Biological Aspects of Optimum Yield

for Georges Bank Haddock

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1. Perspective and Goals

1.1 Biological optimality must be considered in relation to stability of the population. Ideally, considerations should include the ecological setting of the population. For a single species, that would require knowledge of ecosystem interactions, and an understanding of cause and effect. Optimality may also be judged from historical observations which encompass an adequate time span within which the population has been adjusting to changes in the ecosystem. Such observations are available since 1930 for haddock.

Clearly, the population, fishery yields, and recruitment were relatively stable during 1935-1960. The haddock, and the total fish population, has been greatly perturbed since that time. There have been environmental changes as well, but not of a magnitude to indicate serious consequences. It may not be possible to restabilize the haddock population corresponding to the earlier state, but it is at present our best judgment of optimality. Therefore, the goal is to rebuild the population to quantitative and qualitative (age structure, growth, etc.) attributes characterized by the 1935-1960 period. These are characterized by Figures 1-3.

1.2 The events since 1960 have displaced the population drastically from the optimum. Recruitment from 1968 has been reduced by 86% from the optimum (Figure 2). The population (age 2+) dropped during the 1967-1976 period to less than 20% of optimum (Figure 3). In 1977 we had essentially one age group (86% of population in numbers, 68% in weight) in the population, compared to the optimum of at least five age groups contributing significantly to yield and spawning potential. The effects of fishing in 1978 and subsequent years will have a great influence on the ability to achieve optimality, and the time it takes to do so.

2. Estimate of current population and projections

2.1 The 1975 year-class has been estimated at 169 million fish at age 2 from analysis of commercial and survey data, the strongest observed since the 1963 class was produced. The 1976 and 1977 year-classes were estimated at 10 million fish and 2 million fish, respectively, based on the data presently available. The 1975 year-class increased 1977 stock size to an estimated 196 million fish. This is substantially above the long-term average of 145 million (1935-1960). However, the age composition of the current population is quite different because it is dominated by a single year-class (Figure 1).

2.2 Based on the estimated population in 1977 and recruitment in 1978 and 1979 the estimated stock size in 1979 is related to 1978 catches as follows:

Fishing Mortality Rate	Catch in Weight (tons)	% Change from 1978 in numbers of fish age 2+
F = 0.0	-	(-17)
F = 0.028	8,000	(-19)
F = 0.042	12,000	(-21)
F = 0.072	20,000	(-23)

The catch and population changes have been adjusted upward to include the entire Georges Bank-Gulf of Maine area.

The population would remain approximately the same in terms of weight due to a 36% growth of the 1975 year-class.

2.3 A catch of 20,000 tons could be removed for the next three years (1978, 1979, 1980) without significantly increasing the fishing mortality rate. The fishing rate would then need to be increased to maintain that catch and after an additional year the population would be back to the low level observed between 1974 and 1976 unless good recruitment occurs in 1980 and/or 1981.

At the above rate of removals the spawning stock (age 3 and older) would remain at about optimum biomass (130,000 MT) in 1978, 1979, and 1980 based on the 1930-1960 average. By 1982 it would be about the level of 1968 - the beginning of the collapse of consistent recruitment.

If the 1978 year-class is strong than the catch might be increased in 1980-81 without reducing the spawning stock size below optimum.

3. Fishing Strategies.

3.1 In the foreseeable future (3-5 years) we will have to deal with a single year-class population. There is a low probability that recruitment significantly above the long-term average will occur again within that time span. There is one imperative biological implication--spawning potential is dependent on the 1975 year-class for the next three years at least. Thus, to simulate the optimal spawning stock biomass (130,000 MT) over the next 5 years requires the following survivorship of the 1975 year class:

Age group	Year 1978	1979	1980	1981	1982
3	147	-	-	?	?
4	-	158	-	-	?
5	-	-	150	-	-
6	-	-	-	145	-
7	-	-	-	-	130

This assumes that the efficiency of a single age group in successive years is equivalent to a mix of age groups in each year.

Strategy to optimize spawning thus requires removals to be kept at about 6,000 MT per year.

If sporadic recruitment continues in the future and the population continues to be composed of a single dominant age group (which could indeed transpire under inadequate constraint of fishery activities), there will be a repetitive problem of discards, first as small

2-yr olds, and subsequently as a larger by-catch than desired under recovery management. The solution to this problem will have to include one or more of the following measures:

1. 2nd-tier constraints, i.e.,a combined cod and haddock limit.
2. Closed areas, varied to reduce fishing on pre-spawning and spawning aggregations.
3. Effort regulation by area and season.

3.2 The low fishing mortality expected in 1978 as shown in 2.2 is considerably less than the potential effort in the groundfish fleet. Thus the 1978 closure/by-catch problem can be severe. The fishing effort required to catch the cod OY in 1979 is considerably greater than that required to catch 20,000 MT of haddock. This will result in a by-catch problem i.e., haddock limits will be reached before cod limits, unless some additional management measures are used, e.g., second tier cod - haddock regulation.

3.3 Although spawning stock-recruitment relationships have yet to be defined in a satisfactory manner for most fish stocks, including haddock, the objective of maintaining a spawning biomass above some minimum level intuitively has some biological rationale. At most levels of spawning stock biomass, egg production is undoubtedly sufficient to insure strong year-classes; however, environmental factors exercise the ultimate control over the survival of the eggs and larvae. But when spawning biomass is driven below some threshold level and egg production is significantly reduced, the probability of poor year-classes being produced increases. Unfortunately, it is difficult, if not impossible, to define this threshold level of spawning biomass. Examination of past year-class sizes indicates that about 1/3 of those produced during 1930-63 were above the average for that period, whereas during 1964-77 only one year-class (1975), or less than 1/10, were above that previous average and the rest were very poor. Stock size during the latter period averaged less than 1/3 the average size of the former period. It is quite evident, therefore, that the probability of good year-classes in the haddock stock recently has been about 1/3 of what it was previously, which is perhaps the best biological rational for minimizing catch levels so as to improve egg production potential and the probability of better year-classes.

Egg production increases with size and age of fish. The greatest increase usually occurs between age three and four (up to 69% for some year-classes), thus offsetting the decreases in spawning stock numbers from 1978-1979.

4.0 Relationship with the Gulf of Maine Haddock Stock

The analytical assessment has been done for the Georges Bank haddock stock. The stock size numbers and biomass estimates refer to that stock. Historical observations indicate that the trends in the Gulf of Maine stock are parallel to those on Georges Bank. The catch figures given in this document have been increased by 33% (the 1972 to 1976 average) above those calculated for Georges Bank to give values relevant to the entire management area.

5.0 Robustness of the Assessment

The precision of the assessment estimates depends on the adequacy of the data used in the analyses. There are two critical components in this particular assessment. The first is the estimate from the survey of the 1975 year-class at age two. As with any such estimate it has a statistical confidence limit. In this case that means,for example, that there is a 66% chance that the estimate is 30% lower or higher than the value used. Both extremes can be adjusted for in 1979 when more data are available. The gain in growth of haddock from age three to four results in no long-term loss in yield from adjusting catches upward but adjustments to maintain optimum stock size at lower levels would require an immediate sharp decrease in catch. The second critical point is the rate of discard. The time required for the 1975 year-class to decline below optimum spawning stock size will be decreased to the extent that the underestimate of removals due to discarding in 1977 has resulted in an overestimate of the 1978 population. Analyses of future survey cruise and commercial catch trends and age compositions will provide estimates of the effect of the discard. The extent of adjustment in the catches in 1979 and beyond necessary to maintain optimum spawning stock size will depend on the amount discarded in 1977 and 1978.

6.0 References

Final Environmental Impact Statement for the Implementation of a Fishery Management Plan for Atlantic Groundfish - Haddock - Cod - Yellowtail Flounder. Prepared by the New England Regional Fisheries Management Council in Consultation with the Mid-Atlantic Regional Fisheries Management Council, April 1978.

6.0 cont'd.

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Grosslein, M. D., and R. C. Hennemuth. 1973. Spawning stock and other factors related to recruitment of haddock on Georges Bank. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer 164: 77-88.

Figure 1. Age composition of USA haddock landings from Georges Bank, (A) 1935-1960 and (B) 1977.

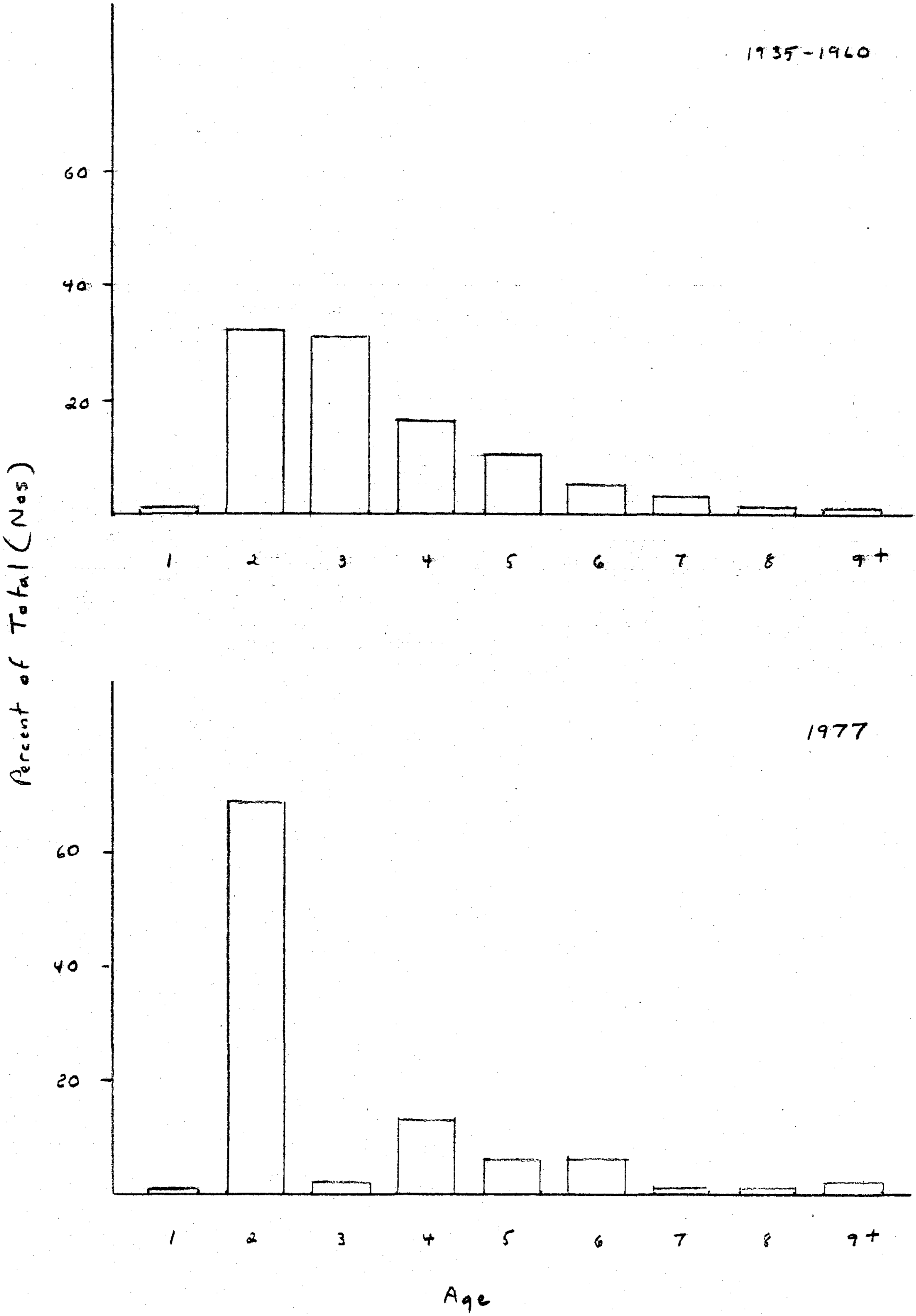

Figure 2. Estimated numbers (millions) of age 2 haddock recruited to the Georges Bank haddock stock, 1932-1979.

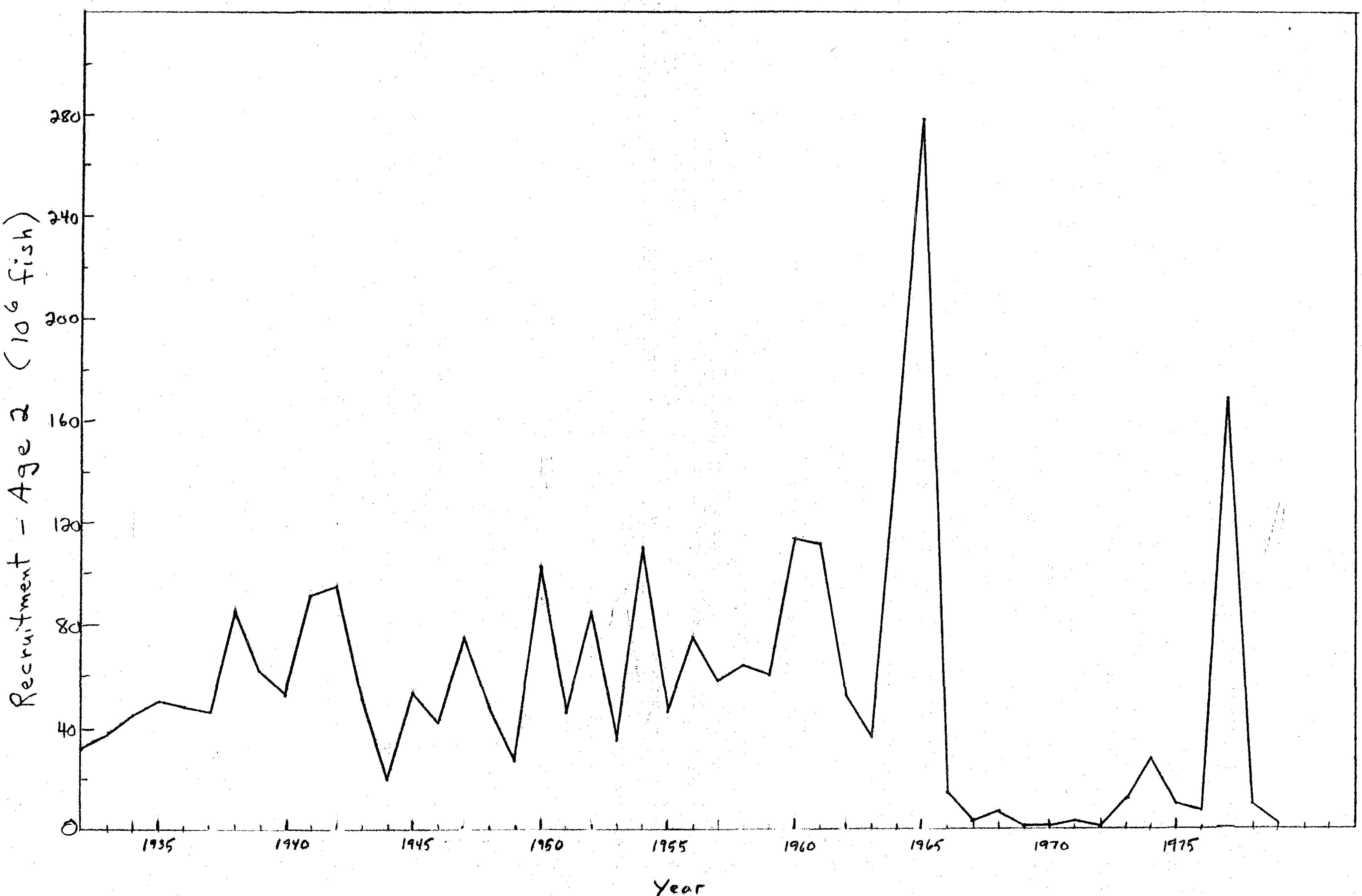

Figure 3. Stock size age 2+ (millions) for Georges Bank haddock, 1935-1979.