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Maturation of Nineteen Species of Finfish off the Northeast Coast of the United States, 1985–1990

Loretta O'Brien
Jay Burnett
Ralph K. Mayo

U.S. Department of Commerce

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U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary
National Oceanic and Atmospheric Administration
D. James Baker, Under Secretary for Oceans and Atmosphere
National Marine Fisheries Service

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LORETTA O'BRIEN, JAY BURNETT, and RALPH K. MAYO

Woods Hole Laboratory
Northeast Fisheries Science Center
Woods Hole, MA 02543

ABSTRACT

Observations on maturation stages of nineteen species of economically important finfish off the Northeast coast of the USA were analyzed to examine relationships between fish size or age, and maturity. Maturation schedules and median lengths (L_{50}) and ages (A_{50}) at maturation were derived by fitting the logistic model to the observed proportions. Analyses were generally restricted to observations from 1985 to 1990 obtained during stratified random bottom trawl surveys conducted in spring and autumn by the Northeast Fisheries Science Center and the Commonwealth of Massachusetts Division of Marine Fisheries in waters of the continental shelf from Nova Scotia to Cape Hatteras, North Carolina. Butterfish, *Peprilus triacanthus,* attained sexual maturity at the smallest median length (11.4 cm, males) and pollock, *Pollachius virens,* at the highest (41.8 cm, males). Median length at maturity for gadiforms ranged from 22.2 to 41.8 cm. Within the pleuronectiforms, median length at maturity ranged from 19.1 to 30.4 cm. Median lengths for the pelagic and miscellaneous demersal species were in the same ranges as the pleuronectiforms. Butterfish also attained sexual maturity at the youngest median age (0.9 yr, both sexes) whereas redfish, *Sebastes fasciatus,* were the latest to mature (5.5 yr, both sexes). For gadids, the median age at maturity ranged from 1.3 to 2.3 yr. Within the pleuronectiforms, median age at maturity ranged from 1.3 to 4.4 yr and, for pelagic species, from 0.9 to 3.0 yr. Median lengths and ages for many species are lower than those reported in earlier studies of the same general region of the Northwest Atlantic.

Introduction

Maturation rates, along with rates of growth and mortality, are vital to the characterization of the population dynamics of fish stocks. The age at first reproduction has a strong influence upon the population growth rate (Cole 1954); Beverton and Holt (1959) Beverton (1963, 1987) and Garrod and Horwood (1984) have all noted the interdependence of lifespan, growth, and age at first maturity implicit in the compensatory response of exploited fish stocks to fishing pressure.

The interactions between growth and maturation are varied and complex. Alm (1959) and Roff (1981, 1982) identified size and age as codeterminants in the onset of maturity in fish, but for most species, size was the more important factor. Several studies (Molander 1925; Alm 1959; Jøgensen 1990; O'Brien 1990) have attributed observed reductions in the age at maturity to increases in growth rates, particularly during the juvenile stage (Godo and Moksness 1987). However, there is some evidence that early maturation is associated with poor growth, i.e. at some point the age effect upon the maturation process overrides the size effect (Elkin 1955; Schaffer and Elson 1975; Mayo et al. 1990). It is also possible that observed changes in median age at maturity values are simply artifacts of changes in growth. For example, a species for which maturation is size-dependent would appear to have lowered its median age at maturity if increased growth caused it to attain the critical size at a younger age. Interpretations of maturity analyses, therefore, should be made carefully and with some consideration of possible changes in growth rates.

Maturity estimates by size or age provide information about trends in maturation as stock sizes and environmental conditions fluctuate, and may be used directly in the evaluation of fishery management programs. Estimates of median length at maturity are used to evaluate mean retention lengths associated with various commercial gear types. Maturity-at-age data are also employed in the calculation of spawning stock biomass per recruit and maximum spawning potential (Gabriel et al. 1989). Estimates of spawning stock biomass and recruitment provide the framework for calculating the biological reference point, F_{rep} (Sissenwine and Shepherd 1987), for 13 of the species analyzed in this study which are included in the Northeast Multispecies Fishery Management Plan (New England Fishery Management Council 1985).

In this report, we provide length- and age-specific maturation ogives and estimates of median length and age at maturity for 19 species which have supported important commercial and recreational fisheries off the northeast coast of the United States. Exploitation rates for most of the species analyzed are at historically high levels and stock sizes are near or at historically low levels. Since growth and maturation rates are likely to change as stock sizes decline in abundance (Templeman and Bishop 1979; Sinclair et al. 1980; Bowering 1989), it is probable that growth rates for many of the species included in our study have increased in recent years. In view of these trends, the primary goal of this study is to provide a comprehensive summary of recent maturity information for these species.

Methods

The data analyzed in this study were collected during stratified random bottom trawl surveys conducted in spring and autumn by the Northeast Fisheries Science Center (NEFSC), National Marine Fisheries Service (Doubleday 1981; NEFC 1988) and the Massachusetts Division of Marine Fisheries (MDMF) (Azarovitz et al. 1989). Surveys conducted by the NEFSC cover the inshore and offshore areas of the continental shelf from Nova Scotia to Cape Hatteras, North Carolina (Fig. 1). The Massachusetts Division of Marine Fisheries conducts surveys in the inshore waters along the coast of Massachusetts (Fig. 1). Data from MDMF were used only for the inshore stocks of winter flounder, *Pleuronectes americanus,* owing to observed mixing of stocks for this species in the offshore NEFSC survey.

During each survey, finfish were sampled for determination of length (to nearest cm), sex, and maturity stage. Fish with forked tails were measured using fork length (FL); otherwise, all fish were measured using total length (TL). Atlantic herring, *Clupea harengus,* were frozen at sea and measured in the laboratory using total length. Black sea bass, *Centropristis striata,* were also measured using total length, excluding the caudal filament. The criteria for seven stages of maturity classification are presented in Table 1 as similarly described by Burnett et al. (1989). Fish were also sampled for age determination by removing either scales or otoliths and were analyzed in the laboratory by using species-specific ageing methods as described by Penttila and Dery (1988).

Nineteen species, comprising twenty-nine stocks, were analyzed to determine the median length (L_{50}) at maturity; fourteen species, comprising twenty-two stocks, were analyzed to determine median age (A_{50}) at matu-

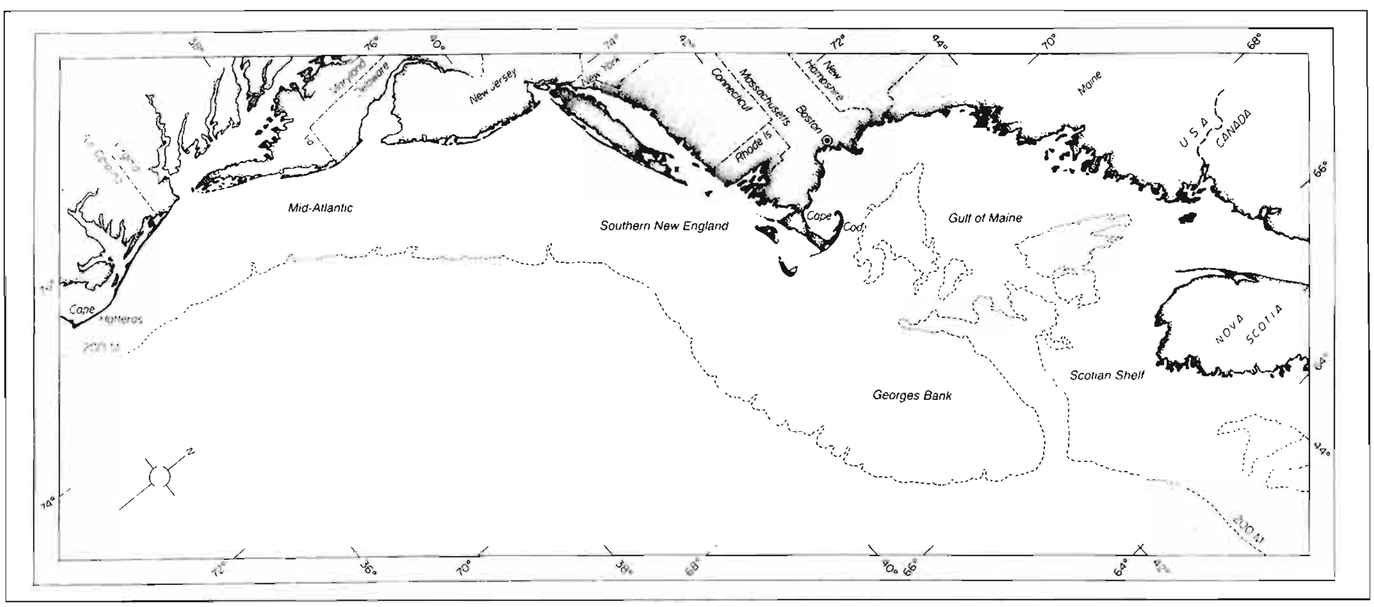

Figure 1
Areas of the continental shelf from Nova Scotia to Cape Hatteras, North Carolina surveyed by the Northeast Fisheries Science Center and the Massachusetts Division of Marine Fisheries spring and autumn bottom trawl surveys.

rity. Maturity classifications were considered as either immature or mature by combining all stages other than immature. Length and age based analyses were generally restricted to the period 1985–1989 or 1990 depending upon the availability of data (Table 2). Exceptions were redfish, *Sebastes fasciatus,* and red hake, *Urophycis chuss,* for which recent age data were not available. Stock areas (Fig. 1) were delineated by NEFSC bottom trawl survey strata (Table 2) as defined by current stock structure (NEFSC 1991). Either spring or autumn data collected closest to the time of spawning were used in the analyses for each species (Table 2). This was done in an attempt to minimize errors in maturity classifications, especially in differentiating between immature and resting gonads (Halliday 1987).

The observed proportion of fish mature at length and age was calculated for each species by stock area, year, season, and sex. Immature fish not identified by

Table 1

Current maturity staging criteria used during Northeast Fisheries Science Center bottom trawl surveys.

Stage	Code	Description and criteria
Females		
Immature	I	Ovary paired, tube-like, small relative to body cavity; colorless to pink jell-like tissue, no visible eggs; thin, transparent outer membrane. Butterfish, *Peprilus triacanthus*: ovary paired and flattened, ovary wall striated or wrinkled. Ocean pout, *Macrozoarces americanus*: ovary **not** paired.
Developing	D	Ovaries large, occupying up to 2/3 of body cavity; blood vessels prominent when present; ovary appears granular as yellow to orange yolked eggs develop. A mixture of less than 50% yolked and hydrated eggs denotes **D**.
Ripe	R	Ovaries large, may fill entire body cavity; a mixture of 50% or more hydrated eggs denotes **R**; transparent ovary wall.
Eyed	E	Redfish *Sebastes fasciatus* only: ovary large, robust, transparent membrane with dark spotted eggs containing developing eyed-stage larvae.
Ripe and Running	U	Eggs flow from vent with little or no pressure to abdomen.
Spent	S	Ovaries flaccid, sac-like, similar in size to ripe ovaries; color red to purple; ovary wall thickened, cloudy and translucent; some hydrated or yolked eggs may adhere to ovary wall.
Resting	T	Ovaries smaller than ripe ovaries, but larger than immature. Interior jell-like, no visible eggs. Haddock, *Melanogrammus aeglefinus*: ovaries small relative to body cavity, wall thick and tough with purplish membrane, blood vessels less prominent and purplish. Pleuronectiformes: ovaries larger relative to the body cavity than in gadids, interior yellow or orange. Ovary wall cloudy or translucent and thicker and tougher than in ripe ovaries.
Males		
Immature	I	Testes small relative to body cavity, colorless to gray and translucent. Butterfish, *Peprilus triacanthus*: similar to ovary, but with a smooth wall. Pleuronectiformes: testis located posterior of body cavity; triangular shape with sharp anterior edge. Winter flounder, *Pleuronectes americanus*: posterior portion of testis extends further back similar to ovary but the shape is different: the endpoint of the testis is rounded, and more flattened as it extends posteriorly. Gadids: testes narrow, lobed and elongated, resembles crimped ribbon. Atlantic herring, *Clupea harengus*, mackerel *Scomber scombrus*, scup, *Stenotomus chrysops*: similar shape as ovary, but there is an edge to the testis vs. being rounded in ovary.
Developing	D	Testes large, grey to off-white, firm consistency with very little or no milt present.
Ripe	R	Testes larger than **D**, chalk white, consistency mostly liquid. Milt flows easily when testis dissected.
Ripe and Running	U	Chalk white milt flows easily from the vent with little or no pressure on abdomen. Once dissected, milt flows easily.
Spent	S	Testes flaccid, may contain residual milt, less robust than **R**. Edges or other parts of the testes starting to turn grey as milt recedes. Gadiformes: edges of lobes reddish to brown or grey as milt recedes.
Resting	T	Testes shrunken in size relative to **R**. Color is yellow, brown, or grey with little or no milt.

sex were assumed to have a 1:1 sex ratio and equal catchability and were included in the analyses by adding the number of unsexed fish at each length to both female and male data sets. As a result, the sample size increased by less than 1% (*U. tenuis*) to 24% (*Stenotomus chrysops*) in 27 of the 29 stock analyses. No other adjustments were made to the observations.

The proportion of fish mature at length and age was estimated by fitting the logistic model to the observed proportions mature at length and age. The form of the logistic was

$$P = \frac{1}{1+e^{-(\alpha+\beta x)}}, \tag{1}$$

where P = proportion mature at age or length
x = either length or age, and
α, β = model parameters to be estimated.

Logistic regressions (Dixon 1981) were performed on each species stock, by sex, to obtain the model parameters. Median length or age at maturity was calculated from the regression coefficients as [-a/b].

The generally low sample sizes for each sex within a stock area did not allow for calculation of reliable annual estimates. Thus, years with similar values of L_{50} and A_{50} that also had relatively stable stock sizes were pooled to achieve the objective of obtaining a representative maturity schedule reflecting current stock conditions. As a result, one or two years of data were excluded for five species and nine analyses. The combined data were then analyzed using the same methods as described above.

The approximate variance for large samples (Ashton 1972) was calculated for given proportions mature (y) at length or age as

$$s^2(y) = \frac{1}{b^2}\left[s^2(a) + \frac{a^2}{b^2}s^2(b) - \frac{2a}{b}cov(a,b)\right]. \tag{2}$$

The computational equation for this formula is

$$s^2(y) = \frac{1}{b^2}\left[s^2(\acute{a}) + (y-\bar{x})^2 s^2(b)\right], \tag{3}$$

where a, b = estimates of α and β
y = length or age at maturity for a given proportion
$s^2(\acute{a})$ = $1 / \Sigma\ (nPQ)$
P = probability of a response
Q = 1 - P
n = number of fish at length or age x
$\bar{x}$ = $\Sigma\ nPQx / \Sigma\ nPQ$
$s(b)$ = standard error of b.

Since exact confidence limits for the statistic y are not available, approximate 95% confidence limits were calculated (Zar 1984) at increments of 0.05 for proportions mature at length and at whole ages for proportions mature at age. The t-distribution was used at an alpha level of 0.05 for varying degrees of freedom (df) with the standard error of y as

$$y \pm t_{0.05,df}\, s(y). \tag{4}$$

Results

Butterfish, *Peprilus triacanthus,* attained sexual maturity at the smallest median length (11.4 cm, males) and pollock, *Pollachius virens,* at the highest (41.8 cm, males) (Table 3). Median length at maturity for the gadids ranged from 22.2 cm (red hake, *U. chuss,* males) to 41.8 cm (pollock, *P. virens,* males). Within the pleuronectiforms, median length at maturity ranged from 19.1 cm (yellowtail flounder, *Pleuronectes ferrugineus,* males) to 30.4 cm (witch flounder, *Glyptocephalus cynoglossus,* females). Median lengths for the pelagic and miscellaneous demersal species were in the same ranges as the pleuronectiforms.

Butterfish, *Peprilus triacanthus,* also attained sexual maturity at the youngest median age (0.9 yr, both sexes) while redfish, *Sebastes fasciatus,* were the latest to mature (5.5 yr, both sexes) (Table 4). For gadids, the median age at maturity ranged from 1.3 yr (haddock, *Melanogrammus aeglefinus,* males) to 2.3 yr (cod, *Gadus morhua,* and pollock, *Pollachius virens,* males). Within the pleuronectiforms, median age at maturity ranged from 1.3 yr (yellowtail flounder, *Pleuronectes ferrugineus,* males) to 4.4 yr (witch flounder, *G. cynoglossus,* females) and, for pelagic species, from 0.9 yr (butterfish, *Peprilus triacanthus*) to 3.0 yr (Atlantic herring, *Clupea harengus,* females). Median lengths and ages for many species are lower than those reported in earlier studies of the same general region of the Northwest Atlantic.

Median lengths vs. median ages at maturation for the gadiforms and pleuronectiforms are plotted in Figure 2. For gadiforms, L_{50} and A_{50} estimates extend over a wide range of lengths within a relatively narrow age span. Pleuronectiforms, however, exhibit an opposite pattern, with estimates extending over a very wide range of ages within a narrow length span. This suggests that, during the study period, the maturation process was age-dependent for the gadiforms and size-dependent for the pleuronectiforms.

In each of the following species sections, tables of the proportion of fish mature at length are presented in 0.05 increments and tables of proportions of fish mature at age are presented in whole ages.

Table 2

Species by stock area, spawning season (Smith 1985[a]), survey season, Northeast Fisheries Science Center offshore strata sets, and years included in each species stock analysis (GB=Georges Bank, NGB=Northern Georges Bank, SGB=Southern Georges Bank, GM=Gulf of Maine, CC=Cape Cod, SNE=Southern New England, MA=Middle Atlantic, N=North, S=South).

Species	Area	Spawning season (peak)	Survey Analyzed	Strata set	Years
Atlantic Cod *Gadus morhua*	GB	Nov–May (Feb–Mar)	Spring	13–25	1985–1990
	GM	Nov–May (Mar–May)	Spring	26–30, 36–40	1985–1990
Haddock *Melanogrammus aeglefinus*	GB	Jan–May (Mar–Apr)	Spring	13–25, 29–30	1985–1989
	GM	Feb–May (Mar–Apr)	Spring	26–28, 36–40	1985–1989
Pollock *Pollachius virens*	GB–GM	Oct–Mar (Dec–Jan)	Autumn	13–34, 351, 36–40	1986–1988
White hake *Urophycis tenuis*	GB–GM	Oct–May	Spring	21–30, 33, 34 351, 36–40	1987–1989
Red hake *Urophycis chuss*	GM–NGB	May–Sep (Jun–Jul)	Spring	20–30, 36–40	1982–1985
	SGB–MA	Mar–Oct (Aug–Sep)	Spring	1–19, 61–76; 1–46[b], 52[b], 55[b]	
Silver hake *Merluccius bilinearis*	GM–NGB	Apr–Oct (May–Aug)	Spring	20–30, 36–40	1985–1989
	SGB–MA	Apr–Oct (May–Sep)	Spring	1–19, 61–76; 1–46[b], 52[b], 55[b]	
Redfish *Sebastes fasciatus*	GM	Apr–Aug (Jun–Jul)	Spring[c] Autumn[d]	24, 26–30 36–40	1975–1980
Scup *Stenotomus chrysops*	All	May–Aug (May–Jun)	Spring	2–3, 61–63, 65–67, 70–71, 74–75	1985 1987–1990
Black sea bass *Centropristis striata*	All	Apr–Oct (Jun)	Spring	1–12, 25, 61–76; 1–61[b]	1985–1990
Ocean pout *Macrozoarces americanus*	SNE	Sep–Oct (Oct)	Spring	1–12, 61–76; 1–52[b]	1985–1990
	GM	Sep–Oct (Sep)	Spring	26–40; 57–66[b]	1985–1990
Yellowtail flounder *Pleuronectes ferrugineus*	GB	Apr–Aug (May–Jun)	Spring	13–21	1985–1990
	CC	Apr–Aug (May–Jun)	Spring	24–26	
	SNE	Apr–Aug (May–Jun)	Spring	5, 6, 9, 10	
Winter flounder *Pleuronectes americanus*	GB	Mar–May (Apr)	Spring	13–22	1985–1989
	N of CC	Apr–May (Apr)	Spring	25–36[e]	
	S of CC	Feb–May (Feb–Mar)	Spring	11–17[e]	
American plaice *Hippoglossoides platessoides*	GM	Feb–Jun (Apr–May)	Spring	26–30, 36–40	1986–1990
Witch flounder *Glyptocephalus cynoglossus*	GM	Apr–Aug (May–Jun)	Spring	22–30, 33–34, 351, 36–40	1986–1990
Summer flounder *Paralichthys dentatus*	All	Aug–Dec (Oct–Nov)	Autumn	1–12, 45–46, 52, 55–76; 1–41[b]	1985–1989
Windowpane *Scophthalmus aquosus*	GB	Jun–Oct (Jul–Aug)	Spring	13–21	1985–1990
	SNE	May–Nov (Sep)	Spring	5–12	
Atlantic herring *Clupea harengus*	SNE,GM	Aug–Dec (Sep–Oct)	Autumn	1–12, 24–30, 33–34, 351, 36–40, 61–76	1987–1989
Atlantic mackerel *Scomber scombrus*	All	Apr–Jul (Apr–Jun)	Spring	1–34, 351, 36–76; 1–81[b]	1987–1989
Butterfish *Peprilus triacanthus*	All	May–Sep (Jun–Jul)	Spring	1–25, 61–76; 1–46[b]	1986–1989

[a] W.G. Smith. 1985. Temperal and spatial spawning patterns of the principal species of fish and invertebrates in the Georges Bank region. NMFS/NEFC, Sandy Hook Laboratory, Lab. Ref. Doc. No. 85–4, 35 p.

[b] Northeast Fisheries Science Center inshore strata.

[c] females only.

[d] males only.

[e] Massachusetts Division of Marine Fisheries strata.

Table 3

Median length (cm) at maturity (L_{50}), parameter values a and b from the logistic regression, standard error (SE) of a and b, and the number of females (F) and males (M) of nineteen species of finfish sampled off the northeast coast of the United States.

Species	Sex	*a*	SE *a*	*b*	SE *b*	L_{50}	*n*
Atlantic cod, *Gadus morhua*							
1985–1990							
Georges Bank	F	-4.932	0.429	0.127	0.009	38.8	983
	M	-5.688	0.464	0.139	0.010	41.0	1034
Gulf of Maine	F	-5.500	0.653	0.171	0.018	32.1	411
	M	-5.048	0.554	0.140	0.014	36.0	394
Haddock, *Melanogrammus aeglefinus*							
1985–1989							
Georges Bank	F	-6.252	0.765	0.210	0.022	29.7	580
	M	-5.064	0.738	0.189	0.022	26.8	478
Gulf of Maine	F	-18.605	11.78	0.539	0.314	34.5	69
	M	-13.111	5.432	0.374	0.146	35.0	49
Pollock, *Pollachius virens*							
1986–1988	F	-6.004	1.120	0.154	0.027	39.1	154
	M	-6.788	1.158	0.162	0.028	41.8	143
White hake, *Urophycis tenuis*							
1987–1989	F	-4.808	0.538	0.137	0.014	35.1	455
	M	-7.790	0.894	0.238	0.026	32.7	346
Red hake, *Urophycis chuss*							
1982–1985							
Gulf of Maine - Northern	F	-13.560	1.665	0.504	0.058	26.9	667
Georges Bank	M	-12.073	1.846	0.543	0.075	22.2	595
Southern Georges							
Bank-Middle	F	-12.767	1.165	0.509	0.043	25.1	1020
Atlantic	M	-11.614	1.138	0.488	0.043	23.8	753
Silver hake, *Merluccius bilinearis*							
1985–1989							
Gulf of Maine - Northern	F	-11.963	0.687	0.519	0.029	23.1	1410
Georges Bank	M	-14.369	0.938	0.646	0.041	22.3	1026
Southern Georges							
Bank-Middle	F	-10.753	0.537	0.464	0.021	23.2	2429
Atlantic	M	-14.263	0.890	0.629	0.037	22.7	1612
Redfish, *Sebastes fasciatus*							
1975–1980	F	-13.240	1.017	0.595	0.044	22.3	1457
	M	-6.929	0.476	0.331	0.020	20.9	1526
Scup, *Stenotomus chrysops*							
1985,1987–1990	F	-14.071	1.944	0.907	0.122	15.5	284
	M	-12.491	1.797	0.801	0.112	15.6	232
Black sea bass, *Centropristis striata*							
1985–1990	F	-4.691	0.535	0.245	0.024	19.1	561
	M	-6.841	0.957	0.360	0.045	19.0	348
Ocean Pout, *Macrozoarces americanus*							
1985–1990							
Gulf of Maine	F	-5.101	2.103	0.195	0.065	26.2	88
	M	-4.455	2.343	0.147	0.057	30.3	55

Table 3 (Continued)

Median length (cm) at maturity (L_{50}), parameter values a and b from the logistic regression, standard error (SE) of a and b, and the number of females (F) and males (M) of nineteen species of finfish sampled off the northeast coast of the United States.

Species	Sex	*a*	SE *a*	*b*	SE *b*	L_{50}	*n*
Southern New England	F	-6.515	1.584	0.208	0.040	31.3	197
	M	-5.920	1.204	0.186	0.032	31.9	205
Yellowtail flounder, *Pleuronectes ferrugineus*							
1985–1990							
Georges Bank	F	-15.136	5.207	0.587	0.181	25.8	167
	M	-8.145	2.776	0.381	0.098	21.4	271
Cape Cod	F	-11.738	1.951	0.430	0.071	27.3	140
	M	-10.103	1.577	0.377	0.058	26.8	165
Southern New England	F	-11.366	2.833	0.445	0.098	25.5	204
	M	-7.331	1.734	0.375	0.066	19.6	367
Winter flounder, *Pleuronectes americanus*							
1985-1989							
Georges Bank	F	-10.855	2.245	0.436	0.084	24.9	204
	M	-7.724	1.551	0.301	0.054	25.6	174
North of Cape Cod	F	-26.646	3.661	0.896	0.121	29.7	320
	M	-16.906	2.416	0.613	0.087	27.6	215
South of Cape Cod	F	-11.895	1.320	0.431	0.046	27.6	398
	M	-17.099	2.130	0.590	0.074	29.0	301
American plaice, *Hippoglossoides platessoides*							
1986–1990	F	-11.255	0.944	0.420	0.034	26.8	714
	M	-7.414	0.612	0.336	0.026	22.1	633
Witch flounder, *Glyptocephalus cynoglossus*							
1986–1990	F	-11.930	2.698	0.392	0.084	30.4	189
	M	-9.405	2.239	0.371	0.078	25.3	233
Summer flounder, *Paralichthys dentatus*							
1985–1989	F	-8.574	1.064	0.306	0.034	28.0	378
	M	-7.636	0.852	0.307	0.030	24.9	497
Windowpane, *Scophthalmus aquosus*							
1985–1990							
Georges Bank	F	-15.260	3.777	0.678	0.150	22.5	343
	M	-15.670	3.535	0.704	0.145	22.2	199
Southern New England	F	-88.592	72.23	4.185	3.441	21.2	143
	M	-19.595	4.553	0.910	0.201	21.5	133
Atlantic herring, *Clupea harengus*							
1987–1989	F	-28.484	3.955	1.123	0.151	25.4	359
	M	-40.461	6.218	1.597	0.243	25.3	307
Atlantic mackerel, *Scomber scombrus*							
1987–1989	F	-16.475	1.601	0.641	0.060	25.7	697
	M	-17.102	1.516	0.658	0.056	26.0	770
Butterfish, *Peprilus triacanthus*							
1986–1989	F	-14.495	1.939	1.213	0.157	12.0	333
	M	-11.029	1.333	0.968	0.112	11.4	341

Table 4

Median age (yrs) at maturity (A_{50}), parameter values a and b from the logistic regression, standard error (SE) of a and b, and the number of females (F) and males (M) of fourteen species of finfish sampled off the northeast coast of the United States.

Species	Sex	*a*	SE *a*	*b*	SE *b*	A_{50}	*n*
Atlantic cod, *Gadus morhua*							
1985–1990							
Georges Bank	F	-2.842	0.301	1.626	0.131	1.7	970
	M	-3.258	0.306	1.725	0.129	1.9	1021
Gulf of Maine	F	-4.690	0.571	2.225	0.233	2.1	409
	M	-3.828	0.451	1.651	0.173	2.3	392
Haddock, *Melanogrammus aeglefinus*							
1985–1989							
Georges Bank	F	-3.283	0.482	2.233	0.250	1.5	580
	M	-2.784	0.494	2.189	0.275	1.3	478
Gulf of Maine	F	-4.423	1.996	2.504	0.792	1.8	69
	M	-4.190	1.915	1.963	0.698	2.1	49
Pollock, *Pollachius virens*							
1986–1988	F	-2.346	0.554	1.173	0.221	2.0	154
	M	-4.415	0.823	1.897	0.347	2.3	143
White hake, *Urophycis tenuis*							
1987–1989	F	-2.441	0.324	1.751	0.180	1.4	455
	M	-3.304	0.418	2.400	0.262	1.4	346
Red hake, *Urophycis chuss*							
1982–1985							
Gulf of Maine - Northern	F	-7.342	1.167	4.166	0.587	1.8	667
Georges Bank	M	-5.725	0.846	3.994	0.473	1.4	595
Southern Georges							
Bank-Middle	F	-5.554	0.485	3.205	0.251	1.7	1020
Atlantic	M	-4.957	0.452	2.799	0.235	1.8	753
Silver hake, *Merluccius bilinearis*							
1985–1989							
Gulf of Maine - Northern	F	-5.825	0.323	3.342	0.175	1.7	1410
Georges Bank	M	-6.349	0.374	3.710	0.213	1.7	1026
Southern Georges							
Bank-Middle	F	-5.748	0.272	3.599	0.152	1.6	2429
Atlantic	M	-6.176	0.337	3.746	0.187	1.6	1612
Redfish, *Sebastes fasciatus*							
1975–1980	F	-6.455	0.563	1.172	0.096	5.5	1457
	M	-3.336	0.331	0.602	0.050	5.5	1526
Yellowtail flounder, *Pleuronectes ferrugineus*							
1985–1990							
Georges Bank	F	-17.150	29.78	9.578	14.89	1.8	167
	M	-5.152	2.219	3.866	1.131	1.3	271
Cape Cod	F	-10.355	1.572	3.933	0.595	2.6	140
	M	-7.388	1.117	2.874	0.427	2.6	165
Southern New England	F	-4.886	1.049	2.967	0.529	1.6	204
	M	-18.942	25.49	10.72	12.75	1.8	367
Winter flounder, *Pleuronectes americanus*							
1985–1989							
Georges Bank	F	-7.164	2.075	3.822	1.011	1.9	204
	M	-4.728	1.155	2.481	0.523	1.9	174
North of Cape Cod	F	-11.903	1.259	3.423	0.355	3.5	320
	M	-8.568	1.221	2.627	0.384	3.3	215
South of Cape Cod	F	-8.286	1.027	2.801	0.334	3.0	398
	M	-7.706	0.927	2.317	0.285	3.3	301

Table 4 (Continued)

Median age (yrs) at maturity (A_{50}), parameter values a and b from the logistic regression, standard error (SE) of a and b, and the number of females (F) and males (M) of fourteen species of finfish sampled off the northeast coast of the United States.

Species	Sex	*a*	SE *a*	*b*	SE *b*	A_{50}	*n*
American plaice, *Hippoglossoides platessoides*							
1986–1990	F	-7.419	0.584	2.089	0.160	3.6	714
	M	-4.975	0.413	1.659	0.132	3.0	633
Witch flounder, *Glyptocephalus cynoglossus*							
1986–1990	F	-6.957	1.562	1.591	0.327	4.4	189
	M	-8.468	2.284	2.340	0.563	3.6	233
Atlantic herring, *Clupea harengus*							
1987–1989	F	-14.503	3.101	4.804	1.018	3.0	359
	M	-11.480	2.245	3.938	0.726	2.9	307
Atlantic mackerel, *Scomber scombrus*							
1987–1989	F	-8.499	1.426	4.511	0.722	1.9	697
	M	-6.068	0.718	3.199	0.366	1.9	770
Butterfish, *Peprilus triacanthus*							
1986–1989	F	-2.608	0.590	3.001	0.521	0.9	333
	M	-2.553	0.574	2.909	0.521	0.9	341

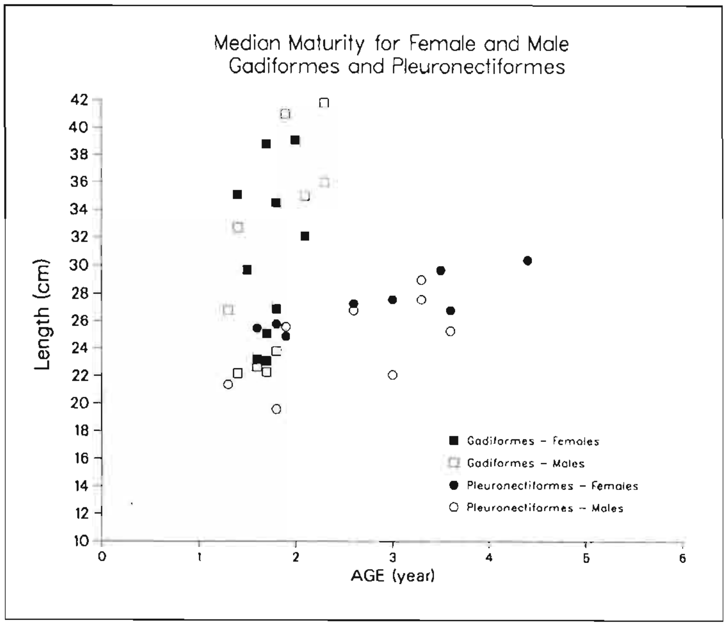

Figure 2

Median length (L_{50}) and median age (A_{50}) at maturity for female and male Gadiformes and Pleuronectiformes.

Atlantic Cod: *Gadus morhua*

Atlantic cod are distributed in the northwest Atlantic from Port Burwell, West Greenland to Cape Lookout, North Carolina (Serchuk and Wood 1979[1]). Within the New England area, four distinct stocks are recognized (Wise 1963): Georges Bank, Gulf of Maine, Southern New England, and the New Jersey coastal cod. The spawning season is from November to May; peak spawning on Georges Bank occurs during February and March and in the Gulf of Maine from March to May (Table 2). Total commercial landings of Atlantic cod from Georges Bank declined from a peak of about 64,000 metric tons (t) in 1982 to a low of about 28,000 t in 1986 and have increased to about 37,000 t in 1989 (NEFSC 1991). Landings from the Gulf of Maine region declined from a peak of about 15,100 t in 1983 to a low of about 8,300 t in 1987 and have recently increased to about 13,000 t in 1989 (NEFSC 1991).

Median length at maturity for female and male Atlantic cod, sampled from Georges Bank during the

[1] F.M. Serchuk and P.W. Wood. 1979. Review and status of the Southern New England - Middle Atlantic Atlantic cod, *Gadus morhua*, populations. NEFC, Woods Hole Laboratory, Lab. Ref. Doc. 79-37, 71 p.

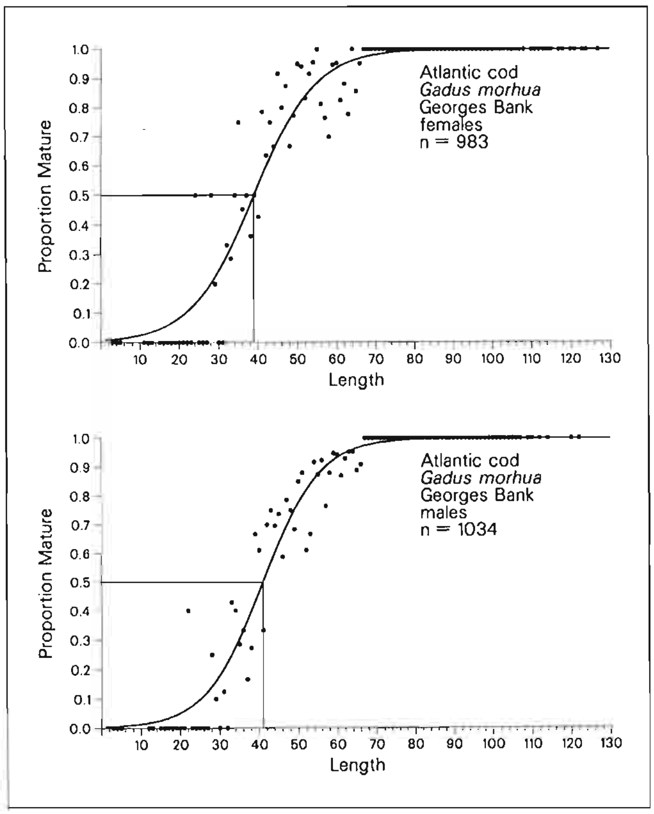

Figure 3
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Georges Bank female (n=983) and male (n=1034) Atlantic cod, *Gadus morhua*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 5
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Georges Bank female (n=983) and male (n=1034) Atlantic cod, Gadus morhua, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Females			
0.05	15.6	11.2	20.1
0.10	21.5	17.8	25.2
0.15	25.2	21.9	28.4
0.20	27.9	25.0	30.8
0.25	30.2	27.6	32.8
0.30	32.2	29.8	34.6
0.35	34.0	31.7	36.2
0.40	35.6	33.6	37.7
0.45	37.2	35.3	39.2
0.50	38.8	37.0	40.6
0.55	40.4	38.7	42.1
0.60	42.0	40.4	43.7
0.65	43.7	42.1	45.3
0.70	45.5	43.9	47.1
0.75	47.5	45.8	49.1
0.80	49.7	48.0	51.5
0.85	52.5	50.5	54.4
0.90	56.1	53.8	58.4
0.95	62.0	59.1	65.0
0.99	75.0	70.4	79.6
Males			
0.05	19.8	15.8	23.7
0.10	25.1	21.9	28.4
0.15	28.5	25.6	31.3
0.20	31.0	28.4	33.5
0.25	33.0	30.7	35.4
0.30	34.9	32.7	37.0
0.35	36.5	34.5	38.5
0.40	38.0	36.2	39.9
0.45	39.5	37.8	41.2
0.50	41.0	39.3	42.6
0.55	42.4	40.8	44.0
0.60	43.9	42.4	45.4
0.65	45.4	43.9	46.9
0.70	47.1	45.6	48.5
0.75	48.9	47.3	50.4
0.80	50.9	49.3	52.6
0.85	53.4	51.7	55.2
0.90	56.8	54.7	58.9
0.95	62.2	59.5	64.8
0.99	74.0	69.9	78.2

[a] Offshore strata 13–25.

spring of 1985-1990, was 38.8 cm and 41.0 cm, respectively (Tables 3 and 5, Fig. 3). From the Gulf of Maine region, L_{50} values were 32.1 cm for females and 36.0 cm for males for Atlantic cod sampled during 1985–1990 (Tables 3 and 7, Fig. 5). Median age at maturity was 1.7 yr and 1.9 yr, respectively, for females and males from Georges Bank (Table 4, Fig. 4) and 2.1 yr and 2.3 yr for females and males from the Gulf of Maine (Table 4, Fig. 6); proportions of mature fish calculated for each age are presented in Tables 6 and 8.

Median maturity values from the present study are noticeably lower for both sexes compared with previous studies. Livingstone and Dery (1976) noted that L_{50} values for Atlantic cod collected from Georges Bank during the spring of 1972 were 51.5 cm and 44.0 cm for females and males, respectively. The A_{50} values were 2.9 yr and 2.6 yr for females and males, respectively. Atlantic cod sampled over the entire region during 1977 (Morse 1979)[2] had L_{50} values of 49.6 cm and 53.7 cm for females and males, respectively.

Beacham (1983a) reported that slower-growing Atlantic cod of the Scotian Shelf area had L_{50} values of 52 cm for females and 51 cm for males in 1963 and that by 1978 the L_{50} values had declined to 35 cm and 38 cm, respectively. Median age values also declined from 3.7 yr and 4.8 yr for females and males, respectively, for the years 1959–1964 to 2.9 yr for females and 2.8 yrs for males during the years 1975–1979.

[2] W.W. Morse. 1979. An analysis of maturity observations of 12 groundfish species collected from Cape Hatteras, North Carolina to Nova Scotia in 1977. NMFS/NEFC Sandy Hook Laboratory Rep. No. SHL 79-32, 21 p.

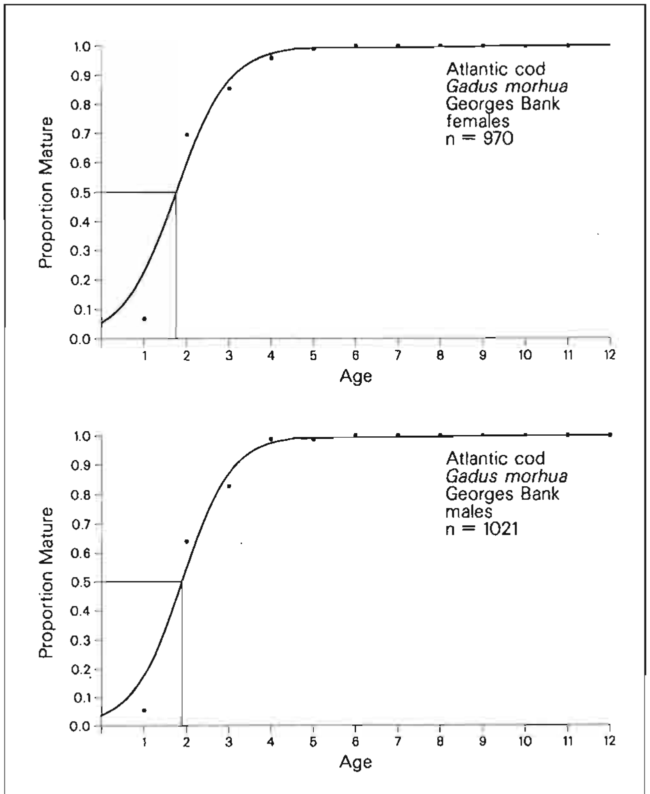

Figure 4
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Georges Bank female (n=970) and male (n=1021) Atlantic cod, *Gadus morhua*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 6
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Georges Bank female (n=970) and male (n=1021) Atlantic cod, *Gadus morhua*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.23	1.0	0.8	1.2
0.60	2.0	1.9	2.1
0.88	3.0	2.8	3.2
0.97	4.0	3.7	4.3
0.99	5.0	4.5	5.5
1.00	6.0	5.4	6.6
1.00	7.0	6.2	7.8
1.00	8.0	7.1	8.9
1.00	9.0	7.9	10.1
1.00	10.0	8.8	11.2
1.00	11.0	9.6	12.4
Males			
0.18	1.0	0.8	1.2
0.55	2.0	1.9	2.1
0.87	3.0	2.8	3.2
0.97	4.0	3.7	4.3
1.00	5.0	4.6	5.4
1.00	6.0	5.4	6.6
1.00	7.0	6.3	7.7
1.00	8.0	7.1	8.9
1.00	9.0	8.0	10.0
1.00	10.0	8.9	11.1
1.00	11.0	9.7	12.3
1.00	12.0	10.6	13.4

[a] Offshore strata 13–25.

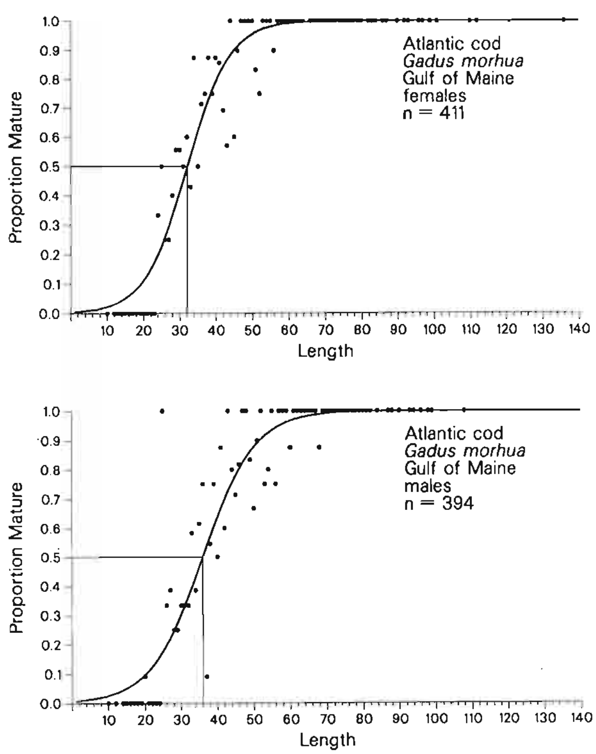

Figure 5

Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Gulf of Maine female (n=411) and male (n=394) Atlantic cod, *Gadus morhua*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 7

Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Gulf of Maine female (n=411) and male (n=394) Atlantic cod, *Gadus morhua*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	14.9	10.4	19.5
0.10	19.3	15.6	23.0
0.15	22.0	18.8	25.2
0.20	24.0	21.2	26.9
0.25	25.7	23.1	28.3
0.30	27.2	24.8	29.6
0.35	28.5	26.3	30.8
0.40	29.8	27.7	31.9
0.45	31.0	29.0	33.0
0.50	32.1	30.2	34.1
0.55	33.3	31.4	35.2
0.60	34.5	32.6	36.4
0.65	35.8	33.9	37.7
0.70	37.1	35.1	39.1
0.75	38.6	36.5	40.7
0.80	40.3	38.0	42.5
0.85	42.3	39.7	44.8
0.90	45.0	42.0	48.0
0.95	49.4	45.6	53.1
0.99	59.0	53.4	64.6
Males			
0.05	15.0	10.1	19.9
0.10	20.3	16.4	24.2
0.15	23.6	20.2	27.0
0.20	26.1	23.1	29.1
0.25	28.1	25.4	30.8
0.30	29.9	27.5	32.4
0.35	31.6	29.3	33.8
0.40	33.1	30.9	35.2
0.45	34.5	32.5	36.6
0.50	36.0	33.9	38.0
0.55	37.4	35.4	39.4
0.60	38.9	36.8	40.9
0.65	40.4	38.2	42.5
0.70	42.0	39.7	44.3
0.75	43.8	41.3	46.2
0.80	45.8	43.1	48.6
0.85	48.3	45.2	51.4
0.90	51.6	48.0	55.2
0.95	56.9	52.4	61.5
0.99	68.7	61.9	75.5

[a] Offshore strata 26–30, 36–40.

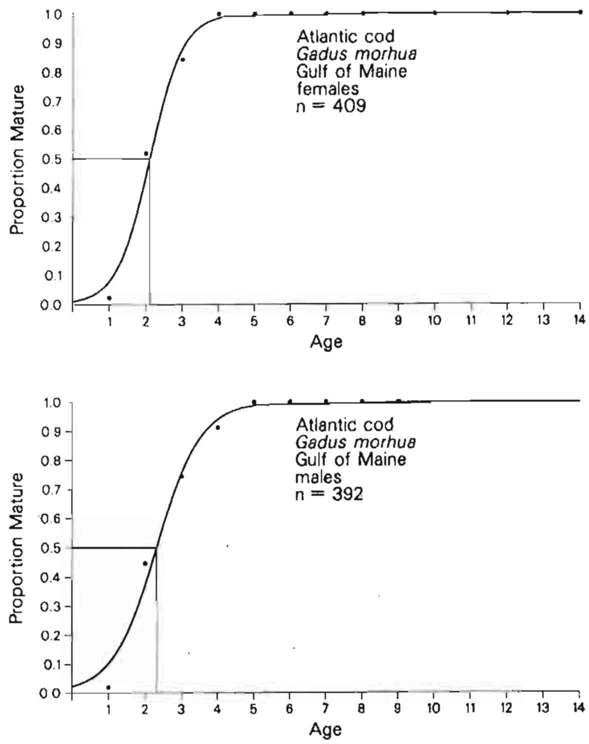

Figure 6

Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Gulf of Maine female (n=409) and male (n=392) Atlantic cod, *Gadus morhua,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 8

Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Gulf of Maine female (n=409) and male (n=392) Atlantic cod, *Gadus morhua,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.08	1.0	0.7	1.3
0.44	2.0	1.8	2.2
0.88	3.0	2.8	3.2
0.99	4.0	3.6	4.4
1.00	5.0	4.4	5.6
1.00	6.0	5.2	6.8
1.00	7.0	6.0	8.0
1.00	8.0	6.8	9.2
1.00	9.0	7.6	10.4
1.00	10.0	8.4	11.6
1.00	11.0	9.2	12.8
1.00	12.0	10.0	14.0
1.00	13.0	10.8	15.2
1.00	14.0	11.6	16.4
Males			
0.10	1.0	0.7	1.3
0.37	2.0	1.8	2.2
0.76	3.0	2.8	3.2
0.94	4.0	3.6	4.4
0.99	5.0	4.5	5.5
1.00	6.0	5.3	6.7
1.00	7.0	6.1	7.9
1.00	8.0	6.9	9.1
1.00	9.0	7.6	10.4

[a] Offshore strata 26–30, 36–40.

Haddock: *Melanogrammus aeglefinus*

Haddock range from West Greenland to Cape Hatteras in the northwest Atlantic, but are most common on the Scotian Shelf and on Georges Bank. Two stocks exist off New England: the major spawning concentration occurs on Georges Bank and a second stock with more dispersed spawning occurs in the Gulf of Maine (Grosslein 1962). Spawning takes place during late winter and early spring with peak activity occurring in March and April (Table 2). Commercial landings of haddock from Georges Bank increased from a long-term annual average of 50,000 metric tons prior to the 1960's to about 150,000 t per year in 1965 and 1966, but declined precipitously thereafter to about 5,000 t annually during the early-to-mid-1970's; after a temporary increase to about 25,000 t per year during the late 1970's and early 1980's, total landings from this stock declined again to less than 10,000 t per year since 1985. Landings from the Gulf of Maine have generally remained below 5,000 t per year except during the early 1980's when the total ranged between 6,000 and 7,000 t annually; landings have since declined to less than 1,000 t per year (NEFSC 1991).

Median length at maturity for female and male had-

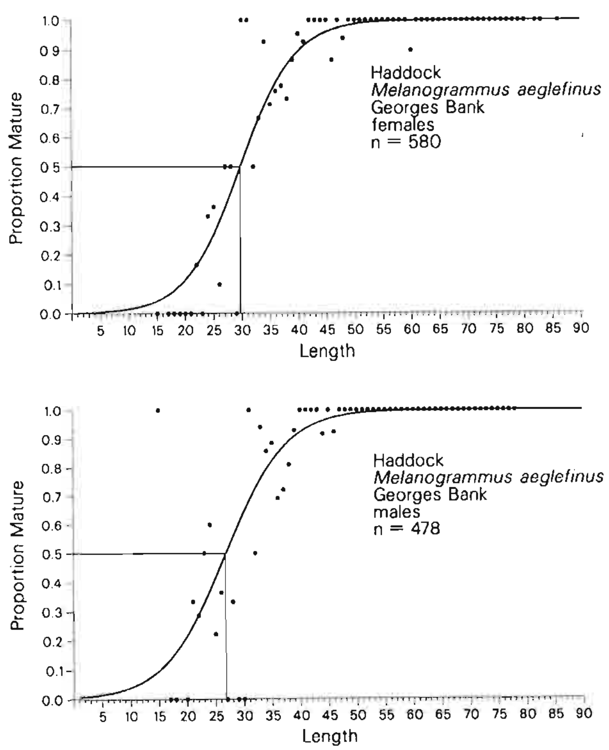

Figure 7
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Georges Bank female (n=580) and male (n=478) haddock, *Melanogrammus aeglefinus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 9
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Georges Bank female (n=580) and male (n=478) haddock, *Melanogrammus aeglefinus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	15.7	11.7	19.7
0.10	19.3	15.9	22.6
0.15	21.5	18.5	24.4
0.20	23.1	20.5	25.8
0.25	24.5	22.1	26.9
0.30	25.7	23.5	27.9
0.35	26.8	24.7	28.8
0.40	27.8	25.9	29.7
0.45	28.8	27.0	30.6
0.50	29.7	28.0	31.4
0.55	30.7	29.1	32.3
0.60	31.6	30.1	33.2
0.65	32.7	31.2	34.1
0.70	33.7	32.3	35.2
0.75	34.9	33.5	36.4
0.80	36.3	34.8	37.8
0.85	38.0	36.3	39.6
0.90	40.2	38.2	42.1
0.95	43.7	41.2	46.2
0.99	51.6	47.7	55.5
Males			
0.05	11.2	6.0	16.4
0.10	15.2	10.9	19.5
0.15	17.6	13.8	21.4
0.20	19.5	16.0	22.9
0.25	21.0	17.9	24.1
0.30	22.3	19.4	25.2
0.35	23.5	20.9	26.2
0.40	24.7	22.2	27.1
0.45	25.8	23.5	28.1
0.50	26.8	24.7	29.0
0.55	27.9	25.9	29.9
0.60	29.0	27.1	30.9
0.65	30.1	28.3	31.9
0.70	31.3	29.5	33.1
0.75	32.6	30.9	34.4
0.80	34.2	32.4	36.0
0.85	36.0	34.0	38.0
0.90	38.5	36.2	40.7
0.95	42.4	39.5	45.4
0.99	51.2	46.4	55.9

[a] Offshore strata 13–25, 29–30.

dock from Georges Bank was 29.7 and 26.8 cm, respectively (Tables 3 and 9, Fig. 7). For haddock from the Gulf of Maine region, values of L_{50} were 34.5 cm for females and 35.0 cm for males (Tables 3 and 11, Fig. 9). Median age at maturity was 1.5 yr for females and 1.3 yr for males from the former region, and 1.8 yr for females and 2.1 yr for males from the latter region (Table 4, Figs. 8 and 10); proportions of mature fish calculated for each age are presented in Tables 10 and 12.

Values of L_{50} above are considerably lower for both sexes than those reported by Morse (1979)[2] for the year 1977 over the entire region. Overholtz (1987), however, concluded that L_{50} values for both sexes on Georges Bank had increased between 1977 and 1983, a period dominated by the relatively large 1975 and 1978 year classes. For the overall 1977–1983 period, the median length at maturity on Georges Bank was 40 cm for females and 37 cm for males. On the southwestern Scotian Shelf, however, median age at maturity declined substantially between the early 1960's and late 1970's from 4.6 to 3.0 yr for females and from 4.7 to 2.8 yr for males (Beacham 1983b). Templeman et al. (1978) and Templeman and Bishop (1979) also noted substantial changes in both L_{50} and A_{50} for haddock on the Grand Bank and St. Pierre Bank, and attributed these to interactions between growth and exploitation.

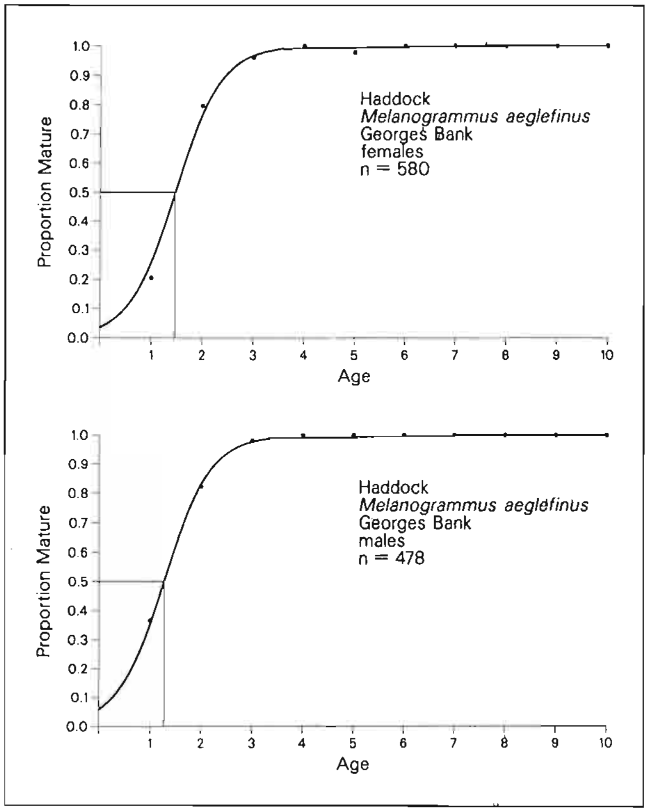

Figure 8
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Georges Bank female (n=580) and male (n=478) haddock, *Melanogrammus aeglefinus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 10
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Georges Bank female (n=580) and male (n=478) haddock, *Melanogrammus aeglefinus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.26	1.0	0.8	1.2
0.77	2.0	1.9	2.1
0.97	3.0	2.7	3.3
1.00	4.0	3.5	4.5
1.00	5.0	4.3	5.7
1.00	6.0	5.1	6.9
1.00	7.0	5.9	8.1
1.00	8.0	6.6	9.4
1.00	9.0	7.4	10.6
1.00	10.0	8.2	11.8
Males			
0.36	1.0	0.8	1.2
0.83	2.0	1.8	2.2
0.98	3.0	2.6	3.4
1.00	4.0	3.4	4.6
1.00	5.0	4.2	5.8
1.00	6.0	4.9	7.1
1.00	7.0	5.7	8.3
1.00	8.0	6.4	9.6
1.00	9.0	7.2	10.8
1.00	10.0	7.9	12.1

[a] Offshore strata 13–25, 29–30.

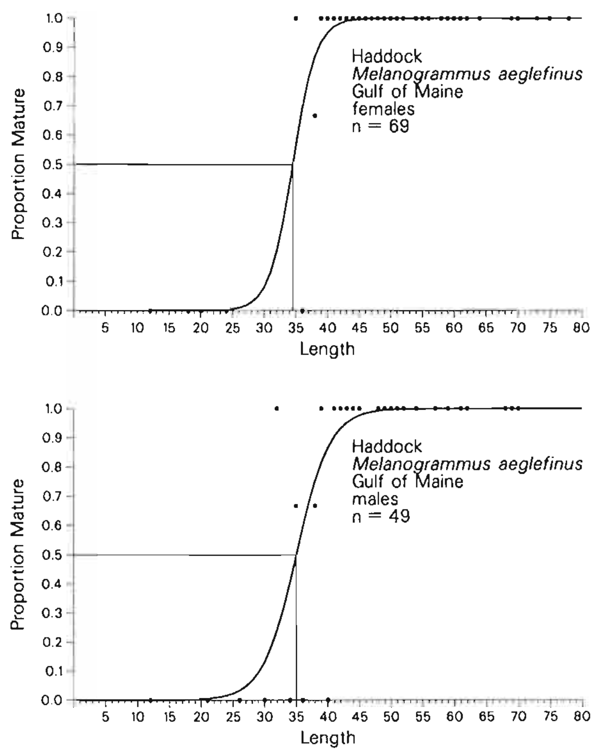

Figure 9

Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Gulf of Maine female (n=69) and male (n=49) haddock, *Melanogrammus aeglefinus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 11

Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Gulf of Maine female (n=69) and male (n=49) haddock, *Melanogrammus aeglefinus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	29.0	18.8	39.2
0.10	30.4	21.8	39.1
0.15	31.3	23.5	39.0
0.20	31.9	24.9	39.0
0.25	32.5	25.9	39.0
0.30	32.9	26.9	39.0
0.35	33.3	27.7	39.0
0.40	33.7	28.5	39.0
0.45	34.1	29.2	39.0
0.50	34.5	29.9	39.1
0.55	34.9	30.6	39.1
0.60	35.2	31.3	39.2
0.65	35.6	32.0	39.3
0.70	36.1	32.6	39.5
0.75	36.5	33.3	39.7
0.80	37.1	34.0	40.1
0.85	37.7	34.6	40.8
0.90	38.6	35.2	41.9
0.95	39.9	35.7	44.2
0.99	43.0	35.9	50.2
Males			
0.05	27.2	18.8	35.5
0.10	29.2	22.2	36.1
0.15	30.4	24.3	36.5
0.20	31.3	25.9	36.8
0.25	32.1	27.1	37.0
0.30	32.8	28.2	37.3
0.35	33.4	29.2	37.6
0.40	33.9	30.0	37.9
0.45	34.5	30.8	38.1
0.50	35.0	31.6	38.5
0.55	35.6	32.3	38.8
0.60	36.1	33.0	39.2
0.65	36.7	33.6	39.7
0.70	37.3	34.3	40.3
0.75	38.0	34.9	41.0
0.80	38.7	35.5	42.0
0.85	39.7	36.0	43.3
0.90	40.9	36.7	45.1
0.95	42.9	37.5	48.3
0.99	47.3	38.8	55.8

[a] Offshore strata 26–28, 36–40.

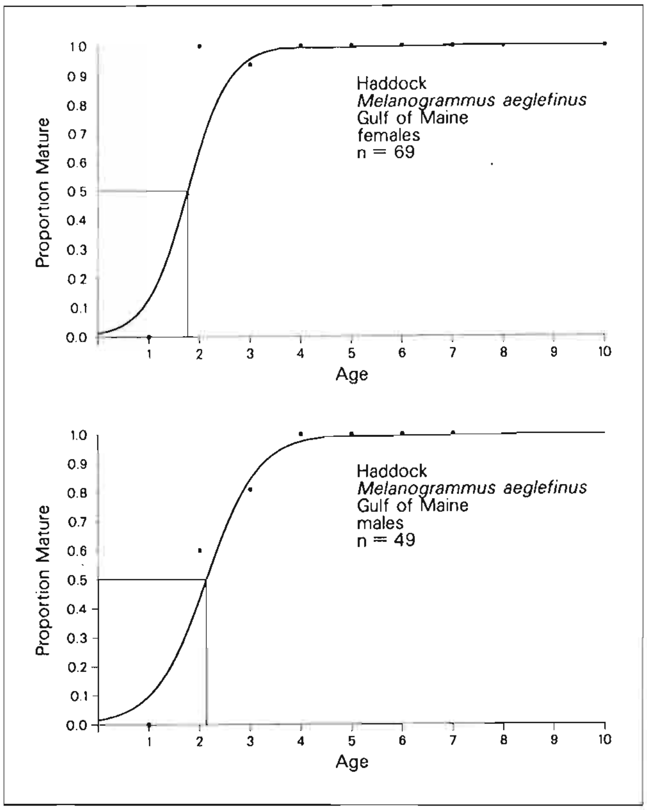

Figure 10

Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Gulf of Maine female (n=69) and male n(=49) haddock, *Melanogrammus aeglefinus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 12

Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Gulf of Maine female (n=69) and male (n=49) haddock, *Melanogrammus aeglefinus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.13	1.0	0.0	2.0
0.64	2.0	1.4	2.6
0.96	3.0	2.4	3.6
1.00	4.0	2.9	5.1
1.00	5.0	3.3	6.7
1.00	6.0	3.7	8.3
1.00	7.0	4.0	10.0
1.00	8.0	4.4	11.6
1.00	9.0	4.8	13.2
1.00	10.0	5.2	14.8
Males			
0.10	1.0	-0.3	2.3
0.43	2.0	1.3	2.7
0.85	3.0	2.5	3.5
0.97	4.0	2.9	5.1
1.00	5.0	3.3	6.7
1.00	6.0	3.6	8.4
1.00	7.0	3.9	10.1

[a] Offshore strata 26–28, 36–40.

Pollock: *Pollachius virens*

Pollock occur on both sides of the north Atlantic. In the northwest Atlantic they are most abundant on the Scotian Shelf and in the Gulf of Maine (Mayo et al. 1989). Spawning takes place during winter with peak activity occurring in December and January (Table 2). Total landings of pollock from the Scotian Shelf-Gulf of Maine region increased sharply from about 38,000 metric tons per year in the mid 1970's to over 68,000 t in 1986, but have since declined to about 50,000 t in 1989 and 1990 (NEFSC 1991).

Median length at maturity for female and male pollock from the Gulf of Maine was 39.1 and 41.8 cm, respectively (Tables 3 and 13, Fig. 11). Median age at maturity was 2.0 yr for females and 2.3 yr for males (Table 4, Fig. 12); proportions of mature fish calculated for each age are presented in Table 14.

Values of L_{50} and A_{50} above are lower than those of Mayo et al. (1989) who reported L_{50} estimates of 47-48 cm for females and 50.5 cm for males, based on USA and Canadian samples collected between 1977 and 1984. Estimates of A_{50} reported by Mayo et al. (1989) (3.2 yr for females and 3.5 yr for males) are at least one full year higher than those given above. Steele (1963) re-

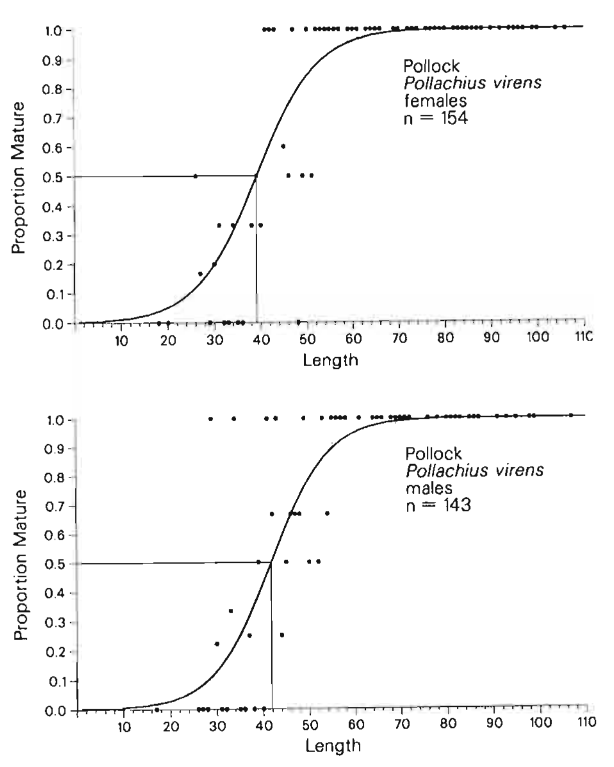

Figure 11
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=154) and male (n=143) pollock, *Pollachius virens*, sampled during Northeast Fisheries Science Center autumn bottom trawl surveys, 1986–1988.

Table 13
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=154) and male (n=143) pollock, *Pollachius virens*, sampled during Northeast Fisheries Science Center autumn bottom trawl surveys[a], 1986–1988.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	19.9	12.0	27.8
0.10	24.8	18.4	31.2
0.15	27.8	22.2	33.4
0.20	30.1	25.1	35.0
0.25	31.9	27.4	36.4
0.30	33.6	29.4	37.7
0.35	35.1	31.2	38.9
0.40	36.5	32.8	40.1
0.45	37.8	34.3	41.3
0.50	39.1	35.7	42.5
0.55	40.4	37.1	43.7
0.60	41.7	38.4	45.1
0.65	43.1	39.7	46.5
0.70	44.6	41.0	48.2
0.75	46.3	42.4	50.1
0.80	48.1	44.0	52.3
0.85	50.4	45.7	55.1
0.90	53.4	47.9	58.9
0.95	58.3	51.4	65.2
0.99	69.0	58.7	79.3
Males			
0.05	23.7	17.1	30.2
0.10	28.3	23.0	33.5
0.15	31.1	26.6	35.6
0.20	33.3	29.2	37.3
0.25	35.0	31.3	38.7
0.30	36.6	33.1	40.0
0.35	38.0	34.7	41.2
0.40	39.3	36.1	42.4
0.45	40.5	37.4	43.7
0.50	41.8	38.7	44.9
0.55	43.0	39.8	46.2
0.60	44.3	41.0	47.6
0.65	45.6	42.1	49.1
0.70	47.0	43.3	50.7
0.75	48.5	44.5	52.6
0.80	50.3	45.9	54.8
0.85	52.5	47.5	57.4
0.90	55.3	49.5	61.1
0.95	59.9	52.8	67.0
0.99	70.1	59.8	80.4

[a] Offshore strata 13–34, 351, 36–40.

ported median maturation values of 62.5 cm at 5–6 yrs for females and 58 cm at 4–5 yrs for males collected from the Bay of Fundy in 1960 and 1961. The corresponding median ages are similar to those presented by Beacham (1983c) for a similar time period from the southern Scotian Shelf. Beacham further noted substantial declines in pollock L_{50} and A_{50} values of 5–6 cm and 1-2 yr between the early 1960's and late 1970's in the same region.

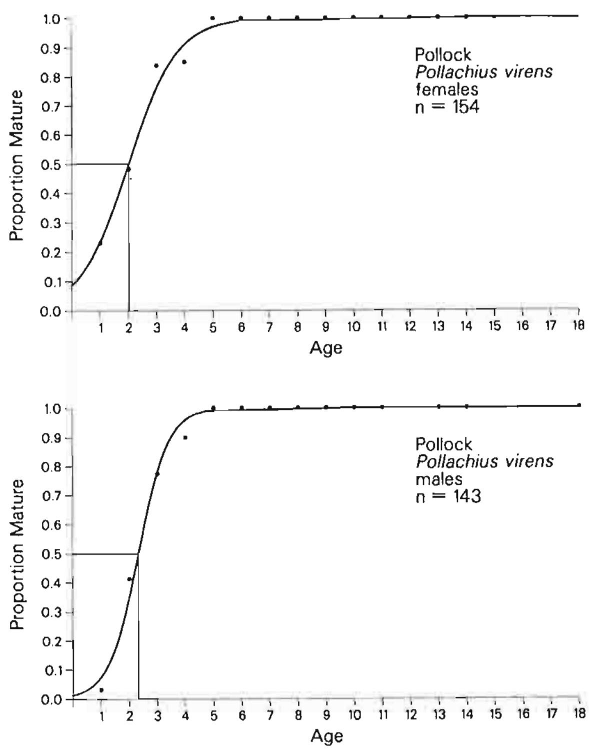

Figure 12
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=154) and male (n=143) pollock, *Pollachius virens*, sampled during Northeast Fisheries Science Center autumn bottom trawl surveys, 1986–1988.

Table 14
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=154) and male (n=143) pollock, *Pollachius virens*, sampled during Northeast Fisheries Science Center autumn bottom trawl surveys[a], 1986–1988.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.24	1.0	0.4	1.6
0.50	2.0	1.6	2.4
0.76	3.0	2.5	3.5
0.91	4.0	3.3	4.7
0.97	5.0	3.9	6.1
0.99	6.0	4.6	7.4
1.00	7.0	5.2	8.8
1.00	8.0	5.8	10.2
1.00	9.0	6.5	11.5
1.00	10.0	7.1	12.9
1.00	11.0	7.7	14.3
1.00	12.0	8.4	15.6
1.00	13.0	9.0	17.0
1.00	14.0	9.6	18.4
1.00	15.0	10.2	19.8
Males			
0.07	1.0	0.5	1.5
0.35	2.0	1.7	2.3
0.78	3.0	2.6	3.4
0.96	4.0	3.3	4.7
0.99	5.0	4.0	6.0
1.00	6.0	4.6	7.4
1.00	7.0	5.3	8.7
1.00	8.0	5.9	10.1
1.00	9.0	6.5	11.5
1.00	10.0	7.2	12.8
1.00	11.0	7.8	14.2
1.00	12.0	8.5	15.5
1.00	13.0	9.1	16.9
1.00	14.0	9.7	18.3
1.00	15.0	10.4	19.6
1.00	16.0	11.0	21.0
1.00	17.0	11.7	22.3
1.00	18.0	12.3	23.7

[a] Offshore strata 13–34, 351, 36–40.

White Hake: *Urophycis tenuis*

White hake are widely distributed from Labrador to Georges Bank, and in deeper slope waters southward to Florida. In U.S. waters, white hake of the Gulf of Maine-Georges Bank region are considered to be a unit stock. Information relative to white hake spawning in this region is both limited and conflicting, although ripe fish have been observed from October to May (Table 2). Commercial landings of white hake averaged 4,700 metric tons per year during 1975–1980, increased to an average of 6,700 t from 1981 to 1988, and subsequently declined to 5,600 t in 1989 (NEFSC 1991).

Median length at maturity for female and male white hake was 35.1 and 32.7 cm, respectively (Tables 3 and 15, Fig. 13). Median age at maturity was 1.4 yr for both sexes (Table 4, Fig. 14); proportions of mature fish calculated for each age are presented in Table 16.

Values of L_{50} above are considerably lower than those obtained by Morse (1979)[2] from 1977 data (47.6 and 43.0 cm for females and males, respectively) and by Burnett et al. (1984)[3] from data collected during 1977–

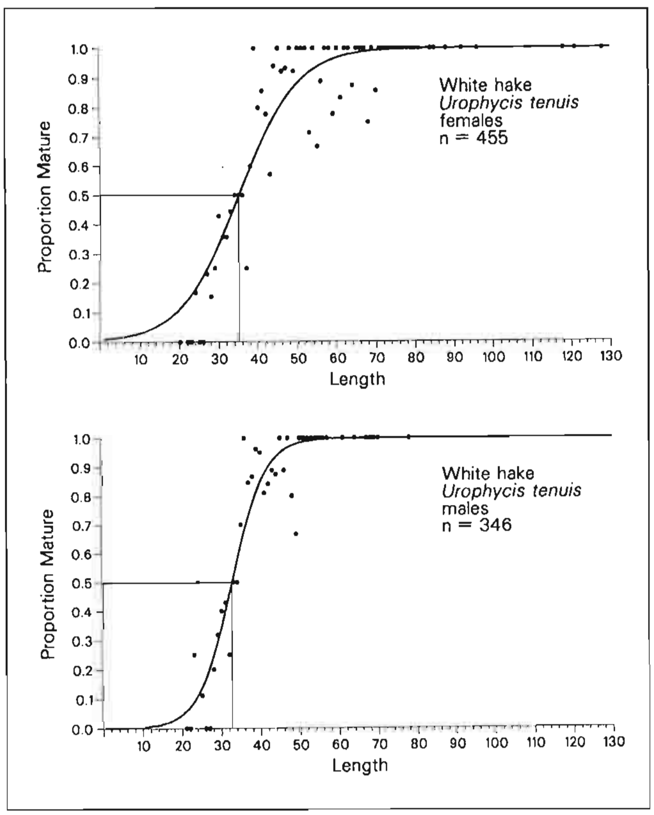

Figure 13
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=455) and male (n=346) white hake, *Urophycis tenuis*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1987–1989.

[3] J. Burnett, S.H. Clark, and L. O'Brien. 1984. A preliminary assessment of white hake in the Gulf of Maine-Georges Bank area. NMFS/NEFC, Woods Hole Lab. Ref. Doc. No. 84–31, 33 p.

Table 15
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=455) and male (n=346) white hake, *Urophycis tenuis*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1987–1989.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Females			
0.05	13.6	8.4	18.8
0.10	19.1	14.9	23.3
0.15	22.5	18.8	26.1
0.20	25.0	21.8	28.3
0.25	27.1	24.2	30.0
0.30	29.0	26.3	31.6
0.35	30.6	28.2	33.1
0.40	32.2	29.9	34.5
0.45	33.7	31.6	35.8
0.50	35.1	33.1	37.2
0.55	36.6	34.7	38.6
0.60	38.1	36.2	40.0
0.65	39.7	37.7	41.6
0.70	41.3	39.3	43.4
0.75	43.2	41.0	45.3
0.80	45.3	42.9	47.7
0.85	47.8	45.1	50.5
0.90	51.2	48.0	54.4
0.95	56.7	52.6	60.8
0.99	68.7	62.5	75.0
Males			
0.05	20.3	17.1	23.6
0.10	23.5	20.9	26.1
0.15	25.4	23.2	27.7
0.20	26.9	24.9	28.9
0.25	28.1	26.3	29.9
0.30	29.2	27.5	30.8
0.35	30.1	28.6	31.6
0.40	31.0	29.6	32.4
0.45	31.9	30.5	33.2
0.50	32.7	31.4	34.0
0.55	33.6	32.3	34.8
0.60	34.4	33.2	35.6
0.65	35.3	34.1	36.5
0.70	36.3	35.0	37.5
0.75	37.3	36.0	38.7
0.80	38.5	37.0	40.0
0.85	40.0	38.3	41.7
0.90	41.9	39.9	44.0
0.95	45.1	42.5	47.7
0.99	52.0	48.1	55.9

[a] Offshore strata 21–30, 33–34, 351, 36–40.

82 (42 cm for both sexes) for the Gulf of Maine-Georges Bank region. Musick (1969) noted that females matured at 48 to 64 cm and males at 40 to 52 cm, but his data included fish from both U.S. and Canadian waters.

Maturation of white hake in the Gulf of Maine-Georges Bank region occurs at a smaller size and younger age than for slower-growing white hake in Canadian waters. Battle (1951) observed no spawning females below 57 cm in size and 4 yr in age within the Bay of Fundy, and Beacham and Nepszy (1980) and Beacham (1983c) reported values of L_{50} ranging from 40.1 to 53.9 cm for females and from 36.6 to 44.1 cm for males in the Gulf of St. Lawrence and Scotian Shelf regions during 1971-78, corresponding to ages of 3 to 5 yr.

However, maturation of white hake in the Gulf of Maine-Georges Bank region may be a moot point in view of evidence that the species does not successfully spawn in that region. Musick (1969) observed that spawning was weak and aperiodic, and hypothesized that recruits from the Scotian Shelf sustained the population. More recently, Fahay and Able (1989) reported the absence of white hake eggs and larvae in the Gulf of Maine, and presented evidence which suggested that the local population was sustained primarily by recruits from a spring-spawning continental slope population and secondarily by recruits from the summer-spawning and fall-spawning Scotian Shelf and southern Gulf of St. Lawrence populations.

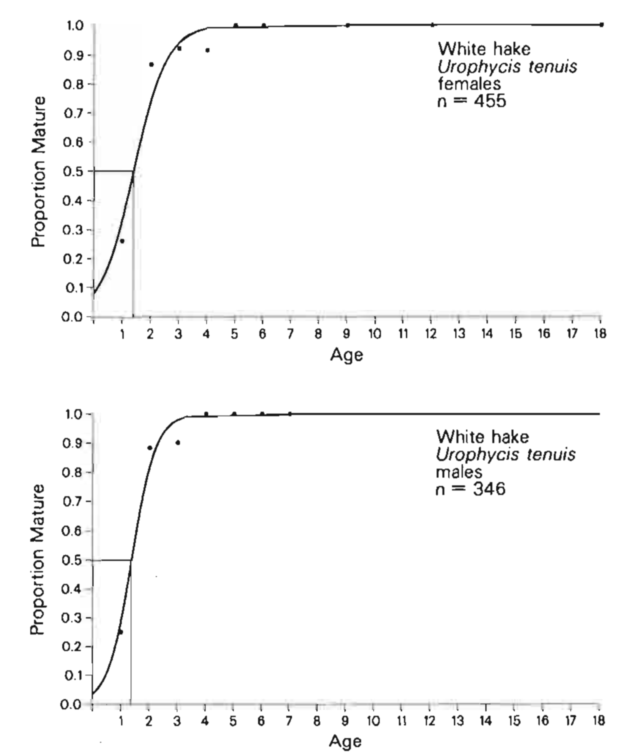

Figure 14
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=455) and male (n=346) white hake, *Urophycis tenuis*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1987–1989.

Table 16
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=455) and male (n=346) white hake, *Urophycis tenuis*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1987–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.33	1.0	0.8	1.2
0.74	2.0	1.8	2.2
0.94	3.0	2.7	3.3
0.99	4.0	3.5	4.5
1.00	5.0	4.3	5.7
1.00	6.0	5.1	6.9
1.00	7.0	5.9	8.1
1.00	8.0	6.7	9.3
1.00	9.0	7.5	10.5
1.00	10.0	8.3	11.7
1.00	11.0	9.1	12.9
1.00	12.0	9.9	14.1
1.00	13.0	10.7	15.3
1.00	14.0	11.5	16.5
1.00	15.0	12.3	17.7
1.00	16.0	13.1	18.9
1.00	17.0	13.9	20.1
1.00	18.0	14.7	21.3
Males			
0.29	1.0	0.8	1.2
0.82	2.0	1.8	2.2
0.98	3.0	2.7	3.3
1.00	4.0	3.4	4.6
1.00	5.0	4.2	5.8
1.00	6.0	5.0	7.0
1.00	7.0	5.8	8.2

[a] Offshore strata 21–30, 33–34, 351, 36–40.

Red Hake: *Urophycis chuss*

Red hake are distributed from the Gulf of St. Lawrence to Cape Hatteras, North Carolina. It is assumed that two stocks exist in U.S. waters, one occupying the Gulf of Maine and the northern portion of Georges Bank, and the other situated on southern Georges Bank and throughout the Southern New England-Middle Atlantic region. Spawning occurs from May to September for the northern stock, with peak activity during June and July, while the southern stock spawns over a protracted period from March to October (Table 2). Commercial landings for this under-exploited species have averaged 1,000 metric tons per year since 1980 for the northern stock, whereas landings from the southern stock have decreased from over 4,000 t in 1980 to 800 t in 1989 (NEFSC 1991).

Median length at maturity for female and male red hake from the Gulf of Maine-northern Georges Bank region was 26.9 and 22.2 cm, respectively (Tables 3 and 17, Fig. 15). For red hake from the Mid-Atlantic-southern Georges Bank region, values of L_{50} were 25.1 cm for females and 23.8 cm for males (Tables 3 and 19, Fig.

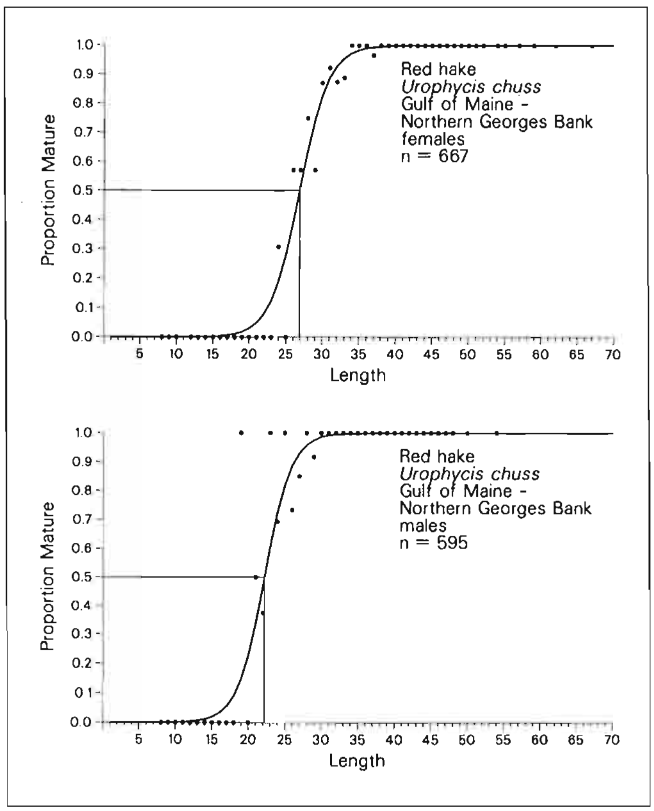

Figure 15
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=667) and male (n=595) red hake, *Urophycis chuss,* from the Gulf of Maine-northern Georges Bank region sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1982–1985.

Table 17
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=667) and male (n=595) red hake, *Urophycis chuss,* from the Gulf of Maine-northern Georges Bank region sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1982–1985.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	21.0	19.2	22.9
0.10	22.5	21.0	24.1
0.15	23.4	22.1	24.8
0.20	24.1	22.9	25.4
0.25	24.7	23.5	25.9
0.30	25.2	24.1	26.3
0.35	25.7	24.6	26.7
0.40	26.1	25.1	27.0
0.45	26.5	25.6	27.4
0.50	26.9	26.0	27.7
0.55	27.3	26.5	28.1
0.60	27.7	26.9	28.5
0.65	28.1	27.3	28.9
0.70	28.6	27.8	29.3
0.75	29.1	28.3	29.8
0.80	29.6	28.8	30.4
0.85	30.3	29.5	31.2
0.90	31.2	30.3	32.2
0.95	32.7	31.5	33.9
0.99	36.0	34.2	37.8
Males			
0.05	16.8	14.5	19.1
0.10	18.2	16.2	20.1
0.15	19.0	17.3	20.8
0.20	19.7	18.1	21.3
0.25	20.2	18.7	21.7
0.30	20.7	19.3	22.1
0.35	21.1	19.8	22.4
0.40	21.5	20.2	22.7
0.45	21.9	20.7	23.0
0.50	22.2	21.1	23.3
0.55	22.6	21.5	23.7
0.60	23.0	22.0	24.0
0.65	23.4	22.4	24.3
0.70	23.8	22.8	24.7
0.75	24.2	23.3	25.2
0.80	24.8	23.8	25.7
0.85	25.4	24.5	26.4
0.90	26.3	25.2	27.3
0.95	27.6	26.4	28.9
0.99	30.7	28.8	32.6

[a] Offshore strata 20–30, 36–40.

17). Median age at maturity was 1.8 yr for females and 1.4 yr for males in the former region and 1.7 yr for females and 1.8 yr for males in the latter region (Table 4, Figs. 16 and 18); proportions of mature fish calculated for each age are presented in Tables 18 and 20.

Morse (1979)[2] reported an L_{50} of 27.8 and 24.8 cm, respectively, for female and male red hake in the same general region during 1977 but did not distinguish between stock areas. Musick (1969) observed that red hake matured at 2 yr of age, with females maturing at 27 to 33 cm and males at 24 to 30 cm. Markle et al. (1982) also reported that maturation occurred essentially at age 2, with most fish mature by 30 cm.

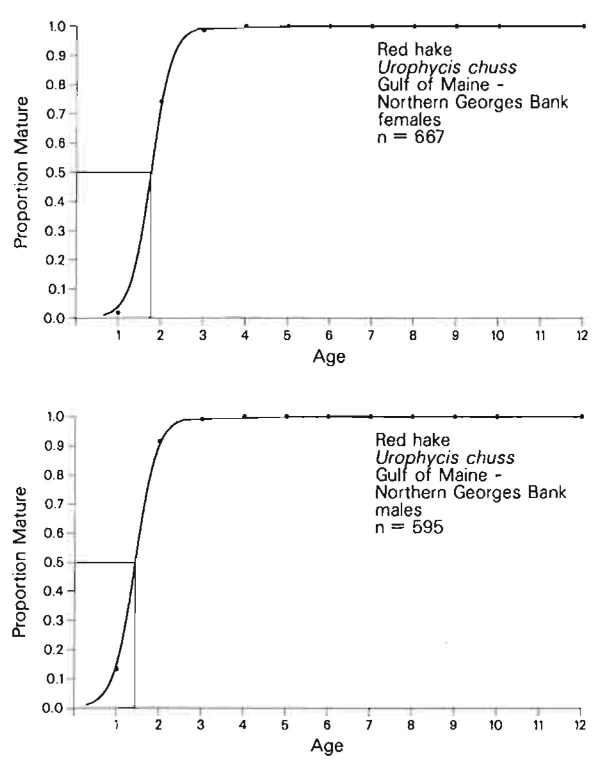

Figure 16
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=667) and male (n=595) red hake, *Urophycis chuss*, from the Gulf of Maine-northern Georges Bank region sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1982–1985.

Table 18
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=667) and male (n=595) red hake *Urophycis chuss* from the Gulf of Maine-northern Georges Bank region sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1982-1985.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.04	1.0	0.7	1.3
0.73	2.0	1.9	2.1
0.99	3.0	2.7	3.3
1.00	4.0	3.4	4.6
1.00	5.0	4.2	5.8
1.00	6.0	4.9	7.1
1.00	7.0	5.6	8.4
1.00	8.0	6.3	9.7
1.00	9.0	7.1	10.9
1.00	10.0	7.8	12.2
1.00	11.0	8.5	13.5
1.00	12.0	9.2	14.8
Males			
0.15	1.0	0.8	1.2
0.91	2.0	1.9	2.1
1.00	3.0	2.7	3.3
1.00	4.0	3.5	4.5
1.00	5.0	4.2	5.8
1.00	6.0	5.0	7.0
1.00	7.0	5.8	8.2
1.00	8.0	6.5	9.5
1.00	9.0	7.3	10.7
1.00	10.0	8.1	11.9
1.00	11.0	8.8	13.2
1.00	12.0	9.6	14.4

[a] Offshore strata 20–30, 36–40.

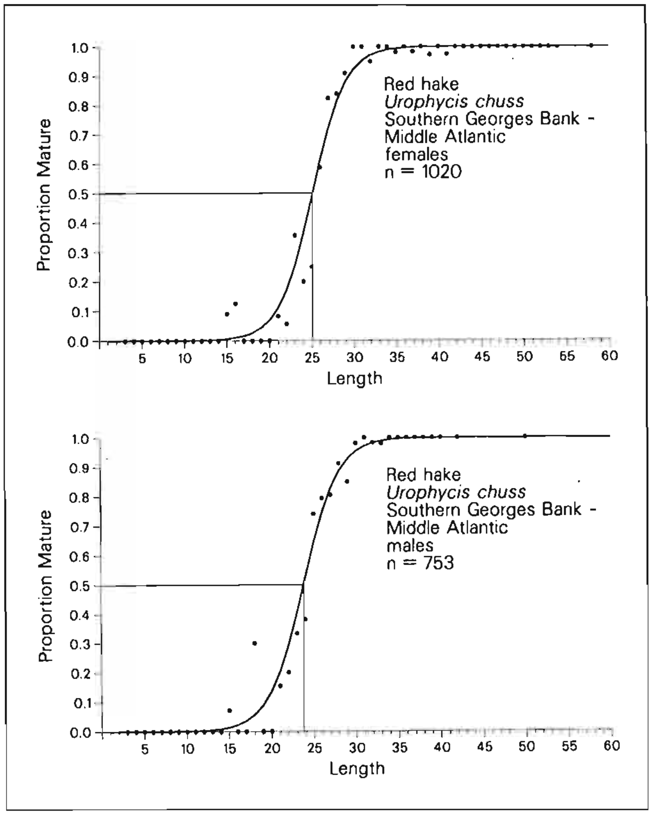

Figure 17

Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=1020) and male (n=753) red hake, *Urophycis chuss*, from southern Georges Bank - Middle Atlantic sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1982–1985.

Table 19

Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=1020) and male (n=753) red hake, *Urophycis chuss*, from southern Georges Bank - Middle Atlantic sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1982–1985.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	19.3	17.9	20.7
0.10	20.8	19.6	22.0
0.15	21.7	20.6	22.7
0.20	22.4	21.4	23.3
0.25	22.9	22.1	23.8
0.30	23.4	22.6	24.3
0.35	23.9	23.1	24.7
0.40	24.3	23.6	25.0
0.45	24.7	24.0	25.4
0.50	25.1	24.4	25.8
0.55	25.5	24.8	26.2
0.60	25.9	25.3	26.5
0.65	26.3	25.7	26.9
0.70	26.8	26.2	27.4
0.75	27.3	26.6	27.9
0.80	27.8	27.2	28.5
0.85	28.5	27.8	29.2
0.90	29.4	28.7	30.2
0.95	30.9	30.0	31.8
0.99	34.1	32.8	35.5
Males			
0.05	17.8	16.2	19.3
0.10	19.3	18.0	20.6
0.15	20.2	19.1	21.4
0.20	21.0	19.9	22.0
0.25	21.5	20.6	22.5
0.30	22.1	21.2	23.0
0.35	22.5	21.7	23.4
0.40	23.0	22.2	23.7
0.45	23.4	22.6	24.1
0.50	23.8	23.1	24.5
0.55	24.2	23.5	24.9
0.60	24.6	24.0	25.3
0.65	25.1	24.5	25.7
0.70	25.5	24.9	26.1
0.75	26.0	25.5	26.6
0.80	26.6	26.0	27.2
0.85	27.3	26.7	28.0
0.90	28.3	27.6	29.0
0.95	29.8	28.9	30.7
0.99	33.2	31.8	34.6

[a] Inshore strata 1–46, 52, 55, offshore strata 1–19, 61–76.

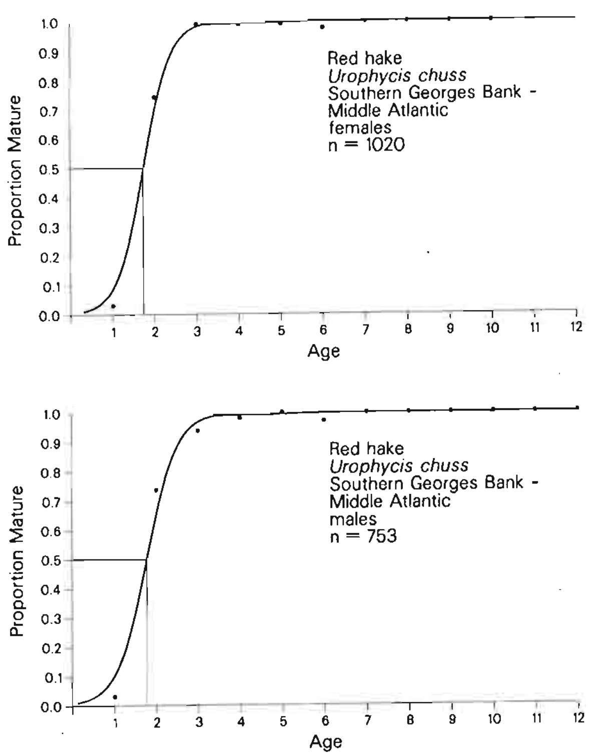

Figure 18

Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=1020) and male (n=753) red hake, *Urophycis chuss,* from southern Georges Bank - Middle Atlantic sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1982–1985.

Table 20

Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=1020) and male (n=753) red hake, *Urophycis chuss,* from southern Georges Bank - Middle Atlantic sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1982–1985.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.09	1.0	0.8	1.2
0.70	2.0	1.9	2.1
0.98	3.0	2.8	3.2
1.00	4.0	3.7	4.3
1.00	5.0	4.5	5.5
1.00	6.0	5.4	6.6
1.00	7.0	6.2	7.8
1.00	8.0	7.1	8.9
1.00	9.0	7.9	10.1
1.00	10.0	8.8	11.2
Males			
0.10	1.0	0.8	1.2
0.66	2.0	1.9	2.1
0.97	3.0	2.8	3.2
1.00	4.0	3.6	4.4
1.00	5.0	4.5	5.5
1.00	6.0	5.3	6.7
1.00	7.0	6.1	7.9
1.00	8.0	7.0	9.0
1.00	9.0	7.8	10.2
1.00	10.0	8.7	11.3
1.00	11.0	9.5	12.5
1.00	12.0	10.3	13.7

[a] Inshore strata 1–46, 52, 55, offshore strata 1–19, 61–76.

Silver Hake: *Merluccius bilinearis*

Silver hake are widely distributed in the northwest Atlantic from Newfoundland to South Carolina, but are most abundant in coastal waters from Maine to New Jersey; two stocks inhabit this region, with Georges Bank as the boundary (Almeida 1987). Spawning of both stocks takes place from spring through early autumn with most activity occurring between May and September (Table 2). Total landings from both stocks combined declined from over 100,000 metric tons annually during the early 1970's, when distant water fleets were dominant, to less than 20,000 t since 1986 (NEFSC 1991).

Median length at maturity for female and male silver hake from the Gulf of Maine-northern Georges Bank stock was 23.1 and 22.3 cm, respectively (Tables 3 and 21, Fig. 19). For silver hake from the southern Georges Bank stock, values of L_{50} were 23.2 cm for females and 22.7 cm for males (Tables 3 and 23, Fig. 21). Median age at maturity for both sexes was 1.7 yr from the former region, and 1.6 yr from the latter region (Table 4, Figs. 20 and 22); proportions of mature fish calculated for each age are presented in Tables 22 and 24.

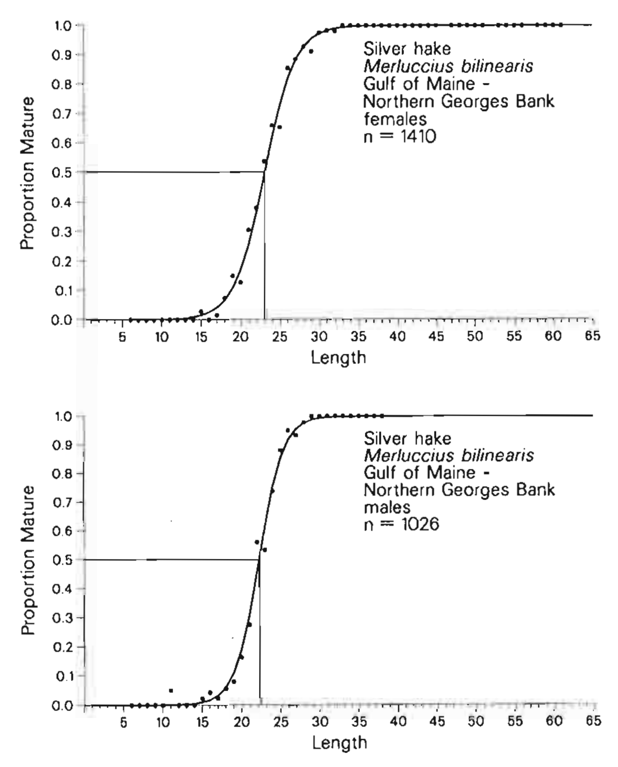

Figure 19
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Gulf of Maine-northern Georges Bank female (n=1410) and male (n=1026) silver hake, *Merluccius bilinearis,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 21
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Gulf of Maine-northern Georges Bank female (n=1410) and male (n=1026) silver hake, *Merluccius bilinearis,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985-1989.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	17.4	16.6	18.2
0.10	18.8	18.2	19.5
0.15	19.7	19.2	20.3
0.20	20.4	19.9	20.9
0.25	20.9	20.5	21.4
0.30	21.4	21.0	21.9
0.35	21.9	21.5	22.3
0.40	22.3	21.9	22.7
0.45	22.7	22.3	23.1
0.50	23.1	22.7	23.5
0.55	23.5	23.1	23.8
0.60	23.8	23.5	24.2
0.65	24.3	23.9	24.7
0.70	24.7	24.3	25.1
0.75	25.2	24.8	25.6
0.80	25.7	25.3	26.2
0.85	26.4	25.9	26.9
0.90	27.3	26.7	27.9
0.95	28.7	28.0	29.4
0.99	31.9	30.9	32.9
Males			
0.05	17.7	17.0	18.4
0.10	18.9	18.3	19.4
0.15	19.6	19.0	20.1
0.20	20.1	19.6	20.6
0.25	20.6	20.1	21.0
0.30	20.9	20.5	21.4
0.35	21.3	20.9	21.7
0.40	21.6	21.2	22.0
0.45	21.9	21.6	22.3
0.50	22.3	21.9	22.6
0.55	22.6	22.2	22.9
0.60	22.9	22.5	23.3
0.65	23.2	22.8	23.6
0.70	23.6	23.2	24.0
0.75	24.0	23.5	24.4
0.80	24.4	23.9	24.9
0.85	24.9	24.4	25.4
0.90	25.7	25.1	26.2
0.95	26.8	26.1	27.5
0.99	29.4	28.4	30.3

[a] Offshore strata 20–30, 36–40.

Values of L_{50} above are 2–4 cm lower for both sexes than those reported by Morse (1979)[2] for the year 1977 over the entire region. Doubleday and Halliday (1975) observed that the median length at maturity for silver hake from the Scotian Shelf occurred at 26–27 cm in females and at 23–24 cm in males, with A_{50} values lying between ages 1 and 2 for both sexes. Beacham (1983c) further noted a decline in L_{50} for females from 31 cm during the 1960's to 26 cm during the late 1970's in the same area. A similar decline from 27 cm to 24 cm was found for males during the same period, although A_{50} values generally remained between 1 and 2 yr for both sexes.

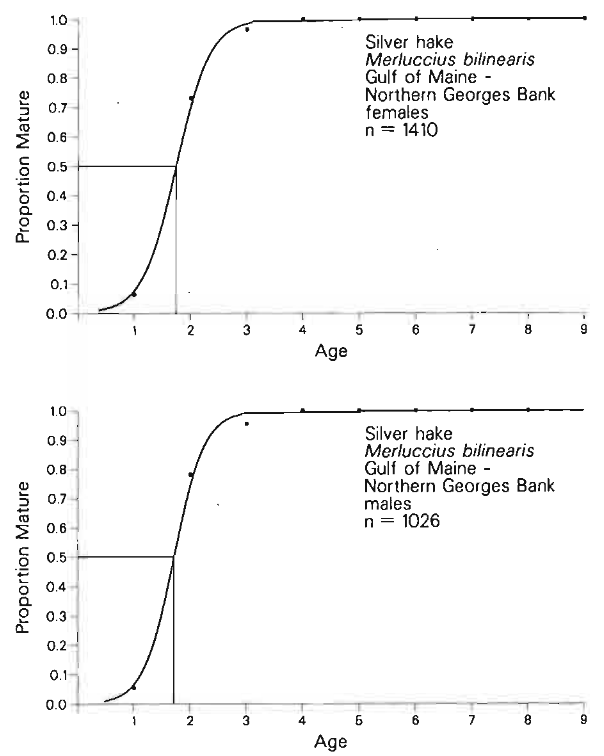

Figure 20
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Gulf of Maine-northern Georges Bank female (n=1410) and male (n=1026) silver hake, *Merluccius bilinearis,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 22
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Gulf of Maine-northern Georges Bank female (n=1410) and male (n=1026) silver hake *Merluccius bilinearis* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.08	1.0	0.9	1.1
0.70	2.0	1.9	2.1
0.99	3.0	2.9	3.1
1.00	4.0	3.8	4.2
1.00	5.0	4.7	5.3
1.00	6.0	5.6	6.4
1.00	7.0	6.5	7.5
1.00	8.0	7.4	8.6
1.00	9.0	8.3	9.7
Males			
0.07	1.0	0.9	1.1
0.74	2.0	1.9	2.1
0.99	3.0	2.8	3.2
1.00	4.0	3.7	4.3
1.00	5.0	4.6	5.4
1.00	6.0	5.5	6.5
1.00	7.0	6.4	7.6
1.00	8.0	7.3	8.7

[a] Offshore strata 20–30, 36–40.

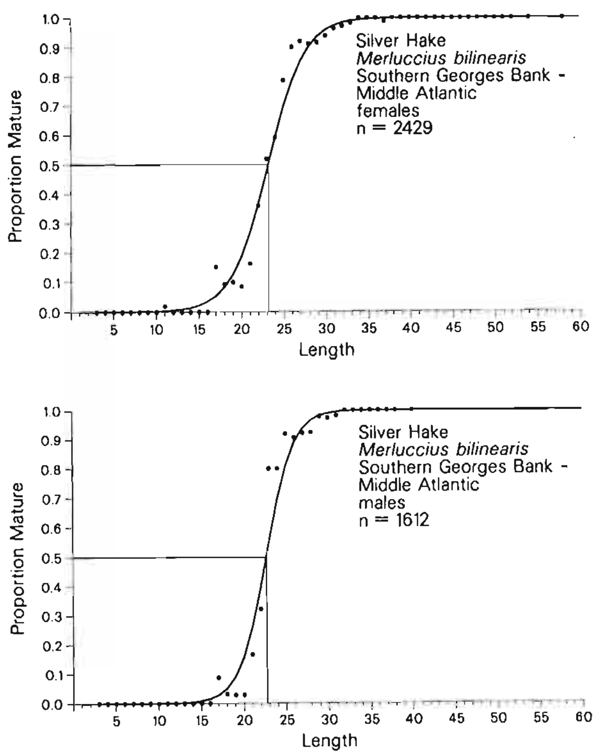

Figure 21

Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of southern Georges Bank - Middle Atlantic female (n=2429) and male (n=1612) silver hake, *Merluccius bilinearis*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 23

Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of southern Georges Bank - Middle Atlantic female (n=2429) and male (n=1612) silver hake, *Merluccius bilinearis*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	16.8	16.0	17.6
0.10	18.4	17.7	19.1
0.15	19.4	18.8	20.1
0.20	20.2	19.6	20.8
0.25	20.8	20.3	21.3
0.30	21.4	20.9	21.8
0.35	21.8	21.4	22.3
0.40	22.3	21.9	22.8
0.45	22.7	22.3	23.2
0.50	23.2	22.8	23.6
0.55	23.6	23.2	24.0
0.60	24.1	23.7	24.4
0.65	24.5	24.1	24.9
0.70	25.0	24.6	25.4
0.75	25.5	25.2	25.9
0.80	26.2	25.8	26.6
0.85	26.9	26.5	27.3
0.90	27.9	27.4	28.4
0.95	29.5	29.0	30.1
0.99	33.1	32.2	33.9
Males			
0.05	18.0	17.2	18.8
0.10	19.2	18.5	19.9
0.15	19.9	19.3	20.5
0.20	20.5	19.9	21.0
0.25	20.9	20.4	21.4
0.30	21.3	20.9	21.8
0.35	21.7	21.3	22.1
0.40	22.0	21.6	22.5
0.45	22.4	22.0	22.8
0.50	22.7	22.3	23.1
0.55	23.0	22.6	23.4
0.60	23.3	23.0	23.7
0.65	23.7	23.3	24.0
0.70	24.0	23.7	24.4
0.75	24.4	24.1	24.8
0.80	24.9	24.5	25.2
0.85	25.4	25.1	25.8
0.90	26.2	25.8	26.6
0.95	27.4	26.9	27.9
0.99	30.0	29.2	30.7

[a] Inshore strata 1–46, 52, 55, offshore strata 1–19, 61–76.

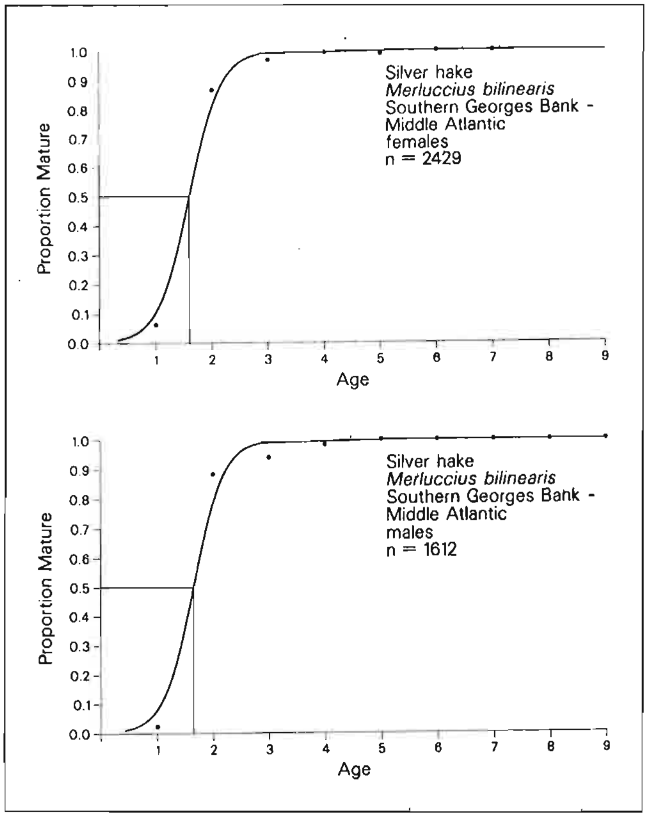

Figure 22
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of southern Georges Bank - Middle Atlantic female (n=2429) and male (n=1612) silver hake, *Merluccius bilinearis,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 24
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of southern Georges Bank - Middle Atlantic female (n=2429) and male (n=1612) silver hake, *Merluccius bilinearis,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.10	1.0	0.9	1.1
0.81	2.0	2.0	2.0
0.99	3.0	2.9	3.1
1.00	4.0	3.8	4.2
1.00	5.0	4.7	5.3
1.00	6.0	5.6	6.4
1.00	7.0	6.6	7.4
Males			
0.08	1.0	0.9	1.1
0.79	2.0	1.9	2.1
0.99	3.0	2.9	3.1
1.00	4.0	3.8	4.2
1.00	5.0	4.7	5.3
1.00	6.0	5.6	6.4
1.00	7.0	6.5	7.5
1.00	8.0	7.4	8.6
1.00	9.0	8.3	9.7

[a] Inshore strata 1–46, 52, 55, offshore strata 1–19, 61–76.

Redfish: *Sebastes fasciatus*

Redfish occur throughout the north Atlantic from Norway to Georges Bank; off New England, *S. fasciatus* are most abundant in deeper waters of the Gulf of Maine where a single stock is thought to exist (Mayo 1980). Reproduction is viviparous and mating takes place in autumn when most males are mature; larval extrusion occurs during the following spring and summer (Table 2). Total commercial landings of this species have declined from a peak of 60,000 metric tons per year in the early 1940's to about 15,000 t in the late 1970's; total landings have declined further to less than 2,000 t per year since 1987 (NEFSC 1991).

Median length at maturity for female and male redfish from the Gulf of Maine was 22.3 and 20.9 cm, respectively (Tables 3 and 25, Fig. 23). Median age at maturity was 5.5 yr for both sexes (Table 4, Fig. 24); proportions of mature fish calculated for each age are presented in Table 26. These results, extracted from Mayo et al. (1990), are representative of the years 1975–1980, the most recent period for which a consistent series of maturation data are available from the Northeast Fisheries Science Center survey. Because of the

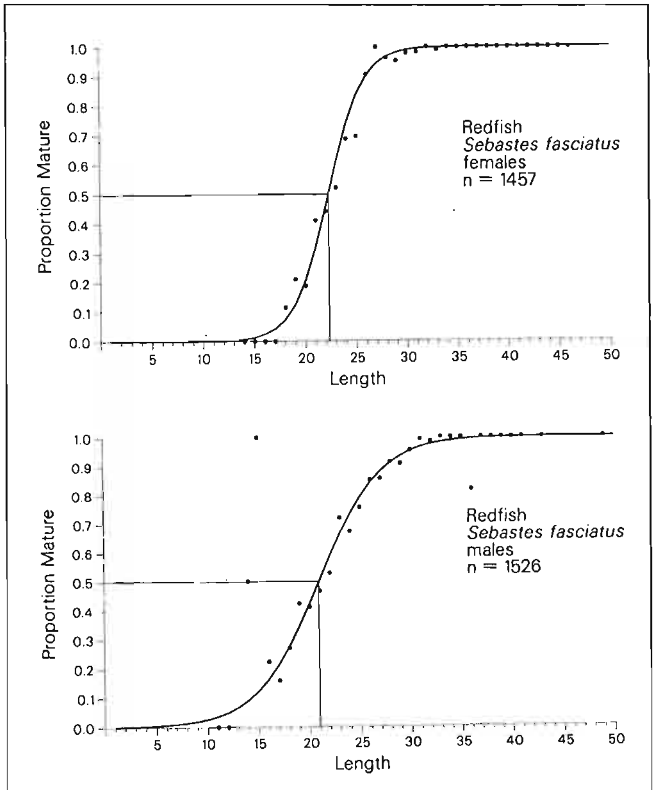

Figure 23
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=1457) and male (n=1526) redfish, *Sebastes fasciatus*, from the Gulf of Maine sampled, respectively, during Northeast Fisheries Science Center spring and autumn bottom trawl surveys, 1975–1980.

Table 25
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=1457) and male (n=1526) redfish, *Sebastes fasciatus*, from the Gulf of Maine sampled, respectively, during Northeast Fisheries Science Center spring and autumn bottom trawl surveys[a], 1975–1980.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Females			
0.05	17.3	16.4	18.2
0.10	18.6	17.8	19.3
0.15	19.3	18.7	20.0
0.20	19.9	19.3	20.5
0.25	20.4	19.9	20.9
0.30	20.8	20.3	21.3
0.35	21.2	20.8	21.7
0.40	21.6	21.1	22.0
0.45	21.9	21.5	22.3
0.50	22.3	21.9	22.7
0.55	22.6	22.2	23.0
0.60	22.9	22.5	23.3
0.65	23.3	22.9	23.7
0.70	23.7	23.3	24.1
0.75	24.1	23.7	24.5
0.80	24.6	24.1	25.0
0.85	25.2	24.6	25.7
0.90	25.9	25.3	26.5
0.95	27.2	26.5	27.9
0.99	30.0	28.9	31.1
Males			
0.05	12.0	10.6	13.5
0.10	14.3	13.1	15.5
0.15	15.7	14.6	16.7
0.20	16.7	15.8	17.7
0.25	17.6	16.8	18.5
0.30	18.4	17.6	19.2
0.35	19.1	18.3	19.8
0.40	19.7	19.1	20.4
0.45	20.3	19.7	20.9
0.50	20.9	20.4	21.5
0.55	21.5	21.0	22.1
0.60	22.2	21.7	22.7
0.65	22.8	22.3	23.3
0.70	23.5	23.0	24.0
0.75	24.3	23.8	24.7
0.80	25.1	24.6	25.6
0.85	26.2	25.6	26.7
0.90	27.6	26.9	28.2
0.95	29.8	29.0	30.7
0.99	34.8	33.4	36.2

[a] Offshore strata 24, 26–30, 36–40.

disparity in seasonal maturation between sexes related to redfish's viviparous reproduction, analyses were performed on spring data for females and autumn data for males.

Values of L_{50} above are comparable to those for both sexes reported by Morse (1979)[2] for the year 1977. However considerable variability in size and age at maturation in relation to early growth and environmental conditions was noted by Mayo et al. (1990). Substantial differences between sexes were observed on the southern Scotian Shelf where Ni and Sandeman (1984) reported L_{50} values of 25.9 and 15.9 cm for *S. fasciatus* females and males, respectively. Information of growth of immature redfish presented by Perlmutter and Clarke (1949) suggested that the median age at maturation in the 1940's was likely to have been in the range of 8–9 yr, in contrast to the more recent value of 5.5 yr noted above.

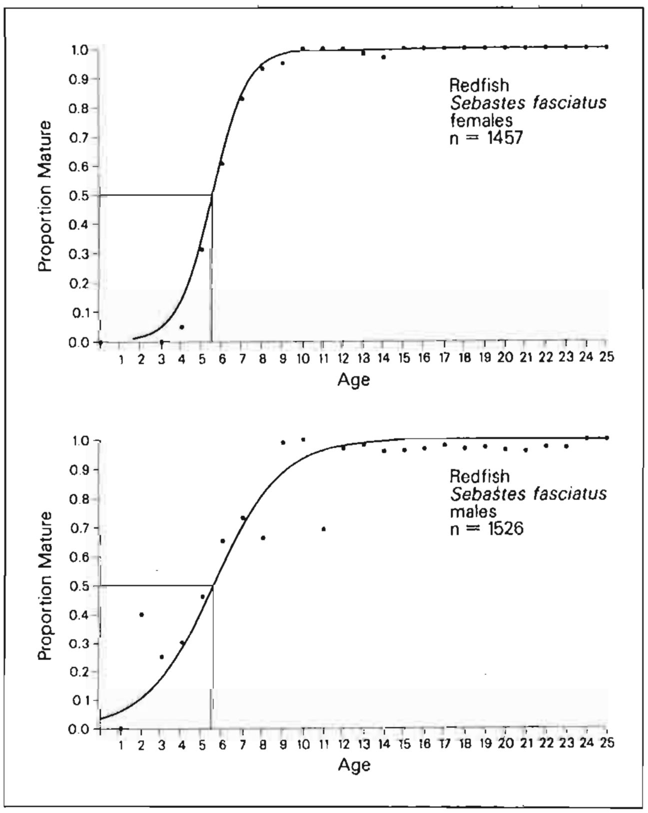

Figure 24
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (*n*=1457) and male (*n*=1526) redfish, *Sebastes fasciatus*, from the Gulf of Maine sampled during Northeast Fisheries Science Center spring and autumn bottom trawl surveys, 1975–1980.

Table 26
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (*n*=1457) and male (*n*=1526) redfish, *Sebastes fasciatus*, from the Gulf of Maine sampled during Northeast Fisheries Science Center spring and autumn bottom trawl surveys[a], 1975–1980.

Proportion mature	Age	95% Confidence interval Lower	95% Confidence interval Upper
Females			
Spring			
0.01	1.0	0.2	1.8
0.02	2.0	1.4	2.6
0.05	3.0	2.5	3.5
0.15	4.0	3.7	4.3
0.36	5.0	4.8	5.2
0.64	6.0	5.8	6.2
0.85	7.0	6.7	7.3
0.95	8.0	7.6	8.4
0.98	9.0	8.5	9.5
0.99	10.0	9.3	10.7
1.00	11.0	10.1	11.9
1.00	12.0	11.0	13.0
1.00	13.0	11.8	14.2
1.00	14.0	12.7	15.3
1.00	15.0	13.5	16.5
1.00	16.0	14.4	17.6
1.00	17.0	15.2	18.8
1.00	18.0	16.0	20.0
1.00	19.0	16.9	21.1
1.00	20.0[b]	17.7	22.3
Males			
Autumn			
0.06	1.0	0.1	1.9
0.11	2.0	1.3	2.7
0.18	3.0	2.4	3.6
0.28	4.0	3.6	4.4
0.42	5.0	4.7	5.3
0.57	6.0	5.7	6.3
0.71	7.0	6.7	7.3
0.81	8.0	7.6	8.4
0.89	9.0	8.5	9.5
0.94	10.0	9.3	10.7
0.96	11.0	10.2	11.8
0.98	12.0	11.0	13.0
0.99	13.0	11.9	14.1
0.99	14.0	12.7	15.3
1.00	15.0	13.6	16.4
1.00	16.0	14.4	17.6
1.00	17.0	15.2	18.8
1.00	18.0	16.1	19.9
1.00	19.0	16.9	21.1
1.00	20.0[b]	17.7	22.3

[a] Offshore strata 24, 26–30, 36–40.
[b] Older ages (21–53) are 100% mature.

Scup: *Stenotomus chrysops*

Scup range from the Gulf of Maine to Cape Hatteras, North Carolina (Bigelow and Schroeder 1953). Spawning occurs in coastal waters from May to August with peak spawning during May and June (Table 2). Commercial landings of scup were between 4,000 and 5,000 metric tons in the early 1970's and by 1980 had increased to about 12,000 t, subsequently declining to about 7,000 t in 1989 (NEFSC 1991).

Median length at maturity was 15.5 cm and 15.6 cm for females and males, respectively, collected during the spring of 1985, and 1987–1990 (Tables 3 and 27, Fig. 25).

Similar values were calculated for scup in the Peconic Bays of eastern Long Island during 1964–1966. Both female and male scup were determined to be sexually mature at age two (Finkelstein 1969b), which corresponded to a length of about 16 cm for both sexes (Finkelstein 1969a).

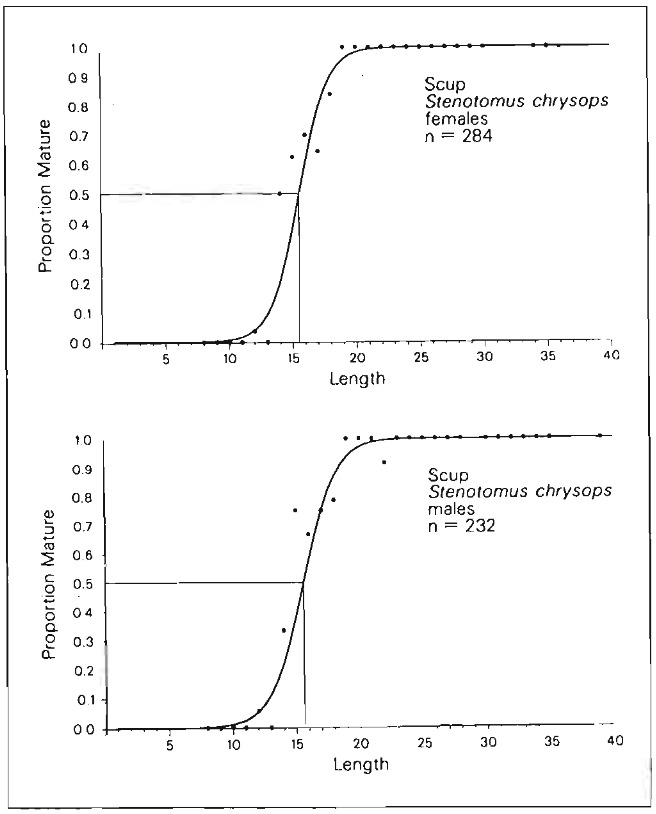

Figure 25
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=284) and male (n=232) scup, *Stenotomus chrysops*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985, 1987–1990.

Table 27
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=284) and male (n=232) scup, *Stenotomus chrysops*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985, 1987–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	12.3	11.2	13.4
0.10	13.1	12.2	14.0
0.15	13.6	12.8	14.4
0.20	14.0	13.2	14.7
0.25	14.3	13.6	15.0
0.30	14.6	13.9	15.2
0.35	14.8	14.2	15.5
0.40	15.1	14.5	15.7
0.45	15.3	14.7	15.9
0.50	15.5	14.9	16.1
0.55	15.7	15.2	16.3
0.60	16.0	15.4	16.5
0.65	16.2	15.6	16.8
0.70	16.4	15.8	17.0
0.75	16.7	16.1	17.4
0.80	17.0	16.4	17.7
0.85	17.4	16.7	18.1
0.90	17.9	17.1	18.7
0.95	18.8	17.8	19.7
0.99	20.6	19.2	22.0
Males			
0.05	11.9	10.6	13.2
0.10	12.9	11.8	13.9
0.15	13.4	12.5	14.4
0.20	13.9	13.0	14.8
0.25	14.2	13.4	15.1
0.30	14.5	13.8	15.3
0.35	14.8	14.1	15.6
0.40	15.1	14.4	15.8
0.45	15.4	14.6	16.1
0.50	15.6	14.9	16.3
0.55	15.9	15.1	16.6
0.60	16.1	15.4	16.8
0.65	16.4	15.7	17.1
0.70	16.7	15.9	17.4
0.75	17.0	16.2	17.8
0.80	17.3	16.5	18.2
0.85	17.8	16.9	18.7
0.90	18.3	17.4	19.3
0.95	19.3	18.1	20.5
0.99	21.3	19.7	23.0

[a] Offshore strata 2, 3, 61–63, 65–67, 70–71, 74–75.

Black Sea Bass: *Centropristis striata*

Black sea bass range from Cape Cod, Massachusetts, to northern Florida, but are most abundant in the Mid-Atlantic region. Meristic and morphometric studies indicate that only one stock exists north of Cape Hatteras, North Carolina (Shepherd 1991). Spawning of this stock progresses northward from March off North Carolina to October in Cape Cod waters (NEFSC 1991). Commercial landings of black sea bass have averaged 1,500 metric tons per year during 1980–1989 while annual recreational landings have fluctuated between 500 t and 8,100 t over the same period (NEFSC 1991).

Median length at maturity for female and male black sea bass was 19.1 and 19.0 cm (TL), respectively (Tables 3 and 28, Fig. 26). These sizes occur between ages 2 and 3 according to growth functions developed by Mercer (1978) for black sea bass north and south of Cape Hatteras and by Wenner et al. (1986) for black sea bass in the South Atlantic. Cupka et al. (1973)[4] reported that both sexes matured between 14 and 18 cm (standard length) in the South Carolina region. Wenner et al. (1986) reported that most females mature at age 2; Mercer (1978) observed mature males in all age groups, including age 1. Maturity analyses are complicated by the fact that black sea bass are protogynous hermaphrodites (Lavenda 1949), and that the proportion of mature males obtained through sex succession of females is still uncertain (Mercer 1978; Wenner et al. 1986).

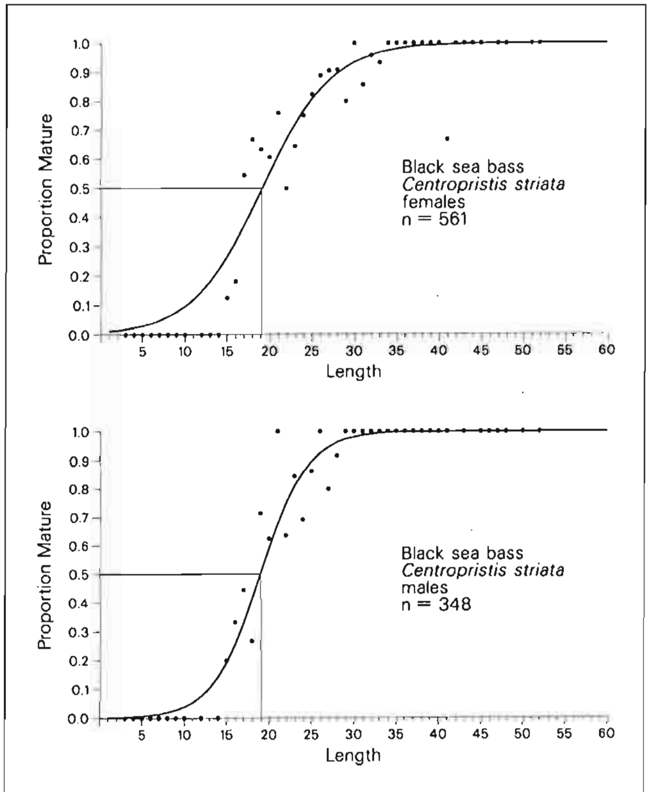

Figure 26
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=561) and male (n=348) black sea bass, *Centropristis striata*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

[4] D.M. Cupka, R.K. Dias and J. Tucker. 1973. Biology of the black sea bass, *Centropristis striata*, from South Carolina waters. Unpubl. manuscr. South Carolina Wildlife and Marine Resources Department, P.O. Box 12559, Charleston, SC 29412, 93 p.

Table 28
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=561) and male (n=348) black sea bass, *Centropristis striata*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	7.1	4.2	10.1
0.10	10.2	7.8	12.6
0.15	12.1	10.0	14.2
0.20	13.5	11.6	15.3
0.25	14.7	13.0	16.3
0.30	15.7	14.2	17.2
0.35	16.6	15.3	18.0
0.40	17.5	16.3	18.7
0.45	18.3	17.2	19.5
0.50	19.1	18.1	20.2
0.55	20.0	19.0	20.9
0.60	20.8	19.9	21.7
0.65	21.7	20.8	22.6
0.70	22.6	21.7	23.5
0.75	23.6	22.7	24.6
0.80	24.8	23.7	25.9
0.85	26.2	25.0	27.5
0.90	28.1	26.6	29.6
0.95	31.2	29.2	33.2
0.99	37.9	34.7	41.1
Males			
0.05	10.8	8.2	13.5
0.10	12.9	10.7	15.1
0.15	14.2	12.3	16.1
0.20	15.1	13.4	16.8
0.25	15.9	14.4	17.5
0.30	16.6	15.2	18.1
0.35	17.3	16.0	18.6
0.40	17.9	16.6	19.1
0.45	18.4	17.3	19.6
0.50	19.0	17.9	20.1
0.55	19.5	18.5	20.6
0.60	20.1	19.1	21.1
0.65	20.7	19.7	21.7
0.70	21.3	20.4	22.3
0.75	22.0	21.0	23.1
0.80	22.8	21.7	23.9
0.85	23.8	22.6	25.0
0.90	25.1	23.7	26.5
0.95	27.2	25.3	29.0
0.99	31.7	28.9	34.6

[a] Inshore strata 1–61, offshore strata 1–12, 25, 61–76.

Ocean Pout: *Macrozoarces americanus*

Ocean pout are distributed from the Gulf of St. Lawrence to Delaware (Olsen and Merriman 1946); off the coast of New England they are abundant in the Gulf of Maine and Southern New England area. Spawning occurs in rocky areas from September to October (Table 2). Landings of ocean pout fluctuated about an average of 600 metric tons during 1975–1983, then increased to a peak of about 2,200 t in 1987 and have recently declined to about 1,300 t (NEFSC 1991).

Median length at maturity for female and male ocean pout from the Gulf of Maine area was 26.2 cm and 30.3 cm, respectively (Tables 3 and 29, Fig. 27). Ocean pout from the Southern New England area had L_{50} values of 31.3 cm and 31.9 cm for females and males, respectively (Tables 3 and 30, Fig. 28).

Larger L_{50} values were calculated by Olsen and Merriman (1946) for ocean pout taken in the Southern New England area in May of 1944. Females were found to be mature at an average length of 55 cm which corresponded to an age of either 6 or 7 yr. All male ocean pout below 25 cm were immature and nearly all

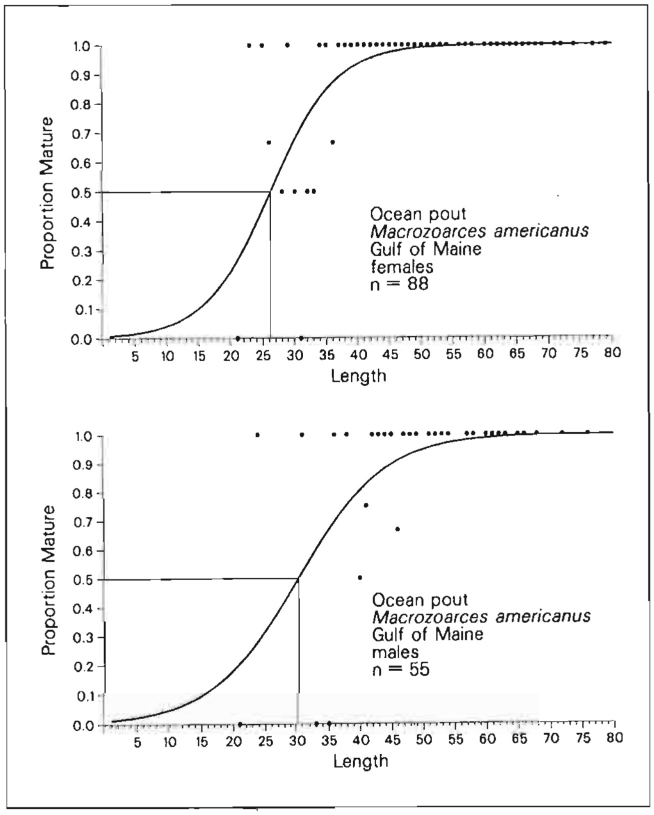

Figure 27
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=88) and male (n=55) ocean pout, *Macrozoarces americanus,* from the Gulf of Maine sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 29
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=88) and male (n=55) ocean pout, *Macrozoarces americanus,* from the Gulf of Maine sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	11.1	-3.3	25.5
0.10	14.9	2.9	26.9
0.15	17.3	6.8	27.8
0.20	19.1	9.6	28.5
0.25	20.6	12.0	29.2
0.30	21.8	14.0	29.7
0.35	23.0	15.8	30.3
0.40	24.1	17.4	30.8
0.45	25.2	19.0	31.3
0.50	26.2	20.5	31.9
0.55	27.2	22.0	32.5
0.60	28.3	23.4	33.2
0.65	29.4	24.8	34.0
0.70	30.5	26.2	34.9
0.75	31.8	27.5	36.1
0.80	33.3	28.9	37.7
0.85	35.1	30.3	39.9
0.90	37.5	31.8	43.2
0.95	41.3	33.7	48.9
0.99	49.8	37.1	62.5
Males			
0.05	10.3	-13.8	34.4
0.10	15.4	-4.9	35.7
0.15	18.5	0.5	36.5
0.20	20.9	4.6	37.1
0.25	22.8	8.0	37.7
0.30	24.6	10.9	38.2
0.35	26.1	13.5	38.7
0.40	27.6	16.0	39.2
0.45	29.0	18.3	39.7
0.50	30.3	20.5	40.2
0.55	31.7	22.6	40.8
0.60	33.1	24.8	41.4
0.65	34.5	26.9	42.2
0.70	36.1	29.1	43.1
0.75	37.8	31.3	44.4
0.80	39.8	33.4	46.1
0.85	42.1	35.6	48.7
0.90	45.3	37.7	52.9
0.95	50.4	40.1	60.7
0.99	61.6	43.5	79.7

[a] Inshore strata 57–66, offshore strata 26–40.

males greater than 39 cm were mature at an age of 3 or 4 yr. A study conducted by Keats et al. (1985) in Newfoundland waters during July and August, 1983–1984, reported that the mean lengths of nesting pairs of ocean pout were 70.5 cm and 81.1 cm for females and males, respectively.

The difference in L_{50} values of females in the present study compared to that of Olsen and Merriman (1946) may be partly due to difficulty in identifying a mature female. Larger females appear to have three different sizes of eggs present while developing; however, Keats et al. (1985) reported that egg masses guarded by females were uniform and appeared to be from one spawning, and concluded that multiple spawning was unlikely. Possibly, immature females develop eggs each year for three years, spawning in the third year. This maturation process would lead to misclassification of immature fish as developing for two years, therefore artificially lowering the L_{50} value.

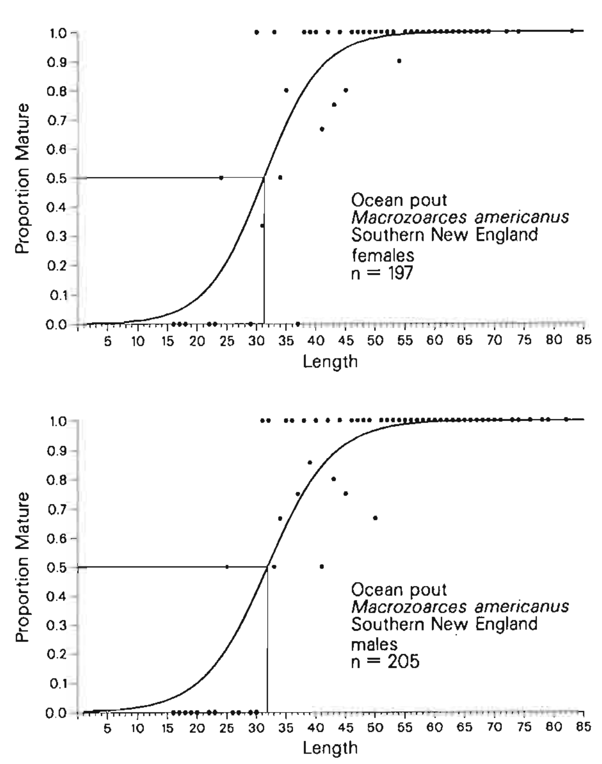

Figure 28
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=197) and male (n=205) ocean pout, *Macrozoarces americanus*, from Southern New England sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 30
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=197) and male (n=205) ocean pout, *Macrozoarces americanus*, from Southern New England sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	17.1	8.4	25.8
0.10	20.7	13.3	28.2
0.15	22.9	16.3	29.6
0.20	24.6	18.5	30.7
0.25	26.0	20.3	31.7
0.30	27.2	21.9	32.5
0.35	28.3	23.3	33.3
0.40	29.3	24.6	34.0
0.45	30.3	25.9	34.7
0.50	31.3	27.1	35.5
0.55	32.2	28.2	36.2
0.60	33.2	29.4	37.0
0.65	34.2	30.6	37.8
0.70	35.3	31.9	38.8
0.75	36.5	33.2	39.9
0.80	37.9	34.6	41.2
0.85	39.6	36.3	42.9
0.90	41.8	38.3	45.3
0.95	45.4	41.1	49.7
0.99	53.3	46.7	60.0
Males			
0.05	16.0	8.4	23.7
0.10	20.0	13.6	26.5
0.15	22.5	16.8	28.3
0.20	24.4	19.2	29.6
0.25	26.0	21.2	30.7
0.30	27.3	22.9	31.8
0.35	28.5	24.4	32.7
0.40	29.7	25.8	33.6
0.45	30.8	27.1	34.5
0.50	31.9	28.4	35.4
0.55	32.9	29.6	36.3
0.60	34.1	30.9	37.2
0.65	35.2	32.1	38.3
0.70	36.4	33.4	39.5
0.75	37.8	34.8	40.8
0.80	39.3	36.2	42.4
0.85	41.2	37.9	44.5
0.90	43.7	40.0	47.4
0.95	47.7	43.1	52.4
0.99	56.6	49.4	63.8

[a] Inshore strata 1–52, offshore strata 1–12, 61–76.

Yellowtail Flounder: *Pleuronectes ferrugineus*

Yellowtail flounder range from Labrador to Virginia with three major stocks occurring off the coast of New England: Georges Bank, Cape Cod, and Southern New England (Royce et al. 1959; Lux 1963). The spawning season is from April to August with peak spawning occurring in May and June (Table 2). Commercial landings for the Georges Bank stock declined from about 15,000 metric tons in the early 1970's to about 4,500 t by 1978, increased to over 11,000 t in 1983, then subsequently declined to a record low of 1,100 t in 1989 (NEFSC 1991). Landings in 1990 were about 12,000 t, attributable to a strong 1987 year class. Landings of the Cape Cod stock increased from about 1,500 t in the early 1970's to a peak of about 5,000 t by 1980, then subsequently declined to about 900 t by 1989 (NEFSC 1991). Commercial landings of the Southern New England stock declined from a high of about 32,000 t in 1969 to a low of 1,700 in 1976, increased to a peak of about 18,000 t in 1983 and subsequently declined to a low of about 900 t in 1988. Landings increased in 1989 to 2,500 t owing to the recruiting 1987 year class (NEFSC 1991).

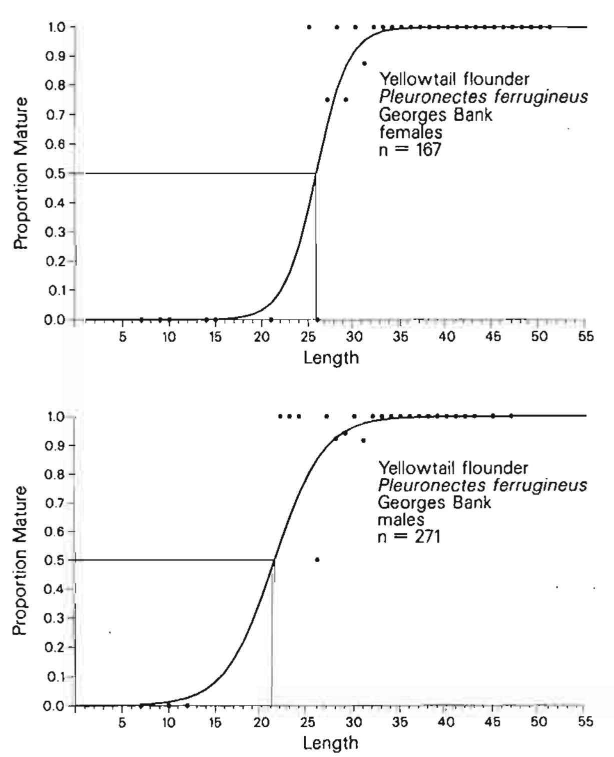

Figure 29

Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Georges Bank female (n=167) and male (n=271) yellowtail flounder, *Pleuronectes ferrugineus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 31

Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Georges Bank female (n=167) and male (n=271) yellowtail flounder, *Pleuronectes ferrugineus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	20.8	15.7	25.9
0.10	22.1	17.7	26.4
0.15	22.8	18.9	26.8
0.20	23.4	19.9	27.0
0.25	23.9	20.6	27.3
0.30	24.4	21.3	27.5
0.35	24.8	21.9	27.6
0.40	25.1	22.4	27.8
0.45	25.5	22.9	28.0
0.50	25.8	23.4	28.2
0.55	26.1	23.9	28.4
0.60	26.5	24.4	28.6
0.65	26.9	24.9	28.8
0.70	27.3	25.4	29.1
0.75	27.7	26.0	29.4
0.80	28.2	26.5	29.8
0.85	28.8	27.2	30.4
0.90	29.6	27.9	31.2
0.95	30.8	28.8	32.9
0.99	33.6	30.2	37.0
Males			
0.05	13.7	6.1	21.2
0.10	15.6	9.0	22.2
0.15	16.8	10.8	22.9
0.20	17.7	12.1	23.3
0.25	18.5	13.3	23.7
0.30	19.2	14.2	24.1
0.35	19.8	15.1	24.4
0.40	20.3	15.9	24.7
0.45	20.9	16.7	25.0
0.50	21.4	17.5	25.3
0.55	21.9	18.2	25.6
0.60	22.4	19.0	25.9
0.65	23.0	19.8	26.2
0.70	23.6	20.6	26.6
0.75	24.3	21.5	27.0
0.80	25.0	22.5	27.5
0.85	25.9	23.7	28.2
0.90	27.1	25.1	29.2
0.95	29.1	27.1	31.1
0.99	33.4	30.1	36.8

[a] Offshore strata 13–21.

Median length at maturity for female and male yellowtail flounder sampled during spring 1985–1990 was, respectively, 25.8 cm and 21.4 cm for the Georges Bank stock (Tables 3 and 31, Fig. 29), 27.3 cm and 26.8 cm for the Cape Cod stock (Tables 3 and 33, Fig. 31), and 25.5 cm and 19.6 cm for the Southern New England stock (Tables 3 and 35, Fig. 33). Median age at maturity for female and male Georges Bank yellowtail flounder was 1.8 yr and 1.3 yr, respectively (Table 4, Fig. 30). For the Cape Cod stock, A_{50} values were 2.6 yr for both sexes (Table 4, Fig. 32). The Southern New England stock had A_{50} values of 1.6 yr for females and 1.8 yr for males (Table 4, Fig. 34). Proportions of mature fish at age are presented in Tables 32, 34, and 36.

Morse and Morris (1981)[5] calculated similar L_{50} values of 27.3 cm and 24.2 cm for female and male yellowtail flounder collected east of 72° long. during 1975–1980. Yellowtail flounder collected over the entire region during 1977 had L_{50} values of 27.5 cm and 24.3 cm for females and males, respectively (Morse 1979)[2]. Scott (1954) examined yellowtail flounder collected during July–September 1946 between Nantucket Shoals and Montauk Point, and determined that there were no immature females over 32 cm, and that 100% maturation was reached by age 3. Royce et al. (1959) determined from Southern New England samples collected in May 1943 that L_{50} for females was 32 cm and that males became sexually mature before recruitment to the commercial catch, at about 26 cm. Female yellowtail had A_{50} values of about 2 yr and males probably matured at about age 1.

Median length at maturity of yellowtail flounder collected during July in the Scotian Shelf area was 24 cm during 1970–1974 for females and increased to 29 cm during 1975–1979; for males, L_{50} remained at about 19–20 cm during the same time periods (Beacham 1983d). Values of A_{50} declined for females and males from 3.1 yr and 3.2 yr, respectively, during 1970–1974 to 2.9 yr and 2.0 yr, respectively, during 1975–1979 (Beacham 1983d).

[5] W.W. Morse and A. Morris. 1981. An analysis of yellowtail flounder, *Limanda ferruginea*, length at maturity east and west of 72° long. for 1975–1980. NMFS/NEFC, Sandy Hook Lab. Rep. No. 81-16, 4 p.

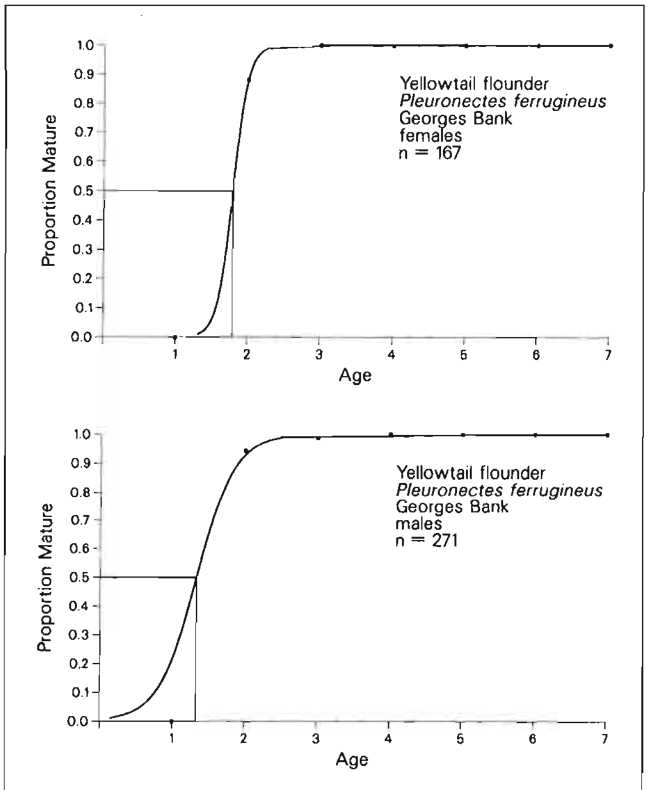

Figure 30

Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Georges Bank female (n=167) and male (n=271) yellowtail flounder, *Pleuronectes ferrugineus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 32

Calculated proportion mature at age with approximate 95 % confidence intervals based on macroscopic observations of whole gonads of Georges Bank female (n=167) and male (n=271) yellowtail flounder, *Pleuronectes ferrugineus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.00	1.0	-2.1	4.1
0.88	2.0	1.9	2.1
1.00	3.0	-0.1	6.1
1.00	4.0	-2.1	10.1
1.00	5.0	-4.2	14.2
1.00	6.0	-6.3	18.3
1.00	7.0	-8.3	22.3
Males			
0.22	1.0	0.4	1.6
0.93	2.0	1.8	2.2
1.00	3.0	2.4	3.6
1.00	4.0	2.8	5.2
1.00	5.0	3.2	6.8
1.00	6.0	3.7	8.3
1.00	7.0	4.1	9.9

[a] Offshore strata 13–21.

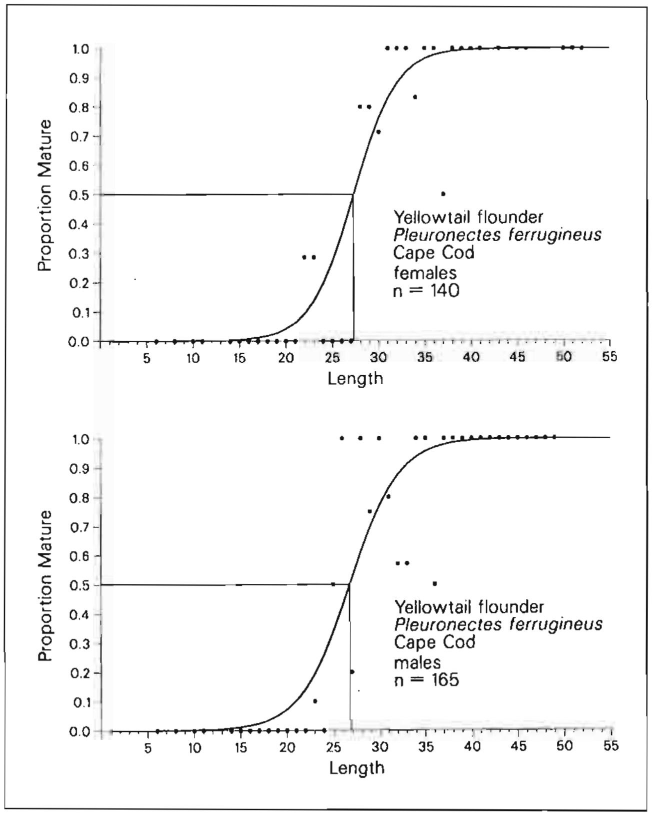

Figure 31
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Cape Cod female (n=140) and male (n=165) yellowtail flounder, *Pleuronectes ferrugineus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 33
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Cape Cod female (n=140) and male (n=165) yellowtail flounder, *Pleuronectes ferrugineus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Female			
0.05	20.5	17.8	23.1
0.10	22.2	20.0	24.4
0.15	23.3	21.3	25.2
0.20	24.1	22.3	25.9
0.25	24.7	23.1	26.4
0.30	25.3	23.8	26.9
0.35	25.9	24.3	27.4
0.40	26.4	24.9	27.8
0.45	26.8	25.4	28.3
0.50	27.3	25.9	28.7
0.55	27.8	26.3	29.2
0.60	28.2	26.8	29.7
0.65	28.7	27.2	30.3
0.70	29.3	27.7	30.9
0.75	29.9	28.2	31.5
0.80	30.5	28.7	32.3
0.85	31.3	29.4	33.3
0.90	32.4	30.2	34.6
0.95	34.1	31.5	36.8
0.99	38.0	34.2	41.8
Males			
0.05	19.0	16.2	21.7
0.10	21.0	18.7	23.2
0.15	22.2	20.3	24.1
0.20	23.1	21.4	24.8
0.25	23.9	22.3	25.4
0.30	24.5	23.1	26.0
0.35	25.1	23.8	26.5
0.40	25.7	24.4	27.0
0.45	26.3	25.0	27.5
0.50	26.8	25.5	28.0
0.55	27.3	26.1	28.6
0.60	27.9	26.6	29.1
0.65	28.4	27.1	29.8
0.70	29.0	27.6	30.4
0.75	29.7	28.2	31.2
0.80	30.5	28.8	32.1
0.85	31.4	29.6	33.2
0.90	32.6	30.5	34.7
0.95	34.6	32.0	37.2
0.99	39.0	35.1	42.8

[a] Offshore strata 24–26.

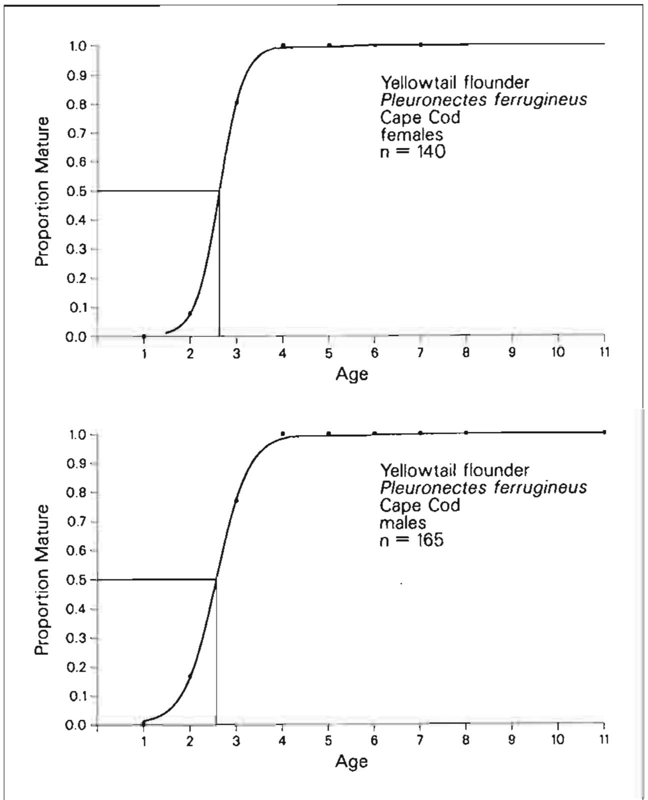

Figure 32
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Cape Cod female (n=140) and male (n=165) yellowtail flounder, *Pleuronectes ferrugineus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 34
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Cape Cod female (n=140) and male (n=165) yellowtail flounder, *Pleuronectes ferrugineus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.00	1.0	0.5	1.5
0.08	2.0	1.8	2.2
0.81	3.0	2.8	3.2
1.00	4.0	3.6	4.4
1.00	5.0	4.3	5.7
1.00	6.0	5.0	7.0
1.00	7.0	5.7	8.3
1.00	8.0	6.4	9.6
Males			
0.01	1.0	0.5	1.5
0.16	2.0	1.8	2.2
0.77	3.0	2.8	3.2
0.98	4.0	3.6	4.4
1.00	5.0	4.3	5.7
1.00	6.0	5.0	7.0
1.00	7.0	5.7	8.3
1.00	8.0	6.4	9.6
1.00	9.0	7.1	10.9
1.00	10.0	7.8	12.2
1.00	11.0	8.5	13.5

[a] Offshore strata 24–26.

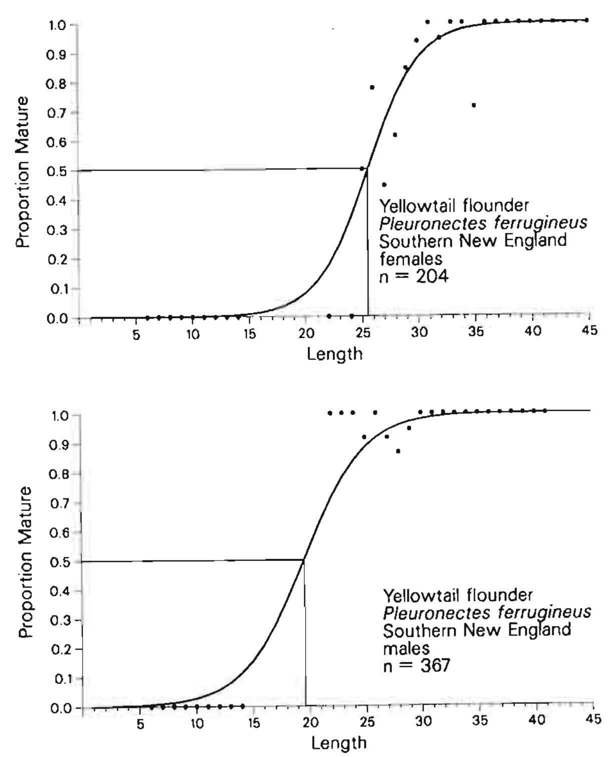

Figure 33
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Southern New England female (n=204) and male (n=367) yellowtail flounder, *Pleuronectes ferrugineus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 35
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Southern New England female (n=204) and male (n=367) yellowtail flounder, *Pleuronectes ferrugineus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	18.9	14.5	23.3
0.10	20.6	16.9	24.3
0.15	21.6	18.4	24.9
0.20	22.4	19.5	25.4
0.25	23.1	20.4	25.7
0.30	23.6	21.2	26.1
0.35	24.1	21.9	26.4
0.40	24.6	22.5	26.7
0.45	25.1	23.2	27.0
0.50	25.5	23.8	27.3
0.55	26.0	24.4	27.6
0.60	26.4	25.0	27.9
0.65	26.9	25.6	28.3
0.70	27.4	26.2	28.7
0.75	28.0	26.9	29.1
0.80	28.6	27.5	29.7
0.85	29.4	28.3	30.6
0.90	30.5	29.1	31.8
0.95	32.1	30.3	34.0
0.99	35.8	32.6	39.1
Males			
0.05	11.7	6.5	16.9
0.10	13.7	9.2	18.2
0.15	14.9	10.8	19.1
0.20	15.9	12.0	19.7
0.25	16.6	13.0	20.2
0.30	17.3	13.9	20.7
0.35	17.9	14.7	21.1
0.40	18.5	15.5	21.5
0.45	19.0	16.2	21.9
0.50	19.6	16.9	22.3
0.55	20.1	17.5	22.7
0.60	20.6	18.2	23.0
0.65	21.2	19.0	23.5
0.70	21.8	19.7	23.9
0.75	22.5	20.5	24.4
0.80	23.3	21.5	25.1
0.85	24.2	22.6	25.8
0.90	25.4	23.9	26.9
0.95	27.4	25.9	29.0
0.99	31.8	29.3	34.3

[a] Offshore strata 5–6, 9–10.

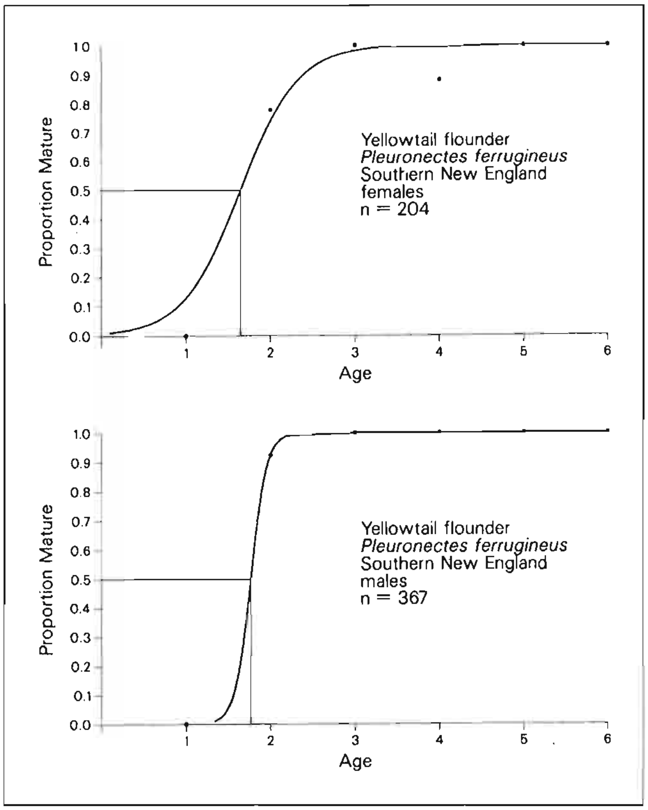

Figure 34
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Southern New England female (n=204) and male (n=367) yellowtail flounder, *Pleuronectes ferrugineus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 36
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Southern New England female (n=204) and male (n=367) yellowtail flounder, *Pleuronectes ferrugineus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.13	1.0	0.6	1.4
0.74	2.0	1.9	2.1
0.98	3.0	2.6	3.4
1.00	4.0	3.3	4.7
1.00	5.0	3.9	6.1
1.00	6.0	4.6	7.4
Males			
0.00	1.0	-1.3	3.3
0.92	2.0	1.9	2.1
1.00	3.0	0.7	5.3
1.00	4.0	-0.7	8.7
1.00	5.0	-2.0	12.0
1.00	6.0	-3.4	15.4

[a] Offshore strata 5–6, 9–10.

Winter Flounder: *Pleuronectes americanus*

Winter flounder are widely distributed in the northwest Atlantic from Labrador to Georgia, but abundance is highest from the Gulf of St. Lawrence to Chesapeake Bay. Tagging and meristic studies indicate three stocks of winter flounder in U.S. waters: two inshore stocks north and south of Cape Cod (Lux et al. 1970; Howe and Coates 1975; Pierce and Howe 1977) and an offshore stock occupying Georges Bank (Lux 1973). Spawning occurs from February to May, with peak activity during February and March in southern areas and April farther north (Table 2). Commercial landings of winter flounder from Georges Bank averaged 3,800 metric tons per year during 1980–1984 but have subsequently declined to about 2,300 t annually since then (NEFSC 1991). Combined commercial and recreational catch for inshore stocks has similarly declined in recent years, from about 6,400 t per year during 1980–1982 to 2,700 t annually since 1983 for the northern stock, and from an average of 14,000 t per year during 1980–1985 to 7,800 t from 1986–1989 for the southern stock (NEFSC 1991).

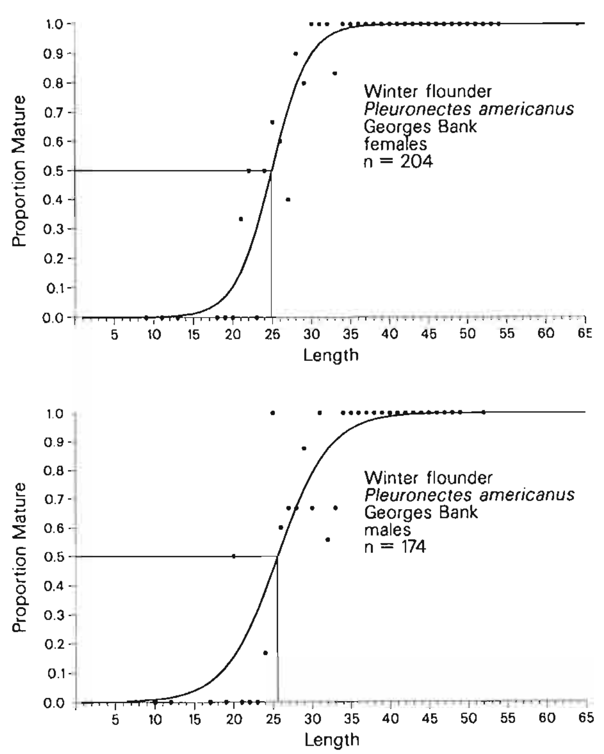

Figure 35
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of Georges Bank female (n=204) and male (n=174) winter flounder, *Pleuronectes americanus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Median length at maturity for female and male winter flounder from Georges Bank was 24.9 and 25.6 cm, respectively (Tables 3 and 37, Fig. 35). For inshore

Table 37
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Georges Bank female (n=204) and male (n=174) winter flounder, *Pleuronectes americanus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Female			
0.05	18.2	14.8	21.6
0.10	19.9	17.1	22.7
0.15	20.9	18.5	23.4
0.20	21.7	19.5	23.9
0.25	22.4	20.4	24.4
0.30	23.0	21.2	24.8
0.35	23.5	21.8	25.2
0.40	24.0	22.4	25.6
0.45	24.5	23.0	25.9
0.50	24.9	23.5	26.3
0.55	25.4	24.1	26.7
0.60	25.9	24.6	27.1
0.65	26.3	25.1	27.6
0.70	26.9	25.6	28.1
0.75	27.4	26.1	28.8
0.80	28.1	26.7	29.5
0.85	28.9	27.3	30.5
0.90	30.0	28.1	31.8
0.95	31.7	29.3	34.0
0.99	35.5	31.8	39.1
Males			
0.05	15.9	11.1	20.6
0.10	18.3	14.4	22.2
0.15	19.9	16.4	23.3
0.20	21.0	17.9	24.1
0.25	22.0	19.2	24.8
0.30	22.8	20.2	25.4
0.35	23.6	21.2	25.9
0.40	24.3	22.1	26.5
0.45	25.0	22.9	27.0
0.50	25.6	23.7	27.5
0.55	26.3	24.5	28.1
0.60	27.0	25.2	28.7
0.65	27.7	26.0	29.4
0.70	28.4	26.8	30.1
0.75	29.3	27.6	31.0
0.80	30.2	28.4	32.0
0.85	31.4	29.4	33.4
0.90	32.9	30.6	35.2
0.95	35.4	32.4	38.4
0.99	40.9	36.1	45.6

[a] Offshore strata 13–22.

stocks, values of L_{50} were 29.7 cm for females and 27.6 cm for males north of Cape Cod, and 27.6 cm for females and 29.0 cm for males south of Cape Cod (Tables 3, 39, and 41, Figs. 37 and 39). Median age at maturity was 1.9 yr for both sexes on Georges Bank (Table 4, Fig. 36); proportions of mature fish calculated for each age are presented in Table 38. For inshore stocks, values of A_{50} were 3.5 yr for females and 3.3 yr for females north of Cape Cod, and 3.0 yr for females and 3.3 yr for males south of Cape Cod (Table 4, Figs. 38 and 40); proportions mature calculated for each age are presented in Tables 40 and 42.

Morse (1979)[2] reported values for L_{50} derived from 1977 data of 26.3 cm for females and 24.8 cm for males, but did not distinguish between inshore stocks and the faster-growing (Lux 1973) Georges Bank winter flounder. Comparisons of maturity analyses from other studies are complicated by the complex stock structure for the species. Perlmutter (1947) observed that winter flounder in the Long Island Sound region mature at 20–25 cm and 2–3 yr of age, while Kennedy and Steele (1971) reported values for L_{50} of 25 cm for females and 21 cm for males in Newfoundland waters, with ages at full maturity of 7 yr for females and 6 yr for males, leaving these authors to conclude that maturation was related to size and not age. However, Beacham (1982) presented evidence that maturation of winter flounder in the Scotian Shelf and southern Gulf of St. Lawrence region was highly variable from year to year, and Burton and Idler (1984) found large numbers of nonreproductive individuals in a given year, suggesting that interpretations of maturity data for winter flounder must be conducted with caution.

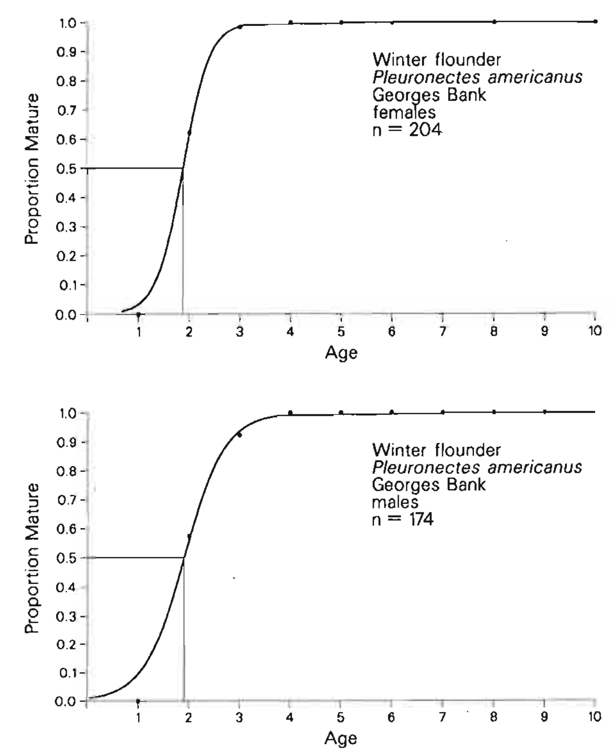

Figure 36
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of Georges Bank female (n=204) and male (n=174) winter flounder, *Pleuronectes americanus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1989.

Table 38
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of Georges Bank female (n=204) and male (n=174) winter flounder, *Pleuronectes americanus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.03	1.0	0.4	1.6
0.62	2.0	1.9	2.1
0.99	3.0	2.5	3.5
1.00	4.0	3.0	5.0
1.00	5.0	3.5	6.5
1.00	6.0	3.9	8.1
1.00	7.0	4.4	9.6
1.00	8.0	4.9	11.1
1.00	9.0	5.4	12.6
1.00	10.0	5.8	14.2
Males			
0.10	1.0	0.5	1.5
0.56	2.0	1.8	2.2
0.94	3.0	2.6	3.4
0.99	4.0	3.2	4.8
1.00	5.0	3.8	6.2
1.00	6.0	4.4	7.6
1.00	7.0	5.0	9.0
1.00	8.0	5.6	10.4
1.00	9.0	6.2	11.8

[a] Offshore strata 13–22.

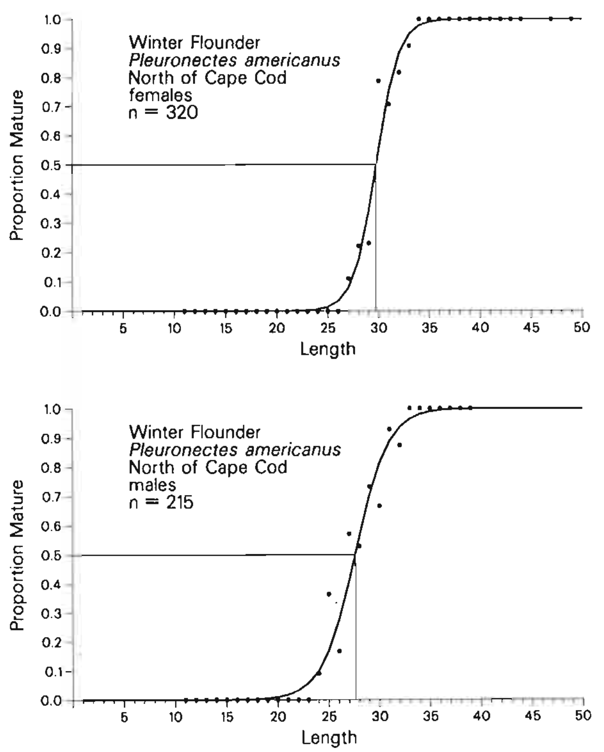

Figure 37
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=320) and male (n=215) winter flounder, *Pleuronectes americanus,* sampled north of Cape Cod during Massachusetts Division of Marine Fisheries spring bottom trawl surveys, 1985–1989.

Table 39
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=320) and male (n=215) winter flounder, *Pleuronectes americanus,* sampled north of Cape Cod during Massachusetts Division of Marine Fisheries spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	26.5	25.3	27.6
0.10	27.3	26.4	28.2
0.15	27.8	27.0	28.6
0.20	28.2	27.5	28.9
0.25	28.5	27.8	29.2
0.30	28.8	28.2	29.4
0.35	29.0	28.5	29.6
0.40	29.3	28.7	29.8
0.45	29.5	29.0	30.1
0.50	29.7	29.2	30.3
0.55	30.0	29.5	30.5
0.60	30.2	29.7	30.7
0.65	30.4	29.9	30.9
0.70	30.7	30.2	31.2
0.75	31.0	30.4	31.5
0.80	31.3	30.7	31.9
0.85	31.7	31.0	32.3
0.90	32.2	31.5	32.9
0.95	33.0	32.1	33.9
0.99	34.9	33.5	36.2
Males			
0.05	22.8	21.2	24.3
0.10	24.0	22.8	25.2
0.15	24.8	23.7	25.8
0.20	25.3	24.4	26.3
0.25	25.8	24.9	26.7
0.30	26.2	25.4	27.0
0.35	26.6	25.8	27.3
0.40	26.9	26.2	27.6
0.45	27.3	26.6	28.0
0.50	27.6	26.9	28.3
0.55	27.9	27.2	28.6
0.60	28.2	27.5	29.0
0.65	28.6	27.9	29.3
0.70	29.0	28.2	29.7
0.75	29.4	28.5	30.2
0.80	29.8	28.9	30.8
0.85	30.4	29.4	31.4
0.90	31.2	30.0	32.4
0.95	32.4	30.9	33.9
0.99	35.1	32.9	37.3

[a] Strata 25–36.

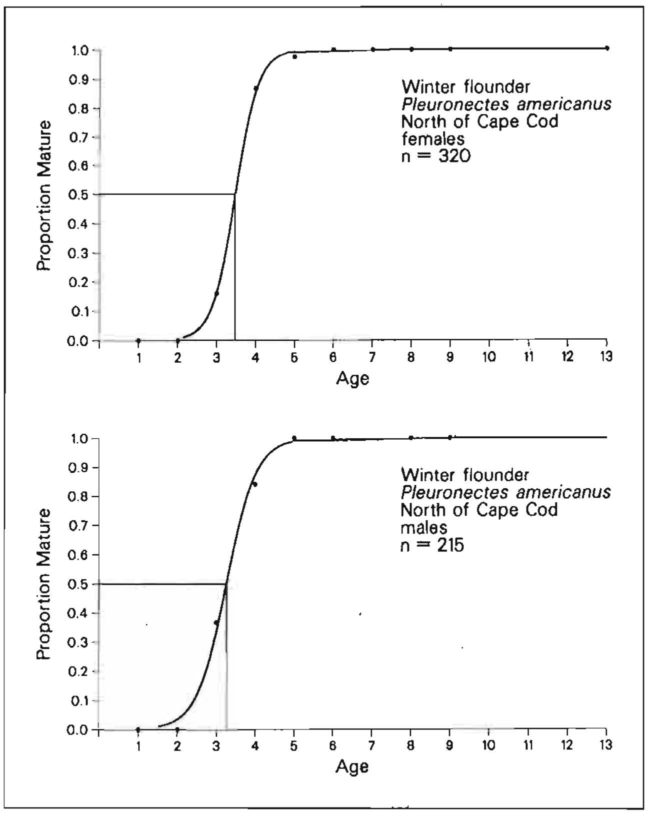

Figure 38

Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=320) and male (n=215) winter flounder, *Pleuronectes americanus,* sampled north of Cape Cod during Massachusetts Division of Marine Fisheries spring bottom trawl surveys, 1985–1989.

Table 40

Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=320) and male (n=215) winter flounder, *Pleuronectes americanus,* sampled north of Cape Cod during Massachusetts Division of Marine Fisheries spring bottom trawl surveys[a], 1985–1989.

Proportion Mature	Age	95% Confidence interval Lower	Upper
Females			
0.00	1.0	0.5	1.5
0.01	2.0	1.7	2.3
0.16	3.0	2.9	3.1
0.86	4.0	3.9	4.1
0.99	5.0	4.7	5.3
1.00	6.0	5.5	6.5
1.00	7.0	6.3	7.7
1.00	8.0	7.1	8.9
1.00	9.0	7.9	10.1
1.00	10.0	8.7	11.3
1.00	11.0	9.5	12.5
1.00	12.0	10.3	13.7
1.00	13.0	11.1	14.9
Males			
0.00	1.0	0.4	1.6
0.04	2.0	1.6	2.4
0.34	3.0	2.9	3.1
0.87	4.0	3.7	4.3
0.99	5.0	4.4	5.6
1.00	6.0	5.2	6.8
1.00	7.0	5.9	8.1
1.00	8.0	6.6	9.4
1.00	9.0	7.3	10.7

[a] Strata 25–36.

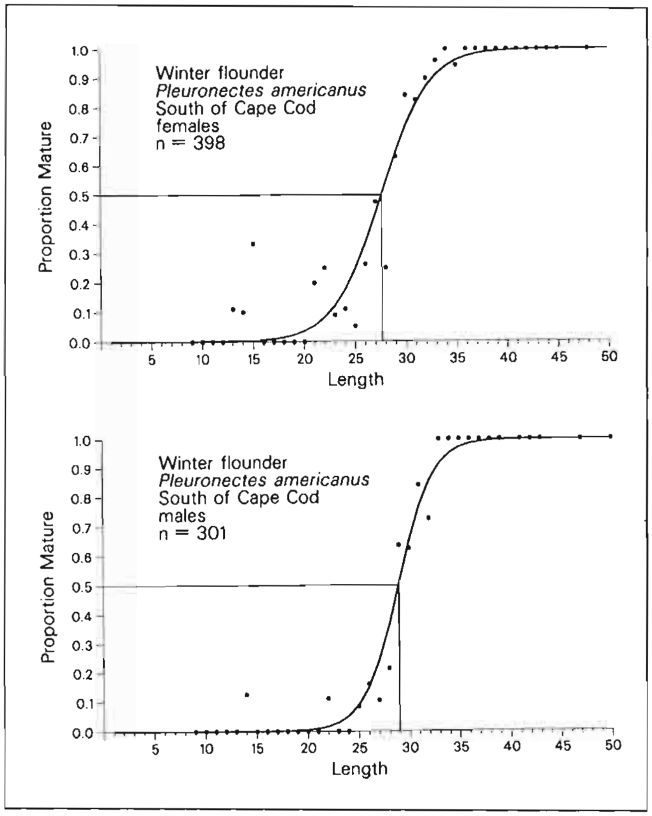

Figure 39

Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=398) and male (n=301) winter flounder, *Pleuronectes americanus*, sampled south of Cape Cod during Massachusetts Division of Marine Fisheries spring bottom trawl surveys, 1985–1989.

Table 41

Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=398) and male (n=301) winter flounder, *Pleuronectes americanus*, sampled south of Cape Cod during Massachusetts Division of Marine Fisheries spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	20.8	19.0	22.5
0.10	22.5	21.0	23.9
0.15	23.6	22.3	24.8
0.20	24.4	23.2	25.5
0.25	25.0	24.0	26.1
0.30	25.6	24.7	26.6
0.35	26.1	25.3	27.0
0.40	26.6	25.8	27.5
0.45	27.1	26.3	27.9
0.50	27.6	26.8	28.3
0.55	28.1	27.3	28.8
0.60	28.5	27.8	29.3
0.65	29.0	28.3	29.8
0.70	29.6	28.8	30.3
0.75	30.1	29.3	30.9
0.80	30.8	29.9	31.7
0.85	31.6	30.6	32.6
0.90	32.7	31.5	33.8
0.95	34.4	33.0	35.9
0.99	38.2	36.1	40.4
Males			
0.05	24.0	22.6	25.3
0.10	25.2	24.1	26.3
0.15	26.0	25.1	27.0
0.20	26.6	25.8	27.5
0.25	27.1	26.3	27.9
0.30	27.5	26.8	28.3
0.35	27.9	27.2	28.6
0.40	28.3	27.6	29.0
0.45	28.6	28.0	29.3
0.50	29.0	28.3	29.6
0.55	29.3	28.6	30.0
0.60	29.7	29.0	30.4
0.65	30.0	29.3	30.7
0.70	30.4	29.6	31.2
0.75	30.8	30.0	31.7
0.80	31.3	30.4	32.2
0.85	31.9	30.9	32.9
0.90	32.7	31.5	33.8
0.95	34.0	32.5	35.4
0.99	36.8	34.7	38.8

[a] Strata 11–17.

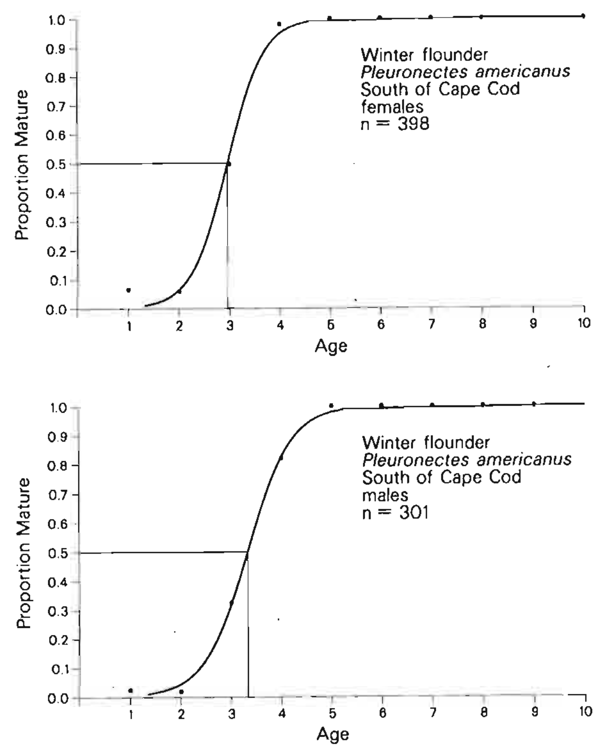

Figure 40

Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=398) and male (n=301) winter flounder, *Pleuronectes americanus,* sampled south of Cape Cod during Massachusetts Division of Marine Fisheries spring bottom trawl surveys, 1985–1989.

Table 42

Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=398) and male (n=301) winter flounder, *Pleuronectes americanus,* sampled south of Cape Cod during Massachusetts Division of Marine Fisheries spring bottom trawl surveys[a], 1985–1989.

Proportion mature	Age	95% Confidence interval	
		Lower	Upper
Females			
0.00	1.0	0.5	1.5
0.06	2.0	1.7	2.3
0.53	3.0	2.9	3.1
0.95	4.0	3.8	4.2
1.00	5.0	4.5	5.5
1.00	6.0	5.3	6.7
1.00	7.0	6.1	7.9
1.00	8.0	6.8	9.2
1.00	9.0	7.6	10.4
1.00	10.0	8.4	11.6
Males			
0.00	1.0	0.4	1.6
0.04	2.0	1.7	2.3
0.32	3.0	2.9	3.1
0.83	4.0	3.8	4.2
0.98	5.0	4.5	5.5
1.00	6.0	5.3	6.7
1.00	7.0	6.1	7.9
1.00	8.0	6.8	9.2
1.00	9.0	7.6	10.4

[a] Strata 11–17.

American Plaice: *Hippoglossoides platessoides*

American plaice, or dab, occurs on both sides of the north Atlantic. In the northwest Atlantic, American plaice are distributed along the continental shelf from southern Labrador to Rhode Island with large commercial concentrations existing off the coast of New England in the Gulf of Maine - Georges Bank region (Sullivan 1981). Spawning takes place from February through June with peak spawning occurring in April and May (Table 2). Total commercial landings of American plaice increased from a low of about 3,000 metric tons in the mid-1970's to a peak of more than 15,000 t in 1982; landings subsequently declined to levels similar to the mid-1970's (NEFSC 1991).

Median length at maturity of American plaice sampled from the Gulf of Maine region during spring 1986–1990 was 26.8 cm for females and 22.1 for males (Tables 3 and 43, Fig. 41). Median age at maturity for females and males was 3.6 yr and 3.0 yr, respectively (Table 4, Fig. 42); proportions of mature fish calculated for each age are presented in Table 44.

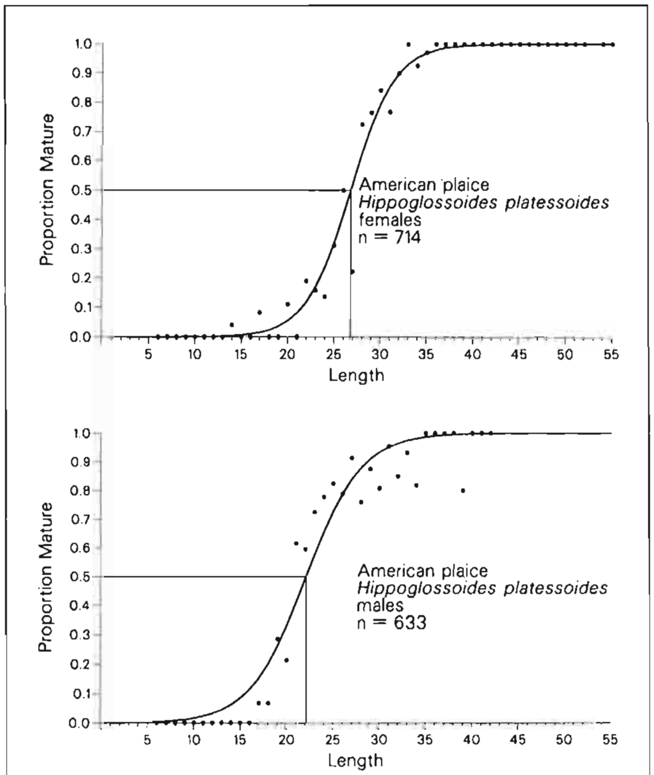

Figure 41
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=714) and male (n=633) American plaice, *Hippoglossoides platessoides,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1986–1990.

These values are similar to those reported by Sullivan (1981) for females but not for males. Samples taken in the Gulf of Maine in spring 1980 had L_{50} and A_{50} values

Table 43
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=714) and male (n=633) American plaice, *Hippoglossoides platessoides*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1986–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	19.8	18.4	21.2
0.10	21.6	20.4	22.7
0.15	22.7	21.7	23.7
0.20	23.5	22.6	24.4
0.25	24.2	23.3	25.0
0.30	24.8	24.0	25.5
0.35	25.3	24.6	26.0
0.40	25.8	25.1	26.5
0.45	26.3	25.6	27.0
0.50	26.8	26.1	27.4
0.55	27.3	26.6	27.9
0.60	27.7	27.1	28.4
0.65	28.3	27.6	28.9
0.70	28.8	28.1	29.5
0.75	29.4	28.7	30.1
0.80	30.1	29.3	30.9
0.85	30.9	30.0	31.8
0.90	32.0	31.0	33.0
0.95	33.8	32.6	35.0
0.99	37.7	35.9	39.5
Males			
0.05	13.3	11.7	14.9
0.10	15.5	14.2	16.8
0.15	16.9	15.8	18.0
0.20	18.0	17.0	18.9
0.25	18.8	17.9	19.7
0.30	19.6	18.7	20.4
0.35	20.2	19.5	21.0
0.40	20.9	20.2	21.6
0.45	21.5	20.8	22.2
0.50	22.1	21.4	22.7
0.55	22.7	22.0	23.3
0.60	23.3	22.6	24.0
0.65	23.9	23.3	24.6
0.70	24.6	23.9	25.3
0.75	25.4	24.6	26.1
0.80	26.2	25.4	27.1
0.85	27.3	26.3	28.2
0.90	28.6	27.5	29.7
0.95	30.9	29.5	32.3
0.99	35.8	33.7	37.9

[a] Offshore strata 26–30, 36–40.

for females of 27.4 cm and 3.4 yr, and 26.5 cm and 3.4 yr for males, respectively. Morse (1979)[2] calculated a larger L_{50} value of 33.6 cm for females and a similar value of 27.2 cm for males for American plaice sampled from Cape Hatteras, N.C. to Nova Scotia during 1977. Median length and age at maturity of female American plaice in the Scotian Shelf area declined from 31.0 cm and 6 yr during 1970–1974 to 30.8 cm and 4.7 yr during 1975–1979. Median values for males similarly declined from 24.8 cm and 4.5 yr, respectively, to 21.9 cm and 3.5 yr, respectively, during the same time periods (Beacham 1983d).

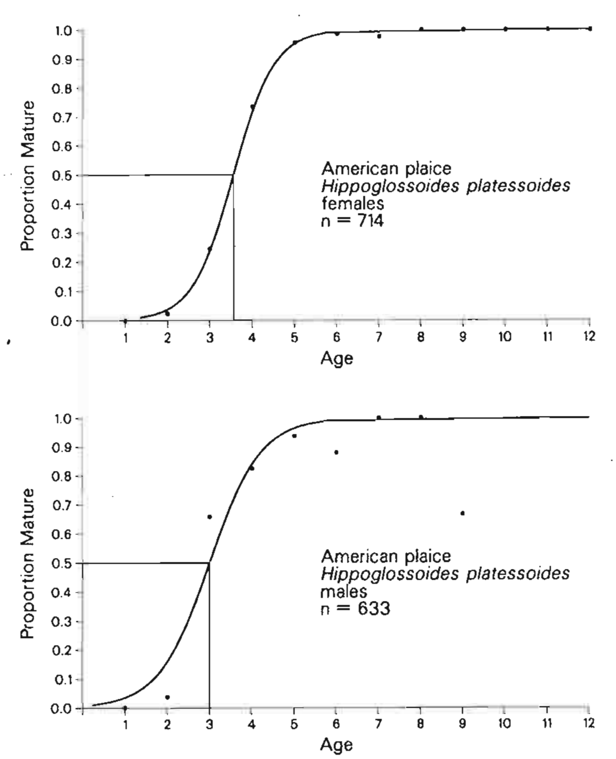

Figure 42
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=714) and male (n=633) American plaice, *Hippoglossoides platessoides,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1986–1990.

Table 44
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=714) and male (n=633) American plaice, *Hippoglossoides platessoides,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1986–1990.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.00	1.0	0.6	1.4
0.04	2.0	1.7	2.3
0.24	3.0	2.9	3.1
0.72	4.0	3.9	4.1
0.95	5.0	4.8	5.2
0.99	6.0	5.6	6.4
1.00	7.0	6.5	7.5
1.00	8.0	7.3	8.7
1.00	9.0	8.2	9.8
1.00	10.0	9.0	11.0
1.00	11.0	9.9	12.1
1.00	12.0	10.7	13.3
Males			
0.04	1.0	0.7	1.3
0.16	2.0	1.8	2.2
0.50	3.0	2.9	3.1
0.84	4.0	3.8	4.2
0.97	5.0	4.7	5.3
0.99	6.0	5.5	6.5
1.00	7.0	6.4	7.6
1.00	8.0	7.2	8.8
1.00	9.0	8.1	9.9

[a] Offshore strata 26–30, 36–40.

Witch Flounder: *Glyptocephalus cynoglossus*

Witch flounder range from Labrador to Cape Hatteras, North Carolina, but are not commercially abundant south of Cape Cod, Massachusetts. The population inhabiting the Gulf of Maine-Georges Bank region is considered to be a unit stock. Spawning in this region is protracted, encompassing a period from early spring to late summer, but peak activity appears to occur during May and June (Table 2). Commercial landings of witch flounder averaged 2,800 metric tons from 1960 to 1981, rose sharply to an average of 5,500 t during 1982–86, and have subsequently declined to 2,100 t in 1989 (NEFSC 1991).

Median length at maturity for female and male witch flounder was 30.4 and 25.3 cm, respectively (Tables 3 and 45, Fig. 43). Median age at maturity was 4.4 yr for females and 3.6 yr for males (Table 4, Fig. 44); proportions of mature fish calculated for each age are presented in Table 46.

Values of L_{50} above are lower than those obtained for witch flounder in the Gulf of Maine-Georges Bank region by Morse (1979)[2] from 1977 data (34.9 cm for females and 33.0 cm for males) and by Burnett et al. (1992) for the period 1977–84 (33.5 and 27.6 cm for females and males, respectively). Additionally, A_{50} for

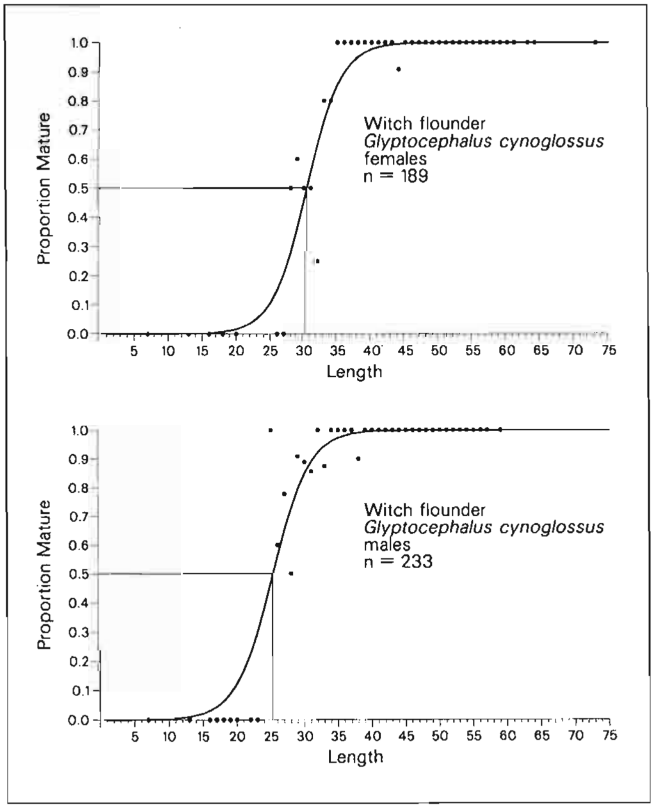

Figure 43
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=189) and male (n=233) witch flounder, *Glyptocephalus cynoglossus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1986–1990.

Table 45
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=189) and male (n=233) witch flounder, *Glyptocephalus cynoglossus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1986–1990.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Females			
0.05	22.9	18.8	27.0
0.10	24.8	21.5	28.2
0.15	26.0	23.1	28.9
0.20	26.9	24.3	29.5
0.25	27.6	25.2	30.0
0.30	28.3	26.1	30.5
0.35	28.8	26.8	30.9
0.40	29.4	27.5	31.3
0.45	29.9	28.1	31.7
0.50	30.4	28.7	32.2
0.55	30.9	29.3	32.6
0.60	31.5	29.8	33.1
0.65	32.0	30.4	33.7
0.70	32.6	30.9	34.3
0.75	33.2	31.5	35.0
0.80	34.0	32.1	35.9
0.85	34.9	32.7	37.0
0.90	36.0	33.6	38.5
0.95	37.9	34.8	41.1
0.99	42.1	37.4	46.9
Males			
0.05	17.4	12.6	22.2
0.10	19.4	15.4	23.5
0.15	20.7	17.1	24.2
0.20	21.6	18.4	24.8
0.25	22.4	19.4	25.3
0.30	23.0	20.3	25.8
0.35	23.7	21.1	26.2
0.40	24.2	21.9	26.6
0.45	24.8	22.6	26.9
0.50	25.3	23.3	27.3
0.55	25.9	24.0	27.7
0.60	26.4	24.7	28.2
0.65	27.0	25.3	28.7
0.70	27.6	26.0	29.2
0.75	28.3	26.7	29.8
0.80	29.1	27.5	30.6
0.85	30.0	28.3	31.7
0.90	31.2	29.3	33.2
0.95	33.3	30.7	35.8
0.99	37.7	33.6	41.8

[a] Offshore strata 22–30, 33–34, 351, 36–40.

both sexes has been reduced by about a year from 1977–84 values (Burnett et al. 1992).

In general, maturation of witch flounder in the Gulf of Maine-Georges Bank region occurs at a similar size but at an earlier age than slower-growing fish in colder Canadian waters. Beacham (1983e) reported ranges for L_{50} of 33.0 to 34.3 cm for females and 29.2 to 33.0 cm for males off Nova Scotia, with corresponding ranges for A_{50} of 7.2 to 8.8 yr and 5.1 to 9.2 yr. Bowering (1976) and Bowering and Brodie (1984) observed that maturation of female witch flounder in Newfoundland waters and the Gulf of St. Lawrence occurred at a greater size and age than in any other region (values of L_{50} ranged from 40.0 to 50.0 cm off Newfoundland and 39.8 to 45.0 cm in the Gulf of St. Lawrence; associated values of A_{50} ranged from 8.4 to 10.2 yr and 9.8 to 14.5 yr), but that maturation of males was comparable to that noted by Beacham (1983e). Recently, Bowering (1987, 1989) has related changes in biological parameters, including maturation rates, for witch flounder in the Labrador and Newfoundland regions to commercial exploitation patterns.

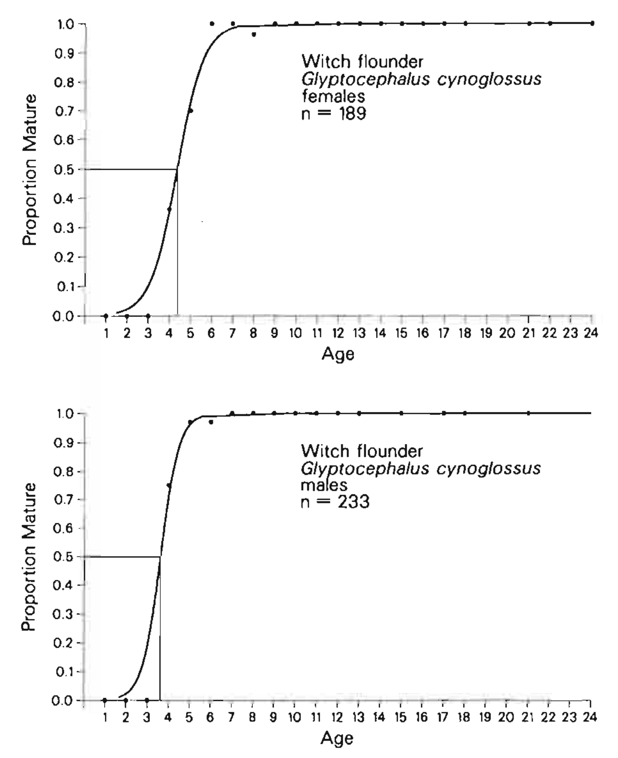

Figure 44

Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=189) and male (n=233) witch flounder, *Glyptocephalus cynoglossus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1986–1990.

Table 46

Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=189) and male (n=233) witch flounder, *Glyptocephalus cynoglossus,* sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1986–1990.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.00	1.0	-0.5	2.5
0.02	2.0	0.8	3.2
0.10	3.0	2.2	3.8
0.36	4.0	3.5	4.5
0.73	5.0	4.6	5.4
0.93	6.0	5.4	6.6
0.98	7.0	6.0	8.0
1.00	8.0	6.6	9.4
1.00	9.0	7.2	10.8
1.00	10.0	7.8	12.2
1.00	11.0	8.4	13.6
1.00	12.0	9.0	15.0
1.00	13.0	9.6	16.4
1.00	14.0	10.2	17.8
1.00	15.0	10.8	19.2
1.00	16.0	11.4	20.6
1.00	17.0	12.0	22.0
1.00	18.0	12.6	23.4
1.00	19.0	13.2	24.8
1.00	20.0	13.8	26.2
1.00	21.0	14.4	27.6
1.00	22.0	15.0	29.0
1.00	23.0	15.6	30.4
1.00	24.0	16.2	31.8
Males			
0.00	1.0	-0.5	2.5
0.02	2.0	1.0	3.0
0.19	3.0	2.5	3.5
0.71	4.0	3.8	4.2
0.96	5.0	4.5	5.5
1.00	6.0	5.0	7.0
1.00	7.0	5.6	8.4
1.00	8.0	6.1	9.9
1.00	9.0	6.6	11.4
1.00	10.0	7.2	12.8
1.00	11.0	7.7	14.3
1.00	12.0	8.2	15.8
1.00	13.0	8.7	17.3
1.00	14.0	9.3	18.7
1.00	15.0	9.8	20.2
1.00	16.0	10.3	21.7
1.00	17.0	10.9	23.1
1.00	18.0	11.4	24.6
1.00	19.0	11.9	26.1
1.00	20.0	12.4	27.6
1.00	21.0	13.0	29.0

[a] Offshore strata 22–30, 33–34, 351, 36–40.

Summer Flounder: *Paralichthys dentatus*

Summer flounder occur from the southern Gulf of Maine to South Carolina but are most common between Cape Cod and Cape Hatteras, where a single stock is thought to exist (Fogarty et al. 1983). Spawning takes place during an autumn migration from coastal embayments to the outer continental shelf with most activity occurring in October and November (Table 2). Commercial landings of summer flounder increased sharply from less than 6,000 metric tons annually prior to 1974 to about 12,000 t per year during the 1980's. An equivalent amount of recreational landings was also taken during the same period (NEFSC 1991).

Median length at maturity for female and male summer flounder was 28.0 and 24.9 cm, respectively (Tables 3 and 47, Fig. 45). These sizes occur at about age 2.5 for females and age 2 for males according to the growth functions presented by Penttila et al. (1989) for the entire northwest Atlantic.

Values of L_{50} above are comparable to those for both sexes reported by Morse (1979)[2] for the year 1977. Gillikin and Holland (1983), however, suggested that female summer flounder collected off the coast of North Carolina in late 1975 and early 1976 first matured at

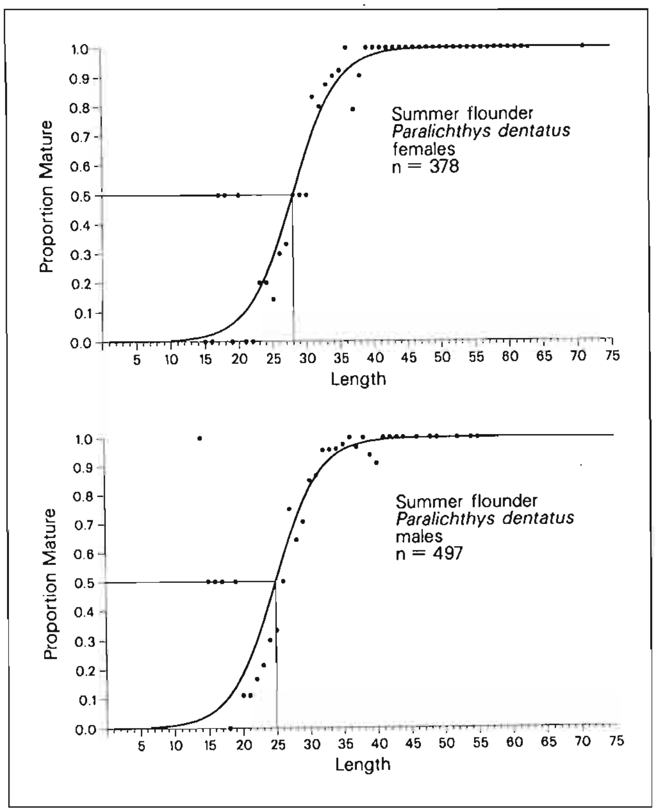

Figure 45
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=378) and male (n=497) summer flounder, *Paralichthys dentatus,* sampled during Northeast Fisheries Science Center autumn bottom trawl surveys, 1985–1989.

Table 47
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=378) and male (n=497) summer flounder, *Paralichthys dentatus,* sampled during Northeast Fisheries Science Center autumn bottom trawl surveys[a], 1985–1989.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Females			
0.05	18.4	15.4	21.3
0.10	20.8	18.4	23.3
0.15	22.3	20.2	24.5
0.20	23.5	21.5	25.4
0.25	24.4	22.6	26.2
0.30	25.2	23.5	26.9
0.35	26.0	24.4	27.5
0.40	26.7	25.2	28.1
0.45	27.3	25.9	28.7
0.50	28.0	26.6	29.3
0.55	28.6	27.4	29.9
0.60	29.3	28.1	30.6
0.65	30.0	28.8	31.2
0.70	30.8	29.5	32.0
0.75	31.6	30.3	32.8
0.80	32.5	31.2	33.8
0.85	33.6	32.2	35.1
0.90	35.2	33.6	36.8
0.95	37.6	35.6	39.6
0.99	43.0	40.0	46.0
Males			
0.05	15.3	12.7	17.9
0.10	17.7	15.5	19.9
0.15	19.2	17.3	21.2
0.20	20.4	18.6	22.1
0.25	21.3	19.7	22.9
0.30	22.1	20.6	23.6
0.35	22.9	21.5	24.2
0.40	23.6	22.3	24.8
0.45	24.2	23.0	25.4
0.50	24.9	23.8	26.0
0.55	25.5	24.5	26.6
0.60	26.2	25.2	27.2
0.65	26.9	25.9	27.9
0.70	27.6	26.7	28.6
0.75	28.5	27.5	29.4
0.80	29.4	28.4	30.4
0.85	30.5	29.5	31.6
0.90	32.0	30.8	33.2
0.95	34.5	33.0	36.0
0.99	39.9	37.4	42.3

[a] Inshore strata 1–41, offshore strata 1–12, 45–46, 52, 55–76.

age 3 with full maturation occurring after age 4. Their study also indicated that some males matured at age 2, but the majority deferred spawning until age 3 at a median length of 33.1 cm. In a more comprehensive study, Morse (1981) reported an increase in L_{50} for males from 25.0 to 27.3 cm between 1974–75 and 1978–79. However, there appeared to be no trend in female L_{50} estimates which fluctuated between 30.2 and 33.3 cm during the same period.

However, a revision to ageing convention (Smith et al. 1981; Almeida et al. 1992) has resulted in median lengths being attained a year earlier than reported above. This interpretation has been supported by recent growth studies by Able et al. (1990) and Szedlmayer et al. (1992).

Windowpane: *Scophthalmus aquosus*

Windowpane are distributed from the Gulf of St. Lawrence to South Carolina, but are commercially abundant only in the Georges Bank-Southern New England region. No information relative to stock structure exists, but differences in growth rates suggest that fish from Georges Bank and Southern New England comprise separate stocks (Thorpe 1991). Spawning occurs from June to October on Georges Bank, with peak activity during July and August; in Southern New England, spawning takes place from May to November with a peak in September (Table 2). Commercial landings of windowpane have averaged 1,100 metric tons from Georges Bank and 600 t from Southern New England during 1976–1989 (Thorpe 1991).

Median length at maturity for female and male windowpane from Georges Bank was 22.5 and 22.2 cm, respectively, and 21.2 cm for females and 21.5 cm for males from the Southern New England region (Tables 3, 48 and 49; Figs. 46 and 47). Applying the growth function of Moore (1947) to these values of L_{50} results in estimates of median age at maturity slightly above age 3; this is consistent with the observation by Moore (1947) that windowpane attain maturity during the third or fourth year.

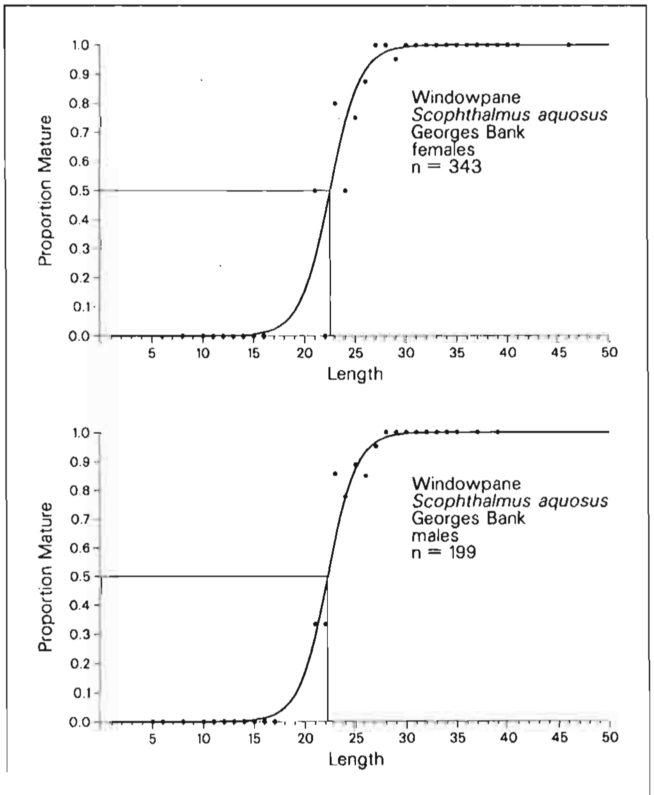

Figure 46
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=343) and male (n=199) windowpane, *Scophthalmus aquosus*, from Georges Bank sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 48
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=343) and male (n=199) windowpane, *Scophthalmus aquosus*, from Georges Bank sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Females			
0.05	18.2	14.9	21.4
0.10	19.3	16.4	22.1
0.15	19.9	17.4	22.5
0.20	20.5	18.1	22.8
0.25	20.9	18.7	23.1
0.30	21.2	19.2	23.3
0.35	21.6	19.6	23.5
0.40	21.9	20.0	23.8
0.45	22.2	20.4	24.0
0.50	22.5	20.8	24.2
0.55	22.8	21.2	24.4
0.60	23.1	21.6	24.6
0.65	23.4	22.0	24.9
0.70	23.7	22.4	25.1
0.75	24.1	22.8	25.4
0.80	24.5	23.3	25.8
0.85	25.1	23.8	26.3
0.90	25.7	24.4	27.0
0.95	26.8	25.4	28.3
0.99	29.3	27.0	31.5
Males			
0.05	18.1	15.4	20.7
0.10	19.1	16.8	21.4
0.15	19.8	17.7	21.8
0.20	20.3	18.4	22.1
0.25	20.7	19.0	22.4
0.30	21.0	19.4	22.6
0.35	21.4	19.9	22.9
0.40	21.7	20.3	23.1
0.45	22.0	20.6	23.3
0.50	22.2	21.0	23.5
0.55	22.5	21.4	23.7
0.60	22.8	21.7	23.9
0.65	23.1	22.1	24.2
0.70	23.4	22.5	24.4
0.75	23.8	22.9	24.7
0.80	24.2	23.3	25.1
0.85	24.7	23.8	25.6
0.90	25.4	24.3	26.4
0.95	26.4	25.2	27.7
0.99	28.8	26.7	30.8

[a] Offshore strata 13–21.

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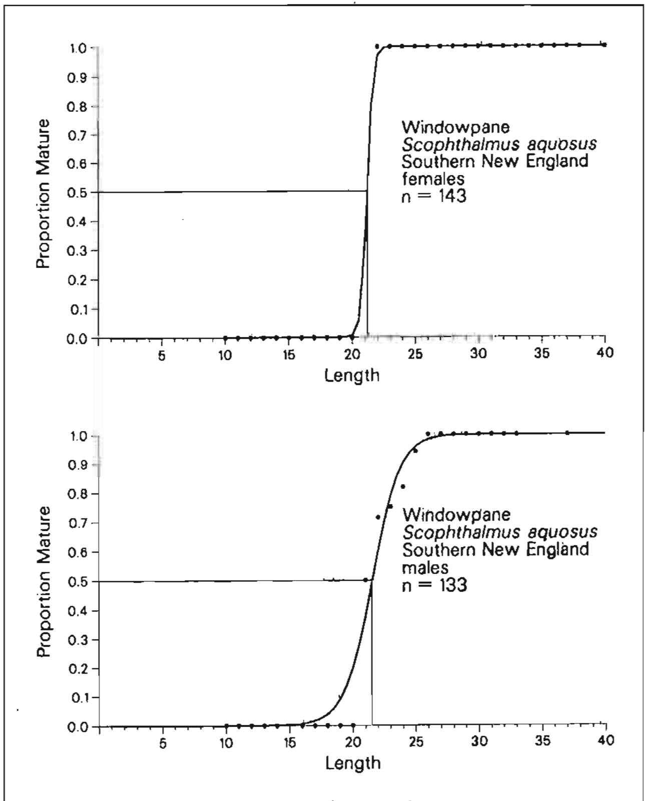

Figure 47

Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=143) and male (n=133) windowpane, *Scophthalmus aquosus,* from Southern New England grounds sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1985–1990.

Table 49

Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=143) and male (n=133) windowpane, *Scophthalmus aquosus,* from Southern New England grounds sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1985–1990.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Females			
0.05	20.5	19.5	21.4
0.10	20.6	19.9	21.3
0.15	20.8	20.2	21.3
0.20	20.8	20.4	21.3
0.25	20.9	20.5	21.3
0.30	21.0	20.6	21.4
0.35	21.0	20.6	21.4
0.40	21.1	20.7	21.5
0.45	21.1	20.7	21.6
0.50	21.2	20.7	21.7
0.55	21.2	20.7	21.8
0.60	21.3	20.7	21.9
0.65	21.3	20.7	22.0
0.70	21.4	20.6	22.1
0.75	21.4	20.6	22.2
0.80	21.5	20.6	22.4
0.85	21.6	20.5	22.6
0.90	21.7	20.5	22.9
0.95	21.9	20.4	23.4
0.99	22.3	20.2	24.4
Males			
0.05	18.3	16.3	20.4
0.10	19.1	17.4	20.9
0.15	19.6	18.1	21.2
0.20	20.0	18.6	21.4
0.25	20.3	19.0	21.6
0.30	20.6	19.4	21.8
0.35	20.9	19.7	22.0
0.40	21.1	20.0	22.2
0.45	21.3	20.3	22.3
0.50	21.5	20.6	22.5
0.55	21.8	20.8	22.7
0.60	22.0	21.1	22.9
0.65	22.2	21.3	23.1
0.70	22.5	21.6	23.3
0.75	22.7	21.9	23.6
0.80	23.1	22.2	24.0
0.85	23.4	22.5	24.4
0.90	24.0	22.9	25.0
0.95	24.8	23.5	26.1
0.99	26.6	24.6	28.6

[a] Offshore strata 5–12

Atlantic Herring: *Clupea harengus*

Atlantic herring are widely distributed in the northwest Atlantic from Labrador to Cape Hatteras, North Carolina. Spawning in the Gulf of Maine occurs from late August to December, with peak activity during September and October (Table 2). Historically, important commercial fisheries in U.S. waters have occurred in the coastal areas of the Gulf of Maine and on Georges Bank. In the former region, the fishery targets juvenile herring; in the latter region, no fishery has been prosecuted since the total collapse of the stock in the mid 1970's. Commercial landings of herring averaged 57,000 metric tons per year during 1942–1963, declined to 31,000 t annually from 1964-1975, increased to 60,000 t per year during the period 1976–1981, and have fluctuated around an average of about 33,000 t per year since then (NEFC 1990).[6]

Median length at maturity for female and male Atlantic herring was 25.4 and 25.3 cm (TL), respectively (Tables 3 and 50, Fig. 48). Median age at maturity was 3.0 yr for females and 2.9 yr for males (Table 4, Fig. 49); proportions of mature fish calculated for each age are presented in Table 51.

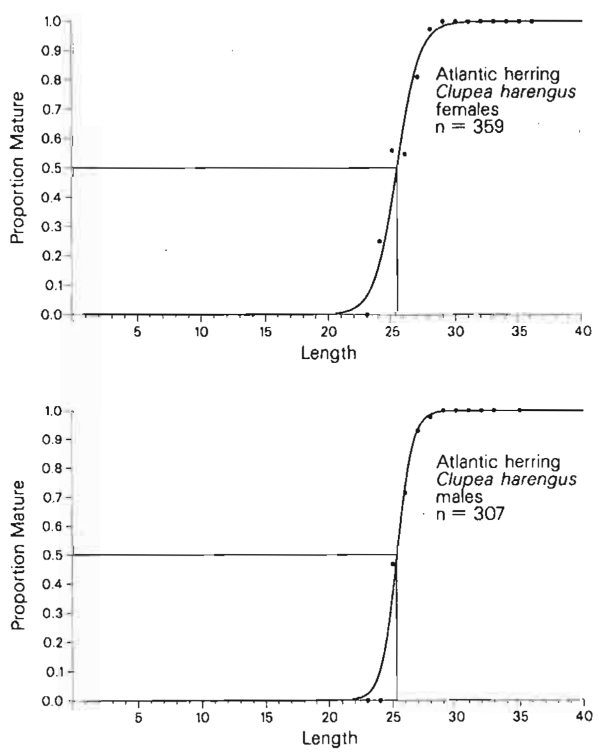

Figure 48
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=359) and male (n=307) Atlantic herring, *Clupea harengus*, sampled during Northeast Fisheries Science Center autumn bottom trawl surveys, 1987–1989.

Table 50
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=359) and male (n=307) Atlantic herring, *Clupea harengus*, sampled during Northeast Fisheries Science Center autumn bottom trawl surveys[a], 1987–1989.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Females			
0.05	22.8	21.8	23.7
0.10	23.4	22.6	24.2
0.15	23.8	23.1	24.5
0.20	24.1	23.5	24.8
0.25	24.4	23.8	25.0
0.30	24.6	24.1	25.1
0.35	24.8	24.3	25.3
0.40	25.0	24.6	25.5
0.45	25.2	24.8	25.6
0.50	25.4	25.0	25.8
0.55	25.6	25.2	25.9
0.60	25.7	25.4	26.1
0.65	25.9	25.6	26.3
0.70	26.1	25.8	26.5
0.75	26.4	26.0	26.7
0.80	26.6	26.2	27.0
0.85	26.9	26.5	27.3
0.90	27.3	26.9	27.8
0.95	28.0	27.4	28.6
0.99	29.5	28.5	30.4
Males			
0.05	23.5	22.8	24.2
0.10	24.0	23.4	24.5
0.15	24.2	23.7	24.8
0.20	24.5	24.0	24.9
0.25	24.6	24.2	25.1
0.30	24.8	24.4	25.2
0.35	24.9	24.6	25.3
0.40	25.1	24.7	25.4
0.45	25.2	24.9	25.5
0.50	25.3	25.0	25.6
0.55	25.5	25.2	25.8
0.60	25.6	25.3	25.9
0.65	25.7	25.4	26.0
0.70	25.9	25.6	26.2
0.75	26.0	25.7	26.3
0.80	26.2	25.9	26.5
0.85	26.4	26.0	26.8
0.90	26.7	26.3	27.1
0.95	27.2	26.6	27.7
0.99	28.2	27.4	29.0

[a] Offshore strata 1–12, 24–30, 33–34, 351, 36–40, 61–76.

Values of L_{50} and A_{50} above are comparable to those reported for Nova Scotia herring for the period 1966-75, during which L_{50} for both sexes combined varied from 25.3 to 27.4 cm (Sinclair et al. 1982), and A_{50} varied between 2.9 and 3.6 yr for females and 2.8 and 3.6 yr for males (Sinclair et al. 1979). Maturity at age (Table 51) is similar to that obtained for Gulf of Maine herring from monthly commercial sampling during 1985–89 (0.39 of age 3 fish, 0.98 of age 4 fish, 1.00 age 5+; NEFC 1990)[6]. However, Sinclair et al. (1982) noted a positive relationship between juvenile growth rates and L_{50}, and Winters (1976) reported decreases in A_{50} with decreasing adult biomass for herring in the Gulf of St. Lawrence, suggesting that density-dependent processes may influence maturation rates of Atlantic herring.

[6] NEFC. 1990. Report of the eleventh NEFC Stock Assessment Workshop Fall 1990. NEFC Ref. Doc., 90-09: 58–65.

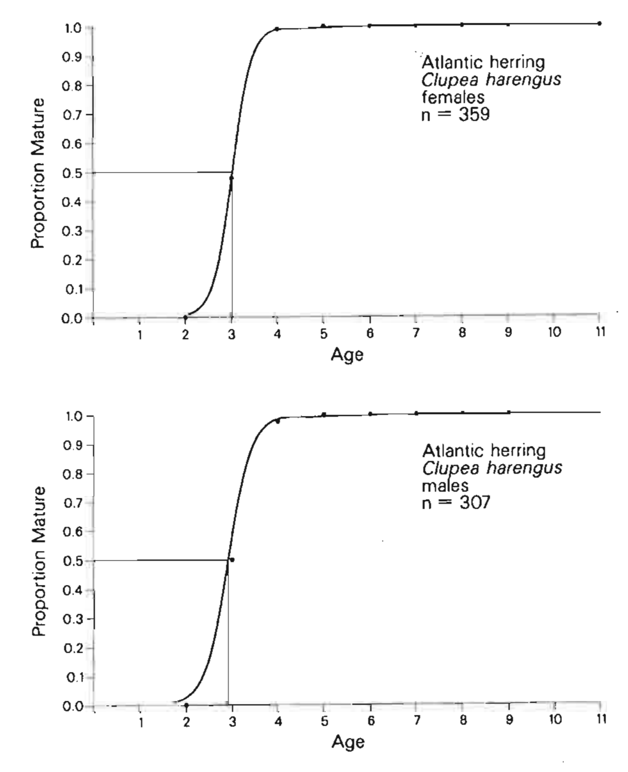

Figure 49
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=359) and male (n=307) Atlantic herring, *Clupea harengus*, sampled during Northeast Fisheries Science Center autumn bottom trawl surveys, 1987–1989.

Table 51
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=359) and male (n=307) Atlantic herring, *Clupea harengus*, sampled during Northeast Fisheries Science Center autumn bottom trawl surveys[a], 1987–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.00	1.0	0.1	1.9
0.01	2.0	1.6	2.4
0.48	3.0	2.9	3.1
0.99	4.0	3.6	4.4
1.00	5.0	4.2	5.8
1.00	6.0	4.8	7.2
1.00	7.0	5.3	8.7
1.00	8.0	5.9	10.1
1.00	9.0	6.5	11.5
1.00	10.0	7.1	12.9
1.00	11.0	7.7	14.3
Males			
0.00	1.0	0.2	1.8
0.03	2.0	1.6	2.4
0.58	3.0	2.9	3.1
0.99	4.0	3.6	4.4
1.00	5.0	4.3	5.7
1.00	6.0	4.9	7.1
1.00	7.0	5.6	8.4
1.00	8.0	6.2	9.8
1.00	9.0	6.8	11.2

[a] Offshore strata 1–12, 24–30, 33–34, 351, 36–40, 61–76.

Atlantic Mackerel: *Scomber scombrus*

The range of the migratory Atlantic mackerel extends from North Carolina to Newfoundland (Sette 1950). Although considered to be a single stock there are two spawning groups: the southern contingent spawns in the Mid-Atlantic Bight from April to July (Table 2) and the northern contingent spawns in the Gulf of St. Lawrence during June and July (NEFSC 1991). Total landings of Atlantic mackerel peaked at about 400,000 metric tons in 1973, then declined to about 30,000 t in the late 1970's, and have recently increased to about 74,000 t in 1989 (NEFSC 1991).

Median length at maturity of female and male Atlantic mackerel was 25.7 cm and 26.0 cm, respectively (Tables 3 and 52, Fig. 50) for samples collected during spring 1987–1989. Median age at maturity was 1.9 yr for both females and males (Table 4, Fig. 51); proportions of mature fish calculated for each age are presented in Table 53.

Mackerel sampled in the Newfoundland area from June–September during 1970–1973 had higher values for L_{50} of 34 cm and 35 cm for females and males, respectively (Moores et al. 1975). MacKay (1967) reported that first spawning for mackerel occurred at age 2 and at lengths greater than 30 cm for Atlantic mack-

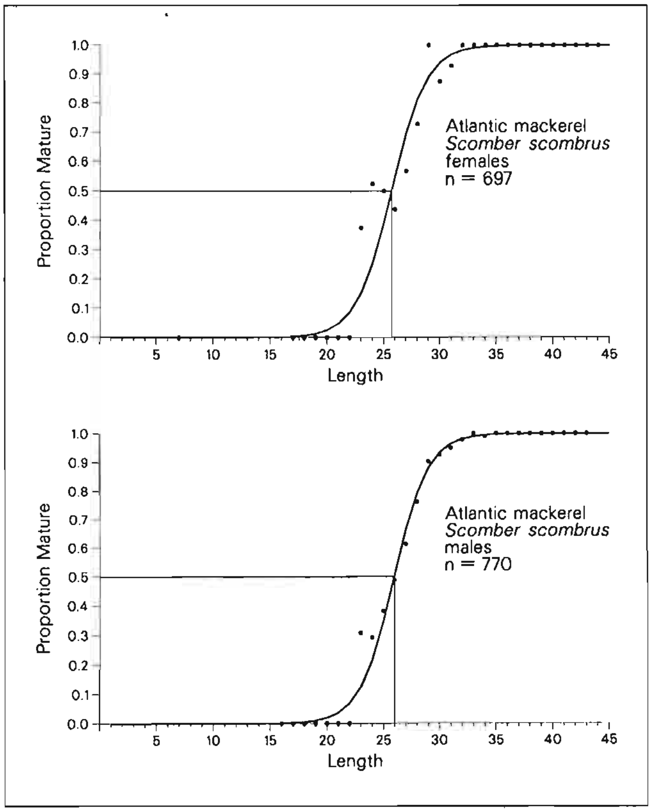

Figure 50
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=697) and male (n=770) mackerel, *Scomber scombrus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1987–1989.

Table 52
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=697) and male (n=770) mackerel, *Scomber scombrus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1987–1989.

Proportion mature	Length (cm)	95% Confidence interval	
		Lower	Upper
Females			
0.05	21.1	20.0	22.2
0.10	22.3	21.3	23.2
0.15	23.0	22.2	23.8
0.20	23.5	22.8	24.3
0.25	24.0	23.3	24.7
0.30	24.4	23.7	25.0
0.35	24.7	24.1	25.4
0.40	25.1	24.5	25.7
0.45	25.4	24.8	26.0
0.50	25.7	25.1	26.3
0.55	26.0	25.5	26.6
0.60	26.3	25.8	26.9
0.65	26.7	26.1	27.2
0.70	27.0	26.5	27.6
0.75	27.4	26.8	28.0
0.80	27.9	27.3	28.5
0.85	28.4	27.8	29.1
0.90	29.1	28.4	29.9
0.95	30.3	29.4	31.2
0.99	32.9	31.6	34.2
Males			
0.05	21.5	20.5	22.5
0.10	22.6	21.8	23.5
0.15	23.3	22.6	24.1
0.20	23.9	23.2	24.5
0.25	24.3	23.7	24.9
0.30	24.7	24.1	25.3
0.35	25.0	24.5	25.6
0.40	25.4	24.8	25.9
0.45	25.7	25.2	26.2
0.50	26.0	25.5	26.4
0.55	26.3	25.8	26.7
0.60	26.6	26.1	27.0
0.65	26.9	26.5	27.4
0.70	27.3	26.8	27.7
0.75	27.6	27.2	28.1
0.80	28.1	27.6	28.6
0.85	28.6	28.1	29.2
0.90	29.3	28.7	29.9
0.95	30.4	29.7	31.2
0.99	33.0	31.8	34.1

[a] Inshore strata 1–81, offshore strata 1–34, 351, 36–76.

erel sampled during May–July 1965–1966, from locations in the Gulf of St. Lawrence and along the coast of Nova Scotia and Massachusetts. The differences in median maturity between these studies and that reported above may be due to the slower growth rate of large year classes that may delay spawning from one to three years (Mackay 1973; Overholtz 1989).

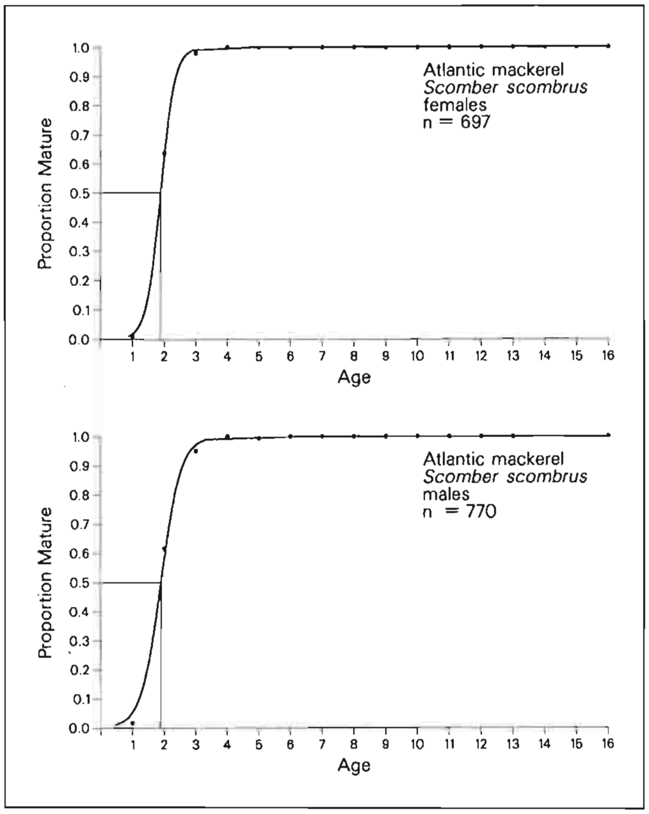

Figure 51
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=697) and male (n=770) Atlantic mackerel, *Scomber scombrus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1987–1989.

Table 53
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=697) and male (n=770) Atlantic mackerel, *Scomber scombrus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1987–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.02	1.0	0.7	1.3
0.63	2.0	1.9	2.1
0.99	3.0	2.7	3.3
1.00	4.0	3.4	4.6
1.00	5.0	4.0	6.0
1.00	6.0	4.7	7.3
1.00	7.0	5.4	8.6
1.00	8.0	6.1	9.9
1.00	9.0	6.8	11.2
1.00	10.0	7.5	12.5
1.00	11.0	8.2	13.8
1.00	12.0	8.8	15.2
1.00	13.0	9.5	16.5
1.00	14.0	10.2	17.8
1.00	15.0	10.9	19.1
1.00	16.0	11.6	20.4
Males			
0.05	1.0	0.8	1.2
0.58	2.0	1.9	2.1
0.97	3.0	2.7	3.3
1.00	4.0	3.5	4.5
1.00	5.0	4.3	5.7
1.00	6.0	5.1	6.9
1.00	7.0	5.9	8.1
1.00	8.0	6.6	9.4
1.00	9.0	7.4	10.6
1.00	10.0	8.2	11.8
1.00	11.0	9.0	13.0
1.00	12.0	9.7	14.3
1.00	13.0	10.5	15.5
1.00	14.0	11.3	16.7
1.00	15.0	12.1	17.9
1.00	16.0	12.8	19.2

[a] Inshore strata 1–81, offshore strata 1–34, 351, 36–76.

Butterfish: *Peprilus triacanthus*

Butterfish are distributed along the Atlantic coast of North America from Newfoundland to Florida, but are most common between Southern New England and Cape Hatteras where a single stock is thought to exist (Murawski and Waring 1979). Spawning takes place in late spring and summer with most activity occurring in June and July (Table 2). Total commercial landings fluctuated between 4,000 and 20,000 metric tons during the 1960's and 1970's, but remained relatively stable at about 5,000 t between 1977 and 1981; landings have since declined to about 2,000 t in 1988 (NEFSC 1991).

Median length at maturity for female and male butterfish was 12.0 and 11.4 cm, respectively (Tables 3 and 54, Fig. 52). Median age at maturity was 0.9 yr for both sexes (Table 4, Fig. 53); proportions of mature fish calculated for each age are presented in Table 55.

Values of L_{50} above are comparable to those for both sexes reported by Morse (1979)[2] for the year 1977. DuPaul and McEachran (1973) also noted that maturation of butterfish collected from Chesapeake Bay commenced at about age 1 and that almost all two-year-old fish were sexually mature. In an earlier work, however, Horn (1970) suggested that maturation may have occurred in fish as small as 12 cm but was not common until about 14 cm.

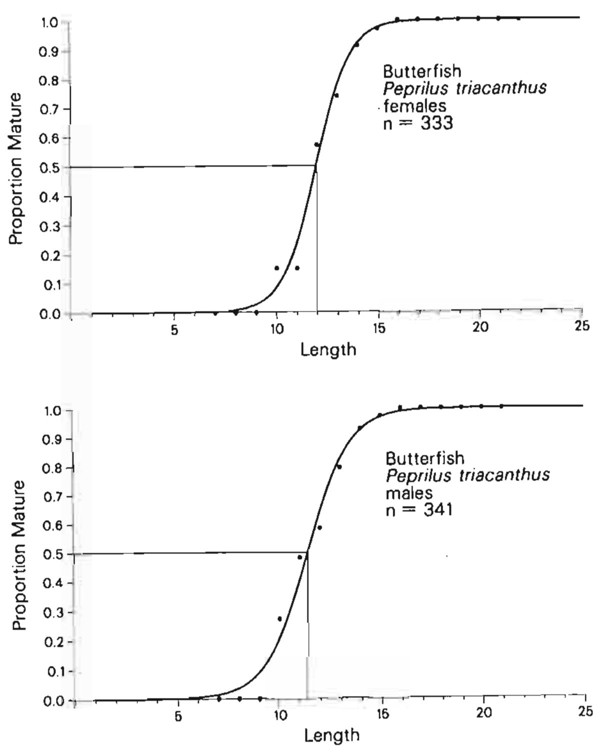

Figure 52
Calculated and observed (·) proportion mature at length based on macroscopic observations of whole gonads of female (n=333) and male (n=341) butterfish, *Peprilus triacanthus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1986–1989.

Table 54
Calculated proportion mature at length with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=333) and male (n=341) butterfish, *Peprilus triacanthus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1986–1989.

Proportion mature	Length (cm)	95% Confidence interval Lower	Upper
Female			
0.05	9.5	8.7	10.3
0.10	10.1	9.5	10.8
0.15	10.5	9.9	11.1
0.20	10.8	10.3	11.3
0.25	11.0	10.6	11.5
0.30	11.3	10.8	11.7
0.35	11.4	11.0	11.9
0.40	11.6	11.2	12.0
0.45	11.8	11.4	12.2
0.50	12.0	11.6	12.3
0.55	12.1	11.8	12.5
0.60	12.3	11.9	12.6
0.65	12.5	12.1	12.8
0.70	12.7	12.3	13.0
0.75	12.9	12.5	13.2
0.80	13.1	12.7	13.5
0.85	13.4	12.9	13.8
0.90	13.8	13.2	14.3
0.95	14.4	13.7	15.0
0.99	15.7	14.8	16.7
Males			
0.05	8.4	7.5	9.2
0.10	9.1	8.4	9.8
0.15	9.6	9.0	10.2
0.20	10.0	9.4	10.5
0.25	10.3	9.8	10.8
0.30	10.5	10.1	11.0
0.35	10.8	10.3	11.2
0.40	11.0	10.6	11.4
0.45	11.2	10.8	11.6
0.50	11.4	11.0	11.8
0.55	11.6	11.3	12.0
0.60	11.8	11.5	12.2
0.65	12.0	11.7	12.4
0.70	12.3	11.9	12.6
0.75	12.5	12.1	12.9
0.80	12.8	12.4	13.2
0.85	13.2	12.7	13.7
0.90	13.7	13.1	14.2
0.95	14.4	13.8	15.1
0.99	16.1	15.1	17.2

[a] Inshore strata 1–46, offshore strata 1–25, 61–76.

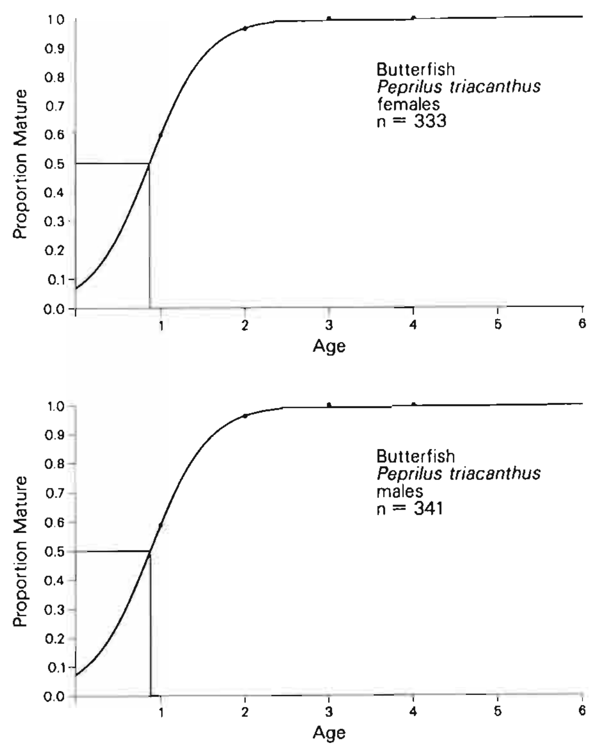

Figure 53
Calculated and observed (·) proportion mature at age based on macroscopic observations of whole gonads of female (n=333) and male (n=341) butterfish, *Peprilus triacanthus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys, 1986–1989.

Table 55
Calculated proportion mature at age with approximate 95% confidence intervals based on macroscopic observations of whole gonads of female (n=333) and male (n=341) butterfish, *Peprilus triacanthus*, sampled during Northeast Fisheries Science Center spring bottom trawl surveys[a], 1986–1989.

Proportion mature	Age	95% Confidence interval Lower	Upper
Females			
0.60	1.0	0.9	1.1
0.97	2.0	1.7	2.3
1.00	3.0	2.3	3.7
1.00	4.0	3.0	5.0
Males			
0.59	1.0	0.9	1.1
0.96	2.0	1.7	2.3
1.00	3.0	2.3	3.7
1.00	4.0	3.0	5.0

[a] Inshore strata 1–46, offshore strata 1–25, 61–76.

Discussion

The results presented in this report are intended to describe current maturation patterns for the nineteen included species. However, it is evident from even a cursory comparison of our results with those from earlier periods that, for most species, A_{50} and, in many cases, L_{50} values have declined substantially in recent years. While it is often difficult to draw conclusions about changes in maturation from diverse studies which may have employed different model fitting techniques, staging criteria, and seasonal sampling schemes, a comparison between our length-based results and those presented by Morse (1979)[2] is warranted since both studies have drawn on the same Northeast Fisheries Science Center trawl survey data base. Our study expands on the initial work of Morse (1979)[2] to include finer spatial and seasonal resolution, and we have fitted logistic curves rather than employing probit analysis. Given the same set of data, however, both fitting techniques will estimate the inflection point (A_{50}, L_{50}) with the same degree of accuracy (Ashton 1972). In addition, we have analyzed maturation data collected on cruises conducted only since 1985, with the exception of red hake and redfish, whereas Morse (1979)[2] restricted analyses only to 1977 cruises.

The changes in median size at maturity between 1977 and the mid-to-late 1980's are substantial enough to suggest a real decline rather than a bias resulting from different sampling techniques. Criteria for maturation stages presently in use on NEFSC and MDMF cruises have not changed appreciably since the 1970's and criteria for discriminating between immature and all other mature stages are identical (Burnett et al. 1989). Our initial analyses of the data on an annual basis indicated a gradual decline from the late 1970's through the present. In addition, studies which were conducted in the same general region of the coast prior to the mid-1970's indicate that maturation for most species occurred at older median ages and larger median sizes than those reported by Morse (1979)[2].

Given these changes, it is clear that current estimates should not be used to represent historical maturation patterns as in the estimation of spawning stock over time in sequential population analyses such as VPA or cohort analysis. Our results are appropriate for use in short-term projections of spawning stock and in spawning stock biomass per recruit analyses (Gabriel et al. 1989) in which the current maturation pattern is expected to represent the short-term equilibrium condition of the stock.

A more comprehensive analysis of the entire data set, with a longer time series, will be required before any definitive conclusions can be drawn about compensatory changes in maturation over time. One such study (O'Brien 1990) found significant declines in median size and age at maturation in year classes of Georges Bank and Gulf of Maine Atlantic cod, *Gadus morhua*, between 1970 and 1987. Similar results were noted by Bowering (1987) for witch flounder, *Glyptocephalus cynoglossus*, and several reports by Beacham (1983 a, b, and d) indicated long-term changes in maturation for several species on the Scotian Shelf.

To ensure the broadest possible synoptic coverage of the maturity data included in our study, we included observations only from standard bottom trawl survey cruises conducted during spring and autumn. We recognize, however, that such multi-purpose sampling programs often impose some limitations on the utility of certain data. In our case, the spring and autumn coverage of the surveys closely coincided with peak spawning periods for most of the species of flounders, but spring coverage for the winter spawning gadids often occurred 1–2 months after peak spawning. As a result, observations for cod, haddock, pollock, and white hake often contained a large proportion of resting fish whose gonads are most similar superficially to immature specimens. Given this greater potential for misclassification of immature and mature fish, the results obtained for some of the gadiforms may be less reliable than those for pleuronectiforms and other spring or autumn spawners. In particular, we note that median sizes and ages at maturity for cod, haddock, pollock, and white hake obtained from our analyses are considerably lower than previously reported.

Determination of maturation stages based on macroscopic examination of gonads generally involves a degree of subjective judgment on the part of the observer. This difficulty, combined with a high turnover of seagoing personnel from year to year may impart a high degree of variability to the observations unless training is continually monitored as noted by Halliday (1987). Since 1986, the NEFSC Woods Hole Laboratory has conducted a series of workshops during each survey season to monitor and calibrate maturity criteria employed by each scientific party involved in data collection. By examining fresh specimens collectively, members of the various teams are able to coordinate their observations through comparison and discussion of staging criteria. Despite these efforts, however, the inherent subjectivity of the approach remains problematic.

To rectify this potential problem in the future, at-sea maturation observations should be coupled with more objective techniques in order to ascertain the degree of precision and bias of the macroscopic method. Other methods which have demonstrated some success include histological identification of reproductive tissue (Morrison 1990), analysis of plasma parameters (Johnson and Casillas 1991), and comparisons with gonadosomatic indices (O'Brien 1990).

Despite these caveats, our results may be viewed as baseline maturation patterns in relation to current stock conditions (abundance, age structure, sex ratio, etc.). In the future, further monitoring of maturation will be required on a routine basis coincident with proposed management actions designed to increase spawning stock biomass. Any compensatory mechanisms which result in declines in median size and age at maturation accompanying declining spawning stock will likely act in reverse if substantial increases in stock biomass occur over the long-term.

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