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A Comparison of Growth Rates for American Plaice, *Hippoglossoides platessoides*, in the Gulf of Maine-Georges Bank Region Derived from Two Different Data Sources

by

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INTRODUCTION

The American plaice, *Hippoglossoides platessoides*, is a right-handed, slow-growing pleuronectid found along the northeast coast of North America from southern Labrador to Rhode Island (Conservation and Utilization Division 1991). In U.S. waters, plaice inhabit the Gulf of Maine and deeper waters of Georges Bank, and traditionally have been taken in fisheries directed at other species. United States landings of plaice reached a record level of 15,000 mt in 1982 but have declined steadily to 2500 mt by 1990. The species is considered overexploited and has been included in the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan.

Until recently, one impediment to an analytical assessment for American plaice has been the lack of commercial age data. The main reason for this has been an emphasis at the Northeast Fisheries Science Center (NEFSC) to age survey samples, resulting in a time series of age data back to 1980, as opposed to commercial samples; the collection of commercial samples has been constrained in some ports because dealers prefer that the heads not be cut for otolith removal. As part of an assessment initiative during 1991-92 for American plaice, however, commercial samples from 1988 were aged by the Fishery Biology Investigation to provide the comparative basis for evaluating the feasibility of applying age-length keys (ALK) derived from survey age data to commercial length frequencies to estimate age compositions for American plaice.

Subsequent analysis revealed for the year in question that neither the ALKs generated from the spring survey age data and second quarter commercial age data, nor from the autumn survey and fourth quarter age data, differed statistically when examined using Fischer's Exact Test (NEFSC 1992). Accordingly, survey ALKs were used for the ensuing assessment (reported in NEFSC 1992). However, the NEFSC did not examine whether growth rates derived from the two data sources were similar. Also, differences in otolith growth patterns between fishes from the Gulf of Maine and Georges Bank were observed by age readers during the aging process. The objective of this study was to compare growth rates for American plaice generated from both survey and commercial age data, and to compare growth rates for plaice in the Gulf of Maine to those of Georges Bank.

METHODS

Age data used in this study were generated from age samples obtained in 1988 from commercial landings and from NEFSC spring and autumn bottom trawl surveys (for details regarding the NEFSC commercial port sampling program, see Burns *et al.* 1983; for details of the NEFSC bottom trawl survey program, see Azarovitz 1981). The year 1988 was selected due to relatively consistent commercial sampling throughout the calendar year and the adequate numbers of large, old fish in the samples. In order to test the hypothesis that American plaice on Georges Bank grow faster than their Gulf of Maine counterparts, commercial and survey samples were partitioned according to the following scheme: Gulf of Maine - NEFSC Statistical Reporting Areas (SAR) 511-515 (Figure 1) and NEFSC offshore bottom trawl survey strata 26-30, 36-40, and inshore strata 57-90 (Figure 2); Georges Bank - SAR 521-522, 525-526, and 561-562 (Figure 1) and offshore strata 13-25 (Figure 2).

Although otoliths are the preferred aging structure for American plaice, some commercial samples consisted of scales. Otoliths were thin-sectioned according to the methodology described by Penttila *et al.* (1988); age determinations were based upon the number of completed hyaline zones (Dery 1988). Scales were impressed in laminated plastic (Penttila *et al.* 1988) and aged using criteria described (Fields 1988) for winter flounder, *Pleuronectes americanus*. Fractional ages were assigned based upon date of sample collection relative to the convention of a January 1 birthdate (Penttila *et al.* 1988).

Growth was modeled by fitting the following linear semi-logarithmic function to mean-length-at-fractional-age data:

$$l_t = a + b\ (\log_e \text{age}),$$

where l_t is the length at a given age and a and b are parameters estimated by the regression. This model has been used for other slow-growing species such as witch flounder, *Glyptocephalus cynoglossus* (Bowers 1960), and Acadian redfish, *Sebastes fasciatus* (Mayo *et al.* 1990). Growth rates were derived for American plaice from the Gulf of Maine and Georges Bank using both survey and commercial age data. Although dimorphic growth has been documented for American plaice (Sullivan 1982), data for both sexes

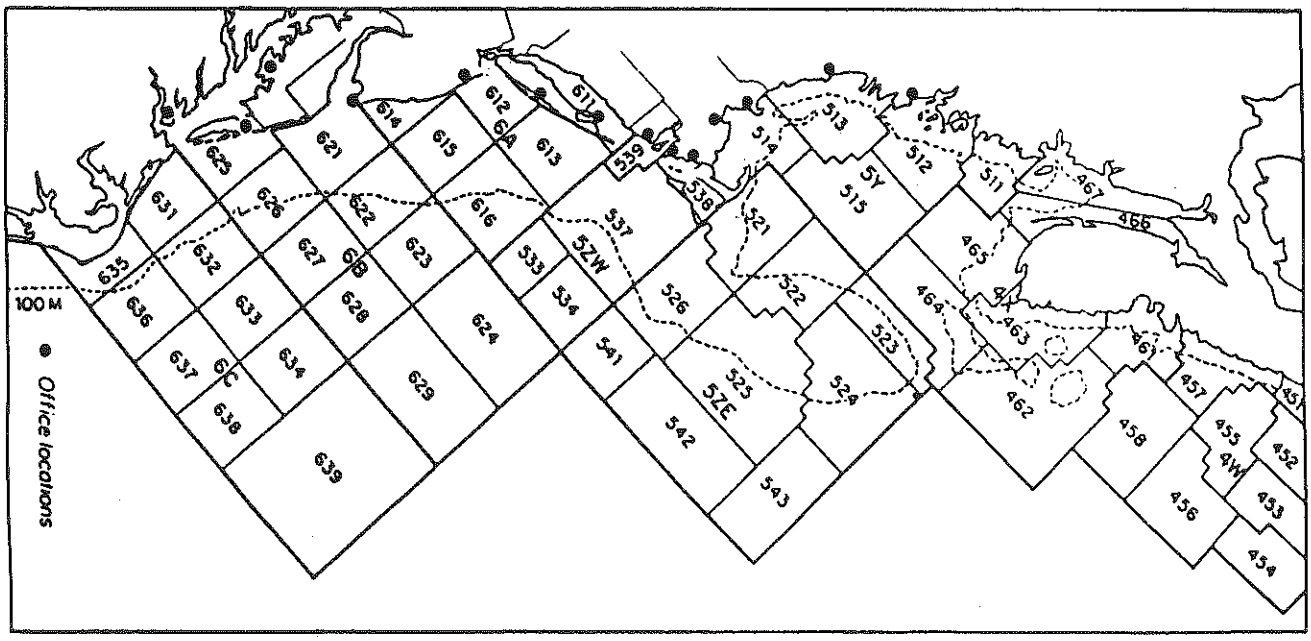

Figure 1. NEFSC Statistical Areas (SAR) used for reporting U.S. commercial fishery statistics. Regions defined for analysis of American plaice growth rates in this study are as follows: Gulf of Maine SAR 511-515; Georges Bank SAR 521-522, 525-526, and 561-562.

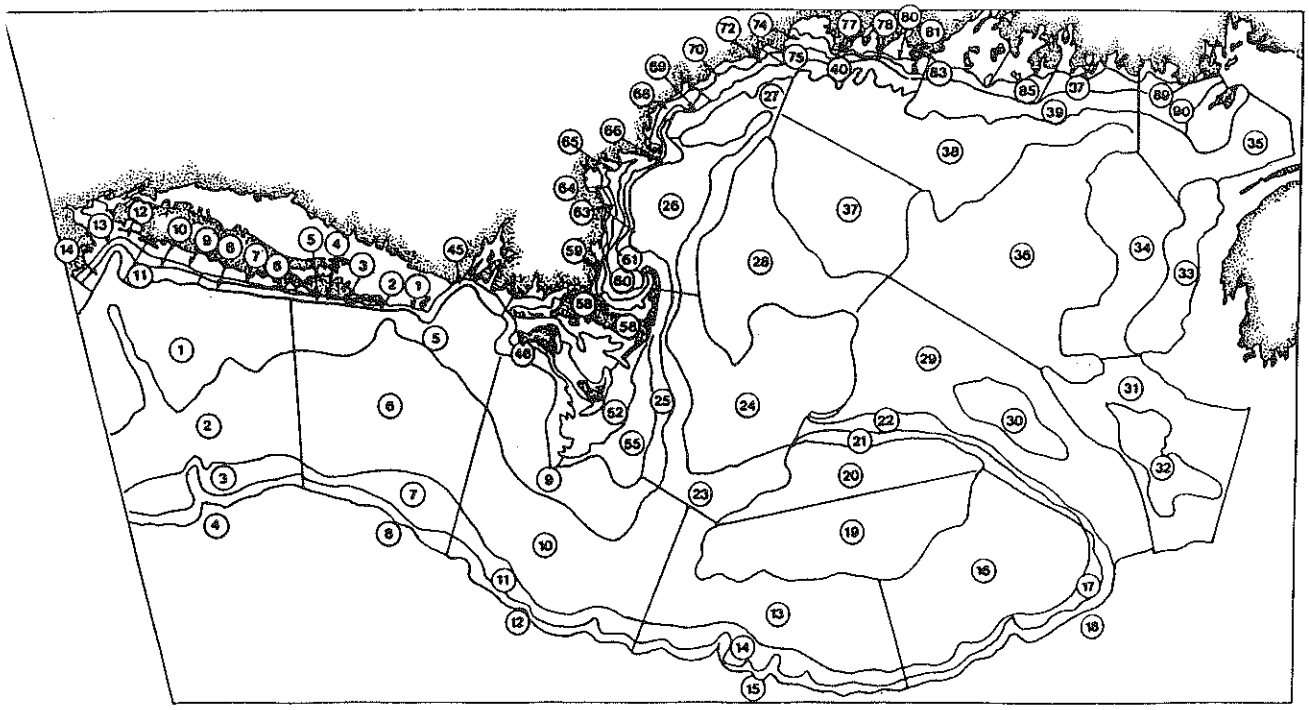

Figure 2. Sampling strata used in NEFSC bottom trawl surveys. Regions defined for analysis of American plaice growth rates in this study are as follows: Gulf of Maine offshore strata 26-30, 36-40, and inshore strata 57-90; Georges Bank offshore strata 13-25.

Table 1. Summary of age determinations for American plaice obtained from 1988 NEFSC commercial and bottom trawl survey sampling by region

Region	Commercial				Survey	
	Q1	Q2	Q3	Q4	Spring	Autumn
Gulf of Maine	259	322	230	209	489	432
Georges Bank	68	215	206	152	70	92

were combined in analysis of survey data in order to be comparable to unsexed commercial samples. The average sex ratio for all season/area subsets of survey data was 1.05:1 males to females.

Growth comparisons were performed through analysis of covariance (Snedecor and Cochran 1967), of the regressions derived above with $\log_e$ age as the covariate. The following four growth rate comparisons were evaluated:

1) Georges Bank versus the Gulf of Maine, using survey data;
2) Georges Bank versus the Gulf of Maine, using commercial data;
3) and 4) for each area, commercially-derived growth rates versus those derived from survey data.

Growth modeling and testing were performed using BMDP 1V and 1R (Dixon 1985).

RESULTS

We obtained 1661 age determinations from the commercial samples, 1020 from the Gulf of Maine, and 641 from Georges Bank (Table 1). Survey sampling provided a total of 1083 age data, 921 from the Gulf of Maine and 162 from Georges Bank (Table 1). Ages ranged from 2 to 18 years in the commercial data and from 1 to 11 in the survey samples. Mean lengths at age (total length, centimeters) and associated statistics are presented for commercial data (Tables 2 and 3) and survey data (Tables 4 and 5). Mean lengths at fractional ages from both data sources are plotted for the Gulf of Maine and Georges Bank, respectively (Figures 3 and 4).

All four linear regressions were highly significant ($p < 0.01$; Table 6), indicating that the semi-logarithmic model adequately described growth of American plaice. Analysis of covariance revealed that significant differences between growth rates existed in all four comparisons (Table 7). In all comparisons, except for commercial growth rate versus survey growth rate in the Gulf of Maine, the slopes were statistically similar but intercepts differed significantly (Table 7). In both area comparisons (using commercial and survey data, respectively), the intercepts were lower for the Gulf of Maine regressions. In the comparisons of growth rates derived from each data source, regression slopes were higher for commercial data than for survey data.

DISCUSSION

Although the von Bertalanffy model is a traditional growth model applied to describe fish growth, problems with data precluded its use in this study. With respect to commercial age data, the combination of a minimum landed size for American plaice of 36 cm and market culling practices resulted in no samples of length less than 27 cm or age less than 2 years. Estimates of the von Bertalanffy parameter t_0, the hypothetical age at which a fish has no length, were unrealistic without data for smaller, younger fish to anchor this portion of the growth curve. Similarly, the inadequate number of larger, older fish in the survey age samples constrained the estimate of L_{inf}, the asymptotic maximum length that fish attain in the von Bertalanffy model. Statistically acceptable fits and reasonable estimates of von Bertalanffy parameters were obtained only by fixing t_0 with the value estimated from the survey data, thus reducing the model by one parameter. For this reason, the von Bertalanffy model was rejected and the semi-logarithmic model used to describe and compare growth rates for American plaice. It should be noted that Sullivan (1982) generated von Bertalanffy growth parameters for American plaice in the Gulf of Maine by sex using NEFSC survey data from 1980, during which time adequate numbers of larger, older fish were collected.

Although American plaice in the Gulf of Maine-Georges Bank region are currently assessed as one stock (NEFSC 1992), results of this study suggest that plaice on Georges Bank grow differently than plaice in the Gulf of Maine; faster growth on Georges Bank has been noted for numerous species that also occur in the Gulf of

Table 2. Mean lengths (TL, cm) at age, standard deviations (SD), and sample sizes (N) calculated by quarter from commercial samples of American plaice (both sexes combined) from the Gulf of Maine (SAR 511-515) in 1988

	1st QTR			2nd QTR			3rd QTR			4th QTR		
Age	Length	(SD)	N	Length	(SD)	N	Length	(SD)	N	Length	(SD)	N
3	28.0	(1.41)	2	32.0	(0.00)	1	33.1	(2.18)	14	33.0	(1.41)	2
4	32.0	(2.58)	21	34.8	(1.85)	30	36.2	(3.20)	21	35.9	(2.82)	13
5	34.8	(2.95)	36	36.9	(2.67)	53	39.1	(3.14)	55	39.9	(3.90)	54
6	40.5	(3.79)	70	41.0	(3.08)	113	44.1	(3.04)	76	43.2	(2.86)	75
7	45.0	(3.65)	40	44.6	(3.18)	55	47.3	(2.55)	27	47.1	(2.62)	36
8	50.5	(4.08)	29	48.9	(3.05)	21	51.2	(2.25)	12	52.5	(2.11)	11
9	53.1	(3.39)	31	52.4	(3.32)	27	53.2	(4.09)	11	52.8	(5.04)	6
10	56.3	(2.95)	17	55.6	(2.75)	13	57.3	(2.60)	8	56.9	(0.69)	7
11	58.0	(2.94)	7	59.8	(1.30)	5	57.5	(0.71)	2	61.0	(4.24)	2
12	61.7	(2.08)	3	57.0	(0.00)	1	62.5	(0.71)	2	61.0	(1.41)	2
13	63.0	(0.00)	1	60.0	(4.58)	3	69.0	(0.00)	1	59.0	(0.00)	1
14	63.5	(0.71)	2	-	-	-						
15	71.0	(0.00)	1									

Table 3. Mean lengths (TL, cm) at age, standard deviations (SD), and sample sizes (N) calculated by quarter from commercial samples of American plaice (both sexes combined) from Georges Bank (SAR 521-522,525-526,561-562) in 1988

	1st QTR			2nd QTR			3rd QTR			4th QTR		
AGE	Length	(SD)	N	Length	(SD)	N	Length	(SD)	N	Length	(SD)	N
2							27.0	(0.00)	1			
3	29.9	(2.20)	9	33.0	(2.29)	9	33.1	(2.64)	26	31.4	(2.30)	5
4	35.3	(1.22)	9	36.4	(2.34)	49	36.7	(2.73)	69	35.9	(2.60)	17
5	39.7	(3.34)	21	39.8	(2.92)	60	41.4	(2.67)	51	39.1	(2.50)	32
6	45.0	(2.95)	12	43.2	(2.56)	35	43.7	(2.93)	30	44.9	(2.84)	36
7	46.7	(3.29)	11	46.6	(2.91)	20	49.4	(3.82)	13	48.7	(3.57)	16
8	52.3	(3.20)	6	49.9	(2.46)	21	54.9	(3.18)	8	51.8	(4.18)	17
9				51.0	(3.24)	9	57.5	(2.12)	2	56.1	(3.02)	11
10				54.3	(2.42)	6	56.2	(2.86)	5	58.6	(1.51)	8
11				58.7	(3.79)	3	-	-	-	59.5	(2.12)	2
12				62.5	(3.54)	2	63.0	(0.00)	1	65.0	(0.00)	2
13				-	-	-				-	-	-
14				-	-	-				66.0	(2.83)	2
15				69.0	(0.00)	1				66.3	(2.52)	3
16										-	-	-
17										-	-	-
18										72.0	(0.00)	1

Table 4. Mean lengths (TL, cm) at age, standard deviations (SD), and sample sizes (N) calculated for American plaice (both sexes combined) collected during NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine (offshore strata 26-30,36-40 and inshore strata 57-90) in 1988

	Spring			Autumn		
Age	Length	(SD)	N	Length	(SD)	N
1	8.9	(1.43)	73	13.7	(1.82)	117
2	16.6	(2.41)	170	20.4	(2.27)	107
3	23.4	(2.58)	92	28.5	(3.09)	114
4	28.4	(4.07)	79	33.8	(2.94)	48
5	34.4	(4.37)	30	39.2	(3.42)	33
6	38.9	(4.14)	25	44.5	(2.00)	8
7	42.8	(5.47)	9	50.0	(4.24)	2
8	45.0	(1.41)	2	-	-	-
9	51.2	(2.99)	6	52.5	(7.78)	2
10	44.5	(12.02)	2	-	-	-
11	51.0	(0.00)	1	58.0	(0.00)	1

Table 5. Mean lengths (TL, cm) at age, standard deviations (SD), and sample sizes (N) calculated for American plaice (both sexes combined) collected during NEFSC spring and autumn bottom trawl surveys from Georges Bank (offshore strata 13-25) in 1988

	Spring			Autumn		
Age	Length	(SD)	N	Length	(SD)	N
1	8.0	(0.00)	1	14.4	(2.26)	31
2	18.0	(2.38)	24	23.3	(2.42)	25
3	28.8	(3.34)	17	31.5	(2.20)	19
4	33.2	(3.21)	16	36.9	(2.93)	9
5	38.9	(3.80)	7	39.0	(1.00)	3
6	42.0	(4.24)	2	-	-	-
7	50.0	(0.00)	1	45.5	(2.12)	2
8	-	-	-	-	-	-
9	53.0	(0.00)	1	46.0	(0.00)	1
10	57.0	(0.00)	1	-	-	-
11				59.0	(9.90)	2

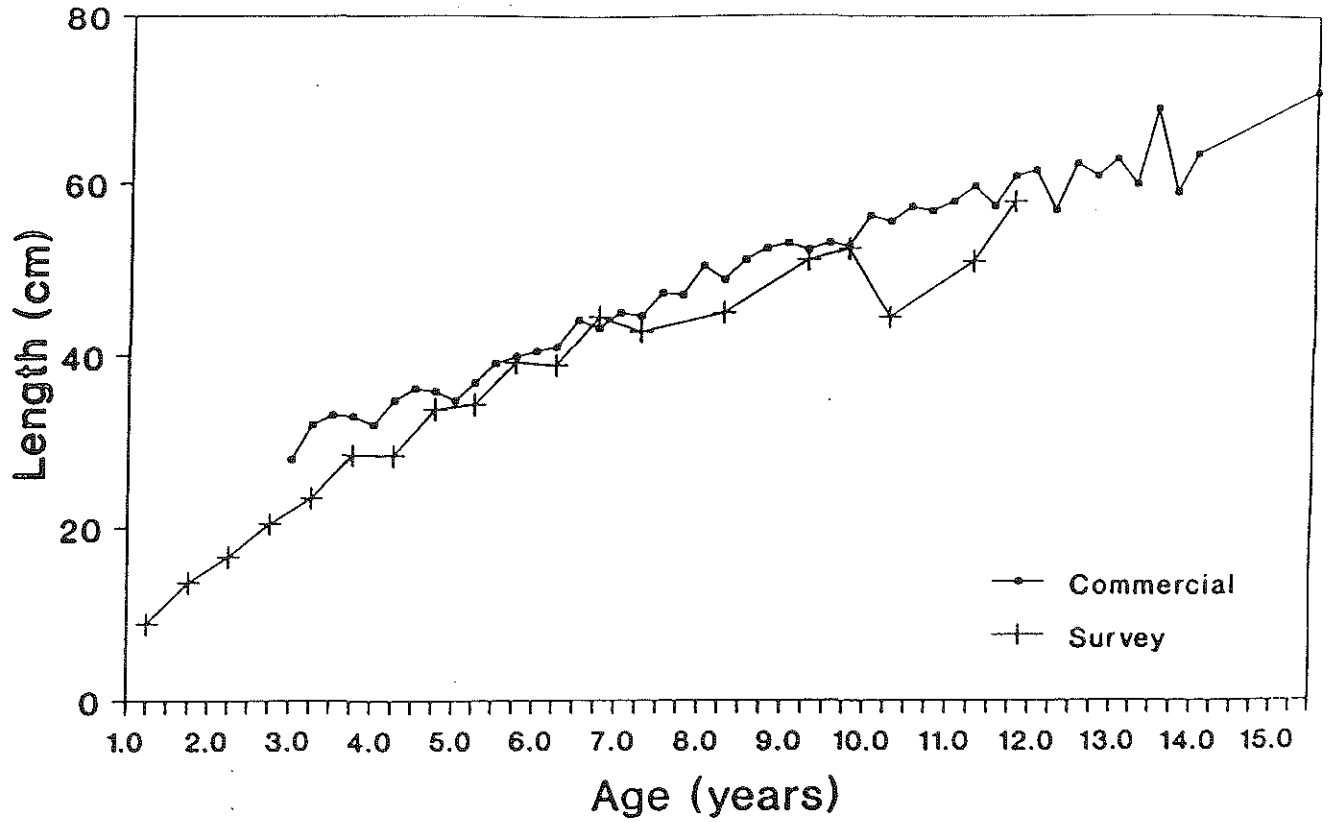

Figure 3. Mean lengths at fractional age for American plaice in the Gulf of Maine region calculated from 1988 commercial and bottom trawl survey data.

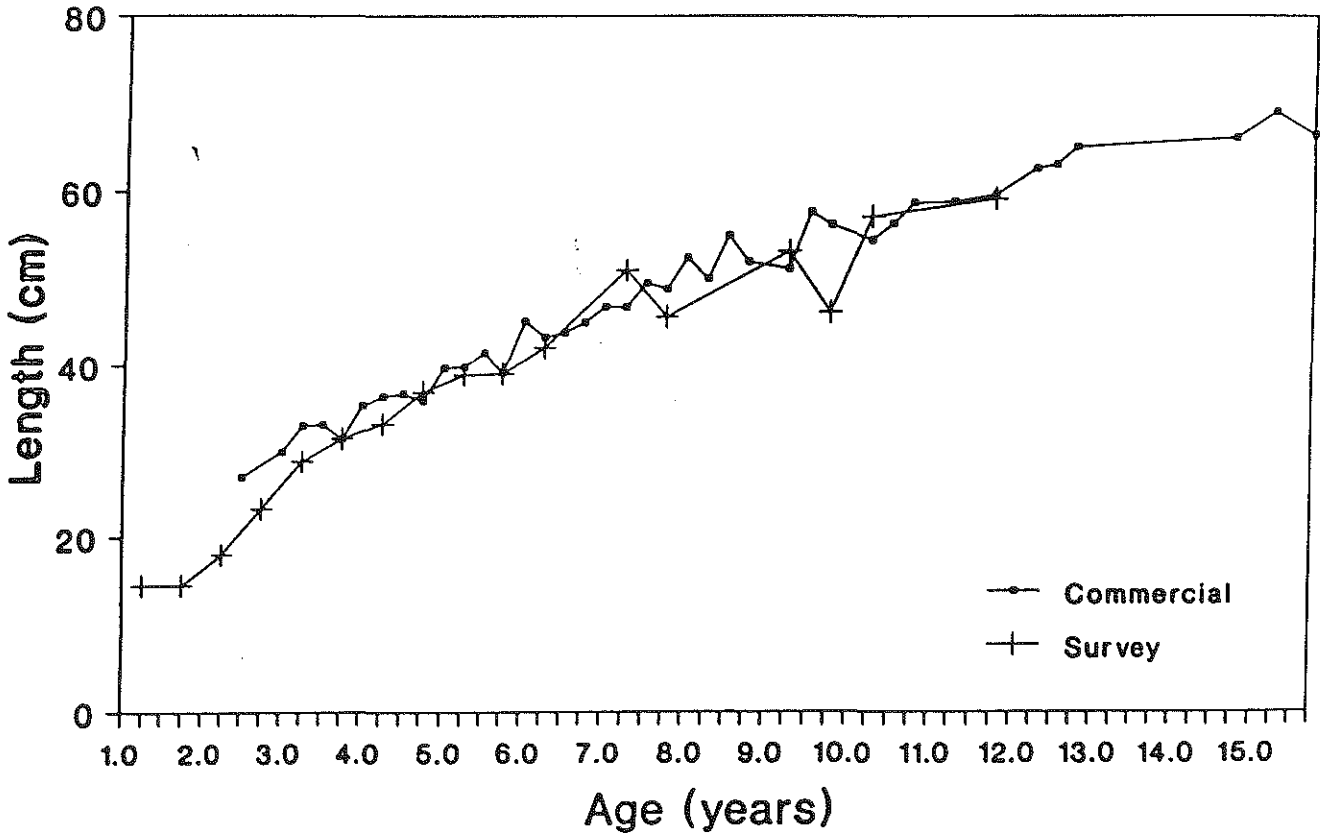

Figure 4. Mean lengths at fractional age for American plaice in the Georges Bank region calculated from 1988 commercial and bottom trawl survey data (one commercial sample of length 72 cm and age 18 is not plotted.)

Table 6. Results of American plaice growth modeling using length *vs* transformed age regressions by region and data source

Statistic	Gulf of Maine	Georges Bank
Commercial Data		
Slope	24.6475	23.5506
Intercept	1.5965	1.8919
df	44	38
R^2	0.96	0.97
p	<0.01	<0.01
Survey Data		
Slope	22.0827	22.7879
Intercept	0.5352	0.6907
df	18	15
r^2	0.96	0.97
p	<0.01	<0.01

Maine (Clark *et al.* 1982 for haddock, *Melanogrammus aeglefinus*; Lux 1973 and Howe and Coates 1975 for winter flounder, *Pleuronectes americanus*; O'Brien 1990 for Atlantic cod, *Gadus morhua*). Generally this is attributed to higher productivity and warmer temperatures of Georges Bank. However, the lack of any statistical difference in regression slopes between regions in this study suggests that it is more likely that size at hatching or larval growth rates are greater for plaice on Georges Bank (manifested by the larger intercept value); it appears that the actual rate of growth beyond age 2 is similar in both regions.

Significant differences in growth rates observed between survey and commercial data are probably due to the likelihood that the commercial fishery is operating upon the faster-growing fish in the population over the partially-recruited age groups. Slower-growing fish are either discarded with respect to the minimum size or have not yet recruited to the adult population that sustains the fishery. Results of our study suggest that use of survey age-length keys applied to commercial length frequencies would bias estimates of stock age composition (Westrheim and Ricker 1978), but the aforementioned analysis (NEFSC 1992) using these same 1988 data found that this was not the case. Thus, we are left to conclude that caution be used in pooling American plaice age data from the two regions, particularly in the derivation of growth parameters for yield per recruit calculations.

Table 7. Results of analysis of covariance for American plaice length *vs* transformed age regressions by region and data source (* = $p < 0.05$, ** = $p < 0.01$)

Comparison	df	SS	Test for slope		Test for elevation	
			F	Prob.	F	Prob.
Gulf of Maine-Georges Bank (survey data)	33	245.7	0.235	0.631	3.567	0.040 *
Gulf of Maine-Georges Bank (commercial data)	82	366.6	1.241	0.269	4.389	0.015 *
Survey data-commercial data (Gulf of Maine)	62	375.9	4.4193	0.040 *		
Survey data-commercial data (Georges Bank)	53	236.4	0.5093	0.479	7.900	0.001 **

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