Northwest Atlantic Fisheries Organization

Serial No. N4502 **NAFO SCR Doc. 01/114**

SCIENTIFIC COUNCIL MEETING – SEPTEMBER 2001
(Deep-sea Fisheries Symposium – Oral)

Preliminary Estimates of Biological and Yield Characteristics of Deep-water Witch Flounder (*Glyptocephalus cynoglossus*) in the Georges Bank- Southern New England Region

by

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Abstract

The existence of a deep-water (greater than 366 meters) resource of witch flounder along the northeastern U.S continental slope and adjacent abyssal plain is suggested by several lines of evidence including: 1) egg and larval distribution patterns; 2) by-catch rates in deep-water surveys for red crab (*Chaceon quinquedens*) and monkfish (*Lophius americanus*); and 3) various special deep-water studies conducted as far south as Virginia. Nothing is known regarding the abundance, biology, and production rates of these fish nor their affiliation to witch flounder in shallower shelf waters. Recent opportunistic sampling at depths ranging from 367-914 meters has provided a limited number of samples for the preliminary estimation of growth and maturation rates. When compared to witch flounder of the shallower regions of the Gulf of Maine and Georges Bank, growth rates for deep-water fish are considerably lower and maturation occurs at an older age.

Production rates (yield per recruit) are calculated for deep-water witch flounder and compared with those for the exploited Gulf of Maine resource (NAFO Division 5Y). Implications for the management of a potential future fishery for currently unexploited deep-water witch flounder are discussed.

Introduction

Witch flounder, *Glyptocephalus cynoglossus,* are commercially abundant off the northeastern coast of the United States, and support an important fishery in the Gulf of Maine region (NAFO Division 5Y, Figure 1; Bigelow and Schroeder 1953, Wigley *et al*. 1999). This stock is well-studied, including studies of ecology and distribution (Bigelow and Schroeder 1953, Burnett *et al*. 1992), length-weight relationships (Lux 1969), age and growth (Burnett *et al*. 1992), reproductive biology (Burnett *et al*. 1992, O'Brien *et al*. 1993), feeding ecology (Bowman and Michaels 1984), egg and larval distributions (Berrien and Sibunka 1999 and Smith *et al*. 1975, respectively), and fishery yield characteristics (Burnett MS 1987, Wigley MS 1994, Wigley *et al* 1999).

The existence of a deep-water population of witch flounder in continental slope waters south of Georges Bank and southern New England (NAFO Division 5Z and Subarea 6; Figure 1) has long been known but remains poorly studied, and the relationship of this population to that of the Gulf of Maine is not understood. Goode and Bean (1895) first reported the occurrence of these deep-water witch, and Bigelow and Schroeder (1953) found them down to depths of 1565 m. Markle and Musick (1974) noted that juvenile witch flounder were a dominant species along a continental slope transect off Virginia at 900 m depth. Markle (1975) found witch, mostly juveniles, at every station between 256 and 1080 m and as deep as 1408 m during deep-water sampling at Norfolk Canyon (Figure 1). During a Northeast Fisheries Science Center (NEFSC) 1980 survey for red crab, *Chaceon quinquedens*, in southern New England slope waters, witch flounder 6-35 cm TL were caught in over half the trawl tows conducted at depths between 273 and 1371 m (unpublished NEFSC data, Appendix Table 1).

Whether these deep-water witch flounder constitute a separate group from the Gulf of Maine fish has not been resolved. Bigelow and Schroeder (1953) observed no spawning of witch flounder west of Cape Cod. Markle (1975), while reporting a few adult-sized fish and some recently metamorphosed postlarvae in the vicinity of Norfolk Canyon, attributed the presence of deep-water juveniles to passive transport via shelf circulation of long-lived larvae from northern spawning contingents, and hypothesized that the deep-water witch flounder represented "stunted expatriates" from the Gulf of Maine stock. However, temporal distribution patterns of eggs (most recently Berrien and Sibunka 1999) and larvae (Smith *et al*. 1975), coupled with NEFSC survey samples of reproductively active fish from deep-water areas, led Burnett (MS 1987) to conclude that spawning occurs among deep-water witch flounder in southern New England slope waters, thus a separate population exists.

Deep-water biological samples of witch flounder from the slope waters south of Georges Bank and southern New England are analyzed in this study. Markle (1975) observed that "an analysis of age and growth of Virginian witch flounder…would be interesting." Thus, our objectives were to: a) describe biological characteristics, including growth and maturation rates and length-weight relationships of deep-water witch flounder; b) compare these attributes with those of the Gulf of Maine and southern New England regions; and c) provide preliminary estimates of production rates.

Methods

Witch flounder samples were collected during NEFSC winter, spring and autumn research vessel bottom trawl surveys (see Azarovitz 1981 for a description of the NEFSC survey program, design, and methodology) and during two series of special surveys conducted to collect information on deep-water fishes and monkfish (*Lophius americanus*), respectively (Table 1). For witch flounder collected during NEFSC surveys, the following information was obtained at sea: total length (cm), total weight (g), and gender and maturity stage. Gender and maturity stage were determined from macroscopic examination of the gonads and classified into the following categories: unsexed, females, or males, and immature, developing, ripe, ripe and running, spent or resting, respectively, based upon criteria described by Burnett *et al*. (1989). Both sagittal otoliths were removed for age determinations. Witch flounder collected during the deep-water surveys were frozen whole at sea and processed as above back at the laboratory after thawing.

Analyses were performed for three geographic regions: 1) the Gulf of Maine and northern Georges Bank region; 2) the southern New England region encompassing the continental shelf area from southern Georges Bank to Cape Hatteras, NC at depths less than 367 m; and 3) deep-water (> 366 m) slope waters. Data used for regions 1 and 2 above were from 1994-1999 NEFSC surveys, encompassing a period of stable growth and maturity rates (Wigley *et al*. 1999), while data for region 3 were collected during 1995-2001. Due to the low number of fish in regions 2 and 3 (137 and 271 fish, respectively; see Table 2) analyses of growth and length-weight relationships were conducted with genders combined for all regions. Data for witch flounder in the deep-water region were further analyzed to evaluate possible trends in growth with increasing depth. Data were partitioned into two depth zones, 367-500 m and greater than 500 m.

Otoliths were thin-sectioned according to the methodology described by Penttila *et al*. (1988) and aged as described by Burnett (1988). Growth was modeled by fitting the following semi-logarithmic function:

$$\text{length} = a + b \ln(\text{age})$$

to length at age data (Bowers 1960, Roff 1980), and regression equations compared between regions and depth zones using tests for heterogeneity of slopes (Sokal and Rohlf 1995). Length-weight relationships were described by the following regression:

$$\ln(\text{weight}) = a + b \ln(\text{length}),$$

and compared as above. Maturity data were analyzed for each region by gender and, for the deep-water region, by depth zone, to estimate proportions mature at length and age using probit analysis (Finney 1971); analyses were based upon data for sampled fish only and not expanded by catch to the population level as suggested by Morgan and Hoenig (1997) due to the use of multiple vessels and gears and unequal tow durations during the opportunistic sampling. Growth, length-weight, and maturity analyses were performed using SAS procedures GLM and PROBIT, respectively (SAS 1985).

Estimates of yield-per-recruit and spawning stock biomass-per-recruit were generated for deep-water witch flounder using the method of Thompson and Bell (1934), and compared to those derived for the Gulf of Maine stock by Wigley *et al*. (1999). The deep-water exploitation pattern was based on mesh selectivity of a 6 inch mesh (152 mm, the regulated mesh for groundfish in the Northeast region since 1994); selection at age was determined by aligning the selection at length pattern of the Gulf of Maine stock with deep-water mean lengths at age. Natural mortality was assumed to be 0.15, following the practice of Burnett (MS 1987) and Wigley *et al*. (1999). While no fishery currently exists for the deep-water group, the proportion of fishing and natural mortality occurring before spawning was assumed to be 0.167, reflecting late winter-early spring spawning (Berrien and Sibunka 1999) and an anticipated corresponding fishery on pre-spawning aggregations (Burnett *et al*. 1992).

Results

Lengths for the 271 deep-water witch flounder ranged from 21 to 52 cm, and ages ranged from 4 to 16 years (Figures 2A and 2B, respectively). There were 172 females and 99 males, with the largest male being 44 cm and the oldest male being age 11. The microstructure of otoliths from deep-water witch flounder revealed many more splits and checks than seen in otoliths from Gulf of Maine fish, probably the result of the very different temperature regimes between regions. Even more unusual was the overall shape of otoliths from most deep-water witch flounder, particularly the right (top) otolith, which had a pronounced domed shape compared to Gulf of Maine otoliths (Figure 3).

Analysis of growth resulted in highly significant ($p < 0.001$) relationships between length and age for all three regions (Table 2). While growth was similar for witch flounder from the Gulf of Maine and southern New England regions, deep-water witch flounder grew more slowly ($p < 0.001$, heterogeneity of slopes, df = 2; Figure 4). Among the deep-water fish, there was no evidence of decreased growth with increasing depth ($p = 0.2121$, heterogeneity of slopes, df = 1; Table 2).

Differences in the length-weight relationship were also noted among the three regions ($p < 0.001$, heterogeneity of slopes, df = 2). The exponent for deep-water witch flounder (3.8) is considerably greater than that of other regions in this study (Table 3), and results in divergence of predicted weight at age compared to Gulf of Maine and Southern New England fish beyond 40 cm (Figure 5). This exponent is greater than any previously published value for witch flounder across the species' entire range (Powles 1967, Lux 1969, Kohler *et al*. MS 1970, Bowering and Stansbury 1984, Steinarsson *et al*. 1989, Nilsen *et al*. 1991).

Although the majority of maturity observations for deep-water witch flounder were of immature fish, several mature fish were encountered (Table 4). The gonads of deep-water witch flounder appeared similar in size and shape from those of the other two regions. One observation was omitted for a 26 cm female due to the poor condition of the gonad following freezing and thawing. The probit model did not provide acceptable fits to maturity data for southern New England witch flounder, and these analyses are not presented. Median size and age at maturity were significantly different for both male and female witch flounder from deep-water compared to the Gulf of Maine (Table 5), with deep-water fish maturing at a slightly larger size but a much greater age. For example, the median size at maturity for females differed by only 2.2 cm, but the median age differed by 3.7 years (Figure 6), further illustrating the much slower growth rate of deep-water witch flounder. Estimates of median length at maturity were not significantly different ($p > 0.05$) between depth zones for either gender (Table 5). Median age of maturity was not estimated due to poor fit of the probit model to maturity at age data by depth zones.

Estimates of yield-per-recruit from deep-water witch flounder were considerably lower than those for the Gulf of Maine, and the flat-top shape of the yield curve was in sharp contrast to the dome-shape curve for the Gulf of Maine. Maximum yield per recruit for deep-water witch flounder was only 48% of the value for the Gulf of Maine and occurred at a higher level of fishing mortality (F = 0.52 vs 0.30; Figure 7, Appendix Table 2), reflecting the delayed entry at age of deep-water witch flounder to the potential fishery due to slower growth. Estimates of spawning stock biomass per recruit for deep-water fish were only about one-half of those for Gulf of Maine witch flounder at low levels of fishing (Figure 7, Appendix Table 2), reflecting the combination of slower growth and delayed maturation.

Discussion

Several lines of evidence would seem to de-couple deep-water witch flounder from the population of witch flounder in the Gulf of Maine-northern Georges Bank region, and thus refute Markle's (1975) hypothesis that deep-water witch flounder south of New England were "stunted expatriates" of that population. First, the presence of witch flounder eggs south of New England during February-April (Berrien and Sibunka 1999) would argue for localized spawning, and against passive transport via shelf water circulation of eggs and larvae from the later-spawning (May-June) Gulf of Maine population. In this study, the observation of 25 males and one female with developing gonads, and three males with spent testes (Table 4), suggests that these deep-water witch flounder are indeed reproductively active.

Secondly, the observed differences in otolith shape and microstructure between regions, combined with differences in length-weight relationships, would seem to suggest that deep-water witch flounder are 'growing' differently, independent of growth rate. Otolith shape would most likely be an artifact of neurocranial anatomy, particularly the supraoccipital bone (Bond 1979). The relatively high exponent in the length-weight equation results in fish which are stubbier in appearance, hence Markle's (1975) description of "stunted". No attempt was made in this study to collect meristic or morphometric data, but traditional stock identification studies or those using newer methodologies involving DNA or elemental composition of otoliths, would be logical topics for future research.

Finally, pronounced differences in biological (growth and maturation) and production (yield and spawning stock biomass per recruit) characteristics between deep-water witch flounder and the Gulf of Maine populations would seem to define them as separate groups. The deep-water population would have to be carefully managed to avoid growth overfishing given its yield characteristics. Gear selectivity would be a critical component in any potential fishery on this group, since discard mortality would be virtually total for the depths at which this fishery would be prosecuted, even for a species lacking a swim bladder.

A more interesting question, although unanswered by this study, is the linkage between deep-water witch flounder and those occurring in continental shelf waters from southern New England southwards. Given the distribution patterns of eggs (Berrien and Sibunka 1999) and larvae (Smith *et al*. 1975), it is possible that these two groups are closely associated. The deep-water fish may represent a component of the shelf population that has moved down the slope, analogous to the observation of Kuzmin (MS 1989) that witch flounder of the Grand Banks population (NAFO Divisions 3LNO) were often distributed at depths greater than 360 m in Newfoundland slope waters. Such movement could alter growth and maturation characteristics due to environmental influences; the constant temperature and darkness associated with greater depths might also eliminate the seasonal stimuli fish require for reproduction (Bye 1984). There are examples in the literature in which such changes in habitat have resulted in cessation of reproduction and the continuation of juvenile growth, creating large, asexual individuals [lanternfish, *Myctophum punctatum* in the Northwest Atlantic (Zurbrigg and Scott 1972) and redfish, *Sebastes* sp. off Newfoundland (Sandeman 1969)]. In this study, the observation of a lower growth rate as well as the presence of mature fish would seem to contradict this scenario, but nothing is known about the reproductive cycle of these deep-water witch flounder, and it is possible that spawning has become non-annual, aperiodic, and asynchronous. Indeed, the additional energy available for somatic growth in the absence of reproduction might well explain the length-weight relationship for this group of fish.

In the end, Markle's (1975) "stunted expatriates" might be exactly that, only originating from a southern New England - Mid-Atlantic continental shelf population that is sustained by its own reproductive efforts and an unknown but certainly diminished contribution from the deep-water component. However, additional research, particularly in the form of increased sampling of the deep-water component, is required before this hypothesis can be adequately evaluated.

Acknowledgments

We wish to thank all participants of the deep-water cruises aboard the F/V Contender, F/V Warrior, F/V Mary K. and F/V Drake as well as NEFSC staff and volunteers aboard the NEFSC bottom trawl surveys who collected the deep-water specimens for this study. We thank, in advance, all reviewers for their helpful comments.

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Table 1. Summary of opportunistic surveys from which deep-water witch flounder were obtained for this study. Location indicates polygons of latitude/longitude.

Vessel	Date	Location	Depth Range (m)	Number of stations	Number of fish
F/V Contender	October, 1995	3952 6958	452	1	18
R/V Albatross IV	March, 1998	3658 7436	560	1	2
F/V Warrior	October, 2000	3918.22 / 3958.29 6953.30 / 7214.45	357 - 618	14	199
R/V Albatross IV	February, 2001	3635.89 7442.42	387	1	4
F/V Mary K	March, 2001	3840.76 7304.32	397	1	5
F/V Mary K	April, 2001	3951.17 / 3953.61 6942.18 / 7036.51	433 - 914	5	43

Table 2. Results of witch flounder growth modeling, including sample sizes, regression coefficients, and associated statistics, by region.

Region	N	Intercept	(SE)	Slope	(SE)	r^2
Gulf of Maine	1953	4.5960	(0.1817)	17.2675	(0.1205)	0.9133
Southern New England	127	2.1864	(0.9000)	17.8559	(0.5448)	0.8950
Deep-water						
All Depths	271	-8.4173	(1.9147)	20.2867	(0.9204)	0.6436
367 - 500 m	173	-5.9345	(2.5713)	19.1770	(1.2456)	0.5809
> 500 m	98	-11.5745	(2.9317)	21.6246	(1.3904)	0.7159

Table 3. Results of witch flounder length-weight modeling including sample sizes, regression coefficients, and associated statistics, by region.

Region	N	Intercept (SE)	Slope (SE)	r2
Gulf of Maine	1945	-12.8990 (0.0248)	3.2416 (0.0074)	0.9898
Southern New England	133	-13.3698 (0.1276)	3.3715 (0.0374)	0.9841
Deep-water	271	-14.9197 (0.1512)	3.8017 (0.0432)	0.9665

Table 4. Summary of maturity observations for deep-water witch flounder by gender. Included in the total are 3 females and 10 males, which were mature but not classified into a maturity stage.

Gender	Immature	Developing	Spent	Resting	Total
Females	111	1	0	56	171
Males	41	25	3	20	99

Table 5. Results of witch flounder maturity analyses, including sample sizes, estimates of median length (L50) and age (A50) at maturity and 95% confidence intervals, by region and gender.

Region and gender	N	L50	(95%CI)	A50	(95%CI)
Gulf of Maine					
Females	855	34.2	(33.6 - 34.8)	5.1	(4.9 - 5.2)
Males	964	27.3	(26.8 - 27.8)	3.5	(3.4 - 3.6)
Deep-water					
All depths					
Females	171	36.4	(35.5 - 37.4)	8.8	(8.2 - 9.7)
Males	99	30.2	(29.3 - 31.2)	6.4	(6.0 - 6.9)
367 - 500 m					
Females	103	36.3	(35.1 - 37.7)		
Males	69	30.3	(29.0 - 31.8)		
> 500 m					
Females	68	36.6	(35.3 - 38.5)		
Males	30	30.0	(26.0 - 31.8)		

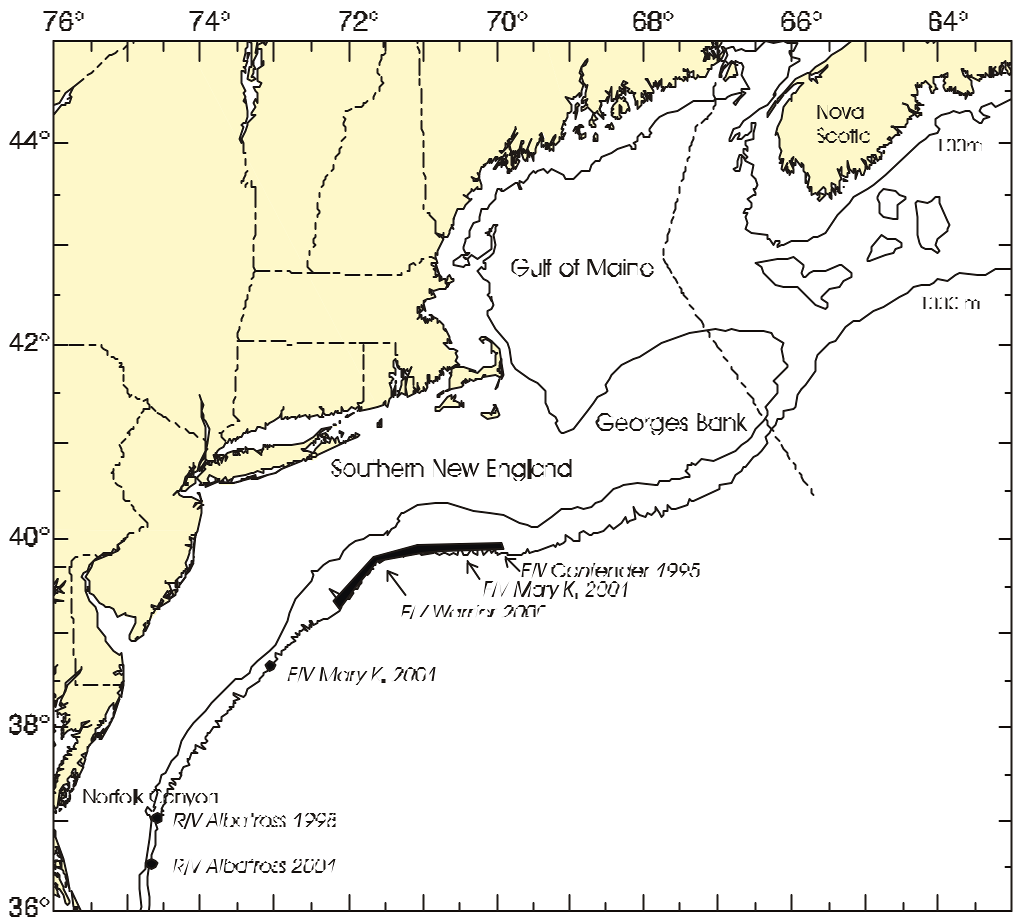

Figure 1. Continental shelf and slope areas along the northeast coast of the United States, with deep-water sampling areas indicated in solid polygons.

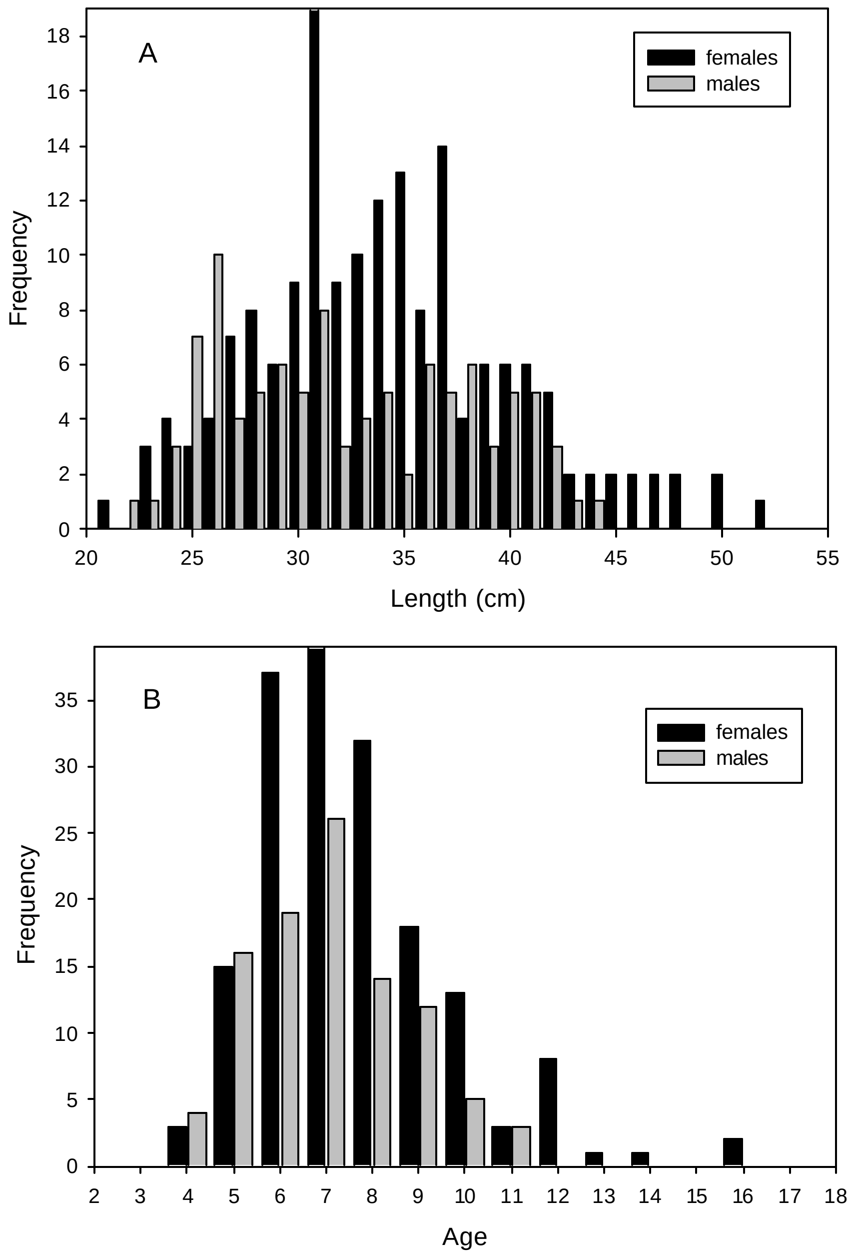

Figure 2. Length (A) and age (B) distributions by gender for 271 deep-water witch flounder collected during 1995-2001 in slope waters of the Georges Bank - southern New England region

Figure 3. Comparison of otolith thin-sections illustrating differences in overall shape between a 45 cm female witch flounder collected in the Gulf of Maine during the NEFSC 1999 autumn bottom trawl survey (top) and a 28 cm female witch flounder caught during a spring 2001 deep water survey aboard the F/V Mary K (bottom). Both fish were determined to be age 10.

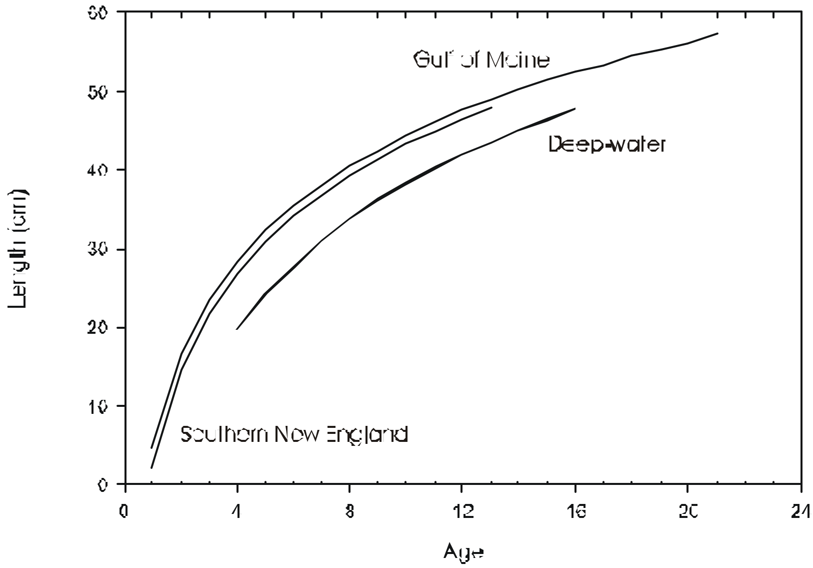

Figure 4. Growth curve comparisons between Gulf of Maine, southern New England and deep-water witch flounder. End points of curves correspond to minimum and maximum ages observed in each region.

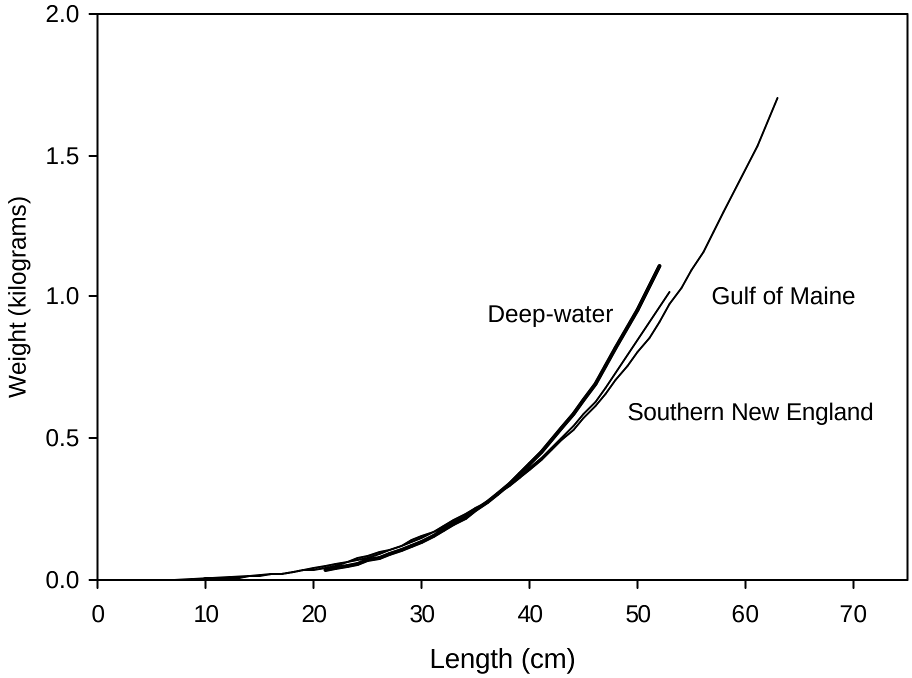

Figure 5. Comparison of length-weight relationships between witch flounder of the Gulf of Maine, southern New England, and deep-water slope regions. End points of curves correspond to minimum and maximum lengths observed in each region.

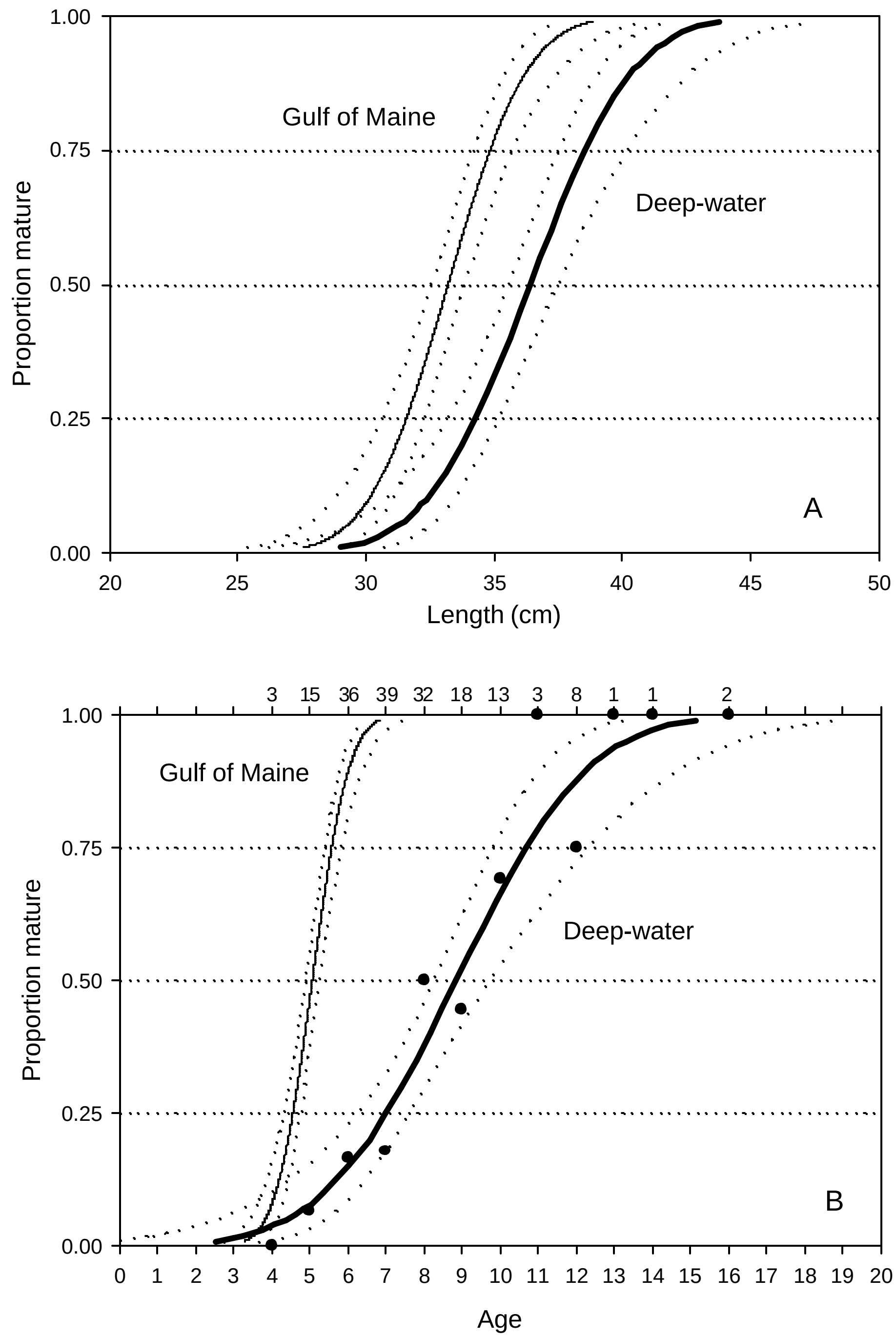

Figure 6. Maturity ogives and associated 95% confidence intervals for female witch flounder from the Gulf of Maine and deep-water regions; estimated proportions mature at length (A) and at age (B) are shown. Data points in B represent observed proportions mature; sample sizes are shown along the top axis.

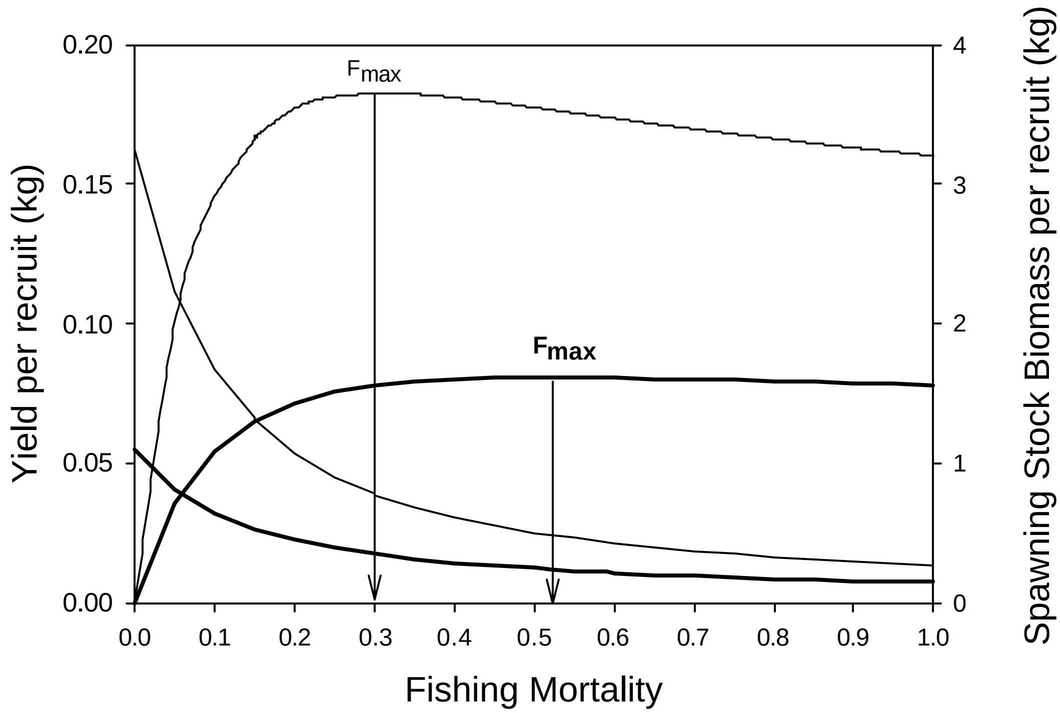

Figure 7. Comparisons of yield and spawning stock biomass per recruit estimates for Gulf of Maine and deep-water witch flounder obtained using the method of Thompson and Bell (1934). The levels of fishing mortality at which maximum yield occurs (F_{max}) are shown. Input values for these analyses are provided in Appendix Table 2.

Appendix Table 1. Numbers and total lengths of witch flounder, *Glyptocephalus cynoglossus*, caught during the NEFSC red crab survey AL 80-05, July 1980, in the southern New England region.

Station	Depth range (m)	Latitude	Longitude	Number	Lengths (cm)
1	273 - 298	39 59	70 36	0	
2	1571 - 1627	39 47	70 45	0	
3	1600 - 1719	39 47	70 47	0	
4	668 - 677	39 53	70 56	4	8, 17, 25, 25
5	936 - 971	39 50	70 59	3	7, 23, 26
6	1117 - 1130	39 46	71 21	1	18
7	513 - 530	39 55	71 03	7	6, 9, 9, 9, 21, 26, 34
8	337 - 338	39 59	70 55	8	19, 26, 28, 29, 29, 31, 32, 35
9	711 - 744	39 52	70 38	0	
10	432 - 443	39 55	70 36	0	
11	549 - 625	39 54	70 32	1	10
12	969 - 1234	39 51	70 30	0	
13	326 - 331	39 59	70 20	1	26
14	358 - 358	39 55	69 49	hang-up	
15	428 - 433	39 53	69 47	3	19, 25, 26
16	777 - 823	39 51	69 50	5	8, 8, 21, 24, 24
17	348 - 366	39 54	69 43	3	7, 16, 29
18	404 - 561	39 54	69 32	0	
19	883 - 1170	39 52	69 32	3	22, 23, 30
20	1015 - 1052	39 51	69 21	0	
21	713 - 841	40 03	69 02	0	
22	366 - 421	40 03	69 01	hang-up	
23	366 - 649	40 03	69 01	0	
24	218 - 221	40 03	68 58	0	
25	1116 - 1371	39 58	68 55	2	26, 29

Appendix Table 2. Input parameters and results from Thompson-Bell yield per recruit modeling for Gulf of Maine and deep-water witch flounder.

Gulf of Maine witch flounder

Proportion of F before spawning: .1667
Proportion of M before spawning: .1667
Natural Mortality is Constant at: .150
Initial age is: 1; Last age is: 14
Last age is a PLUS group;

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0010	1.0000	.0000	.009	.009
2	.0050	1.0000	.0000	.018	.018
3	.0130	1.0000	.0000	.056	.056
4	.0730	1.0000	.0800	.140	.140
5	.2330	1.0000	.4500	.247	.247
6	.4730	1.0000	.8500	.357	.357
7	1.0000	1.0000	1.0000	.484	.484
8	1.0000	1.0000	1.0000	.615	.615
9	1.0000	1.0000	1.0000	.764	.764
10	1.0000	1.0000	1.0000	.907	.907
11	1.0000	1.0000	1.0000	1.040	1.040
12	1.0000	1.0000	1.0000	1.170	1.170
13	1.0000	1.0000	1.0000	1.309	1.309
14+	1.0000	1.0000	1.0000	1.541	1.541

Slope of the Yield/Recruit Curve at F=0.00: --> 3.0111
F level at slope=1/10 of the above slope (F0.1): -----> .147
Yield/Recruit corresponding to F0.1: -----> .1663
F level to produce Maximum Yield/Recruit (Fmax): -----> .304
Yield/Recruit corresponding to Fmax: -----> .1827
F level at 20 % of Max Spawning Potential (F20): -----> .371
SSB/Recruit corresponding to F20: --------> .6506

	FISH MORT	TOTAL CATCHN	TOTAL CATCHWT	TOTAL STOCKN	TOTAL STOCKWT	SPAWN STOCKN	SPAWN STOCKWT	% MSP
	.00	.00000	.00000	7.1792	3.5838	3.5290	3.2535	100.00
	.05	.11648	.10073	6.4045	2.5600	2.7572	2.2381	68.79
	.10	.18710	.14590	5.9355	1.9824	2.2912	1.6673	51.25
F0.1	.15	.23223	.16630	5.6362	1.6388	1.9947	1.3290	40.85
	.15	.23477	.16723	5.6194	1.6203	1.9781	1.3107	40.29
	.20	.26931	.17722	5.3908	1.3764	1.7524	1.0715	32.94
	.25	.29564	.18146	5.2168	1.2034	1.5815	.9025	27.74
	.30	.31648	.18270	5.0794	1.0755	1.4471	.7780	23.91
Fmax	.30	.31808	.18271	5.0688	1.0660	1.4368	.7687	23.63
	.35	.33347	.18232	4.9676	.9777	1.3383	.6832	21.00
F20%	.37	.33960	.18189	4.9272	.9440	1.2992	.6506	20.00
	.40	.34765	.18109	4.8744	.9010	1.2481	.6091	18.72
	.45	.35971	.17942	4.7952	.8393	1.1720	.5497	16.90
	.50	.37015	.17754	4.7269	.7887	1.1068	.5013	15.41
	.55	.37930	.17558	4.6671	.7465	1.0500	.4610	14.17
	.60	.38741	.17362	4.6141	.7107	1.0001	.4271	13.13
	.65	.39468	.17170	4.5668	.6800	.9558	.3981	12.24
	.70	.40124	.16984	4.5240	.6534	.9161	.3731	11.47
	.75	.40722	.16805	4.4851	.6300	.8803	.3512	10.80
	.80	.41270	.16633	4.4495	.6093	.8478	.3320	10.20
	.85	.41776	.16469	4.4167	.5908	.8181	.3148	9.68
	.90	.42245	.16312	4.3863	.5741	.7908	.2995	9.21
	.95	.42681	.16162	4.3580	.5590	.7655	.2857	8.78
	1.00	.43090	.16019	4.3316	.5453	.7422	.2732	8.40

Appendix Table 2. Continued.

Deep-water witch flounder

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Proportion of F before spawning:  .1667
Proportion of M before spawning:  .1667
Natural Mortality is Constant at:  .150
Initial age is:  1; Last age is: 14
Last age is a PLUS group;
```

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0000	1.0000	.0000	.000	.000
2	.0000	1.0000	.0000	.000	.000
3	.0010	1.0000	.0150	.007	.007
4	.0070	1.0000	.0380	.028	.028
5	.0110	1.0000	.0800	.061	.061
6	.0200	1.0000	.1500	.104	.104
7	.0730	1.0000	.2500	.156	.156
8	.2000	1.0000	.3900	.214	.214
9	.3500	1.0000	.5300	.278	.278
10	.4700	1.0000	.6800	.346	.346
11	.6230	1.0000	.7800	.417	.417
12	1.0000	1.0000	.8700	.491	.491
13	1.0000	1.0000	.9400	.567	.567
14+	1.0000	1.0000	.9700	.725	.725

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Slope of the Yield/Recruit Curve at F=0.00: -->    1.0020
  F level at slope=1/10 of the above slope (F0.1): ----->    .198
    Yield/Recruit corresponding to F0.1: ----->     .0712
  F level to produce Maximum Yield/Recruit (Fmax): ----->    .517
    Yield/Recruit corresponding to Fmax: ----->     .0807
  F level at 20 % of Max Spawning Potential (F20): ----->    .588
    SSB/Recruit corresponding to F20: -------->     .2189
```

	FISH MORT	TOTAL CATCHN	TOTAL CATCHWT	TOTAL STOCKN	TOTAL STOCKWT	SPAWN STOCKN	SPAWN STOCKWT	% MSP
	.00	.00000	.00000	7.1792	1.4392	2.1568	1.0945	100.00
	.05	.06572	.03566	6.7420	1.1404	1.7447	.8100	74.00
	.10	.10634	.05440	6.4723	.9618	1.4944	.6417	58.63
	.15	.13434	.06510	6.2865	.8431	1.3252	.5312	48.53
F0.1	.20	.15414	.07124	6.1552	.7623	1.2079	.4569	41.75
	.20	.15509	.07150	6.1489	.7585	1.2023	.4535	41.43
	.25	.17128	.07542	6.0418	.6951	1.1085	.3960	36.18
	.30	.18439	.07782	5.9551	.6457	1.0342	.3520	32.16
	.35	.19533	.07927	5.8829	.6061	.9735	.3172	28.98
	.40	.20466	.08011	5.8213	.5735	.9229	.2891	26.41
	.45	.21277	.08055	5.7678	.5463	.8798	.2659	24.29
	.50	.21993	.08071	5.7206	.5231	.8425	.2465	22.52
Fmax	.52	.22224	.08072	5.7054	.5157	.8307	.2404	21.97
	.55	.22633	.08069	5.6785	.5030	.8099	.2300	21.01
F20%	.59	.23081	.08060	5.6490	.4893	.7875	.2189	20.00
	.60	.23210	.08056	5.6405	.4855	.7811	.2158	19.71
	.65	.23736	.08034	5.6059	.4700	.7553	.2034	18.59
	.70	.24219	.08007	5.5742	.4561	.7320	.1926	17.60
	.75	.24665	.07976	5.5449	.4437	.7109	.1830	16.72
	.80	.25079	.07944	5.5177	.4324	.6916	.1744	15.93
	.85	.25465	.07910	5.4923	.4221	.6740	.1667	15.23
	.90	.25827	.07875	5.4685	.4127	.6576	.1598	14.60
	.95	.26168	.07841	5.4461	.4040	.6425	.1534	14.02
	1.00	.26490	.07807	5.4250	.3960	.6284	.1477	13.49