DEFINITION OF HADDOCK STOCKS BASED ON VERTEBRAL NUMBERS

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on

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Clark and Vladykov (1960) separated northwestern Atlantic haddock into five major stocks based on differences in average vertebral number related to temperature on the spawning grounds. Significant differences were found between the average vertebral count of Georges Bank haddock (53.32)(part of the New England stock) and of Browns Bank haddock (53.58) (part of the western Nova Scotian stock). Significant differences were also found in average numbers of vertebrae among individual year classes on Georges and Browns Banks. A near perfect correlation between vertebral numbers and estimated surface temperatures during the spawning period in different years was demonstrated.

Because it appeared that Clark's methods of determining vertebral numbers and of estimating spawning temperature were possibly not as precise as the statistically significant differences in vertebral numbers and correlations with spawning temperatures given in his paper would indicate, the following assessment of his methods and comparisons with other and more concurrent data were made.

TEMPERATURE

There are indications that Clark's basic temperature data may be in error. Clark states that the average spawning temperature for Georges Bank is 38.0° F. and for Browns Bank is 36.5°F. This temperature data was based on average surface temperature plots of unpublished W.H.O.I. data (Fuglister)--mid March for Georges and early April for Browns. The average surface temperature based on readings taken in areas of spawning (areas where early stage eggs were found) on Georges Bank during March 1931, 1940, 1941, 1950, 1953, 1955, and 1956 is 39.4°F. (table 1). The average surface temperature based on readings taken in the area of spawning on Georges Bank during February, March, and April, ;931, 1932, 1940, 1941, 1950, 1953, 1955, and 1956 is 39.8°F. (table 1). The average surface temperature based on readings taken in areas of spawning on Browns Bank during April 1950, 1953, 1955, and 1956 was 39.6°F and during March, April, and May during these same years was 39.7° F. (table 1.). The 1950-1956 average spawning temperature for Georges Bank was 40.4° F. and for Browns Bank was 39.7°F. These temperatures are considerably higher than Clark's (possibly due in some part to a warming trend during the early 1950's) and also show that the surface temperature conditions over the 2 banks at the time of spawning are not as different as indicated by Clark's data.

Another method used by Clark was to estimate Georges Bank spawning temperature from the March-April Eastport mean plus 2.5 degrees and the Browns Bank spawning temperature from the April Eastport mean. This estimate, according to Clark's paper, was based on comparison of 1950 Albatross III cruise data (cruises 33 and 34) and Eastport readings. The actual temperature conditions at Eastport and on Georges and Browns Banks during 1950 do not bear this out. The average surface temperatures in the approximate area of spawning on Georges during March 20-25, 1950, was 42.4° F, while the average Eastport plus 2.5 degrees temperature was 38.3°F. and the Eastport March-April mean plus 2.5 degree was 39.3°F. The average surface temperature in the approximate area of spawning during April 25-May 2, 1950 was 39.6°F. while the average Eastport temperature was 39.2°F. and the Eastport April mean was 37.4°F. Actually the basis for these estimates was W.H.O.I. surface plots and the 1950 data served merely as a check (a poor one, as the comparisons of Eastport and Georges and Browns Bank temperature data shown in table 1 reveal that the differences in readings were greater during 1950 than in most other years).

Comparisons of Eastport and Georges Bank surface temperatures (table 1) show that:

1. The average Eastport surface temperature plus 2.5 degrees averages 1 degree lower than the Georges Bank surface temperature for similar periods (1931 - 56 and 1953 - 56).

2. The average Eastport March-April mean plus 2.5 degrees averages 1 degree lower than the Georges Bank temperature during the above periods (1931 - 1956), but only 0.2 degrees lower (1953 - 1956).

3. The Eastport temperature plus 2.5 degrees averaged 1.6 degrees lower than the Georges Bank temperature at the time of maximum spawning (1953 - 1956).

4. The Eastport March-April average temperature plus 2.5 degrees averaged 0.3 degrees lower than the Georges Bank temperature at the time of maximum spawning (1953-1956).

5. The average Eastport surface temperature was identical to Browns Bank surface temperature for similar periods (1953-1956).

6. The average Eastport April mean temperature averaged 1.4 degrees lower than Browns Bank temperature during the above periods (1953-1956).

7. The Eastport temperature averaged 1 degree higher than the Browns Bank temperature at the time of maximum spawning (1953-1956).

8. The Eastport April mean temperature was identical to the Browns Bank temperature at the time of maximum spawning (1953-1956).

In general, the Eastport readings plus 2.5 degrees underestimate the temperature conditions in the areas of spawning on Georges Bank during similar periods. The Eastport March-April mean plus 2.5 degrees also underestimates average spawning temperature conditions, but was suprisingly close to the approximated average temperature at the time of maximum spawning on Georges during 1953, 1955, and 1956. Eastport readings are an excellent indication of Browns Bank temperatures during similiar periods. The Eastport April mean temperature tends to underestimate Browns Bank spawning temperatures for in general spawning in this area is at its height towards the end of April. Thus it would appear better to use the Eastport April 15-30 mean to estimate Browns Bank spawning temperatures. Limited Mt. Desert data indicate that possibly these readings might be a better indication of Georges Bank spawning temperature conditions. Inshore temperatures in general tend to underestimate Bank conditions in winter and early spring and overestimate them in late spring. Because of this, it might be prudent to consider using Texas tower data as they average about 1 degree higher than temperatures in the spawning area (Northern Edge) during March and April.

It is suggested that <u>all available</u> Gulf of Maine temperature data be analyzed and comparisons made.

Table 1.--Comparison of spawning and inshore temperature data (surface readings). Temperature data for the banks are for areas where early stage eggs were found. The 1950 data is approximated

Date	Location	Cruise number	Av. temp.	Av. Eastport temp.	Av. Eastport temp. + 2.5°	Eastport Mar.-Apr. av. + 2.5°	Eastport Apr. av.	Av. Mt. Desert temp.	Mt. Desert Mar.-Apr. av.
Mar. 19-31, 1931	Georges	Alb. II	39.4	36.0	38.5	38.9		41.0	41.0
Apr. 16-29, 1931	Georges	Alb. II	42.1	38.3	40.8			40.7	
Average 1931			40.8	37.2	39.7			40.9	
Apr. 1-15, 1932	Georges	Alb. II	38.8	37.4	39.9	38.3		37.8	37.0
Mar. 21-Apr. 2, 1940	Georges	Atl. 95	36.6	No readings	No readings	36.8		37.2	39.5
Mar. 21-Apr. 2, 1941	Georges	Atl. 112	37.0	33.6	36.1	38.3			
Mar. 20-25, 1950	Georges	Alb. 33	42.4	35.8	38.3	39.3		38.7	
Mar. 27-Apr. 1, 1953	Georges	Alb. 46	41.4	39.0	41.5	41.6		40.0	41.5
Feb. 23-Mar. 1, 1955	Georges	Alb. 57	40.6	37.1	39.6	40.3		40.3	40.9
Mar. 20-21, 1955	Georges	Alb. 58	40.0	36.7	39.2			40.9	
Apr. 21, 1955	Georges	Alb. 60	41.9	39.9	42.4			41.5	
Average 1955			40.8	37.9	40.4			40.9	
Feb. 22-29, 1956	Georges	Alb. 71	39.4	34.9	37.4	38.2		38.6	39.2
Mar. 23-29, 1956	Georges	Alb. 72	38.7	34.3	36.8			39.8	
Apr. 23-27, 1956	Georges	Alb. 73	39.3	37.1	39.6			39.1	
Average 1956			39.1	35.4	37.9			39.2	
Average 1931-1956			40.4	36.7	39.2	39.4		39.9	39.9
Average 1950-1956			40.4	37.0	39.5	40.0		40.0	40.5
Apr. 25-May 2, 1950	Browns	Alb. 34	39.6	39.2			37.4		
Apr. 27-May 5, 1953	Browns	Alb. 48	41.3	41.5			40.5		
Apr. 28-May 5, 1953	Browns	Alb. 48	40.9	41.5					
Average 1953			41.1	41.5					
Mar. 21-29, 1955	Browns	Alb. 58	37.2	36.7			38.8		
Apr. 21-May 1, 1955	Browns	Alb. 60	39.2	39.3					
May 18-21, 1955	Browns	Alb. 61	42.0	42.0					
Average 1955			39.5	39.3					
Apr. 19-25, 1956	Browns	Alb. 73	37.1	37.2			36.6		
May 22-23, 1956	Browns	Alb. 75	40.2	40.4					
Average 1956			38.7	38.8					
Average 1950-1956			39.7	39.7			38.3		

Location	Year	Max. spawning date	Approx. temp.	Eastport temp.	Eastport temp. + 2.5°	Eastport Mar.-Apr. av. + 2.5°	Eastport Apr. av.	Mt. Desert temp.	Mt. Desert Mar.-Apr. av.
Georges Bank	1953	Mar. 19	41.6	37.1	39.6	41.6		40.0	41.5
	1955	Mar. 15	40.3	37.3	39.8	40.3		41.0	40.9
	1956	Apr. 1	39.0	34.2	36.5	38.2		41.0	39.2
Average			40.3	36.2	38.7	40.0		40.7	40.5
Browns Bank	1953	Apr. 15	39.5	40.4			40.5		
	1955	Apr. 20	39.2	40.8			38.8		
	1956	Apr. 20	37.1	38.0			36.6		
Average			38.6	39.7			38.6		

Date	Location	Cruise number	Av. temp.	Av. Texas Tower temp.	Av. Eastport temp.	Av. Mt. Desert temp.	Mt. Desert Mar.-Apr. av.	Texas Tower Mar.-Apr. av.
Mar. 23-Apr. 2, 1957	Georges	Alb. 89	40.4	41.7	35.8	41.8	42.3	41.8
Apr. 12-15, 1957	Georges	Alb. 90	40.9	41.9	37.0	44.0		
Apr. 25-May 1, 1957	Georges	Alb. 92	42.0	45.0	38.1	44.1		
Apr. 1-15, 1932	Georges	Alb. II	38.5					
	So. Channel	Alb. II	40.1					
Feb. 23-Mar. 1, 1955	Georges	Alb. 57	40.6					
	So. Channel	Alb. 57	41.9					

Sampling techniques and vertebral counts

Although there is apparently some error in Clark's basic temperature data and although surface temperature conditions during the period of spawning on Georges and Browns Banks did not vary as much as Clark's data would indicate (bottom temperatures even less), his vertebral count data indicate a marked difference (in terms of 0.1 vertebra) in total count between Georges Bank and Browns Bank and a near perfect correlation between vertebral numbers and estimated surface temperature. This is all the more surprising considering that possibly there are sampling errors involved. For example the 1942 - 1949 data is based on a sample of 1300 fish. These data are broken down into 2 banks and 8 year classes so that each year class is represented by less than 100 fish. The 1955 zero haddock data indicate that the variation in vertebral numbers between a areas, adjoining stations, and depths from such small samples are considerable (see fig. 1).

Clark's vertebral counts were based on "field counts" of filleted fish and on X-ray counts in the laboratory. Fish with fused vertebrae were excluded (according to Clark). An analysis of the various methods of counting vertebrae indicates that there is a possibility of a counting error if the vertebral number is based on X-ray counts and field counts and if fish with fused vertebrae are excluded from the counts. Some comparisons of vertebral numbers based on various counting techniques are given in table 2.

Table 2.--Comparisons of vertebral numbers using various counting techniques

Alb. III cruise No. 65, station 2, 35 zero haddock										
	Reader 1			Reader 2			Reader 3			Reader 4
	Abd.	Caud.	Total	Abd	Caud.	Total	Abd.	Caud.	Total	Total
X-rayed (20% agreement)	20.21	32.91	53.12	20.06	33.44	53.50	20.12	33.17	53.29	53.16
Filleted & stained (100% agreement)	20.03	33.46	53.49	20.03	33.46	53.49	20.03	33.46	53.49	

Alb. III cruise No. 119, station 69, 180 one- and two-year-old haddock						
	Filleted & stained 1/ (180 fish)	X-rayed 2/ (115 fish)	Filleted & stained (115 fish)	Filleted & stained w/o fused vert. 3/ (145 fish)	Filleted & unstained (72 fish)	Filleted & stained (72 fish)
Average number of vertebrae	53.43	53.28	53.47	53.30	53.19	53.42

1/ 3 readers, 100% agreement.
2/ Clark's reader could only read 115 of the 180 fish.
3/ 20% of the fish had fused vertebrae in the caudal region.

It can be concluded that:

1. Serious errors are introduced when counts are based on unstained filleted fish or on X-rays.

2. Fused vertebrae cannot be detected in unstained material or X-rays and by excluding fish with fused vertebrae (intentionally or unintentially) or by counting fused vertebrae as 1 vertebra instead of 2 vertebrae significant errors result.

3. Even with stained material at least 2 people should make the counts, compare readings, and settle differences.

Comparisons with 1955 zero-haddock data

There were greater differences in the average vertebral counts of zero haddock caught in September, 1955, between adjoining stations and subareas than between the counts given by Clark for Georges Bank and Browns Bank (fig. 1). The average vertebral count for all zero haddock caught in September, 1955, was 53.54 which would indicate Browns Bank origin (Clark-53.57). From spawning locations and times, drift of eggs, larvae, and bottles, zero haddock size, and estimates of growth rates, we had assumed that most of these zero haddock were of Browns Bank origin (April spawning). However, from Clark's vertebral number vs. spawning temperature curve (fig. 7, p. 289), a 53.54 vertebral count would indicate an average surface temperature in the area of spawning of 36.0°F. The minimum vertebral count in stations where 20 or more fish were caught was 53.37 and would indicate an average surface temperature of 37.5°F. The maximum vertebral number in stations where 20 or more fish were caught was 53.70 and would indicate an average surface temperature of 34.8°F.

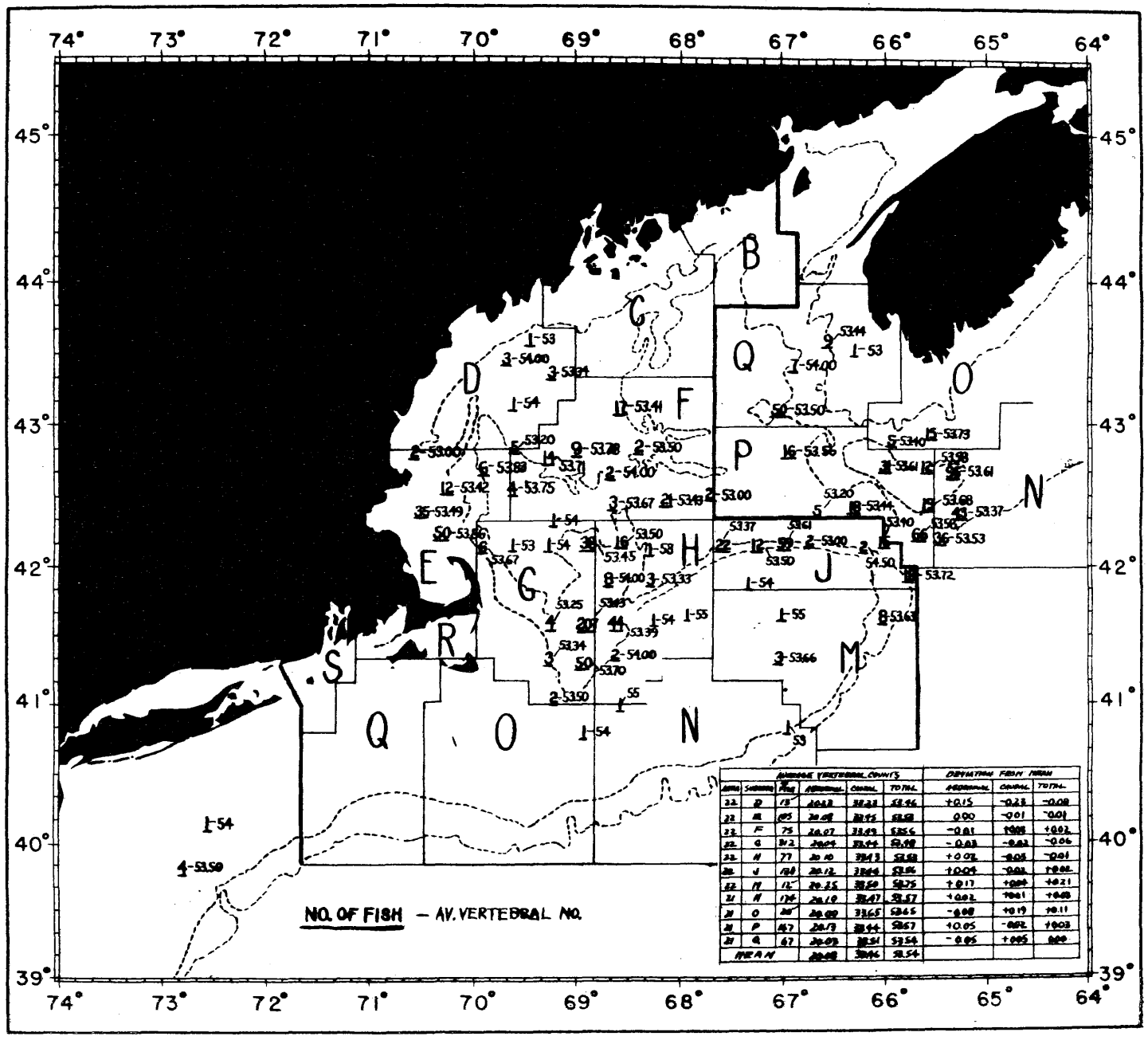

Figure 1 - Vertebral counts of zero-ring-haddock, Albatross III Cruises Nos. 65 and 66, September 7 - 28, 1955.

During 1955 the maximum production of eggs was on Browns Bank (rather than on Georges as in 1953 and 1956) at an average date of April 20. There was limited spawning on Browns Bank during the end of March (average surface temperature - 37.2° F.), maximum spawning in April (average surface temperature - 39.2° F.) and limited spawning in May (average surface temperature - 42.0° F.). Surface temperature at the time of maximum spawning on Georges Bank (March 15) averaged 40.3° F. and ranged from 40.2° F. in February to 41.9° F. in April. The March-April Eastport mean plus 2.5 degrees (used by Clark as an estimate of Georges Bank spawning temperature) was 40.4° F. The Eastport April mean (used by Clark as an estimate of Browns Bank temperature) was 38.8° F. Bottom temperatures in the areas of spawning were all above 40.0° F. Water as cold as 36.0° F. did not exist over any of the spawning areas in the Gulf of Maine-Georges Bank area in 1955. The only 36.0° F. surface water occurred on the eastern part of Browns Bank and along southeastern Nova Scotia in February and east of Browns Bank and South of Nova Scotia in March.

It would appear that either these fish did not come from Browns Bank (although their average vertebral count, etc. indicate that they did) or that something is amiss with Clark's temperature - vertebral count data.

Recommendations

1. Complete review of the literature.

2. Complete analysis of existing temperature data.

3. More exact analysis of meristic characters including:

   A. Total, abdominal, and caudal vertebrae

   B. Occurrence of fused vertebrae

   C. Fin ray counts, etc.--For example, Sanders (1952) found that herring along the east coast agreed closely in one meristic character (vertebral counts) and at the same time varied markedly in another (scute counts). This may be interpreted to mean that different meristic characters are laid down at different stages of embryonic development and thus under different hydrographic conditions. The development of one meristic character might be subject to the same temperature effect in 2 stocks of fish, whereas another character developing sooner or later, would not. Also, different meristic characters may manifest different degrees of sensitivity to hydrographic conditions.

4. Detailed analysis of vertebral count data of zero haddock caught in 1953, 1955, 1956, and 1958.

5. Establishment of exact criterea for reading vertebrae.

6. Recommended reading:-

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