Northeast Fisheries Science Center Reference Document 96-05e

Influence of Temperature and Depth on Distribution and Catches of Yellowtail Flounder, Atlantic Cod, and Haddock in NEFSC Bottom Trawl Surveys

by

Thomas E. Helser and Jon K.T. Brodziak

June 1996

Northeast Fisheries Science Center Reference Document 96-05e

A Report of the 21st Northeast Regional Stock Assessment Workshop

Influence of Temperature and Depth on Distribution and Catches of Yellowtail Flounder, Atlantic Cod, and Haddock in NEFSC Bottom Trawl Surveys

by

Thomas E. Helser[1] and Jon K.T. Brodziak[2]

[1]*National Marine Fisheries Serv., Highlands, NJ 07732*

[2]*National Marine Fisheries Serv., Newport, OR 97365*

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

June 1996

The *Northeast Fisheries Science Center Reference Document* series comprises informal reports produced by the Center for timely transmission of results obtained through work at various Center laboratories. The reports are reviewed internally before publication, but are not considered formal literature. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these reports. To obtain additional copies of this report, contact: Research Communications Unit, Northeast Fisheries Science Center, Woods Hole, MA 02543-1026 (508-548-5123 x 260).

This report may be cited as: Helser, T.E.; Brodziak, J.K.T. 1996. Influence of temperature and depth on distribution and catches of yellowtail flounder, Atlantic cod, and haddock in NEFSC bottom trawl surveys. *Northeast Fish. Sci. Cent. Ref. Doc.* 96-05e; 24 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

This report is a product of the 21st Northeast Regional Stock Assessment Workshop (21st SAW). Proceedings and products of the 21st SAW are scheduled to be documented and released as subissues (denoted by a lower case letter) of *Northeast Fisheries Science Center Reference Document* 96-05 (*e.g.*, 96-05a) . Tentative titles for the 21st SAW are:

An index-based assessment of winter flounder populations in the Gulf of Maine

Assessment of winter flounder in Southern New England and the Mid-Atlantic

Influence of temperature and depth on distribution and catches of yellowtail flounder, Atlantic cod, and haddock in NEFSC bottom trawl surveys

Predicting spawning stock biomass for Georges Bank and Gulf of Maine Atlantic cod stocks with research vessel survey data

Preliminary results of a spatial analysis of haddock distribution applying a generalized additive model

Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW): Public Review Workshop

Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments

Stock assessment of northern shortfin squid in the Northwest Atlantic during 1993

The Lorenz curve method applied to NEFSC bottom trawl survey data

Influence of Temperature and Depth on the Distribution and Catches of Yellowtail Flounder, Atlantic Cod, and Haddock in NEFSC Bottom Trawl Surveys

Table of Contents

List of Tables

List of Figures

Introduction

The continental shelf of the Northwest Atlantic is a heterogeneous land mass broken by numerous banks, basins, canyons and ledges. The hydrography overlying the shelf of this region is complex due to interactions between the bottom topography and mixture of water masses of varying temperature and density. A shelf/slope water front is a permanent thermal structure, continuous at about the 100 m contour, along the entire shelf break from the Middle Atlantic Bight to Nova Scotia (Butman and Beardsley 1987). Along with other local features including substrate type and prey, temperature and depth are recognized to be important ecological determinants of fish distribution (Mahon and Smith 1989, Gabriel 1992). Off the northeast coast of North America the distribution of many demersal fishes has been correlated with bottom temperature and depth (Overholtz and Tyler 1985, Mahon 1985, Murawski and Finn 1988, Perry and Smith 1994). Furthermore, particular groups or assemblages of species have a tendency to co-occur, or exhibit a "preference" for particular habitat types (Murawski and Finn 1988, Gabriel 1992).

In this paper, we examine the influence of temperature and depth on the distribution and catches of yellowtail flounder, cod and haddock in NEFSC spring and autumn bottom trawl surveys during 1963-1994.

Materials and Methods

Research survey data were analyzed from NEFSC spring (1968-1994) and autumn (1963-1994) bottom trawl surveys in the Southern New England, Georges Bank and Gulf of Maine regions (strata sets 1-30, 36-40, 73-76; Figure 1). In these surveys, locations or stations are selected randomly with the number of stations within each stratum roughly in proportion to stratum size. At each station the survey trawl is hauled for 30 minutes at a constant speed of 3.5 knots. Generally, fewer tows are made in deeper waters because the survey area is stratified by depth (depth boundaries of 55, 110, 185 and > 185 meters) and deeper strata occupy a smaller proportion of the total survey area. Depths in the surveys analyzed ranged from 30 to greater than 300 meters. At each station, measurements of bottom temperature and depth were taken using an expendable bathythermograph (XBT) or CTD device. Average depth for each station was taken as the average of the set and haul back depths. Total numbers of yellowtail, cod and haddock caught at each station was expressed as the catch-per-tow in numbers. No adjustments were made to data to account for door or vessel changes that have occured over the time series. A more thorough description of the NEFSC survey design and methodology is provided by Azarovitz (1981) and NEFSC (1988).

Perry and Smith (1994) developed a nonparametric univariate test of association between the cumulative distribution function of an environmental variable $f(t)$ and the cumulative distribution function of the same variable weighted by catch, $g(t)$. The cumulative distribution function for any habitat variable (x_{hi}) is constructed as

$$f(t)=\sum_h \sum_i \frac{W_h}{n_h} I(x_{hi}) \qquad (1)$$

where:

W_h = proportion of the survey area in stratum h.

n_h = number of tows or sets in stratum h.

x_{hi} = value of the environmental variable in tow i and stratum h.

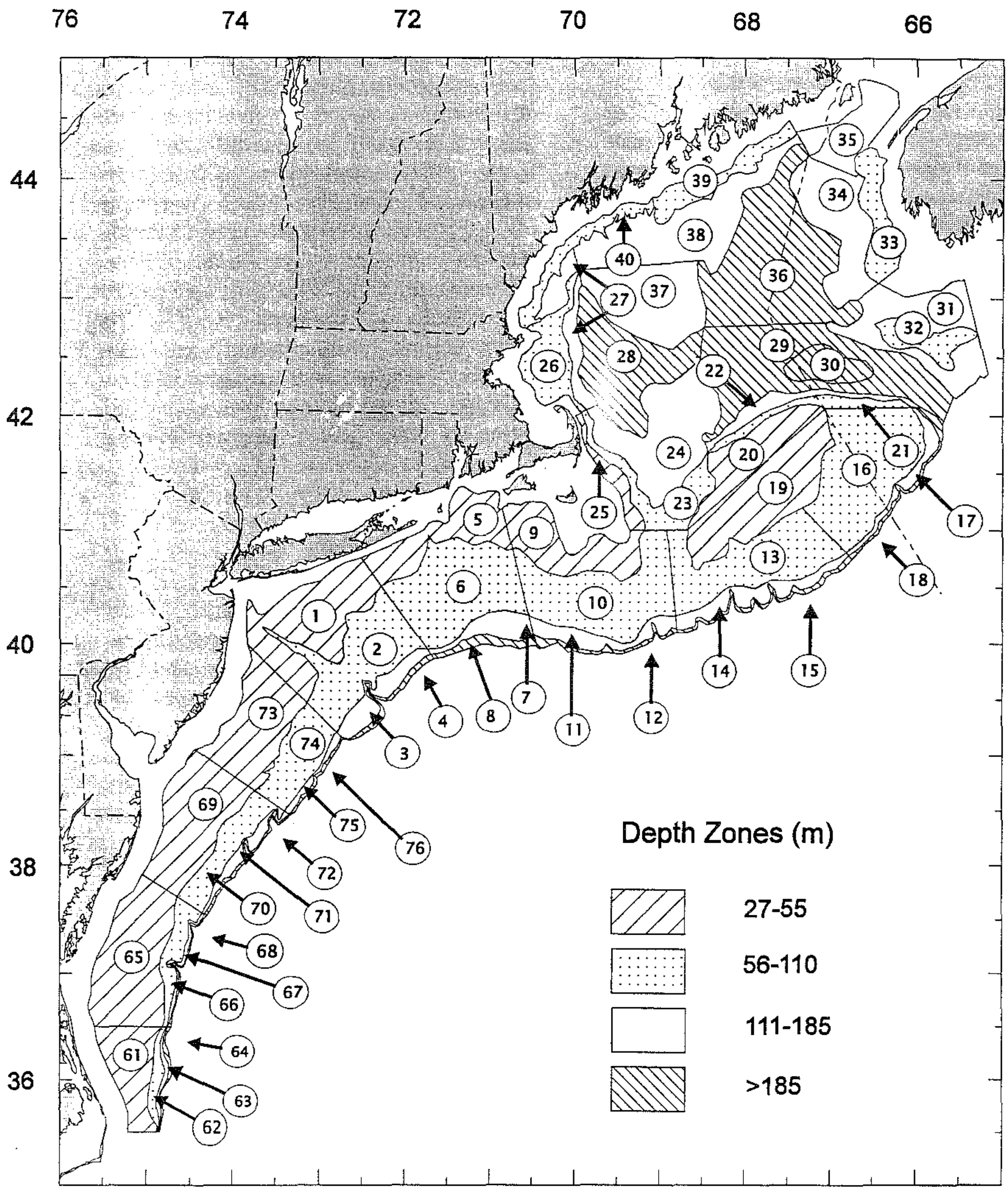

Figure 1. Area of the Northwest Atlantic continental shelf showing Northeast Fisheries Science Center's (NEFSC) bottom trawl survey strata sets. Strata sets used in this analysis included 1-30, 36-40, and 73-76.

$I(x_{hi}) = 1$ if $x_{hi} \leq t$; 0 otherwise.

Here, t represents an index ranging from the lowest to the highest value of an environmental variable, and $f(t)$ is calculated over all the measurements (x_{hi}) made. Once the cumulative distribution is derived, interquartiles (25th, 50th and 75th percentiles) of the environmental variable over the survey area can be determined.

The catch of a given species can be paired with an environmental variable and used as a weighting factor. The cumulative distribution function for a catch-weighted environmental variable can be computed as

$$g(t)=\sum_h \sum_i \frac{W_h y_{hi}}{n_h \bar{y}_{st}} I(x_{hi}) \qquad (2)$$

where: y_{hi} = number of fish of a particular species caught in tow $i(i=1, ..., n_h)$ and stratum h, and y_{st} = the stratified mean number per tow of fish caught in the defined survey area (consisting of h strata). Here, the value of the habitat variable is weighted by catch and scaled by the stratified mean number of fish caught so that the cumulative distribution function sum to 100% or unity (1). The difference between the catch-weighted and habitat cumulative distribution functions is an indication of the degree to which catch of a given species is associated with a certain range of habitat values; the greater the deviation between the two curves the greater the association with this subset of values. Perry and Smith (1994) suggest the use of the maximum absolute vertical distance between $g(t)$ and $f(t)$ as a statistic of the strength of association and calculate it as

$$\delta_o=\max_{\forall t}|g(t)-f(t)| \qquad (3)$$

Here, δ_o is the observed value of the maximum vertical distance between $g(t)$ and $f(t)$ at any point t within the range of the habitat values. To determine whether $g(t)$ is different from $f(t)$, as measured by the δ_o statistic, Perry and Smith (1994) employed a randomization procedure (Noreen 1989). In this procedure, the observed cumulative distribution functions for the unweighted and catch-weighted environmental variable are generated and the test statistic (δ_o) computed as in (3). The environmental measurements are then randomly sampled with replacement and reassigned to the catches. New CDF's are generated along with a new test statistic, denoted as

$$\delta_o^*=\max_{\forall t}|g(t)-f(t)| \qquad (4)$$

where all symbols are defined as in (3) but * indicates that computations are based on randomized data. This step is repeated a large number of times to generate a probability density function of the test statistic ($\delta(t)^*$) under the null hypothesis that the association between catch and the environmental variable is random. Finally, the observed test statistic (δ_o) is compared to the distribution of test statistics ($\delta(t)^*$) from the randomization procedure to evaluate whether the null hypothesis of random association can be rejected. The null hypothesis is rejected at significance level α when [$\delta_o > \delta_\alpha$], where the critical value, δ_α, is chosen such that

$$prob[\delta(t)^* \geq \delta_\alpha] = \alpha \qquad (5)$$

calculated under H_o. In randomization tests, no assumptions are made concerning the shape of the underlying probability distribution function of a statistic; rather the distribution is derived empirically by repeated randomization and allocation of the original data. However, randomization tests do assume that samples have been randomly taken from the population (Manly 1991), an assumption which is reasonably satisfied by the stratified random sampling design used in the NEFSC trawl surveys.

Using data from spring (1968-1994) and autumn (1963-1994) NEFSC bottom trawl surveys, univariate tests of association were conducted between catches of yellowtail flounder, cod and haddock and with bottom temperatures and average depths using a program developed by Brodziak and Ling (1995). Stations where temperature or depth were not measured/recorded were excluded from analysis for that variable. A total of 2,000 randomizations were performed providing a total of 2,001 test statistics (the original data pairing was included, cf. Perry and Smith (1994)). Differences between unweighted and catch-weighted CDF's were considered to be significant when the test statistic exceeded the critical value at the α=0.05 probability level.

Results

Significant associations were detected in many years between catches of yellowtail, cod and haddock in the NEFSC spring and autumn bottom trawl surveys and depth and bottom temperature (Tables 1 and 2). An illustration of one such association (haddock with bottom temperature) is shown in Figure 2 using data from the 1965 autumn survey. Haddock catches during this survey were distributed to warmer bottom temperatures (50% of the catch-weighted temperatures were > 12.2°C) of the area surveyed (50% of the unweighted temperatures were > 8.6°C) (Figure 2a). For this example the observed test statistic (δ_o) or the maximum absolute difference (labelled "max') between the cumulative distribution functions of environment temperatures ($f(t)$; equation 1) and the catch-weighted temperatures ($g(t)$; equation 2) was 0.403 (Figure 2a) and occured at a bottom temperature of 12.0°C. Comparison of the observed test statistic to the cumulative distribution function of the test

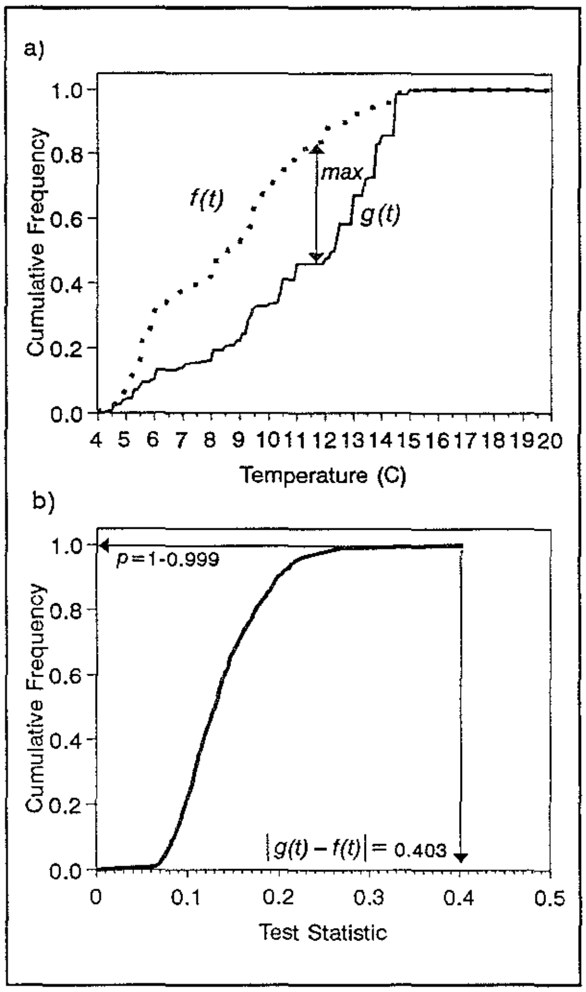

Figure 2. (a) Cumulative distribution functions for observed ($f(t)$) and catch-weighted ($g(t)$) bottom temperatures for haddock in 1965 autumn bottom trawl survey. (b) Cumulative distribution function of the test statistic ($\delta(t)^*$) generated by randomization of the data.

Table 1. Probability levels of random association between catches of yellowtail flounder, cod and haddock in NEFSC spring bottom trawl surveys, 1968-1994, and bottom water temperatures and depth.

	Bottom Temperature			Average Depth		
Year	Yellowtail	Cod	Haddock	Yellowtail	Cod	Haddock
1968	***	**	ns	***	ns	ns
1969	***	***	*	***	**	ns
1970	ns	***	**	***	***	ns
1971	***	***	ns	***	**	ns
1972	ns	***	*	***	***	ns
1973	**	***	ns	***	ns	ns
1974	***	***	***	***	***	*
1975	***	***	**	**	**	*
1976	***	***	***	*	***	ns
1977	**	ns	ns	*	***	ns
1978	***	***	**	***	**	ns
1979	***	***	ns	***	*	ns
1980	**	*	ns	ns	*	*
1981	*	ns	ns	***	**	*
1982	ns	ns	***	***	ns	ns
1983	**	ns	ns	***	**	**
1984	**	**	ns	***	**	ns
1985	ns	ns	ns	ns	**	**
1986	*	**	ns	**	*	ns
1987	*	**	ns	**	**	ns
1988	**	***	ns	**	***	**
1989	*	**	ns	***	*	ns
1990	ns	*	ns	***	ns	ns
1991	ns	***	**	***	ns	ns
1992	***	ns	ns	*	ns	**
1993	***	ns	ns	*	ns	ns
1994	ns	ns	ns	ns	ns	ns

ns = not significant at the $p = 0.05$ level.
* = significant at $p < 0.05$.
** = significant at $p < 0.01$.
*** = significant at $p < 0.001$.

Table 2. Probability levels of random association between catches of yellowtail flounder, cod And haddock in NEFSC autumn bottom trawl surveys, 1963-1994, and bottom water temperatures and depth.

	Bottom Temperature			Average Depth		
Year	Yellowtail	Cod	Haddock	Yellowtail	Cod	Haddock
1963	ns	ns	*	***	ns	ns
1964	**	*	*	*	ns	***
1965	ns	*	***	**	ns	***
1966	***	ns	*	*	***	ns
1967	*	ns	ns	***	**	ns
1968	ns	ns	*	***	ns	ns
1969	ns	**	***	***	ns	**
1970	ns	ns	ns	**	ns	ns
1971	ns	ns	*	***	ns	ns
1972	ns	ns	**	ns	ns	**
1973	ns	ns	ns	ns	*	ns
1974	ns	**	***	**	ns	ns
1975	*	*	ns	ns	ns	ns
1976	ns	ns	ns	ns	ns	ns
1977	ns	***	***	ns	ns	ns
1978	**	***	ns	***	ns	ns
1979	ns	ns	ns	***	*	ns
1980	ns	***	ns	ns	ns	ns
1981	ns	ns	***	**	ns	**
1982	ns	ns	ns	**	ns	[illegible]
1983	ns	ns	ns	*	ns	ns
1984	ns	ns	ns	**	ns	ns
1985	ns	**	ns	**	ns	ns
1986	ns	***	*	ns	ns	ns
1987	ns	*	ns	ns	ns	ns
1988	ns	ns	ns	***	ns	ns
1989	ns	ns	ns	ns	ns	ns
1990	ns	ns	ns	ns	ns	ns
1991	ns	***	ns	ns	ns	ns
1992	ns	**	ns	ns	ns	ns
1993	ns	***	*	ns	ns	ns
1994	ns	ns	*	ns	ns	ns

statistic ($\delta(t)^*$) generated by repeated randomization of the data indicate a highly significant difference (p<0.001); i.e. a test statistic as large or larger than 0.403 was obtained in only 1 out of 2000 randomizations (Figure 2b).

During the spring surveys, yellowtail flounder catch was significantly associated with bottom temperature in 20 of 27 years (74%) and with depth in 25 of 27 years (89%) (Table 1). Significant associations with bottom temperature and average depth were also found for cod in 19 of 27 years (70%). Haddock distributions showed less association with bottom temperature and average depth; significant associations were evident in only 1/3 of the 27 years of the spring surveys (Table 1).

In the autumn survey, there were far fewer associations between species distribution and bottom temperature and depth (Table 2). For yellowtail flounder, significant associations with bottom temperature were found in 5 of the 32 years (16%) and with depth in 18 of 32 years (56%). For cod, significant associations with bottom temperature occured in only 15 years (47%) and in only 4 years (13%) with depth. For haddock, significant associations with bottom temperature were detected in 14 years (44%) and with depth in six years (19%) (Table 2). Significant associations with bottom temperature and depth were not necessarily concordant among species or between the spring and autumn surveys for any one of the three species in any given year. Moreover, years in which significant associations occured with temperature were not necessarily those years in which significant associations were found with depth.

In nearly all years, the catch-weighted depths (50th percentiles) for all three species were shallower than the 50th percentile of the unweighted average depth in the spring survey. Table 1 of appendix 1 summarize the 25th, 50th and 75th percentiles of average depth and catch-weighted depth in the NEFSC spring surveys, and Figure 3 compares the 50th percentiles of the catch-weighted depths by species to the interquartiles of the average depth during these surveys. Relative to cod and haddock, yellowtail flounder were concentrated in the shallowest depths (average of the 50th percentile = 55 meters) slightly below the 25th percentile of the average depth of the survey (55.6 meters). Atlantic cod were distributed at greater depths than yellowtail flounder (average of the 50th percentile = 72 meters) and haddock were concentrated at greater depths than cod (average of the 50th percentile = 81 meters).

Although depth preferences for yellowtail, cod and haddock showed little annual variability in the spring survey over the time series (Figure 3), temperature preferences fluctuated substantially. Interquartiles (25th and 75th percentiles) of the ambient bottom temperatures in the survey area ranged from 3.3°C to 9.2°C with a pronounced rise during the early to mid-1970's (Appendix 1 Table 2). Inter-annual changes in catch-weighted bottom temperatures for yellowtail, cod and haddock generally mimicked those in the environment (Figure 3). In most years, yellowtail and cod were concentrated at temperatures less than the 25th percentile of the environment (4.8°C) while haddock were most frequently associated with temperatures between the 25th and 50th percentile. Unlike depth for which significant differences in habitat preference existed among the three species, catch-weighted bottom temperature for the three species were similar. The average 50th percentile of the catch-weighted bottom temperatures for yellowtail, cod and haddock

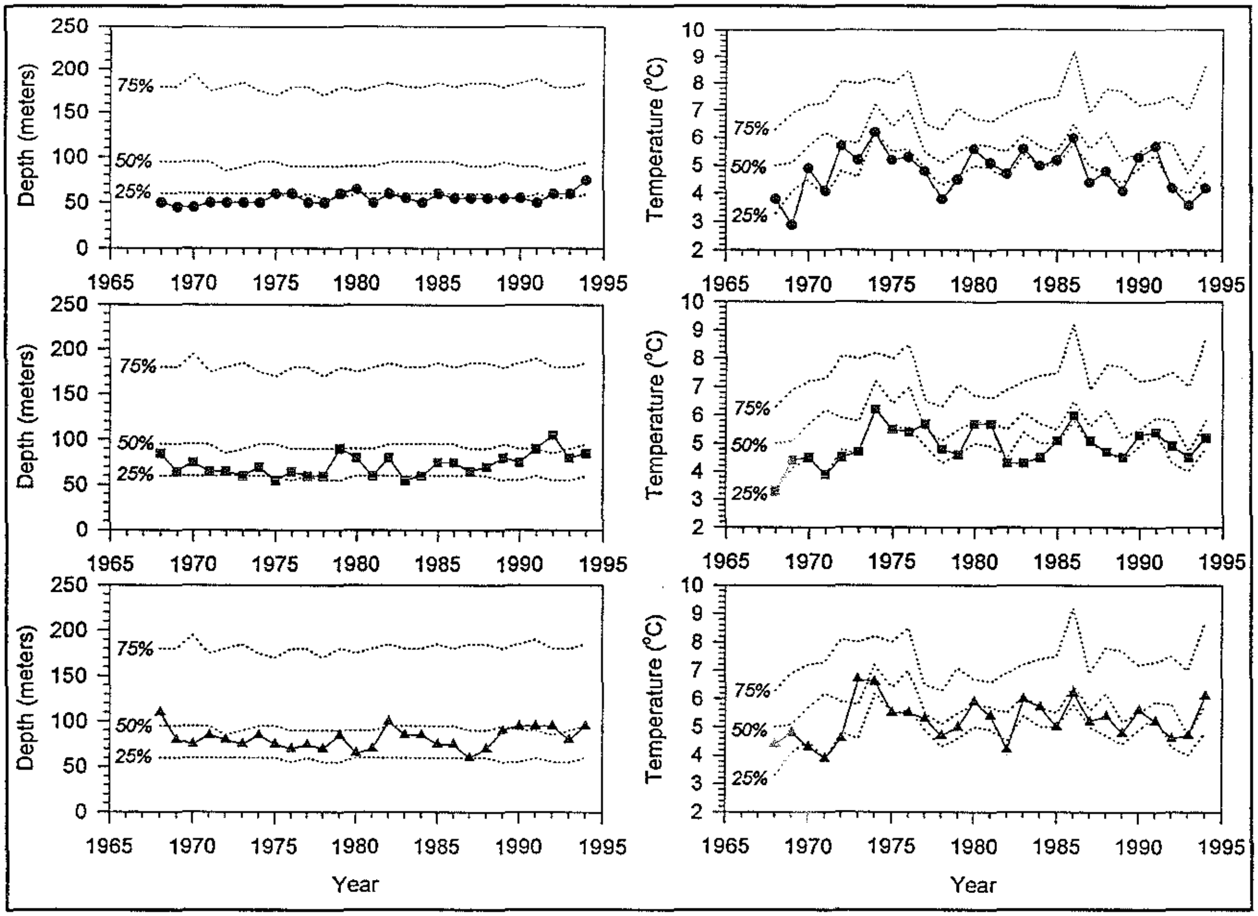

Figure 3. Spring habitat environmental variables and catch-weighted average depths (meters) and bottom temperatures (°C) for yellowtail flounder (circle), cod (square) and haddock (triangle) from 1968-1994. Interquartiles (25th, 50th and 75th percentiles) of habitat variables are shown as dotted lines and 50th percentile of catch-weighted depths and temperatures are given for comparison.

were 4.8°C, 4,9°C and 5.2°C, respectively.

Catch-weighted depth and bottom temperature distributions of cod and haddock were markedly different in the NEFSC autumn surveys than in the spring. During autumn, cod and haddock were concentrated in deeper waters and exhibited greater interannual variation in their depth preferences than during spring (Appendix 1 Table 3; Figure 4). Yellowtail flounder, however, were associated with similar depth regimes in both the spring (50th percentile: 55 meters) and autumn (50th percentile:58 meters) surveys with very little interannual variation during either survey series.

As in the spring surveys, bottom temperatures during the autumn surveys were more variable than those for depth (Appendix 1 Table 4; Figure 4). Similar to the spring surveys, ambient bottom temperatures during autumn surveys increased during the early to mid-1970's. However, catch-weighted bottom temperatures for yellowtail, cod and haddock did not trend upward during these years as they did in the spring surveys. With the exception of a few years, catch-weighted

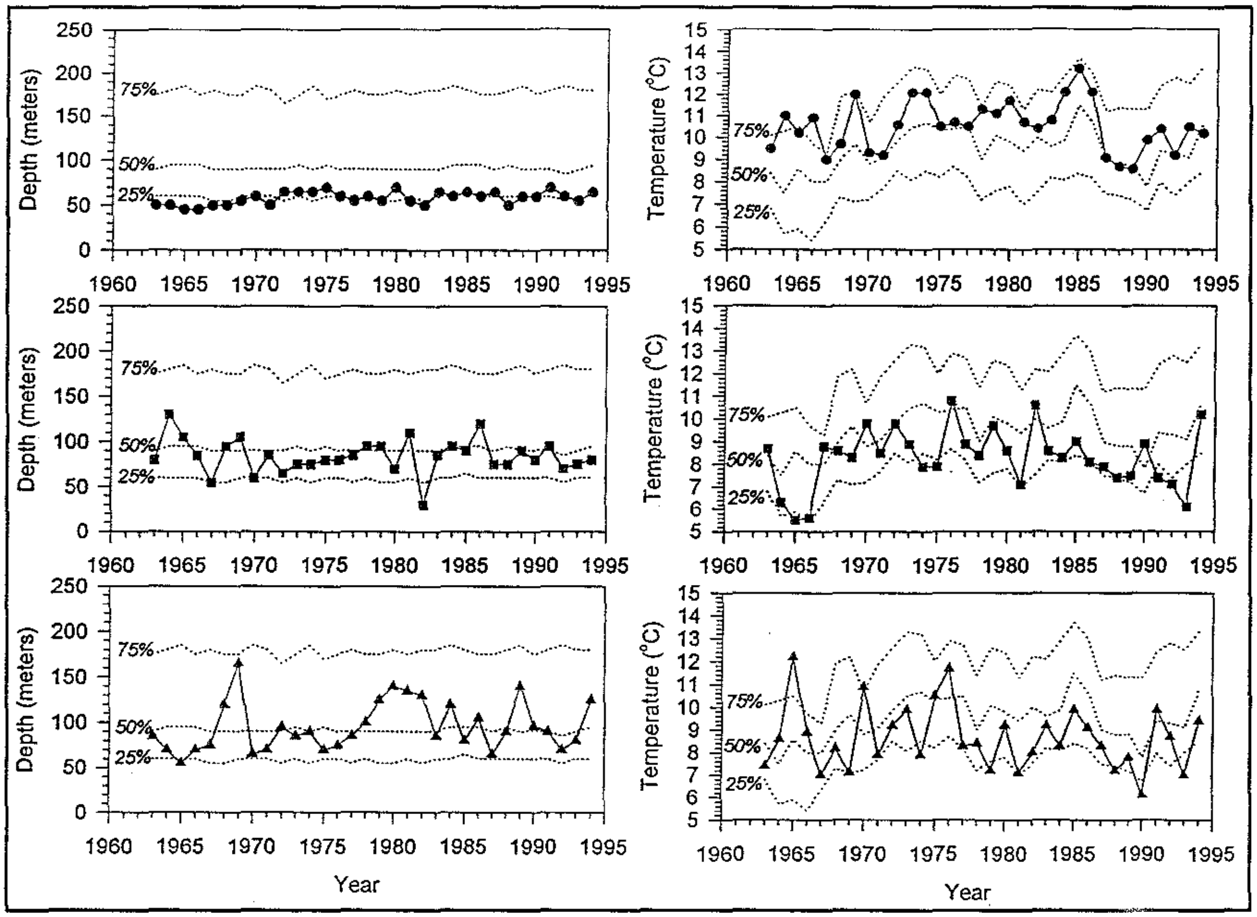

Figure 4. Autumn habitat environmental variables and catch-weighted average depths (meters) and bottom temperatures (°C) for yellowtail flounder (circle), cod (square) and haddock (triangle) from 1963-1994. Interquartiles (25th, 50th and 75th percentiles) of habitat variables are shown as dotted lines and 50th percentile of catch-weighted depths and temperatures are given for comparison.

yellowtail flounder bottom temperatures were generally between the 50th and 75th percentile of the environment temperature, while cod and haddock were distributed in cooler waters between the 25th and 50th percentiles of the environment. The average 50th percentile of the catch-weighted bottom temperatures in autumn for yellowtail, cod and haddock were 10.5, 8.3 and 8.6°C, respectively (Appendix 1 Table 4).

Discussion

Yellowtail flounder, cod and haddock show, to a greater or lesser extent, a "preference" or association to certain depth and temperature regimes. Our results indicate that yellowtail flounder maintain a rather constant preference for shallow depths (< 55 meters) and tolerate a wide range in temperatures (4.8 to 10.5°C) between spring and autumn. These findings are similar to those for yellowtail on the Scotian Shelf (Scott 1982, Perry and Smith 1994) and suggest that depth may be a more important determinant than temperature in influencing yellowtail flounder distribution patterns.

In contrast, Atlantic cod were strongly associated with particular depth (< 72 meters) and temperature (< 4.9°C) ranges during spring, but showed comparatively little association between depth and temperature during the autumn. This suggests that cod "preferred" depth/temperature regimes changed seasonally. While not showing much of a depth preference during either spring or autumn, haddock were generally significantly associated with certain temperature ranges that differed between seasons. These results are in contrast to those from the Scotian Shelf where haddock were considered "temperature - keepers", and maintained a rather constant temperature regime between seasons (Perry and Smith 1994).

Indentification of habitat assocations for groundfish has some important implications for sampling programs and stock assessment methods. By understanding how fish are spatially and temporally distributed in response to oceanographic features, insight is gained into some of the sampling variation frequently observed in large-scale trawl surveys. Large variations in abundance estimates from year to year may in some cases be explained by changes in catchability of fish to the trawl survey due to distribution changes in temperature/depth regimes. Habitat associations may also provide a means for adjusting or improving survey abundance estimates (Smith et. al. 1991). Where strong associations exist with particular habitat conditions, habitat variables might be explicitly incorporated into spatial models as covariates in order to predict fish distribution patterns (Swartzman et. al. 1992).

Acknowledgements

We thank the Northern Demersal Subcommittee and Fred Serchuk of the Northeast Fisheries Science Center in Woods Hole for reviewing the mansucript and providing many constructive comments.

References

Brodziak, J.K.T., and Wei Ling. 1995. An examination of the influences of environmental conditions on spring survey catches of Atlantic Mackerel. Northeast Fisheries Science Center Reference Document 95-15, Woods Hole, MA.

Butman, B.J., and R.C. Beardsley. 1987. Physical oceanography, in Georges Bank (eds. R.A. Backus and D.W. Bourne), MIT Press, Cambridge MA, pp. 88-98.

Gabriel, W.L. 1992. Persistence of demersal fish assemblages between Cape Hatteras and Nova Scotia, Northwest Atlantic. J. Northw Atl. Fish. Sci., Vol. 14:29-46.

Mahon, R., and R.W. Smith. 1989. Demersal fish assemblages on the Scotian Shelf, Northwest Atlantic: spatial distribution and persistence. Can. J. Fish. Aquat. Sci., 46(Suppl 1):134-152.

Mahon, R. [ED.] 1985. Towards the inclusion of fishery interactions in management advice. Can. Tech. Rep. Fish. Aquat. Sci. 1347: 220p.

Manly, B.F.J. 1991. Randomization and Monte-Carlo methods in biology. Chapman and Hall. London. 281 pp.

Murawski, S.A., and J.T. Finn. 1988. Biological basis for mixed-species fisheries: species co-distribution in relation to environmental and biotic variables. Can. J. Fish. Aquat. Sci. 45: 1720-1735.

Noreen, E.W. 1989. Computer-intensive methods for testing hypotheses: an introduction. John Wiley & Sons, New York, NY.

Overholtz, W.J., and A.V. Tyler. 1985. Long-term responses of the demersal fish assemblages of Georges Bank. U.S. Fish. Bull. 83:507-520.

Perry, R.I., and S.J. Smith. 1994. Identifying habitat associations of marine fishes using survey data: an application to the Northwest Atlantic. Can. J. Fish. Aquat. Sci. 51:589-602.

Scott, J.S. 1982. Depth, temperature and salinity preferences of common fishes of the Scotian Shelf. Can. J. Fish. Aquat. Sci. 3: 29-40.

Smith, S.J. 1990. Use of statistical models for the estimation of abundance from groundfish trawl surverys. Can. J. Fish. Aquat. Sci. 47: 894-903.

Smith, S.J., R.I. Perry, and L.P. Fanning. 1991. Relationships between water mass characteristics and estimates of fish population abundance from trawl surveys. Environ. Monit. Assess. 17: 227-245.

Swartzman, G., C. Huang, and S. Kaluzny. 1992. Spatial analysis of Bering Sea groundfish survey data using Generalized Linear Models. Can. J. Fish. Aquat. Sci. 49: 1366-1378.

Appendix 1
Supplementary tables 1-4

Table 1. Percentiles of average depth and catch-weighted average depth for yellowtail flounder cod and haddock during NEFSC spring bottom trawl surveys, 1968-1994.

	Environment (Average Depth)			Yellowtail			Atlantic Cod (Catch-weighted Average Depth)			Haddock		
	Percentile											
Year	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
1968	60	95	180	45	50	60	60	85	130	75	110	175
1969	60	95	180	35	45	55	40	65	105	65	80	165
1970	60	95	195	35	45	55	45	75	115	70	75	90
1971	60	95	175	40	50	65	50	65	110	80	85	160
1972	60	85	180	40	50	50	50	65	80	75	80	85
1973	60	90	185	40	50	65	55	60	70	75	75	80
1974	60	95	175	40	50	65	50	70	90	65	85	90
1975	60	95	170	50	60	75	50	55	80	70	75	85
1976	55	90	180	40	60	80	45	65	90	65	70	80
1977	60	90	180	35	50	65	45	60	100	60	75	85
1978	55	90	170	40	50	60	45	60	85	55	70	85
1979	55	90	180	50	60	65	55	90	140	85	85	90
1980	60	90	175	50	65	95	50	80	100	55	65	75
1981	60	90	180	40	50	60	50	60	90	60	70	105
1982	60	95	185	50	60	70	80	80	85	80	100	110
1983	60	95	180	45	55	65	45	55	100	60	85	130
1984	60	95	180	45	50	65	50	60	115	70	85	95
1985	60	95	185	45	60	75	45	75	120	70	75	85
1986	60	95	180	45	55	65	55	75	125	70	75	90
1987	60	90	185	45	55	60	55	65	90	55	60	65
1988	60	90	185	45	55	65	50	70	90	65	70	85
1989	55	95	180	45	55	65	55	80	110	80	90	100
1990	55	90	185	40	55	60	45	75	115	80	95	100
1991	60	90	190	50	50	65	60	90	135	90	95	100
1992	55	85	180	50	60	65	60	105	170	70	95	100
1993	55	90	180	50	60	75	55	80	160	80	80	120
1994	60	95	185	60	75	80	70	85	150	80	95	110
Avg	58.7	92.0	180.9	44.3	54.8	66.3	52.4	72.2	109.3	70.6	81.5	101.5

Table 2. Percentiles of bottom temperature and catch-weighted bottom temperature for yellowtail flounder, cod and haddock during NEFSC spring bottom trawl surveys, 1968-1994.

	Environment (Average Temperature)			Yellowtail			Atlantic Cod (Catch-weighted Average Temperature)			Haddock		
	Percentile											
Year	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
1968	3.3	5.0	6.3	2.2	3.8	4.2	2.1	3.3	5.1	3.6	4.4	5.1
1969	4.1	5.1	6.9	2.3	2.9	4.2	3.1	4.4	4.9	4.3	4.8	5.1
1970	4.5	5.7	7.2	4.3	4.9	5.4	3.9	4.5	5.0	3.9	4.3	5.4
1971	3.9	6.2	7.3	3.4	4.1	4.9	3.7	3.9	4.7	3.7	3.9	5.8
1972	4.8	5.9	8.1	4.9	5.7	6.3	4.1	4.5	4.8	4.5	4.6	5.8
1973	4.6	5.8	8.0	4.6	5.2	5.9	4.5	4.7	4.9	6.0	6.7	7.1
1974	6.2	7.2	8.2	5.8	6.2	7.1	5.8	6.2	6.9	6.1	6.6	6.8
1975	5.5	6.4	8.0	4.8	5.2	5.7	5.1	5.5	5.7	5.1	5.5	5.7
1976	5.6	7.0	8.5	5.2	5.3	5.6	5.2	5.4	5.9	5.4	5.5	5.6
1977	4.9	5.5	6.5	3.7	4.8	5.4	4.9	5.7	6.4	4.8	5.3	5.9
1978	4.3	5.1	6.3	2.8	3.8	4.3	4.4	4.8	5.2	4.6	4.7	4.8
1979	4.6	5.5	7.1	4.3	4.5	5.2	4.0	4.6	5.3	4.8	5.0	5.8
1980	5.0	5.8	6.7	4.9	5.6	5.8	4.9	5.7	6.0	5.7	5.9	6.0
1981	4.9	5.7	6.6	4.6	5.1	5.8	5.0	5.7	6.2	5.1	5.4	6.0
1982	4.5	5.5	6.9	4.4	4.7	5.7	4.2	4.3	4.8	4.1	4.2	4.4
1983	5.4	6.1	7.2	4.7	5.6	6.2	3.9	4.3	4.9	5.4	6.0	6.2
1984	5.0	5.7	7.4	4.0	5.0	5.6	3.5	4.5	5.5	5.5	5.7	6.7
1985	5.0	5.5	7.5	5.0	5.2	5.4	5.0	5.1	5.0	5.0	5.0	5.1
1986	5.8	6.5	9.2	4.4	6.0	6.4	5.8	6.0	6.0	6.0	6.2	6.8
1987	5.0	5.6	6.9	3.9	4.4	5.1	4.1	5.1	5.3	5.2	5.2	5.3
1988	4.7	6.2	7.8	4.2	4.8	5.1	4.3	4.7	5.0	4.0	5.4	7.9
1989	4.4	5.2	7.7	4.0	4.1	4.4	4.0	4.5	4.7	4.5	4.8	5.1
1990	4.9	5.5	7.2	4.7	5.3	5.7	4.7	5.3	5.5	5.4	5.6	6.7
1991	5.4	5.9	7.3	5.4	5.7	6.4	5.0	5.4	5.7	5.1	5.2	5.3
1992	4.3	5.8	7.5	3.9	4.2	5.1	4.3	4.9	6.6	4.1	4.6	5.3
1993	4.0	4.7	7.0	3.2	3.6	4.5	3.3	4.5	5.3	4.5	4.7	5.2
1994	4.8	5.8	8.7	3.9	4.2	5.1	4.0	5.2	6.1	6.0	6.1	6.1
Avg	4.79	5.77	7.41	4.20	4.81	5.43	4.33	4.91	5.46	4.90	5.23	5.81

Table 3. Percentiles of average depth and catch-weighted average depth for yellowtail flounder cod and haddock during NEFSC autumn bottom trawl surveys, 1963-1994.

	Environment (Average Depth)			Yellowtail			Atlantic Cod (Catch-weighted Average Depth)			Haddock		
	Percentile											
Year	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
1963	60	90	175	45	50	65	55	80	155	55	85	155
1964	60	95	180	45	50	75	75	130	195	55	70	85
1965	60	95	185	45	45	55	55	105	125	45	55	80
1966	60	95	175	40	45	55	55	85	100	55	70	150
1967	55	90	180	45	50	55	50	55	80	65	75	185
1968	55	90	175	40	50	60	55	95	140	75	120	205
1969	60	90	175	50	55	65	60	105	155	95	165	190
1970	60	90	185	50	60	65	45	60	125	60	65	160
1971	60	90	180	45	50	55	55	85	110	55	70	175
1972	55	90	165	55	65	70	50	65	90	80	95	115
1973	60	95	175	55	65	75	50	75	95	80	85	100
1974	55	90	185	60	65	75	60	75	115	65	90	150
1975	60	95	170	65	70	90	55	80	100	60	70	155
1976	60	90	175	55	60	65	75	80	125	75	75	85
1977	55	90	180	45	55	75	65	85	140	80	85	130
1978	60	90	175	65	60	65	65	95	135	55	100	190
1979	55	90	175	45	55	70	75	95	155	120	125	145
1980	55	90	180	55	70	85	60	70	120	60	140	195
1981	60	90	175	45	55	65	70	110	120	95	135	175
1982	55	90	180	45	50	60	25	30	105	105	130	110
1983	60	90	180	55	65	70	50	85	130	75	85	145
1984	60	95	185	50	60	70	85	95	120	95	120	200
1985	65	95	180	50	65	70	70	90	130	70	80	90
1986	60	95	175	50	60	70	85	120	140	85	105	200
1987	60	90	175	50	65	75	70	75	100	60	65	75
1988	60	95	180	40	50	65	40	75	110	80	90	115
1989	60	90	185	55	60	70	65	90	105	100	140	265
1990	60	90	175	55	60	70	75	80	110	80	95	195
1991	60	90	180	60	70	80	80	95	150	85	90	115
1992	55	85	185	45	60	75	65	70	95	55	70	80
1993	60	90	180	45	55	80	70	75	105	80	80	85
1994	60	95	180	55	65	80	65	80	120	85	125	255
Avg	58.8	91.4	178.3	50.2	58.1	69.4	61.7	84.1	121.9	74.5	95.3	148.6

Table 4. Percentiles of bottom temperature and catch-weighted bottom temperature for yellowtail flounder, cod and haddock during NEFSC autumn bottom trawl surveys, 1963-1994.

	Environment (Average Temperature)			Yellowtail (Catch-weighted Average Temperature)			Atlantic Cod (Catch-weighted Average Temperature)			Haddock (Catch-weighted Average Temperature)		
	Percentile											
Year	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
1963	6.8	8.4	10.1	8.7	9.5	10.3	6.7	8.7	9.0	6.5	7.4	9.0
1964	5.7	7.5	10.3	8.4	11.0	11.7	5.7	6.3	7.2	7.3	8.6	10.7
1965	5.9	8.6	10.5	9.4	10.2	12.0	4.6	5.5	9.0	9.1	12.2	13.5
1966	5.4	8.0	9.7	9.8	10.9	12.2	4.8	5.6	10.9	5.3	8.9	12.0
1967	6.3	8.0	9.3	8.7	9.0	10.6	6.9	8.8	9.0	5.7	7.0	8.9
1968	7.3	9.0	11.9	8.8	9.7	11.6	6.3	8.6	10.0	6.2	8.2	9.1
1969	7.1	9.7	12.2	10.8	12.0	13.2	6.9	8.3	10.1	6.0	7.1	8.3
1970	7.2	8.8	10.7	8.0	9.3	10.5	8.1	9.8	11.8	7.3	10.9	11.8
1971	7.7	9.1	11.9	7.7	9.2	11.6	7.8	8.5	10.2	6.9	7.9	10.2
1972	8.5	9.9	12.6	10.5	10.6	11.6	8.4	9.8	10.0	8.3	9.2	10.2
1973	8.1	10.5	13.3	10.5	12.1	13.2	7.3	8.9	10.9	7.5	9.9	10.9
1974	8.5	10.7	13.2	10.8	12.1	13.6	7.4	7.9	10.6	6.8	7.9	9.0
1975	8.2	10.3	12.0	9.7	10.5	11.5	7.6	7.9	10.5	8.3	10.5	11.7
1976	8.7	10.4	12.9	9.9	10.7	13.0	7.8	10.8	11.8	11.5	11.7	11.8
1977	8.2	10.5	12.7	10.0	10.5	11.8	7.2	8.9	10.4	7.3	8.3	9.3
1978	7.2	9.0	11.4	10.7	11.3	12.7	6.7	8.4	9.4	6.4	8.4	12.5
1979	7.6	10.1	12.6	10.1	11.1	12.9	7.2	9.7	12.0	7.1	7.2	8.3
1980	7.8	9.8	12.4	9.2	11.7	12.9	6.8	8.6	9.2	8.2	9.2	11.6
1981	7.0	9.4	11.3	9.6	10.7	12.3	5.8	7.1	9.7	5.8	7.1	8.3
1982	7.5	10.0	12.2	10.1	10.4	13.2	9.4	10.6	10.7	7.2	8.0	10.1
1983	8.2	9.6	12.1	10.1	10.8	12.2	7.7	8.6	9.8	8.3	9.2	9.3
1984	8.1	9.9	12.9	9.4	12.1	12.5	6.3	8.3	8.5	6.3	8.3	11.3
1985	8.4	11.5	13.7	10.0	13.2	13.4	7.8	9.0	9.5	9.2	9.9	11.2
1986	8.2	10.7	13.0	11.1	12.1	13.0	7.6	8.1	8.8	8.2	9.1	9.2
1987	7.5	9.0	11.2	8.1	9.1	10.3	7.1	7.9	8.1	8.1	8.3	8.3
1988	7.4	8.8	11.4	8.6	8.7	10.9	7.4	7.4	8.8	6.0	7.2	8.6
1989	7.2	8.8	11.3	7.7	8.6	10.3	6.9	7.5	7.7	7.7	7.8	8.8
1990	6.7	7.8	11.3	7.0	9.9	11.3	7.5	8.9	9.3	6.0	6.1	6.1
1991	8.0	9.4	12.4	9.9	10.4	10.4	6.8	7.4	8.9	7.4	9.9	11.1
1992	7.4	9.3	12.8	7.0	9.2	9.2	6.5	7.1	9.2	7.0	8.7	10.0
1993	8.0	9.1	12.5	10.0	10.5	10.5	5.9	6.1	7.4	6.9	7.0	8.6
1994	8.5	10.7	13.3	9.5	10.2	13.0	7.6	10.2	13.4	7.3	9.4	9.5
Avg	7.51	9.45	11.91	9.37	10.54	11.86	7.02	8.29	9.74	7.28	8.64	9.98