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AN EVALUATION OF THE EFFECT OF MINIMUM FISH SIZE ON YIELD PER RECRUIT FOR GEORGES BANK HADDOCK

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Abstract

The minimum size of fish captured, which would optimize the yield per recruit under an F0.1 management strategy, was determined. The results indicated that the optimal minimum size is between 51 and 59 cm for the haddock fishery in Division 5Z. The associated fishing mortality on fully recruited ages also increases but to a greater degree than the yield per recruit.

Résumé

La taille minimale des poissons capturés qui permettrait d'optimiser le rendement par recrue dans le cadre d'une stratégie de gestion basée sur le $F_{0,1}$ a été déterminée. Les résultats indiquent que cette taille minimale se situe entre 51 et 59 cm dans le case de la pêche à l'aiglefin dans la division 5Z. La mortalité par pêche associée aux âges pleinement recrutés augmente également, mais plus que le rendement par recrue.

Introduction

During 1985, Canadian haddock landings from NAFO Division 5Z ranged in size between 33 and 87 cm with a mode at 43 cm. Capture of haddock while increases due to growth exceed losses from natural mortality translate into a loss of yield to the fishery. An analysis was undertaken to determine what minimum size would optimize yield per recruit under an F0.1 management strategy. The impact of this minimum fish size on spawning stock size and subsequent recruitment is discussed.

Method and Results

Gavaris and Waiwood (1986) concluded that 2-yr-old haddock were fully recruited to the Canadian fishery in 1985. The age-length table from the 1985 Canadian fishery (Table 1) was therefore considered suitable for deriving partial recruitment vectors at various minimum sizes. The partial recruitment value for minimum size m was calculated as:

$$pr_i = \sum_{j \geq m} f_{ij} \Big/ \sum_{j} f_{ij}$$

where pr_i = partial recruitment at age i
f_{ij} = the frequency at age i and length j.

Table 2 shows the derived partial recruitment vectors for minimum sizes between 35 and 63 cm. It was assumed that older fish were fully recruited to the fishery. This is discussed further below. Examination of average weight at age in recent years did not reveal any trends; therefore, the average weight at age from the 1985 commercial fishery was employed (Table 2). Assuming a natural mortality of 0.2, the Thompson-Bell yield-per-recruit calculations were performed. As expected the F0.1 and the average weight of fish at F0.1 increased with increasing minimum size (Fig. 1). The yield per recruit at F0.1 increased to a maximum of 0.79 kg at a minimum size of 51 cm, and decreased for minimum sizes greater than 55 cm. The F0.1 level for a minimum size of 51 cm was 0.24. The present situation is most closely approximated by the 35-cm minimum size.

There is some evidence that older fish are not fully recruited to the Canadian fishery, perhaps due to age-specific distribution patterns (Gavaris and Waiwood 1986). To approximate this condition, the partial recruitment for ages 5 and 6 were set to 0.5 and for ages 7 and older to 0.1 in the derived partial recruitment vectors (Table 3). Under these conditions, it did not make sense to examine minimum size greater than 51 cm since older fish were less available to the fishery. Again, the F0.1 and the average weight of fish at F0.1 increased with increasing minimum size (Fig. 2). The yield per recruit at F0.1 was highest, 0.81 kg, at the largest minimum size examined, 51 cm. The F0.1 level for a minimum size of 51 cm was 0.74.

The use of average weight at age from the 1985 fishery does not take into account the potential change in average size at age of captured fish due to the change in partial recruitment. The response of the population growth rate to removals of the larger individuals in each cohort is difficult to predict. To examine the impact of a potential change in average size at age, it was assumed that the remaining smaller individuals at any given age would grow to fill in the entire size spectrum at the next age. This assumption, though unlikely, will provide an estimate of average weight at age which would approximate an upper bound. The resulting average weight at age for a given minimum size limit would likely be some value between those based on these calculations and the ones used to obtain the previous results. Table 4 shows the calculated average weight at age for each minimum size limit. The results of the yield-per-recruit analysis are illustrated in Fig. 3 and 4 in a comparable fashion to those given previously. The yield per recruit at F0.1 would be maximized at 59 cm when older ages are assumed fully recruited. When older ages are assumed partially recruited, the yield per recruit at F0.1 is highest at 51 cm, the largest minimum size limit applicable.

Discussion

Two scenarios were examined, older ages fully recruited to the fishery and older ages partially recruited. In both instances, the yield per recruit at F0.1 would increase if minimum size were increased to 51 cm from 35 cm, the size approximating present conditions. For fully recruited older ages, increasing minimum size beyond 51 cm did not result in any further increase. For partially recruited older ages, increasing minimum size beyond 51 cm is not meaningful since these larger fish are considered less available. Although the yield per recruit for 51-cm minimum size is higher than for 35-cm minimum size, greater fishing mortality on fully recruited ages would be required to harvest this yield. For fully recruited older ages, the yield-per-recruit increase is 11% associated with a 41% increase in the fully recruited fishing mortality, while for partially recruited older ages, the comparable figures are 23% and 95%, respectively.

Examination of the impact on the results due to change in the average weight at age of the captured fish indicated that the optimal minimum size could be higher, up to 59 cm. The associated fully recruited fishing mortality also increased. The actual optimum minimum size for an F0.1 management strategy is likely between 51 and 59 cm for either fully recruited or partially recruited older ages.

A minimum size of 51 cm implies low recruitment until age 4 (Table 2). Information on maturity suggests that about half of the age 2 haddock are mature and almost all haddock are mature by age 3 (Clark et al. 1982). Implementing management measures which limit catching haddock that are less than 51 cm should result in substantial increases to the spawning stock size. Although a deterministic relationship between spawning stock size and subsequent recruitment has not been demonstrated, Overholtz et al. (1986) argue that the probability of good recruitment is greater for spawning stock biomass between 70,000 and 200,000 t. Based on available evidence, therefore, it is likely that limiting catches of haddock less than 51 cm could enhance recruitment.

References

Clark, S. H., W. J. Overholtz, and R. C. Hennemuth. 1982. Review and assessment of the Georges Bank and Gulf of Maine haddock fishery. J. Northw. Atl. Fish. Sci. 3: 1-27.

Gavaris, S., and K. G. Waiwood. 1986. Assessment of haddock in NAFO Division 5Z. CAFSAC Res. Doc. 86/87.

Overholtz, W. J., M. P. Sissenwine, and S. H. Clark. 1986. Recruitment variability and its implications for managing and rebuilding the Georges Bank haddock (Melanogrammus aeglefinus) stock. Can. J. Fish. Aquat. Sci. 43: 748-753.

Table 1. Age length table for the 1985 Canadian commercial fishery of haddock in NAFO Division 5Z.

Length	Age 1	2	3	4	5	6	7	8	9
35	0	7	0	0	0	0	0	0	0
37	0	56	1	0	0	0	0	0	0
39	0	184	0	0	0	0	0	0	0
41	0	401	2	2	2	0	0	0	0
43	0	466	59	0	2	0	0	0	0
45	0	405	54	0	6	0	0	0	0
47	0	246	71	17	2	1	0	0	0
49	0	167	23	3	1	0	0	0	0
51	0	42	30	6	11	0	0	0	0
53	0	21	29	4	7	1	0	0	0
55	0	10	14	9	11	5	1	0	0
57	0	0	10	18	8	7	1	0	0
59	0	0	8	22	4	1	1	4	1
61	0	0	1	13	10	4	9	4	2
63	0	0	2	11	6	7	14	1	1
65	0	0	1	3	9	6	13	1	2
67	0	0	0	2	5	11	11	4	3
69	0	0	0	1	2	4	18	0	1
71	0	0	0	1	5	3	9	3	2
73	0	0	0	1	0	3	4	3	2
75	0	0	0	0	0	2	3	1	4
77	0	0	0	1	0	0	2	1	0
79	0	0	0	0	0	0	1	0	0

Table 2. Derived partial recruitment at age of Georges Bank haddock for minimum size limits between 35 and 63 cm. The average weight at age (kg) used for the yield per recruit calculations is shown.

Age	Avg Wt	Minimum Size 35	43	47	51	55	59	63
1	0.60	0.50	0.00	0.00	0.00	0.00	0.00	0.00
2	1.00	1.00	0.70	0.25	0.04	0.00	0.00	0.00
3	1.27	1.00	1.00	0.60	0.30	0.10	0.04	0.00
4	1.92	1.00	1.00	1.00	0.80	0.70	0.50	0.20
5	2.40	1.00	1.00	1.00	0.90	0.70	0.50	0.30
6	2.87	1.00	1.00	1.00	1.00	1.00	0.75	0.65
7	3.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	3.54	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	3.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	4.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	5.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	5.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	5.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	5.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	5.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	5.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	6.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. Modified partial recruitment at age of Georges Bank haddock for minimum size limits between 35 and 51 cm to account for partially recruited older ages. The average weight at age (kg) used for the yield per recruit calculations is shown.

Age	Avg Wt	Minimum Size 35	43	47	51
1	0.60	0.50	0.00	0.00	0.00
2	1.00	1.00	0.70	0.25	0.04
3	1.27	1.00	1.00	0.60	0.30
4	1.92	1.00	1.00	1.00	1.00
5	2.40	0.50	0.50	0.50	0.50
6	2.87	0.50	0.50	0.50	0.50
7	3.03	0.10	0.10	0.10	0.10
8	3.54	0.10	0.10	0.10	0.10
9	3.93	0.10	0.10	0.10	0.10
10	4.50	0.10	0.10	0.10	0.10
11	5.00	0.10	0.10	0.10	0.10
12	5.20	0.10	0.10	0.10	0.10
13	5.40	0.10	0.10	0.10	0.10
14	5.60	0.10	0.10	0.10	0.10
15	5.70	0.10	0.10	0.10	0.10
16	5.80	0.10	0.10	0.10	0.10
17	5.90	0.10	0.10	0.10	0.10
18	6.00	0.10	0.10	0.10	0.10

Table 4. Derived average weight at age of Georges Bank haddock for minimum size limits between 35 and 63 cm. Calculations were based on the age length table and a length weight relationship.

	Minimum Size						
Age	35	43	47	51	55	59	63
1	0.60	0.60	0.60	0.60	0.60	0.60	0.60
2	1.00	1.10	1.30	1.60	1.90	1.90	1.90
3	1.30	1.30	1.50	1.80	2.10	2.50	2.90
4	1.90	2.10	2.30	2.40	2.50	2.70	3.20
5	2.40	2.40	2.40	2.40	2.60	3.00	3.30
6	2.87	2.87	3.00	3.00	3.00	3.30	3.40
7	3.00	3.00	3.40	3.40	3.40	3.40	3.50
8	3.50	3.50	3.50	3.60	3.60	3.60	3.70
9	3.90	3.90	3.90	3.90	3.90	3.90	3.90
10	4.50	4.50	4.50	4.50	4.50	4.50	4.50
11	5.00	5.00	5.00	5.00	5.00	5.00	5.00
12	5.20	5.20	5.20	5.20	5.20	5.20	5.20
13	5.40	5.40	5.40	5.40	5.40	5.40	5.40
14	5.60	5.60	5.60	5.60	5.60	5.60	5.60
15	5.70	5.70	5.70	5.70	5.70	5.70	5.70
16	5.80	5.80	5.80	5.80	5.80	5.80	5.80
17	5.90	5.90	5.90	5.90	5.90	5.90	5.90
18	6.00	6.00	6.00	6.00	6.00	6.00	6.00

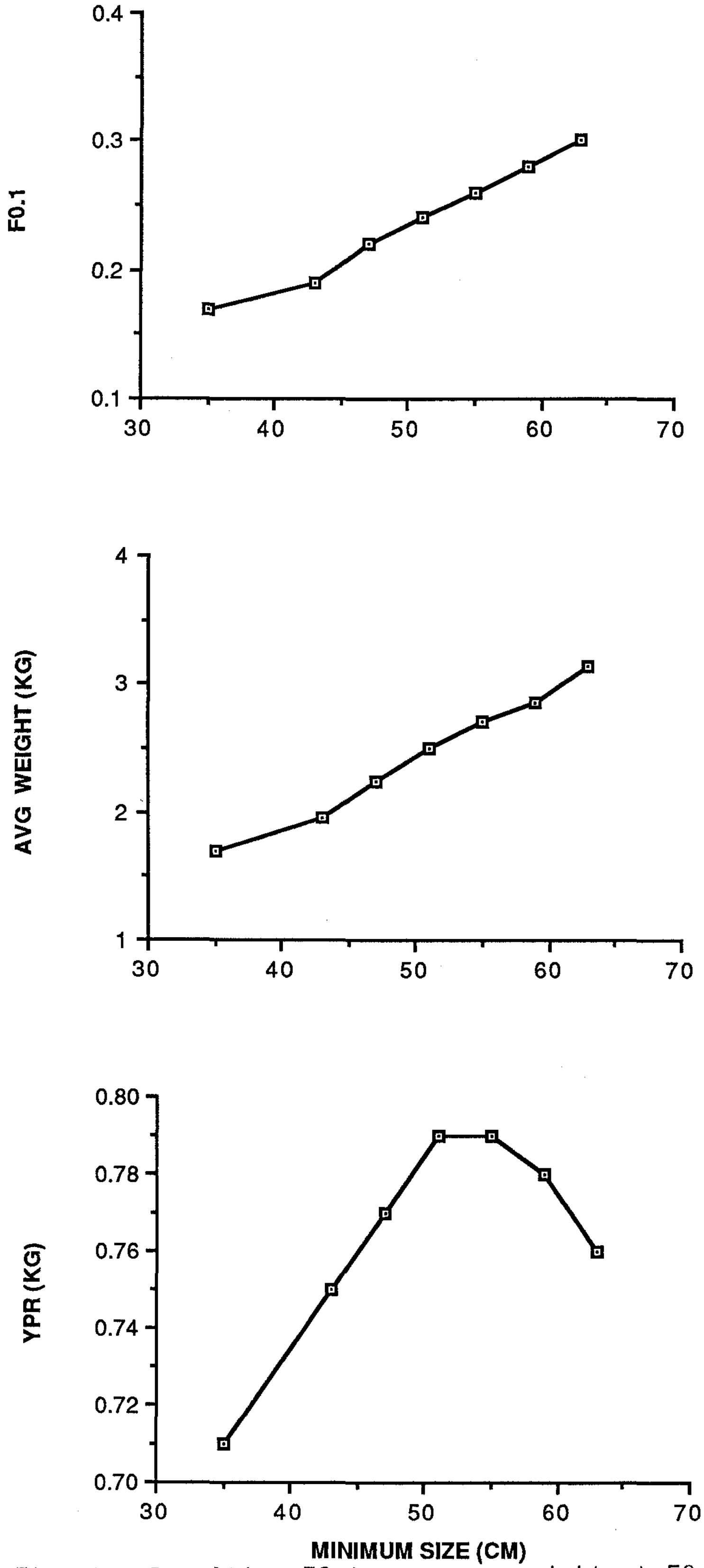

Fig. 1. Resulting F0.1, average weight at F0.1, and yield at F0.1 of haddock in Division 5Z for minimum sizes between 35 and 63 cm. Older haddock were assumed to be fully recruited.

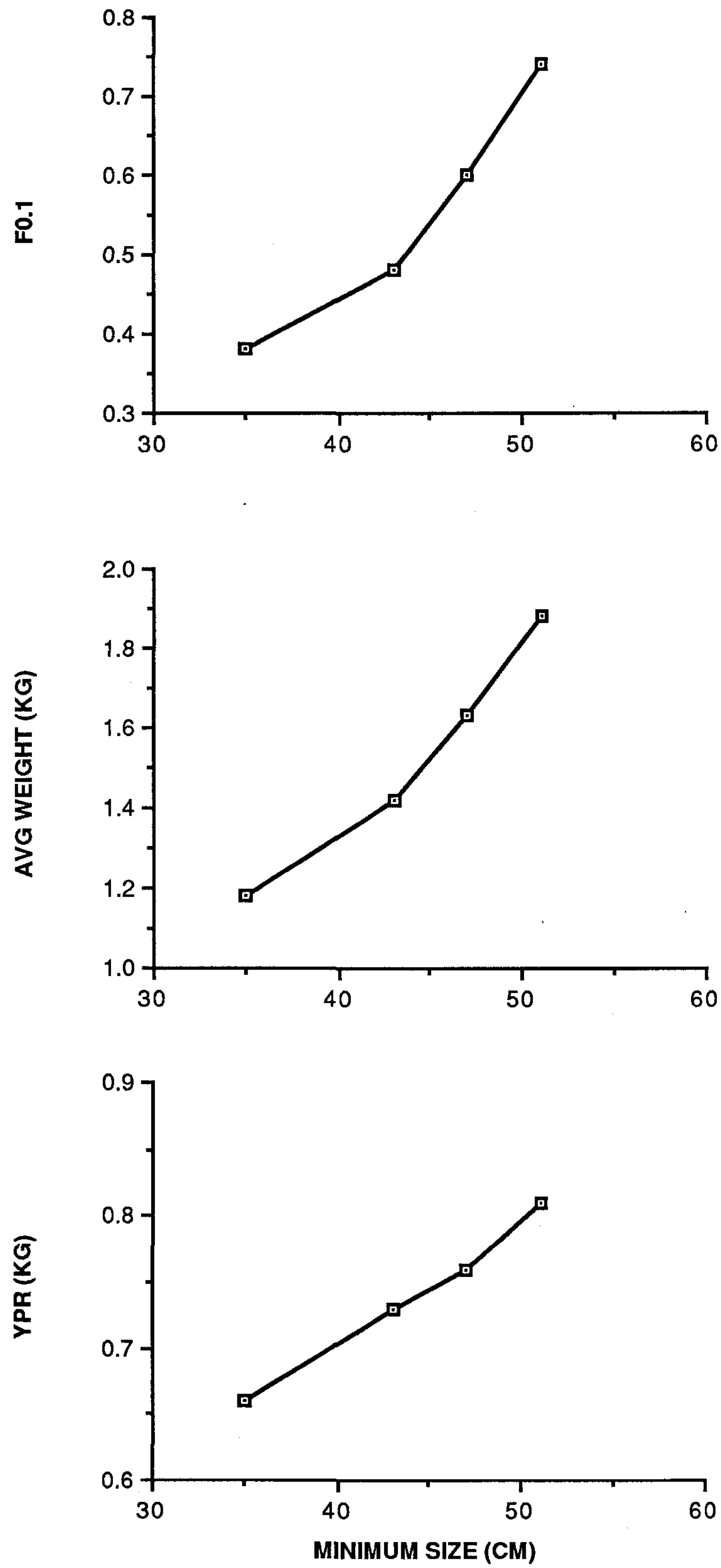

Fig. 2. Resulting F0.1, average weight at F0.1, and yield at F0.1 of haddock in Division 5Z for minimum sizes between 35 and 51 cm. Older haddock were assumed to be partially recruited.

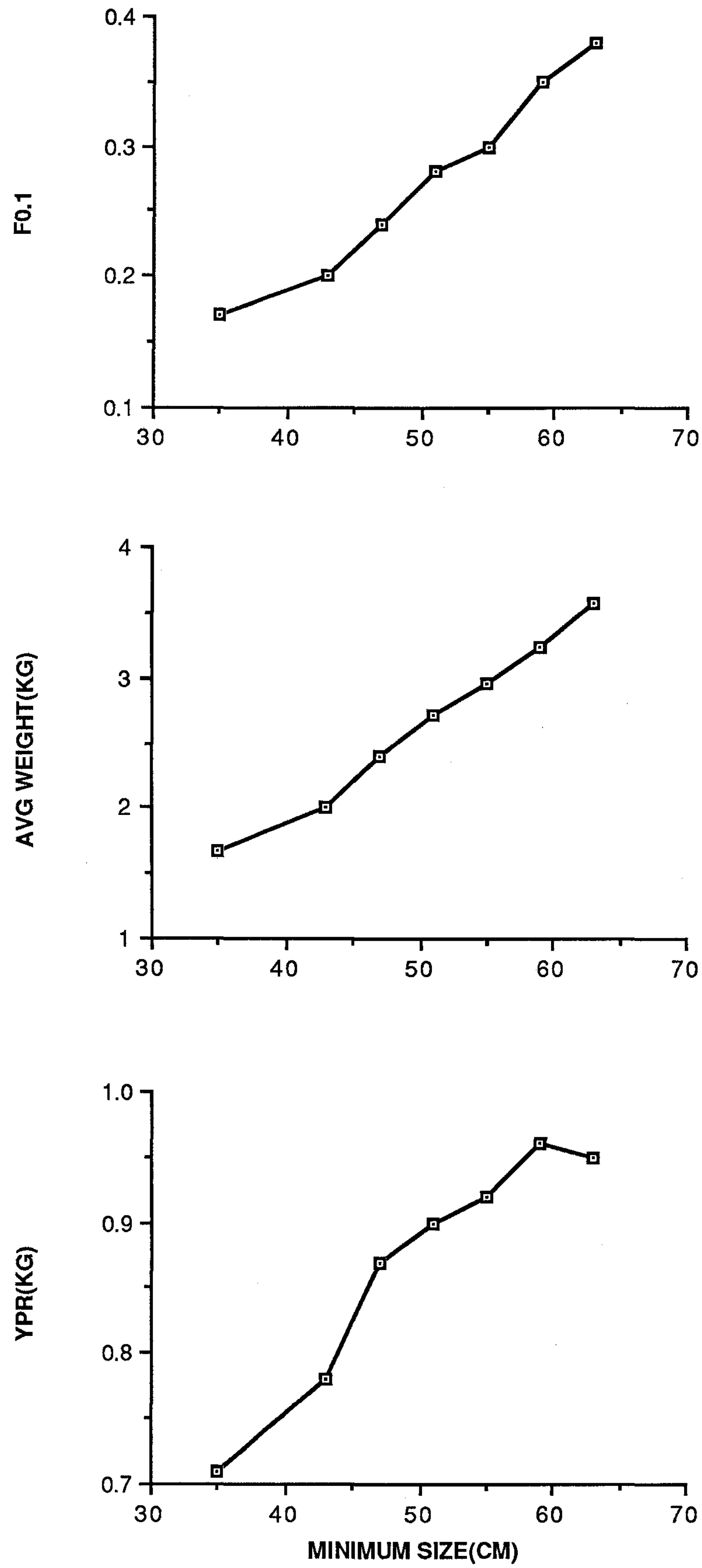

Fig. 3. Resulting F0.1, average weight at F0.1, and yield at F0.1 of haddock in Division 5Z for minimum sizes between 35 and 63 cm. Average weights at age were modified to account for the changed selectivity and older haddock were assumed to be fully recruited.

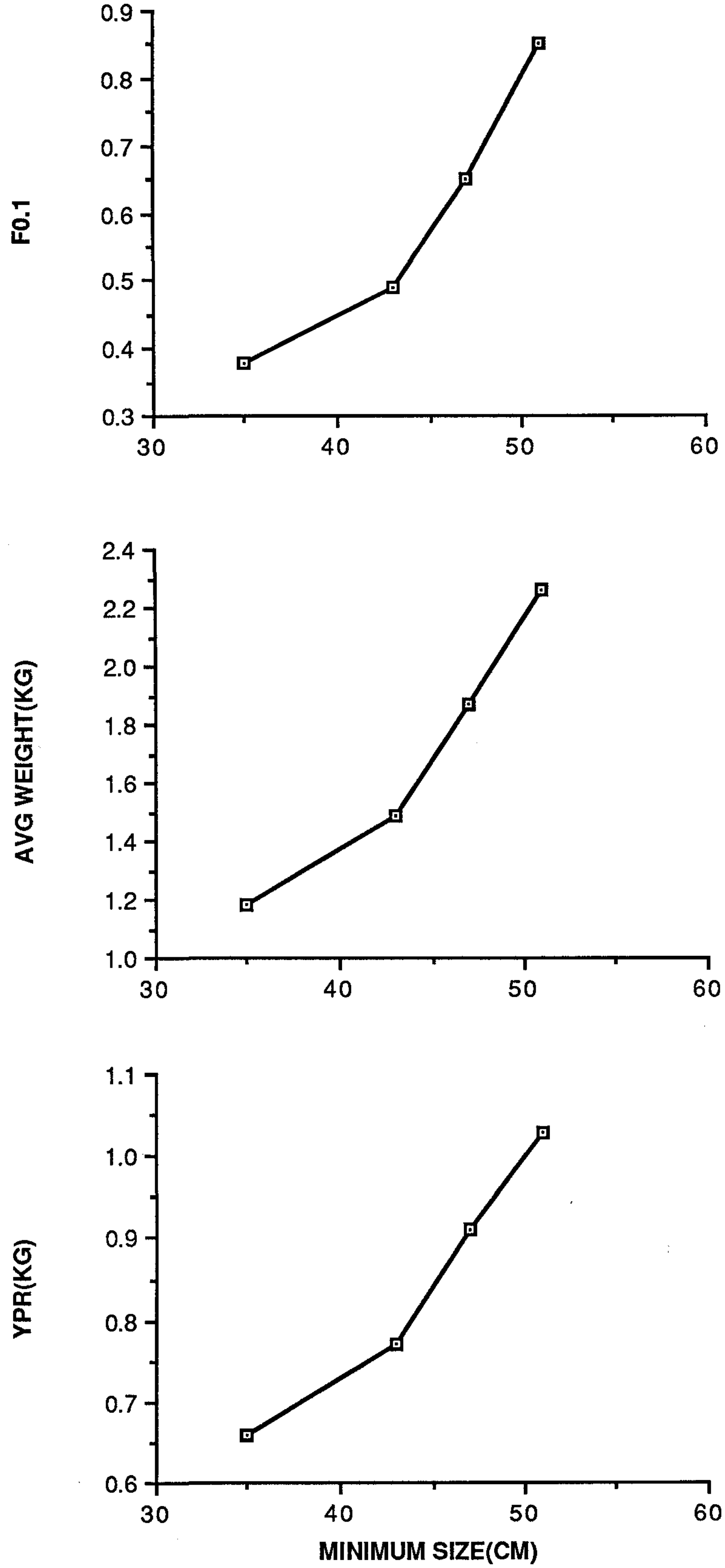

Fig. 4. Resulting F0.1, average weight at F0.1, and yield at F0.1 of haddock in Division 5Z for minimum sizes between 35 and 51 cm. Average weights at age were modified to account for the changed selectivity and older haddock were assumed to be partially recruited.