

Assessment of the Haddock Stocks in the  
Gulf of Maine - Georges Bank Area

by

Stephen H. Clark and Joan E. Palmer

Laboratory Reference No. 78-05  
National Marine Fisheries Service  
Northeast Fisheries Center  
Woods Hole, MA 02543  
January 15, 1978

## Background

Grosslein (1962) recognized three haddock stocks off the northeastern USA coast: the Georges Bank stock, and two small stocks in the western Gulf of Maine, one of which appears to be resident to the Nantucket Shoals-Jeffreys Ledge area while the remaining stock undertakes seasonal migrations between this area and the Passamaquoddy Bay region (McCracken 1960). The latter two stocks overlap to some degree and movement from the Jeffreys Ledge and Nantucket Shoals areas out to the northwestern part of Georges Bank has also been documented; however, Georges Bank haddock appear to be relatively discrete from haddock on Browns Bank (Grosslein 1962). In view of current low levels of abundance and stock interrelationships, haddock off the northeastern USA coast have been managed as a unit in recent years although analytical assessment work has been performed only for the Georges Bank stock.

From the early 1900's until the mid-1960's, the Georges Bank haddock fishery was an important mainstay of the New England fishing industry. Hennemuth (1969) calculated an MSY of 50,000 tons for this stock, the approximate annual average landed during the 1935-1960 period (46,300 tons). Recruitment of the strong 1962 and 1963 year-classes during the mid-1960's, however, resulted in a substantial increase in effort by foreign nationals, and total landings reached 150,300 tons and 121,300 tons in 1965 and 1966, respectively (Table 1). Continued unrestricted exploitation throughout the late 1960's, coupled with poor recruitment, resulted in continued declines in landings and stock abundance and led to establishment of a Total Allowable Catch (TAC) by ICNAF of 12,000 tons for Georges Bank and the Gulf of Maine

in 1970 and 1971. Further declines in stock abundance led to a reduction to 6,000 tons for 1972 and 1973. For 1974, the TAC was set at zero and only incidental by-catches were allowed; however, the TAC was again set at 6,000 tons for 1975 and 1976 under the assumption that incidental catches up to this level are unavoidable.

The current Fishery Management Plan for groundfish (April 1977) sets a TAC of 6,200 tons for the Georges Bank-western Gulf of Maine area, 6,000 tons of which applies to commercial by-catch. For 1974-1976, commercial landings averaged 6,000 tons under incidental catch limitation; USA landings have averaged 4,300 tons (72%). Saltwater angling surveys (1960, 1965, and 1970) indicate recreational catches of 800, 9,700, and 1,147 tons, respectively; however, the NMFS 1974 regional survey indicated a catch of only 200 tons. Practically all recreational catches have been taken north of Cape Cod.

#### Current Assessment

The available data base for assessment of the Georges Bank haddock stock includes commercial catch at age data based on sampling of the commercial catch and autumn and spring bottom trawl survey data collected by the R/V Albatross IV and Delaware II (beginning in 1963 and 1968, respectively). Research vessel survey data have become increasingly important in recent years due to reduced commercial sampling activity, increased levels of discard, and changes in fishing patterns.

Provisional statistics indicate a nominal catch in 1977 of 12,500 tons for Georges Bank and the western Gulf of Maine, of which approximately 8,000 tons would apply to Georges Bank. Albatross IV autumn bottom trawl survey data (Table 2)

indicate a continued decline in abundance from 1967-1974 (with 1974 autumn indices for weight and numbers being the lowest on record). Numbers and weight per tow increased substantially in 1975 and again in 1976 with appearance of the strong 1975 year-class; preliminary data for autumn 1977 indicate a sharp decrease in numbers as compared to 1976 although weight was similar due to growth. Spawning stock size (numbers) as evidenced by the autumn age 2+ index appears to be at its highest level since 1967. Spring indices appear to be generally consistent with autumn indices (Table 2).

Total mortality coefficients ( $Z$ ) calculated from autumn bottom trawl survey data have averaged approximately 0.5 since 1967; assuming  $M = 0.2$  for this species (Halliday 1971) this indicates that  $F$  values have approximated 0.3 in recent years (Table 3).

Growth parameters for this stock have been calculated by applying the Von Bertalanffy growth equation to length at age data from spring and autumn bottom trawl surveys during 1968-1975 ( $L_{\infty} = 75.47$ ,  $K = 0.290$ , and  $t_0 = -0.461$ ). Results agree reasonably well with those reported earlier for Georges Bank ( $L_{\infty} = 73$ ,  $K = 0.28$ ; Beverton 1965).

Information currently available indicates that most USA vessels engaged in groundfishing operations in the Georges Bank-Gulf of Maine area (hake and redfish vessel data excluded) are employing polyamide trawls with an observed modal cod end mesh size range of 120-124 mm (ICNAF, 1976). Holden (1971) reported a mesh selection factor of 3.4 for haddock (polyamide netting); applying this factor to the midpoint of the above range a mean selection length ( $l_c$ ) of 41.5 cm is obtained corresponding to a mean age at recruitment ( $t_c$ ) of approximately 2.5 years.

Hennemuth (1969) determined that maximum yield-per-recruit was obtained at  $F = 0.5$  ( $t_c = 2.75$  years); Halliday (1974) assumed  $F_{max} = 0.5$  for haddock in Nova Scotian waters. Use of the Beverton-Holt yield model, with the above growth parameter estimates, indicates  $F_{max} = 0.49$  and  $F_{0.1} = 0.26$  for a  $t_c$  of 2.5 years. It therefore appears that  $F$  levels have approximated  $F_{0.1}$  in recent years.

The current Fishery Management Plan calls for a minimum size of 40.6 cm (16 inches) for this species for 1977, slightly below the  $l_c$  value of 41.5 cm calculated for polyamide trawls. An increase in  $t_c$  to 3.5 years (corresponding to an  $l_c$  of 51.5 cm) could be achieved by increasing cod end mesh size to 152 mm. Yield-per-recruit calculations indicate an increase of from 1-14% as  $t_c$  increases from 2.5 to 3.5 years and  $F$  increases from 0.3-0.8.

Stock size estimates (age 2+) for 1968-1979 have been calculated beginning with an estimated level of 69 million fish in 1968 as determined from virtual population analysis. The VPA suggests a decline in abundance (age 2+) to a minimum level in 1972, followed by a modest increase; however, commercial sampling since 1974 has been inadequate in certain quarters and little data is currently available relative to discarding. Consequently, a procedure was adopted in which stock size estimates for recent years were projected from recruitment estimates (age 2) based on research vessel survey catch-at-age data and known rates of removal as determined from mean weight at age data in USA landings. VPA estimates for the 1966-1970 year-classes at age 2 were accepted, as commercial sampling data for the 1968-1972 period appeared adequate to evaluate the relative strength of these year-classes. (Results were consistent with survey data in indicating all of these year-classes to have been extremely weak.) Recruitment estimates for the 1971-1975

year-classes were predicted from a regression of estimated numbers at age 2 from virtual population analysis based on commercial sampling on stratified mean catch-per-tow at age 1 from autumn bottom trawl surveys ( $r^2 = 0.90$ ) using data for the 1962-1970 year-classes. Estimates for the 1976 and 1977 year-classes were calculated using the survey young-of-year index provided by Grosslein (1969). Results are given in Table 4.

The above estimate indicates that the 1975 year-class is by far the strongest since 1963. The regression provides an estimate of 169 million fish at age 2, comparable to the strong 1962 year-class (152 million fish at age 2). Under this assumption, stock size in terms of numbers recovered to above the long-term average level in 1977, but would decline in 1978 and 1979 due to estimated poor recruitment from the 1976 and 1977 year-classes (Table 4). However, Grosslein's young-of-year index (35 million fish, Table 5) and a preliminary analysis of 1977 autumn survey data both suggest the 1975 year-class to be smaller than indicated. Autumn survey catch for this year-class declined considerably between 1976 (age 1) and 1977 (age 2) suggesting that the age 1 survey index value used in the above prediction may be anomalously high (although mortality in 1977 from commercial harvest and discard may also have been higher than assumed). The lower boundary of the 95% confidence interval on the predicted value of 169 million fish at age 2 is 79 million fish; this value is also included in the projections (Table 4).

It must be stressed that remaining year-classes are poor (approximately 89% of the haddock taken during the 1977 autumn bottom trawl survey on Georges Bank were 1975 year-class fish). Use of the age 2 estimate of 79 million fish for the 1975 year-class (Table 4) with the remaining data results in an estimated 1979 stock size of 71 million fish, approximately one-half the projected value given by the previous estimate.

The 1975 year-class will not enter fully into the spawning stock until mid-1978. Allowing it to do so would enhance the objective of stock rebuilding by maintaining the highest possible level of stock size until several year-classes resulting from this spawning stock recruit to the adult population. Fishing at the lower option in 1978 should not result in a loss in yield, as yield-per-recruit studies indicate an increase of 3% as  $t_c$  increases from 2.5 to 3.5 years (corresponding to the autumn, 1977 to autumn, 1978 period for the 1975 year-class) at levels of  $F$  which have been observed in recent years (0.30).

Stock size projections for 1979 (Table 6) have been calculated under two catch options for 1978 (equal to and double current levels) the two 1978 estimates provided in Table 4, and three estimates of recruitment. Catch options for Subarea 5 were calculated by applying the Subarea 5 to Georges Bank catch ratio (1.33, averaged over the 1972-1976 period) to the Georges Bank values. The range of recruitment estimates used appears realistic in that Grosslein's index suggests the 1977 year-class to be extremely weak (Table 5). It can be seen that under each catch option estimates decline below the long-term average as catch levels increase and for the lower 1978 stock size estimate the reduction is substantial.

Literature Cited

- Beverton, R. J. H. 1965. Catch/effort assessment in some ICNAF fisheries. Res. Bull. Int. Comm. N.W. Atlant. Fish. 2: 59-72.
- Grosslein, M. D. 1962. Haddock stocks in the ICNAF convention area. Int. Comm. Northw. Atlant. Fish. Redbook 1962, Part III, p. 124-131.
- \_\_\_\_\_. 1969. Haddock recruitment predictions from bottom trawl catches of 0-group fish in Subarea 5 and Division 4X. Annu. meet. Int. Comm. Northw. Atlant. Fish. 1969, Res. Doc. No. 89, 14 p.
- Halliday, R. G. 1971. Recent events in the haddock fishery of the eastern Scotian Shelf. Res. Bull. Int. Comm. Northw. Atlant. Fish. 8: 49-58.
- \_\_\_\_\_. 1974. Current status of the ICNAF Div. 4X haddock stock. Annu. meet. Int. Comm. Northw. Atlant. Fish. 1974, Res. Doc. No. 91, 24 p.
- Hennemuth, R. C. 1969. Status of the Georges Bank haddock fishery. Annu. meet. Int. Comm. Northw. Atlant. Fish. 1969, Res. Doc. No. 90, 21 p.
- Holden, M. J. 1971. Report of the ICES/ICNAF working groups on selectivity analysis. Coop. Res. Rept. ICES (A) No. 25. 144 p.
- ICNAF. 1976. Summary of trawl materials and mesh size sampling, 1975. Annu. meet. Int. Comm. Northw. Atlant. Fish. 1976, Summ. Doc. No. VI/45, 6 p.
- McCracken, F. D. 1960. Studies of haddock in the Passamaquoddy Bay Region. J. Fish. Res. Bd. Canada 17: 175-180.

Table 1. Commercial landings of haddock (tons, live) from Georges Bank and the western Gulf of Maine<sup>1</sup> by country, 1960-1976.

Year	COUNTRY								Total
	Canada	Poland	Romania	Spain	UK	USSR	USA	Other <sup>2</sup>	
Western Gulf of Maine <sup>3</sup>									
1960	383	-	-	-	-	-	4541	-	4924
1961	56	-	-	-	-	-	5297	-	5353
1962	107	-	-	-	-	-	5003	-	5110
1963	3	-	-	-	-	44	4742	-	4789
1964	70	-	-	-	-	-	5383	-	5453
1965	159	-	-	-	-	-	4204	-	4363
1966	1125	-	-	-	-	-	4579	-	5704
1967	589	-	-	-	-	-	4907	-	5496
1968	120	-	-	-	-	-	3437	-	3557
1969	59	-	-	230	-	-	2423	-	2712
1970	38	-	-	63	-	-	1457	14	1562
1971	85	-	-	26	-	-	1194	1	1306
1972	23	-	-	-	-	4	909	-	936
1973	49	-	-	-	-	-	509	-	558
1974	198	-	-	-	9	-	622	-	829
1975	79	-	-	4	-	-	1180	-	1263
1976 <sup>4</sup>	1254	-	-	-	-	-	1865	-	3119
Georges Bank <sup>3</sup>									
1960	77	-	-	-	-	-	40800	-	40877
1961	133	-	-	-	-	-	46384	-	46517
1962	3461	-	-	-	-	1134	49409	-	54004
1963	8379	-	-	-	-	2317	44150	-	54846
1964	11625	-	-	2	464	5483	46512	-	64086
1965	14889	28	730	10	-	81882	52823	-	150362
1966	18292	29	449	1111	29	48409	52918	37	121274
1967	13040	-	12	1355	3	2316	34728	15	51469
1968	9323	1286	402	3014	-	1397	25469	32	40923
1969	3990	458	66	1201	-	65	16456	17	22253
1970	1978	15	-	782	-	103	8415	7	11300
1971	1630	1	225	1310	-	374	7306	16	10862
1972	609	1	14	1098	-	137	3869	5	5733
1973	1563	-	-	386	-	602	2777	3	5331
1974	462	-	-	764	559	109	2396	-	4290
1975	1358	-	-	61	-	8	3989	4	5420
1976 <sup>4</sup>	161	-	-	46	-	4	2904	9	3124
Total All Areas									
1960	460	-	-	-	-	-	45341	-	45801
1961	189	-	-	-	-	-	51681	-	51870
1962	3568	-	-	-	-	1134	54412	-	59114
1963	8382	-	-	-	-	2361	48892	-	59635
1964	11695	-	-	2	464	5483	51895	-	69539
1965	15048	28	730	10	-	81882	57033	-	154731
1966	19417	29	449	1111	29	48516	57510	37	127098
1967	13629	-	12	1355	3	2316	39659	15	56989
1968	9443	1327	402	3014	-	1397	28914	33	44530
1969	4049	458	66	1431	-	65	18892	17	24978
1970	2016	15	-	845	-	103	9874	11	12864
1971	1715	1	225	1336	-	374	8508	17	12176
1972	632	1	14	1098	-	141	4779	5	6670
1973	1612	-	-	386	-	602	3289	3	5892
1974	660	-	-	764	568	111	3018	-	5121
1975	1437	-	-	65	-	8	5169	5	6684
1976 <sup>4</sup>	1415	-	-	46	-	4	4769	9	6243

<sup>1</sup>ICNAF Subarea 5 and Statistical Area 6.

<sup>2</sup>Includes landings for Bulgaria, Cuba, France, FRG, GDR, Ireland, and Japan.

<sup>3</sup>From ICNAF Statist. Bulletins 10-25 and ICNAF Summ. Doc. 77/VI/29; 5NK landings assigned to Div. 5Z

<sup>4</sup>From provisional ICNAF Statistics for 1976 (incomplete).

Table 2. Stratified mean catch per tow in numbers and weight (kg) for haddock from ALBATROSS IV spring and autumn bottom trawl surveys on Georges Bank (strata 13-25, 29 and 30), 1967-1976.

Year	Nos.	Spring		Nos.	Autumn	
		nos. (age 3+)	Wt. (kg)		nos. (age 2+)	Wt. (kg)
1967	-	-	-	11.40	7.35	16.87
1968	9.15	8.98	13.61	5.06	4.94	10.20
1969	5.15	4.79	10.37	2.28	1.99	5.59
1970	4.02	3.41	11.34	5.17	2.37	8.94
1971	1.87	1.10	3.30	2.83	1.19	3.71
1972	4.27	1.52	4.89	7.62	1.37	5.61
1973	(14.78) <sup>1</sup>	(0.84)	(5.99)	9.99	1.78	6.48
1974	(7.46)	(1.40)	(6.90)	2.71	1.02	2.64
1975	(2.44)	(1.69)	(3.19)	20.74	4.56	10.01
1976	(32.65)	(0.82)	(6.12)	47.69 <sup>2</sup>	1.73 <sup>2</sup>	23.68
1977	(14.55)	(1.91)	(10.35)	18.79 <sup>2</sup>	17.47 <sup>2</sup>	22.72 <sup>2</sup>

<sup>1</sup>Values in parentheses computed by adjusting stratified mean catch per tow values for the #41 Yankee trawl by a factor of 1.7.

<sup>2</sup>Preliminary

Table 3. Total mortality coefficients (Z) for Georges Bank haddock, computed from ALBATROSS IV autumn bottom trawl survey data<sup>1</sup>, 1967-1976.

Age group	Year								
	67-68	68-69	69-70	70-71	71-72	72-73	73-74	74-75	75-76
II	0.98	1.18	-0.93	1.03	-0.51	0.00	1.64	-1.60	0.29
III	1.11	0.00	0.05	0.00	-0.18	0.99	0.00	-1.08	1.78
IV	0.56	0.69	-0.69	0.24	0.92	0.69	2.56	0.00	1.13
V	0.25	0.93	-1.13	2.20	0.92	0.00	1.79	-0.69	0.00
VI	1.83	0.92	0.10	1.73	-0.69	0.18	0.00	0.00	0.41
VII	0.24	1.10	0.06	0.61	1.10	1.39	2.30	-0.69	-2.64
VIII	-0.17	1.01	-1.10	0.76	-0.06	0.69	-0.69	-0.69	-1.10
IX+	3.18	0.62	0.69	1.91	-0.55	0.58	1.39	-0.13	0.19
Z <sub>4</sub> <sup>2</sup>	0.48	0.90	-0.12	0.88	-0.03	0.58	1.54	-0.29	0.56
							$\bar{Z}_4^3 = 0.51$		

<sup>1</sup>Stratified mean catch per tow (numbers) at age.

<sup>2</sup>Computed as  $\ln \left( \frac{\sum 4 \text{ and older (1967)}}{\sum 5 \text{ and older (1968)}} \right)$ , etc.

<sup>3</sup>Computed as  $\ln \left( \frac{\sum 4 \text{ and older (1967+)}}{\sum 5 \text{ and older (1968+)}} \right)$ .

Table 4. Stock size projections and recruitment estimates for Georges Bank haddock, 1968-1979.

	Mean <sup>1</sup>	Yearly estimates (millions of fish)														
	1935-1960	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979			
Stock (2+)	145	69 <sup>2</sup>	33	18	13	6	15	38	38	35	196	106	164	91	131	71
Removals																
Total	63	36	16	8	7	3	5	10	10	8	42 <sup>4</sup>	25 <sup>4</sup>	35	22	-	-
Fishing <sup>3</sup>	41	26	11	5	5	2	3	3	3	2	6 <sup>4</sup>	6 <sup>4</sup>	6	6	-	-
Natural	22	10	5	3	2	1	2	7	7	6	36	19	29	16	-	-
Recruits(2)	54	7 <sup>2</sup>	-- <sup>2,5</sup>	1 <sup>2</sup>	3 <sup>2</sup>	-- <sup>2,5</sup>	12 <sup>6</sup>	28 <sup>6</sup>	10 <sup>6</sup>	7 <sup>6</sup>	169 <sup>6</sup>	79 <sup>6</sup>	10 <sup>7</sup>	10 <sup>7</sup>	2 <sup>7</sup>	2 <sup>7</sup>

<sup>1</sup>From ICNAF Redbook 1970.

<sup>2</sup>Estimated from virtual population analysis, M = 0.2.

<sup>3</sup>Values calculated on basis of mean weight at age in USA landings.

<sup>4</sup>Assumes a catch of approximately 8,000 tons in 1977 for the Georges Bank area with a mean weight of 1.25 kilos per fish.

<sup>5</sup>Less than 0.5 million fish.

<sup>6</sup>Predicted from a regression of stock size at age 2 from VPA on autumn survey catch per tow data (age 1) for the 1962-1970 year-classes. The smaller 1977 value is taken as the lower boundary of the 95% confidence interval around the predicted value for the 1975 year-class.

<sup>7</sup>Calculated using Grosslein's (1969) index (Table 5).

Table 5. Young-of-year indices for Georges Bank haddock, 1967-1976, and age 2 recruitment estimates obtained by relating these values to the 1958-1959 average<sup>1</sup>.

Year-class	Young-of-year index <sup>2</sup>	Index relative to 1958-1959	Recruitment estimate (millions) <sup>3</sup>
1953-1962 average	4.20	0.46	52(40)
1967	1.00	0.11	12(0)
1968	1.05	0.12	13(1)
1969	1.07	0.12	13(1)
1970	1.00	0.11	12(0)
1971	1.38	0.15	17(5)
1972	2.05	0.23	26(14)
1973	1.75	0.19	22(10)
1974	1.26	0.14	16(4)
1975	3.77	0.42	47(35)
1976	1.74	0.19	22(10)
1977	1.12	0.12	14(2)

<sup>1</sup>Assuming an average population size of  $113 \times 10^6$  fish (age 2) for the 1958 and 1959 year-classes as determined by virtual population analysis and a corresponding young-of-year index of 9.05.

<sup>2</sup>All values equivalent to mean of  $\log_{10}$  (no. of young-of-year haddock caught/tow + 1) values, antilogged, for stations in selected strata.

<sup>3</sup>Values in parentheses adjusted for bias associated with zero values, e.g.,  $\text{antilog}(0) = 1$ , implying an age 2 stock size of  $1/9.05 \times 113 = 12$  million fish for the 1967 and 1970 year-classes although VPA results suggest both to have been almost complete failures (<0.5 million fish). Consequently, recruitment estimates have been adjusted downward by subtracting 12 from each value.

Table 6. Stock size projections for 1979 under two catch options assuming three different levels of recruitment. Values in parentheses are calculated for Subarea 5 based on the observed catch ratio between Subarea 5 and Georges Bank during 1972-1976.

Recruitment 1979		Stock size in 1978 = 164 million fish		
	Catch <sup>1</sup> (millions)	Stock size (millions)	Catch <sup>1</sup> (millions)	Stock size (millions)
0	6(8)	129	12(16)	124
5	6(8)	134	12(16)	129
10	6(8)	139	12(16)	134
Stock size in 1978 = 91 million fish				
0	6(8)	69	12(16)	64
5	6(8)	74	12(16)	69
10	6(8)	79	12(16)	74

<sup>1</sup> Assuming a mean weight of 1.5 kilos per fish in the current year, catches would be approximately 9,000 tons (12,000 tons) and 18,000 tons (24,000 tons), respectively.