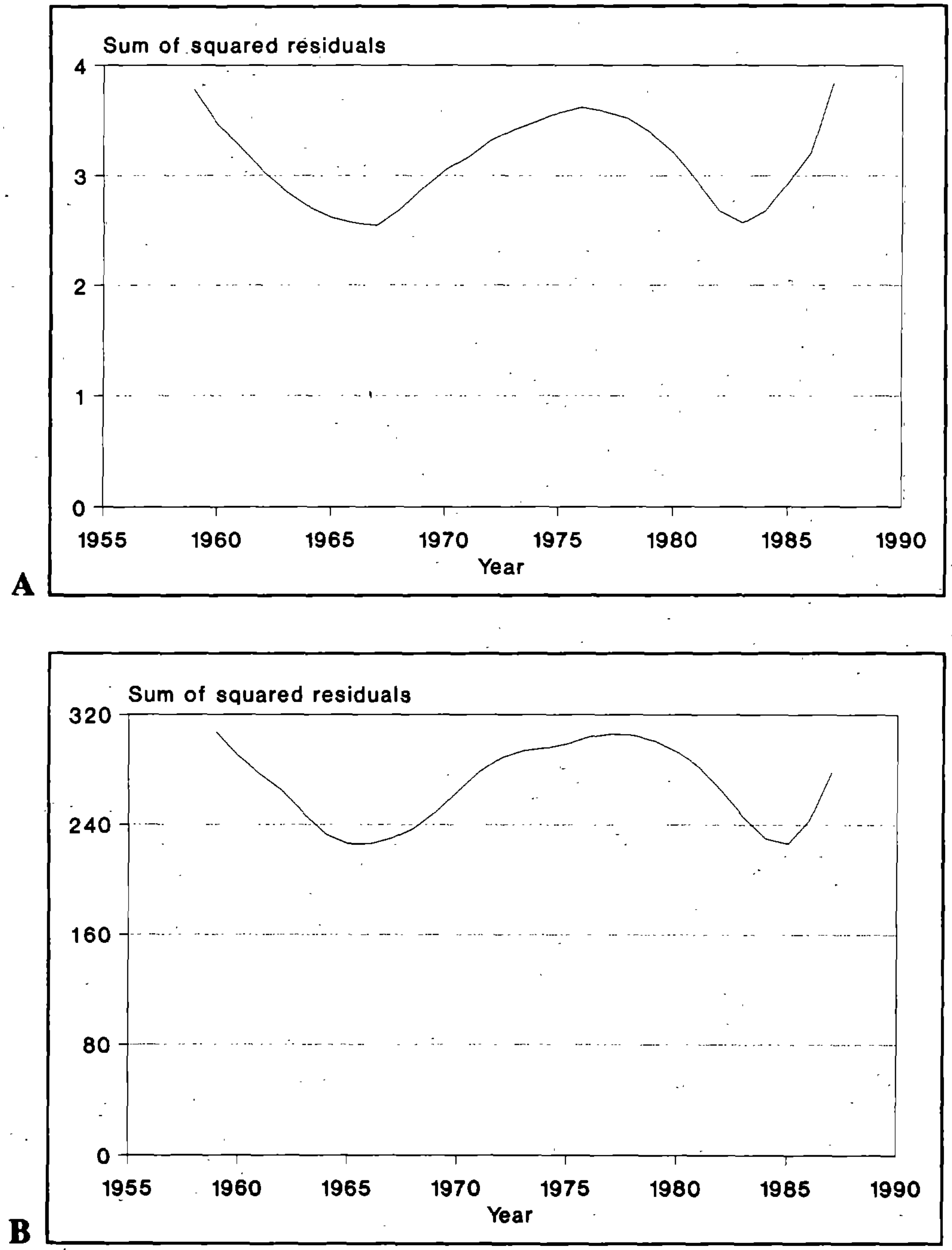

Figure 3. Residual sum of squares from regressions of: (a) *per capita* consumption of fresh or frozen seafood; and (b) price during the years 1958-88.

the data from range I. The local minimum from range II is 1984, although the value of the residual sum of squares is virtually identical to that for the optimal change-point.

IMPLICATIONS

The evidence of structural changes in preferences for seafood--particularly fresh or frozen seafood--has implications for fishery research and management. Three implications are highlighted here.

Although time-series data on retail sales of particular species to consumers do not exist, ignoring strengthened preferences for fresh or frozen seafood products could lead to biased estimation of derived demand models in landings markets. To see this, let the short run ex-vessel demand model be:

$$p_{ex_t} = b_t x_t$$

where p_{ex_t} is ex-vessel price during time period t, x_t is a matrix of regressors, including determinants of consumer demand, and b_t is a matrix of parameters, the values of which vary across time periods[19]. If, instead, derived demand is estimated with a **constant**-parameter model,

$$p_{ex_t} = b_c x_t,$$

then the estimates of the true parameters, b_t, will be biased. Specifically, estimates of the constant-parameter vector, b_c, will be the weighted average of the individual b_t (Rausser *et al.* 1982). Thus, with increasing preferences for seafood, a constant-parameter model would underestimate quantity demanded at all prices, including forecasts of demand[20].

A second, related implication concerns benefit estimation. If overlooking stronger preferences for seafood leads to underestimates of current and future demand, then it follows that changes in surplus benefits for consumers and the seafood sector will be underestimated, too, if a constant-parameter model is specified[21]. Furthermore, in the context of benefit-cost analyses of fishery management plans which are intended to protect or rebuild fish stocks, or, of increasing importance, to allocate fish among commercial and recreational fishermen, the degree of underestimation will worsen to the extent that future shifts in demand due to structural changes in preferences for seafood are not forecasted.

Finally, a host of issues concerns the prospect of even greater fishing effort on stocks of marine fish and shellfish, many of which are already subjected to growth overfishing and even recruitment overfishing[22]. Depending on the degree of monopsonistic power in landings markets and on future supplies from trade and aquaculture, increases in retail prices could bring the fishing industry higher ex-vessel prices, causing effort to increase in the longer run. This was illustrated in dramatic fashion recently in the red drum fishery in the Gulf of Mexico following rapid acceptance of blackened redfish by consumers, but the same communication between retail and landings markets probably functions in other fisheries too.

If recent history portends future events, continued growth in preferences for fresh or frozen seafood will further increase fishing effort on already overfished stocks in order to satisfy Americans' growing appetite for fish. And with the continuation of virtual open-access conditions in the majority of U.S. fisheries, of ineffective controls on effort and harvest, and of average or less-than-average stock recruitment, increased fishing effort will, in turn, further lower the yield of fish resources and, in a negative feedback, decrease the net benefits that the nation derives from its publicly owned fish stocks.

The public sector's role in resolving multiple-use conflicts should not be overlooked either. Conflicts among incompatible fishing practices and between commercial fishing and both sport fishing and marine mammal protection should grow in direct proportion to increased preferences for seafood and higher ex-vessel prices. Many current events seem to support this statement. For example, in New England, the use of otter trawls to catch lobsters in traditional pot fisheries is steadily increasing. Concerning conflicts with sport fishing, the regional fishery management councils in the eastern United States recently conferred virtual gamefish status on billfish in order to eliminate the small but growing commercial fishery (South Atlantic Fishery Management Council 1988). Ongoing efforts to sequester other gamefish species such as bluefish and sharks are being justified, in part, on similar grounds. Finally, the incidental killing of turtles, dolphins, whales, and seals trapped in fishing gear, such as gillnets and purse seines, more and more elicits a storm of protest from proponents of marine mammal protection.

SUMMARY AND CONCLUSIONS

The Graphical Analysis section provides strong evidence of structural changes in preferences for seafood, probably in response to medical evidence about both the nutritional value of fish and shellfish and the health benefits of omega-3 fatty acids. *Per capita* consumption of seafood has increased since the early 1960s despite concurrent increases in the relative prices of seafood. Also, the mid-1960s and early 1980s appear to mark periods of accelerated change.

Attempts to quantify and test apparent trends in seafood consumption yielded mixed results. Severe collinearity between *per capita* income and the time period undermined most tests of a linear time trend in *per capita* consumption and price. However, the robust change-point results in the reduced-form models for price and consumption of fresh or frozen seafood suggest that preferences accelerated during the mid-1960s and early 1980s. I do not know why similar change-points were not identified for consumption of canned seafood, although it may be due to the fact that most consumption of seafood still takes place in restaurants and other types of eateries where canned fish and shellfish generally are not sold. Also, the absence of a **negative** change-point for salted, smoked, and other types of cured fish would have been consistent with concerns about nutrition and health. Nevertheless, the steady decline in *per capita* consumption of cured seafood since 1935 has at least been reflected by the negative coefficient on the linear time trend.

It is also interesting to note that the change-points identified for fresh or frozen seafood and for price match times of structural change in demands reported for red meats and poultry (Chavas 1983; Choi and Sosin 1990; Dahlgran 1987; Eales and Unnevehr 1988; Goodwin 1989; Moschini and Meilke 1989; Nyankori and Miller 1982; Purcell 1989; Thurman 1987). Thus, my study helps to complete the general picture of how consumers have responded to nutrition and health messages from the medical profession.

Stronger consumer preferences for fresh or frozen seafood have important implications for economic research and fishery management. Fishery economists should begin to test variable-parameter structures in derived, ex-vessel demand models in order to control for possible preference change among consumers. Otherwise, we will continue to risk estimating biased models and underestimating welfare. In addition, fishery managers are well-advised to anticipate both greater fishing effort on already overfished stocks and an era of allocating stocks among commercial fishing, sport fishing, and marine mammal protection. Indeed, the national advertising campaign to induce consumers to "eat fish and seafood twice a week" and proposed federal legislation for seafood inspection should further stimulate preferences and exacerbate management.

NOTES

1. Respondents to Jones and Weimer's (1981) survey of the American diet reported the following net changes in meat consumption during the late 1970s: (a) a 15-percent and 3-percent increase in consumption of fish and shellfish, respectively; (b) a 16-percent increase in consumption of poultry; (c) a 14-percent decrease in consumption of beef; (d) a 14-percent decrease in consumption of fresh pork; and (e) a 21-percent decrease in consumption of bacon and sausage. These changes were attributed to concerns about nutrition and health.

2. Often, seafood demand is either omitted from a system of structural equations, such as the almost-ideal-demand system, (e.g., Choi and Sosin 1990), or is lumped in with all other foods (e.g., Chavas 1983; Eales and Unnevehr 1988).

3. Purcell (1989) used only a graphical analysis of time-series data to show that preferences for beef declined during at least the first half of the 1980s. This conclusion conflicts with results reached from AIDS models (*e.g.*, Wohlgenant 1985) and from nonparametric studies of expenditures (Chalfant and Alston 1988). Yet, Purcell (1989) is adamant when he scolds economists about "...looking at the data again. ...[W]e have to get reacquainted with theoretical and conceptual rigor in dealing with phenomena we cannot effectively quantify. And we need to stop substituting technique for thinking." (p. 19).

4. These seafood consumption data are for edible meat from domestically-caught and imported fish and shellfish entering U.S. markets (Fisheries Statistics Division, National Marine Fisheries Service 1989). They are adjusted for beginning and ending inventories and trade, but they exclude unknown consumption of sport-caught fish, negligible amounts of cultured catfish prior to 1973, and recent surimi production. For comparison, Icelanders and Japanese consume four-to-five-times more fish than Americans currently consume (Fisheries Statistics Division, National Marine Fisheries Service 1989). Also for comparison, annual *per capita* consumption of poultry and red meat in the United States in 1988 was 57.3 and 114.8 pounds (boneless-equivalent weights), respectively (Putnam 1989). The discussion is limited to the post-1935 period for comparison with relative prices. In addition, *per capita* consumption prior to the 1930s is only approximated by the National Marine Fisheries Service.

5. The CPI for seafood includes prices of a wide variety of fresh, frozen, canned, and cured products. I have used the CPI for total seafood because separate indices for canned seafood and for fresh and frozen seafood were not reported until 1978.

6. The prices of seafood relative to pork and to all foods are not shown because they closely overlap that for beef and veal.

7. For example, prior to 1967, Catholics were forbidden from eating meat on non-Lent Fridays (Bell 1968).

8. In the Implications section, I briefly convey Rausser *et al.*'s (1982) explanation for how the time period can be used in a variable-parameter specification to test for structural changes in preferences. Nevertheless, you should consult their survey and synthesis for details on how to model structural change.

9. I should at least acknowledge that this behavioral interpretation raises the specter of heterogeneous preferences and a censored population of seafood consumers. These have implications for estimating models based on average, or *per capita*, consumption. However, I wish to point out that the many published studies of AIDS models in the food-demand literature suffer the same deficiencies. These issues should be researched in the near future. For example, see Maddala (1984) for a discussion of estimation procedures for censored data.

10. The following exercise illustrates my point. Let the structural demand model be

$$Q = a(t) - b(t)P + c(t)M$$

$$= at - (b/t)P + ctM$$

and the structural supply model be

$$Q = e + fP - gW$$

where t is the time period, the other lower case letters are parameters (those in the demand model are variable parameters which are a function of time), Q is quantity, P is price, M is income, and W is input price for the retailers. The variable-parameter structure of the demand model is arbitrary, but it suits our purpose. [See Rausser *et al.* (1982) for how variable-parameter specifications are routinely used to model structural change.] Consider it a linear approximation of a demand model derived from a utility function with preferences indicated and aggregated over consumers. With the passage of time, quantity demanded increases.

The reduced-form equations can be determined by setting demand equal to supply, solving for P*, and then substituting the solution for P* into the demand model in order to solve for Q*:

$$P^* = [(at + ctM) - (e - gW)]/[f + (b/t)]$$

$$Q^* = (at + ctM)\{1 - [b/(tf + b)]\} + b[(e - gW)/(tf + b)]$$

First consider P*. The term (at + ctM) must be positive in order for quantity demanded to be positive, and the numerator must be positive [*i.e.*, (at + ctM) > (e - gW)] in order for demand and supply to intersect. Thus, as t increases, P* increases--just what one should expect if preferences strengthened.

What happens to Q* as t increases can be seen by taking its limit as t goes to infinity. Accordingly, the last term goes to zero, the second multiplicand of the first term goes to 1, and the first multiplicand of the first term goes to infinity. Thus, Q* increases with time--again, what one should expect if preferences strengthened.

Because I do not presume to know the utility and production functions that underlay the structural model, it is important for me to emphasize that what I estimated are linear approximations to unknown reduced-form models. Nevertheless, positive coefficients on the time trends in my models are consistent with the above results. Thus, it is unnecessary to try to recover any structural coefficients or to know elasticities of demand to test for evidence of preference change.

11. Implicit here is the assumption that food comprises a subutility function in a multistage budgeting process. This is a common assumption in the food-demand literature (*e.g.*, Choi and Sosin 1990). Also, strictly speaking, seafood should have been excluded from the CPI for all foods when the relative price of seafood was calculated. However, because seafood is such a negligible part of total food expenditures, this adjustment was not made.

12. For example, when estimating structural models of specific seafood markets (*e.g.*, groundfish in New England), researchers have had to specify price linkages between market levels instead of retail supply relationships (*e.g.*, Bockstael 1976; Crutchfield 1985; Felixson *et al.* 1987).

13. Solow (1987) shows that such data dredging results in a threefold increase in the test statistic.

14. Solow (1987) explains that the t-test on a_2 or b_2 should not be used to test for a change-point because estimates of these parameters are positively biased.

15. None of the determinants of individual household expenditures on seafood reported by Cheng and Capps (1988)--race, coupon value, household size, geographic region, urbanization, and seasonality--were specified in my analysis. Except for racial composition, these factors are not congruous to a time-series analysis of nationwide aggregate consumption patterns. When racial composition was added to the models reported in Table 1, the change-point results did not change appreciably, but the severe multicollinearity among it, the time period, and *per capita* income became apparent from changes in coefficient estimates on these regressors. Regardless, although according to Cheng and Capps (1988) nonwhites spend about eight percent more than whites on seafood, the small increase in the relative size of the non-white population during the study period--about five percent--combined with this difference in expenditures falls far short of accounting for the 50-percent increase in *per capita* consumption.

    I considered two other demographic trends. Even if coastal residents eat more seafood, the tiny increase in the relative size of the coastal population from 52 to 53 percent since 1960 could not account for much of the observed increase in seafood consumption. Finally, the interrelated trends of more women in the workforce and eating away from home more often could not account for increased *per capita* consumption of seafood at higher relative prices.

16. Seeing two minima as in Figure 3a may suggest to you that a three-phase regression procedure would be appropriate. However, choosing a three-phase model **after** having seen the results from the two-phase analysis is data dredging too (Solow 1987). Consequently, I kept to the two-phase models, understanding that the local minima may, in fact, be statistically significant as well as noteworthy.

17. A comparison of the results from estimating models with only t and $(t - d)D_{d(t)}$ with the results reported in Table 1 underscored the severe collinearity between t and M. In each "pure" time-series model, the coefficients on t were positive and significant. However, the change-point results (*i.e.*, estimates of a_2, b_2, and d) were very stable regardless of specification or range of data. The additional models are available upon request.

18. The apparent contradiction between the likelihood ratio test on U and the t-test on a_2 in this model and in the regression for cured seafood from data in range II is probably due to the positive bias in a_2. See Solow (1987).

19. Most ex-vessel demand models are estimated with monthly or seasonal data. Within these time frames, landings are usually assumed to be independent of ex-vessel price. This assumption would not be valid, though, over the longer run as prices and stock abundance change.

20. See Rausser *et al.* (1982) for a summary of the literature on how to model structural changes in consumer preferences (and production technology), and for a synthesis of the various types of variable-parameter structures.

21. If properly specified, an ex-vessel demand model would capture consumer surplus and all producer surpluses in the seafood sector except for harvesters. See chapter 6 in Just *et al.* (1982) for the theory of welfare estimation with general equilibrium models.

22. In the Northwest Atlantic Ocean, fishing effort on groundfish species long favored by consumers (*e.g.*, cod, halibut, flounders) increased recently despite decreases in stock abundance and reduced catch per unit of effort (Conservation & Utilization Division, Northeast Fisheries Center 1988).

ACKNOWLEDGMENTS

Phil Logan, David Terkla, Stanley Wang, Andrew Solow, and Richard Raulerson made helpful comments. The two anonymous reviewers helped me clarify several points of confusion.

REFERENCES CITED

Bell, F.W. 1968. The Pope and the price of fish. *Amer. Econ. Rev.* 58: 1346-1350.

Bockstael, N.E. 1976. Analysis of investment behavior and price analytical input for the formation of policy in the fisheries. Ph.D. Dissertation. University of Rhode Island, Kingston, R.I. 159 pp.

Chalfant, J.A., and J.M. Alston. 1988. Accounting for changes in tastes. *J. Polit. Econ.* 96: 391-410.

Chavas, J-P. 1983. Structural change in the demand for meat. *Amer. J. Agr. Econ.* 65: 148-153.

Cheng, H-T., and O. Capps, Jr. 1988. Demand analysis of fresh and frozen finfish and shellfish in the United States. *Amer. J. Agr. Econ.* 70: 533-542.

Choi, S., and K. Sosin. 1990. Testing for structural change: the demand for meat. *Amer. J. Agr. Econ.* 72: 227-236.

Clancy, K.L. 1986. Overview of current food safety and quality issues and policies. Pages 1-26 in K.L. Clancy, ed. Consumer demands in the market place: public policies related to food safety, quality, and human health. Resources for the Future, Inc., Washington, D.C.

Conservation & Utilization Division, Northeast Fisheries Center. 1988. Status of the fishery resources off the northeastern United States for 1988. *NOAA* [Nat. Ocean. Atmos. Admin.] *Tech. Mem. NMFS* [Nat. Mar. Fish. Serv.]-*F/NEC*-50. 132 pp.

Crutchfield, S.R. 1985. An econometric model of the market for New England groundfish. *Northeast. J. Agr. Resour. Econ.* 14: 128-143.

Dahlgran, R.A. 1987. Complete flexibility systems and the stationarity of U.S. meat demands. *West. J. Agr. Econ.* 12: 152-163.

Eales, J.S., and L.J. Unnevehr. 1988. Demand for beef and chicken products: separability and structural change. *Amer. J. Agr. Econ.* 70: 521-532.

Felixson, T., P.G. Allen, and D.A. Storey. 1987. An econometric model of the market for fresh New England groundfish with emphasis on the role of Canadian imports. *Northeast. J. Agr. Resour. Econ.* 16: 24-34.

Fisheries Statistics Division, National Marine Fisheries Service. 1989. Fisheries of the United States, 1987. *Nat. Mar. Fish. Serv. Curr. Fish. Stat.* No. 8700. pp.

Goodwin, B.K. 1989. Multivariate gradual switching systems and the stability of U.S. meat demands: a Bayesian analysis. *Kan. St. Univ. Dept. of Agr. Econ. Contrib.* No. 90-18-D. 24 pp.

Hinkley, D.V. 1971. Inference in two-phase regression. *J. Amer. Stat. Assoc.* 66: 736-743.

Huang, K.S. 1988. An inverse demand system for U.S. composite foods. *Amer. J. Agr. Econ.* 70: 903-909.

Jones, J.L., and J. Weimer. 1981. Health-related food choices. *Fam. Econ. Rev.* 1981: 16-19.

Just, R.E., D.L. Hueth, and A. Schmitz. 1982. Applied welfare economics and public policy. Prentice Hall, Inc., Englewood Cliffs, N.J. 491 pp.

Lees, R.S. 1988. The impact of dietary fat on human health. *Mass. Inst. Technol. Sea Grant Rep.* MITSG 88-3. 28 pp.

Maddala, G.S. 1984. Limited-dependent and qualitative variables in econometrics. Cambridge University Press, New York. 401 pp.

Moschini, G., and K.D. Meilke. 1989. Modeling the pattern of structural change in U.S. meat demand. *Amer. J. Agr. Econ.* 71: 253-261.

Nyankori, J.C.O., and G.H. Miller. 1982. Some evidence of implications of structural changes in retail demand for meats. *Amer. J. Agr. Econ.* 14: 65-70.

Pope, R., R. Green, and J. Eales. 1980. Testing for homogeneity and habit formation in a flexible demand specification of U.S. meat consumption. *Amer. J. Agr. Econ.* 62: 778-784.

Purcell, W.D. 1989. The case of beef demand: a failure by the discipline. *Choices* 1989(2): 16-19.

Putnam, J.J. 1989. Food consumption, prices, and expenditures, 1966-1987. *U.S. Dept. Agr. Econ. Res. Serv. Stat. Bull.* No. 773. 111 pp. [Other publications in the series also.]

Rausser, G.C., Y. Mundlak, and S.R. Johnson. 1982. Structural change, updating, and forecasting. Chapter 20 (pages 659-717) in G.C. Rausser, ed. New directions in econometric modeling and forecasting in U.S. agriculture. North Holland Publishing Co., New York.

South Atlantic Fishery Management Council. 1988. Fishery management plan, final environmental impact statement, regulatory impact review, and initial regulatory flexibility analysis for the Atlantic billfishes. South Atlantic Fishery Management Council, Charleston, S.C. 149 pp.

Solow, A.R. 1987. Testing for climate change: an application of the two-phase regression model. *J. Climat. Appl. Meteorol.* 26: 1401-1405.

Thurman, W.N. 1987. The poultry market: demand stability and industry structure. *Amer. J. Agr. Econ.* 69: 30-37.

White, K.J. 1987. SHAZAM: a general computer program for econometric methods (version 5). *Amer. Stat.* 41: 80.

Wohlgenant, M.K. 1985. Estimating cross elasticities of demand for beef. *West. J. Agr. Econ.* 10: 322-329.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1992--600-031--60003

(continued from inside front cover)

68. **MARMAP Surveys of the Continental Shelf from Cape Hatteras, North Carolina, to Cape Sable, Nova Scotia (1984-87). Atlas No. 3. Summary of Operations.** By John D. Sibunka and Myron J. Silverman. July 1989. iv + 197 p., 36 figs., 2 tables. NTIS Access. No. PB90-160656/AS.

69. **The 1988 Experimental Whiting Fishery: A NMFS/Industry Cooperative Program.** By Frank P. Almeida, Thurston S. Burns, and Sukwoo Chang. August 1989. v + 16 p., 9 figs., 11 tables, 1 app. NTIS Access. No. PB90-160664/AS.

70. **Summer Distribution of Regulated Species on Georges Bank with Reference to the 1988 Experimental Whiting Fishery.** By Frank P. Almeida, Sukwoo Chang, and Thurston S. Burns. September 1989. v+ 25 p., 74 figs., 1 table. NTIS Access. No. PB90-206525/AS.

71. **Allocation of Statewide-Reported MRFSS Catch and Landings Statistics between Areas: Application to Winter Flounder.** By Frank P. Almeida. September 1989. v + 18 p., 5 figs., 6 tables, 2 app. NTIS Access. No. PB90-246745.

72. **Status of the Fishery Resources off the Northeastern United States for 1989.** By Conservation and Utilization Division, Northeast Fisheries Center. December 1989. iv + 110 p., 50 figs., 93 tables. NTIS Access. No. PB90-170622/AS.

73. **Surface and Bottom Temperature Distribution for the Northeast Continental Shelf.** By David G. Mountain and Tamara J. Holzwarth. December 1989. iii + 32 p., 31 figs. NTIS Access. No. PB90-252172/AS.

74. **Shell Disease of Crustaceans in the New York Bight.** By C.J. Sindermann (chair.), F. Csulak (EPA coord.), T.K. Sawyer (rapp.), R.A. Bullis, D.W. Engel, B.T. Estrella, E.J. Noga, J.B. Pearce, J.C. Rugg, R. Runyon, J.A. Tiedemann, and R.R. Young. December 1989. vii + 47 p., 7 figs., 4 tables, 4 app. NTIS Access. No. PB90-195058/AS.

75. **An Indexed Bibliography of Northeast Fisheries Center Publications and Reports for 1988.** By Jon A. Gibson. December 1989. iii + 32 p. NTIS Access. No. PB91-112912.

76. **Finfish Maturity Sampling and Classification Schemes Used during Northeast Fisheries Center Bottom Trawl Surveys, 1963-89.** By Jay Burnett, Loretta O'Brien, Ralph K. Mayo, Jeffrey A. Darde, and Margot L. Bohan. December 1989. iii+14 p., 11 tables, 1 app. NTIS Access. No. PB91-128389/AS.

77. **Shell Disease among Red Crabs Inhabiting Submarine Canyons of the New York Bight.** By Randall R. Young. December 1989. iii+9 p., 18 figs., 5 tables. NTIS Access. No. PB90-194762/AS.

78. **Seasonal Distribution Patterns of Commercial Landings of 45 Species off the Northeastern United States during 1977-88.** By Sukwoo Chang. October 1990. v+130 p., 246 figs. NTIS Access. No. PB91-160846.

79. **Contaminants in Sediment and Fish Tissue from Estuarine and Coastal Sites of the Northeastern United States: Data Summary for the Baseline Phase of the National Status and Trends Program Benthic Surveillance Project, 1984-1986.** By Vincent S. Zdanowicz and Donald F. Gadbois. December 1990. x + 138p., 67 figs., 21 tables. NTIS Access. No. PB92-147453/AS.

80. **Distribution of Sexually Immature Components of 10 Northwest Atlantic Groundfish Species Based on Northeast Fisheries Center Bottom Trawl Surveys, 1968-86.** By Susan E. Wigley and Wendy L. Gabriel. January 1991. iv + 17 p., 23 figs., 3 tables. NTIS Access. No. PB92-101617.

81. **Status of the Fishery Resources Off the Northeastern United States for 1990.** By Conservation and Utilization Division, Northeast Fisheries Center. January 1991. iv + 130 p., 50 figs., 82 tables. NTIS Access. No. PB91-213785.

82. **Response of the Habitat and Biota of the Inner New York Bight to Abatement of Sewage Sludge Dumping: Third Annual Progress Report--1989.** By Anne L. Studholme, Merton C. Ingham, and Anthony Pacheco, eds. February 1991. vi + 57 p., 74 figs., 20 tables, 1 app. NTIS Access. No. PB91-208199.