

ASSESSMENT OF THE HADDOCK STOCKS IN THE
GULF OF MAINE - GEORGES BANK AREA
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by

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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 uncertainty relative to 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 TAC of 12,000 tons for Subarea 5 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 Draft Fishery Management Plan for groundfish (February, 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, total landings have averaged 6,000 tons under incidental catch limitations; 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

Provisional statistics indicate a nominal catch of 6,300 tons for Georges Bank and the western Gulf of Maine, down somewhat from the total of 6,700 tons reported

for 1975 (Table 1). ALBATROSS IV autumn bottom trawl survey data (Table 2) indicate a continued decline in abundance from 1967-1974 (with autumn indices for weight and numbers being the lowest on record). For 1976, numbers and weight per tow increased sharply, coincident with appearance of the strong 1975 year-class; however, spawning stock size (as evidenced by catch in numbers of age 3+ fish during spring surveys and age 2+ fish during autumn surveys) remained at a very low level. 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 $t_0 = -0.461$). While subject to bias associated with changes in growth rates in recent years, results nevertheless agree reasonably well with those reported earlier for Georges Bank ($L_{\infty} = 73$, $K = 0.28$; Beverton 1965).

Holden (1971) reported a mesh selection factor of 3.4 for haddock... (polyamide netting); applying this factor to the recommended minimum codend mesh size of 130 mm in the current Draft Fishery Management Plan for groundfish, a mean selection length (l_c) of 44.2 cm is obtained corresponding to a mean age at recruitment (t_c) of approximately 2.5 years.

(It should be noted that use of smaller codend mesh sizes is widespread in the USA groundfish fisheries (ICNAF 1976) implying that t_c is actually lower).

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 Scotia waters. Use of the Beverton-Holt yield model, with the above growth parameter estimates, indicates $F_{max} = 0.50$ and $F_{0.1} = 0.24$ for a t_c of 2.5 years; corresponding estimates for the Ricker model are 0.64 and 0.32, respectively. It therefore appears that F levels have approximated $F_{0.1}$ in recent years.

The current Draft Plan calls for a minimum size of 40.6 cm (16 inches) for this species for 1977, somewhat below the l_c value calculated for polyamide trawls. For 1978, the plan proposes an increase in minimum size to 52.0 cm; if minimum size is set at l_c , an increase in codend mesh size to 153 mm is implied, which would increase t_c to 3.5 years. Yield per recruit calculations indicate an increase of from 1-14% as t_c increases from 2.5 to 3.5 and F increases from 0.3-0.8.

Since the collapse of this stock in the late 1960's, stock size and recruitment estimates have been difficult to obtain. Virtual population analysis indicates a decline in abundance (age 2+) to a low point in 1972, followed by a modest increase; however, commercial sampling in certain quarters has been inadequate and little data is

currently available relative to discarding. Consequently, stock size estimates (age 2+) since 1968 have been projected from recruitment estimates calculated from survey data and known rates of removal beginning with an assumed stock size of 69 million fish in 1968 (Table 4). Stock size estimates have been calculated in terms of age 2+ fish in that substantial numbers have been landed (or discarded) at age 2 in recent years.

For the purposes of the current assessment, recruitment estimates for 1969-1977 were calculated from a regression of estimated numbers at age 2 from virtual population analysis on stratified mean catch per tow at age 1 as determined from autumn bottom trawl surveys. The regression was calculated using data for the 1962-1972 year-classes ($r^2 = 0.90$). The estimate for the 1978 year-class was calculated using the young-of-year index provided by Grosslein (1969). Resulting values are given in Table 4.

All available data agree in indicating that the 1975 year-class is by far the strongest in recent years. The above regression for age 1 data provides an estimate of 168 million fish at age 2, indicating that this year-class may be as strong as the 1962 year-class (152 million fish at age 2). However, Grosslein's (1969) young-of-year index suggests it to be slightly smaller than the 1953-1962 average (Table 5). Until additional evidence become available, from autumn bottom trawl surveys and other sources, a tentative estimate of 90 million fish (the lower boundary of the 95% confidence interval on the predicted value of 168 million fish at age 2) appears reasonable. If not subjected to high fishing mortality in the current year, this year-class should increase

spawning stock size in 1978, although the strong 1962 and 1963 year-classes have passed through the fishery and remaining year-classes are poor (note also that the 1976 year-class also appears to be weaker than average, Table 5).

Current projections indicate that, assuming a constant average recruitment at the 1973-1978 level (27 million fish, Table 4) and removals averaging approximately 3 million fish as observed for 1972-1976 (Table 4), this stock could not rebuild to the 1935-1960 level but would stabilize at a somewhat lower level in the latter part of the next decade. (It will also be noted that the above average includes the estimated value for the 1975 year-class and recent year-classes have usually been considerably weaker, Table 4). Consequently, prospects for recovery of this stock remain problematical, and every effort should be made to hold fishing mortality to the lowest possible level.

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Table 1. Commercial landings of haddock (tons, live) from Georges Bank and the western Gulf of Maine¹ by country, 1960-1976.

Year	COUNTRY								Total
	Canada	Poland	Romania	Spain	UK	USSR	USA	Other ²	
Western Gulf of Maine ³									
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 ⁴	-	-	-	-	-	-	1865	-	-
Georges Bank ³									
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 ⁴	-	-	-	-	-	-	2904	-	-
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 ⁴	1415	-	-	46	-	4	4771	9	6245

¹ICNAF Subarea 5 and Statistical Area 6.

²Includes landings for Bulgaria, France, FRG, GDR, Ireland, and Japan.

³From ICNAF Statist. Bulletins 10-25 and ICNAF Summ. Doc. 77/VI/8; 54K landings assigned to Div.52

⁴From 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. (age 3+)	Wt. (kg)	Nos.	Autumn 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) ¹	(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	1.73	23.68

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

Table 3. Total mortality coefficients (Z) for Georges Bank haddock, computed from ALBATROSS IV autumn bottom trawl survey data¹, 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 ₄₊ ²	0.48	0.90	-0.12	0.88	-0.03	0.58	1.54	-0.29	0.56
							$\bar{Z}_{4+}^3 = 0.51$		

¹Stratified mean catch per tow (numbers) at age.

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

³Computed 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, 1968-1978.

	Mean ¹ 1935-1960	Yearly estimates (millions of fish)										
		1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Stock (2+)	145	69 ²	36	23	27	22	25	44	40	34	116	99
<u>Removals</u>												
Total	63	36	16	9	9	6	7	11	10	8	27	
Fishing ⁴	41	26	11	5	5	2	3	3	3	2	7 ³	--
Natural	22	10	5	4	4	4	4	8	7	6	20	
Recruits(2) ⁵	54	--	3	3	13	4	9	26	7	4	90	(10)

¹From ICNAF Redbook 1970.

²Estimated from virtual population analysis, $M = 0.2$

³Assumes a catch of approximately 10,000 tons in 1977, \bar{x} wt 1.5 kilos.

⁴Values calculated on basis of mean weight at age in USA landings.

⁵Calculated from a regression of stock size at age 2 from VPA on autumn survey datch per tow data (age 1) for the 1962-1972 year-classes. The 1977 value is taken as the lower boundary of the confidence interval around the predicted value for the 1975 year-class.

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 average¹.

Year-class	Young-of-year index ²	Index relative to 1958-1959	Recruitment estimate (millions) ³
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)

¹Assuming an average population size of 113×10^6 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.

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

³Values in parentheses calculated adjusting for bias associated with zero values ($\text{antilog}(0) = 1$).