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The Effect of Temporal Trends in Size-at-age on $F_{0.1}$ for 4VW Haddock

by

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Abstract

The observed changes in size-at-age of 4VW haddock from 1948 to 1982 were sufficient to produce an average absolute error of 5.4% (SD = 3.2%) in $F_{0.1}$ projected for 2 years. In estimating $F_{0.1}$, partial recruitment was held constant as there were no apparent trends in partial recruitment corresponding to the trends in weight-at-age. Possible causes of the changes in size-at-age are discussed.

Résumé

Les variations de la taille moyenne par groupe d'âge chez l'aiglefin de la zone 4VW entre 1948 et 1982 étaient suffisantes pour produire une erreur moyenne absolue de 5,4 % (E.-t.= 3,2 %) dans les prédictions de $F_{0,1}$ sur deux ans. Pour estimer $F_{0,1}$, le recrutement partiel fut maintenu constant puisqu'il ne montrait pas de tendances correspondant à celles observées dans les poids moyens à l'âge. Les causes possibles des fluctuations de la taille moyenne par groupe d'âge sont discutées.

Introduction

The assessment for haddock in 4VW in 1981 reported a trend of decreasing size-at-age beginning in about 1977 (Mahon et al. MS 1982). Consequently, although 1981 nominal catch was about 13% below the TAC, a fishing mortality equal to that used to set the TAC was achieved. A similar situation occurred in 1982 (Mahon et al. MS 1983). Generally, the projections on which TACs are based have used the average weight-at-age for the 3-4 most recent years, rather than weights for the last year only. This practice could further increase errors arising from trends in size-at-age.

In this paper we review the size-at-age history of 4VW haddock to determine the extent and magnitude of variation in size-at-age, and explore the effects of this variation on projected $F_{0.1}$ and thus, TAC.

Historical Pattern of Size-At-Age

The lengths-at-age for 4VW haddock sampled from otter trawl catches (Jan.-Dec.) show substantial variation through the period for which data are available (1948-1981) (Table 1, Figure 1). The mean sea surface temperature on the eastern Scotian Shelf (1948-1979) (Trites 1982) is shown on Figure 1. The sample size for each mean length in Table 1 is given in Table 2, and the history of sampling from otter trawl catches summarized in Figure 2.

Changes in $F_{0.1}$

The $F_{0.1}$ and F_{max} values for each year were estimated using the method of Thompson and Bell (Appendix 1) for ages 2-16. The weight-length relationships (a = 0.0085; b = 3.034) and partial recruitment were assumed to be constant through time. Values from the 1983 assessment were used for the latter (Mahon et al. 1983). Natural mortality was set at 0.2 throughout. The resulting $F_{0.1}$ and F_{max} values are given in Table 3 and the trend in $F_{0.1}$ through time shown in Figure 3. The percentage differences in $F_{0.1}$ values for lag periods of 1-5 years are shown in Figure 4. Although the average absolute error may be within acceptable bounds error may sometimes be substantial.

The Assumption of Constant Weight-Length Parameters

It is to be expected that fish whose growth is limited by food will also be "skinny" fish. However, fish which are small for their age owing to their growth record in years past or whose growth is limited by temperature may be in good condition at the time of sampling. Therefore the effects of changes in condition on $F_{0.1}$ may not correspond at all closely with changes in size-at-age. This aspect requires closer examination.

The Assumption of Constant Partial Recruitment

Changes in the partial recruitment-at-age would have been expected to accompany the observed changes in size-at-age. As size-at-age decreases, the partial recruitment-at-age should decrease, shifting the age composition of the catch towards older ages, and vice versa. Therefore, there should be an opposite trend in mean age of the catch to that in size-at-age. This is not at all evident in Figure 5a (see also Figure 6). Instead, mean age of the catch was relatively constant through to the mid-sixties then declined from the late sixties to mid-seventies after which it increased again. In effect mean age tracked stock biomass. Therefore, there is no strong indication that the errors in $F_{0.1}$ due to changes in size-at-age are likely to be biased in any regular way by size-at-age related changes in partial recruitment.

Evidently, partial recruitment is not directly connected to fish size and gear selectivity. Since the otter trawlers fish primarily on pre and post spawning aggregations the age composition of the catch may be more reflective of the size-at-age of the spawning aggregation than that of the entire stock.

Explanations for the Variation in Size-At-Age

Changes in observed size-at-age in fish populations could have resulted from a variety of sources:

a) Changes in the proportions of catch from different seasons, population subunits with different growth rates, or from fleet components with differing selectivities. This could include changes in the distribution of both the populations and fishing activity.

b) Sampling variation, including the effects of variable sampling intensity on catch components differing as described for (a) above.

c) Changes in size-selective mortality during recruitment to the fishery or possibly by predators.

d) Changes in growth rate due to temperature effects, food availability, and density-dependence.

We are unable to categorically eliminate any of these possible sources. In the case of 4VW haddock, however, we suspect that c and d are the most likely causes; the latter also having been observed for haddock on the Grand Banks of Newfoundland (Templeman and Bishop 1979). Sources a and b are unlikely since the analysis is for otter trawlers only and through most of its history the fishery has been dominated by large trawlers TC4&5 fishing during the February to June period around the Middle, Western, and

Sable Island Bank areas. The exception is 1980 when a large proportion of the catch was taken in the fall. However, there have been changes in haddock distribution associated with the fluctuations in stock size.

We have not yet analysed the data for possible relationships between size-at-age, temperature and stock or cohort biomass. However, a first look indicates that these avenues could be fruitful. In Figure 1 there appears to be some correspondence between the trends in temperature and size-at-age. However, the trends in size-at-age since about 1965 could also be interpreted as a density dependent response since biomass of 4VW haddock first declined through to the mid-1970's then increased again.

Conclusions

Observed temporal changes in size-at-age for 4VW haddock could result in appreciable changes in $F_{0.1}$ over the 2 year interval for which projections are made. Having recognized this, the next step would be an attempt to forecast size-at-age. Once the possible effects of sampling variability have been considered, past growth, temperature and stock biomass should be examined as possible predictors of size-at-age.

References Cited

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Trites, R.W. 1982. Overview of oceanographic conditions in NAFO Subareas 2, 3, and 4 during the 1970-79 decade. NAFO Sci. Coun. Studies 5: 51-78.

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	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
2	35	40	35	35	35	35	35	35	36	35	37	35	35	30	35	35	39	29	28
3	48	43	40	46	41	44	43	41	41	41	40	40	42	42	41	41	42	42	33
4	48	48	46	46	46	46	46	46	43	45	46	44	44	43	43	45	43	43	41
5	53	50	50	49	50	51	47	49	49	48	49	48	46	47	46	47	47	46	46
6	58	55	55	52	53	54	52	51	51	52	52	52	51	52	50	50	50	50	50
7	63	61	58	59	57	59	56	56	53	55	56	55	55	55	55	54	53	55	52
8	65	65	60	61	61	63	56	59	57	56	58	58	57	59	58	58	56	58	59
9	66	66	62	59	66	67	63	59	59	60	59	60	61	61	63	61	60	60	60
10	67	67	63	63	66	70	60	63	60	59	61	63	62	63	63	64	63	63	63
11	66	67	68	70	69	67	66	65	63	62	64	64	62	67	66	66	61	64	66
12	70	68	69	62	73	68	69	67	57	61	65	64	67	67	68	65	60	71	63
13	67	71	70	73	81	70	70	70	63	59	79	59	65	70	69	70	66	73	70
14	72	67	71	73	75	73	73	73	81	57	68	69	69	75	81	64	81	73	75
15	81	77	71	77	77	86	77	77	77	77	77	77	77	76	67	77	77	77	77
16	79	76	77	77	77	77	75	77	77	77	77	77	73	77	77	77	77	77	77

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
2	34	35	35	35	37	30	39	35	35	34	42	35	38	35	38	34
3	36	35	40	39	40	41	40	39	39	36	44	41	42	41	42	40
4	42	43	44	44	45	45	45	46	45	50	48	47	49	46	45	45
5	48	47	49	49	50	51	51	54	50	56	52	53	53	50	49	49
6	52	53	53	52	54	56	55	57	57	58	56	57	59	56	54	53
7	55	58	59	57	57	58	60	63	62	60	61	61	62	61	58	59
8	58	58	63	61	60	60	62	66	65	64	62	65	63	64	63	64
9	62	62	67	65	65	65	66	63	69	63	65	67	70	67	65	67
10	64	65	67	72	68	72	68	69	65	65	68	67	66	68	69	68
11	66	67	66	65	70	69	67	70	73	72	69	70	69	69	70	72
12	71	72	72	72	69	68	70	68	68	70	59	68	68	72	75	73
13	68	67	77	74	65	70	73	70	70	70	73	70	81	78	75	70
14	73	66	73	77	76	73	83	73	73	73	73	75	75	73	73	73
15	77	77	77	77	83	77	77	77	77	77	77	77	73	75	81	77
16	77	77	77	77	77	77	77	77	77	77	77	77	77	77	77	77

Table 1. Length-at-age for 4VW haddock sampled from otter trawl catches. (for ages where no fish were sampled mean length for other years at that age are inserted.)

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	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
2	3	0	0	0	0	0	0	0	0	10	0	9	0	0	0	0	0	1	0
3	100	25	38	1	18	5	3	3	42	116	22	268	67	7	3	18	6	13	24
4	47	280	46	77	132	29	61	78	119	694	199	344	175	158	299	82	250	33	88
5	342	396	163	81	146	203	162	569	269	135	929	183	165	283	638	427	222	196	78
6	111	127	106	147	37	172	242	101	566	157	184	551	106	137	347	351	569	73	121
7	61	122	16	86	39	69	76	112	160	187	141	55	218	107	110	105	280	114	36
8	11	86	9	8	20	29	22	64	154	58	105	46	25	93	86	48	71	62	43
9	2	39	8	16	2	13	10	24	59	93	26	46	14	22	68	19	17	16	19
10	2	36	6	4	1	4	1	3	21	22	21	11	18	9	17	12	4	4	4
11	0	16	3	11	2	2	0	2	4	7	8	6	6	9	6	3	1	2	2
12	3	10	6	2	2	0	1	4	1	3	5	6	6	4	3	0	1	1	0
13	1	3	0	0	0	0	1	2	1	0	0	2	4	3	2	0	0	1	0
14	2	1	2	0	0	0	0	0	0	1	2	2	2	1	0	0	0	0	0
15	1	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
2	12	13	0	0	0	1	1	1	0	0	235	27	0	3	0	12
3	66	75	13	22	73	20	35	3	67	17	78	290	47	100	180	43
4	298	196	64	78	237	56	61	14	9	43	20	136	146	309	468	661
5	168	243	96	115	202	77	85	10	31	24	53	120	26	168	316	543
6	48	105	84	105	210	33	61	5	22	13	16	43	33	34	147	314
7	82	41	25	51	170	25	25	3	4	5	18	9	12	25	22	119
8	22	56	13	15	53	33	18	1	1	2	2	8	2	3	9	12
9	14	20	14	7	11	8	10	1	0	1	1	2	1	1	2	10
10	5	16	4	6	5	1	1	1	1	0	1	1	1	1	1	2
11	1	5	3	2	2	1	2	0	0	0	0	1	0	1	1	2
12	0	3	1	1	2	0	0	0	0	0	0	0	0	0	0	2
13	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. The number of fish in each age class on which the data in Table 1 are based

Year	$F_{0.1}$	F_{max}
1948	0.26	0.73
1949	0.25	0.68
1950	0.25	0.66
1951	0.25	****
1952	0.22	0.56
1953	0.24	0.63
1954	0.24	****
1955	0.24	0.93
1956	0.25	0.92
1957	0.27	0.97
1958	0.24	0.95
1959	0.25	0.73
1960	0.24	0.79
1961	0.23	0.64
1962	0.22	0.57
1963	0.23	0.80
1964	0.23	****
1965	0.22	0.58
1966	0.21	0.45
1967	0.22	0.49
1968	0.23	0.47
1969	0.22	0.47
1970	0.22	0.46
1971	0.23	0.59
1972	0.23	0.55
1973	0.23	0.53
1974	0.25	0.54
1975	0.24	0.48
1976	0.26	0.68
1977	0.26	0.88
1978	0.25	0.56
1979	0.25	0.65
1980	0.23	0.51
1981	0.22	0.52
1982	0.22	0.46

Table 3. $F_{0.1}$ and F_{max} for 4VW haddock (1948-1981). F_{max} greater than one was not computed (****)

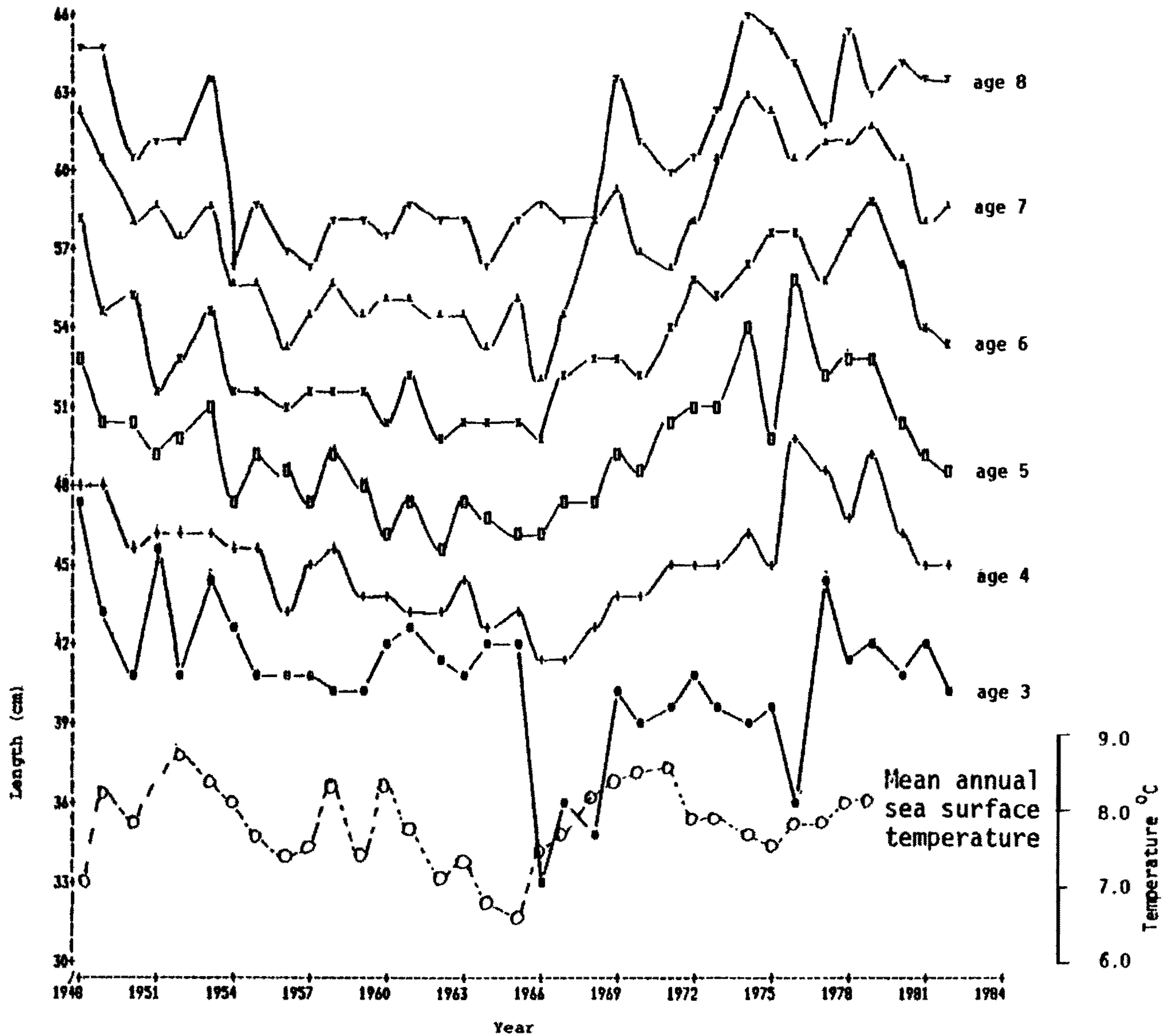


Figure 1. The lengths at ages 3-8 for 4VW haddock sampled from otter trawl catches (1948-1981) with the mean annual sea surface temperature on the Scotian Shelf

Figure 2. The history of sampling and ageing of haddock from otter trawls in 4VW

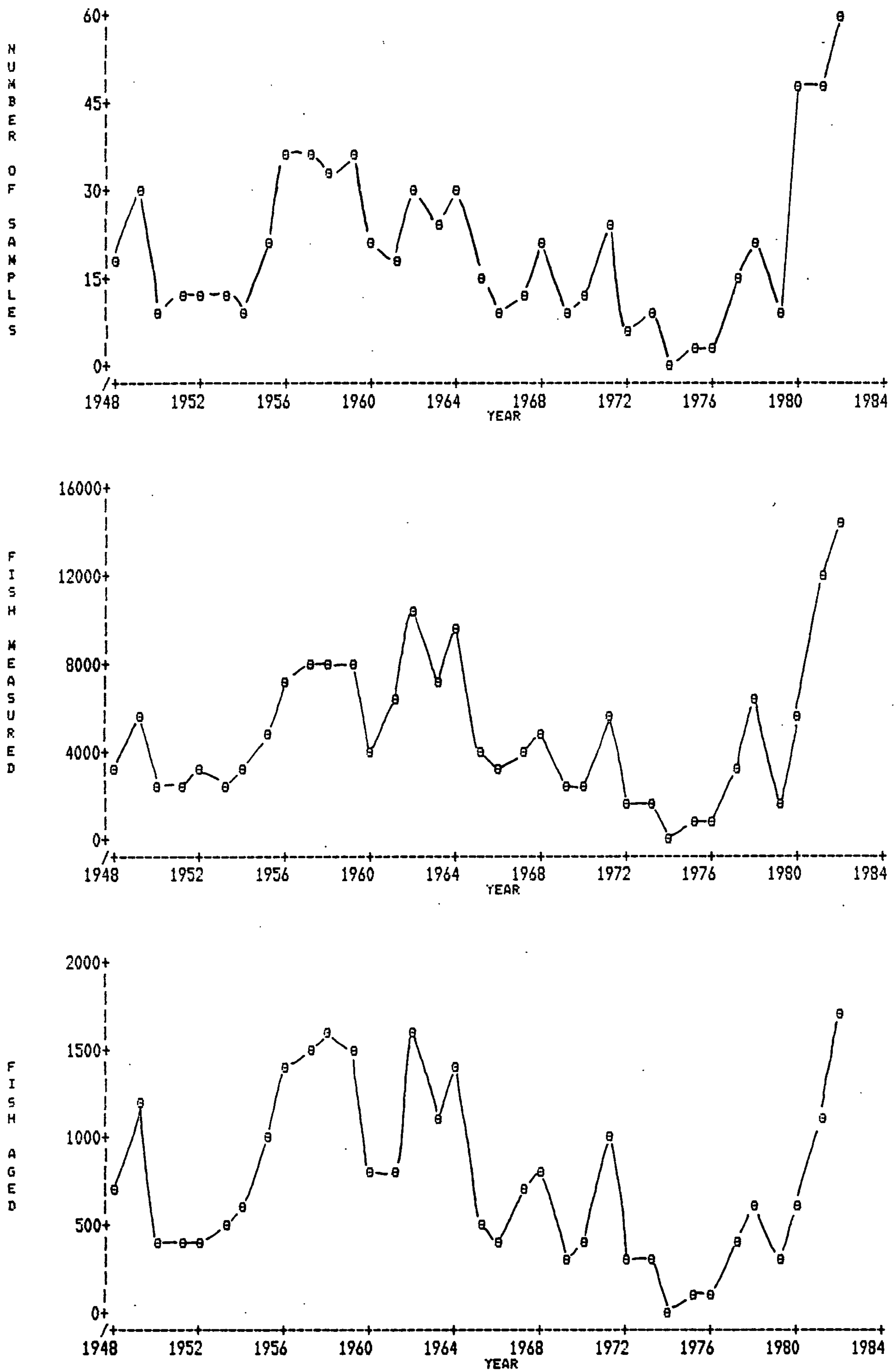
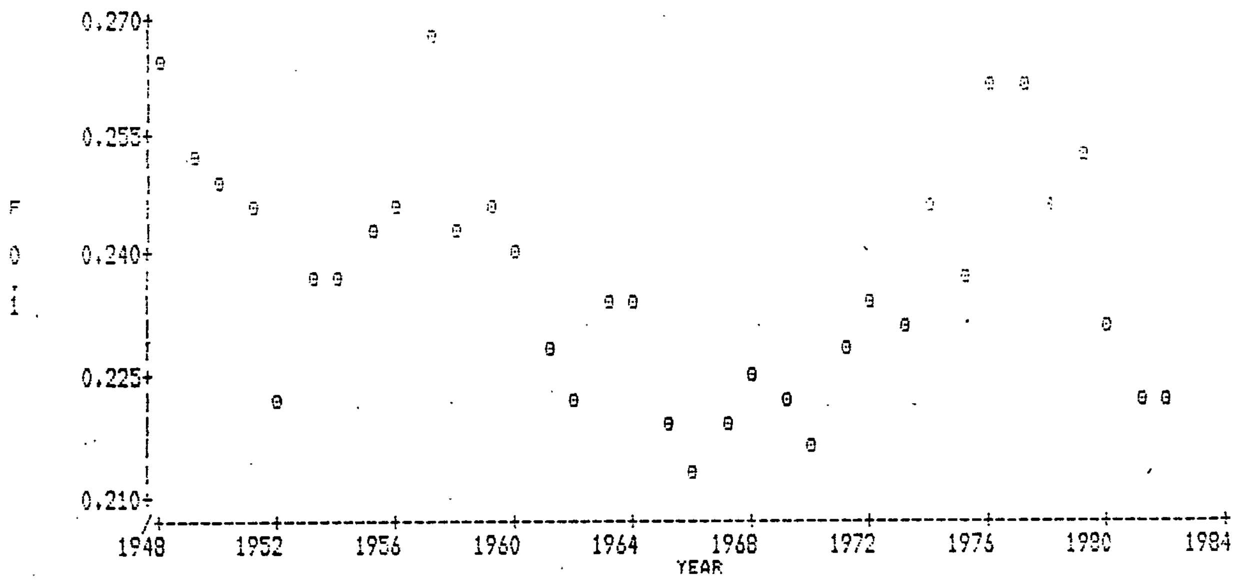


Figure 3. Trends in $F_{0.1}$ through time for 4VW haddock



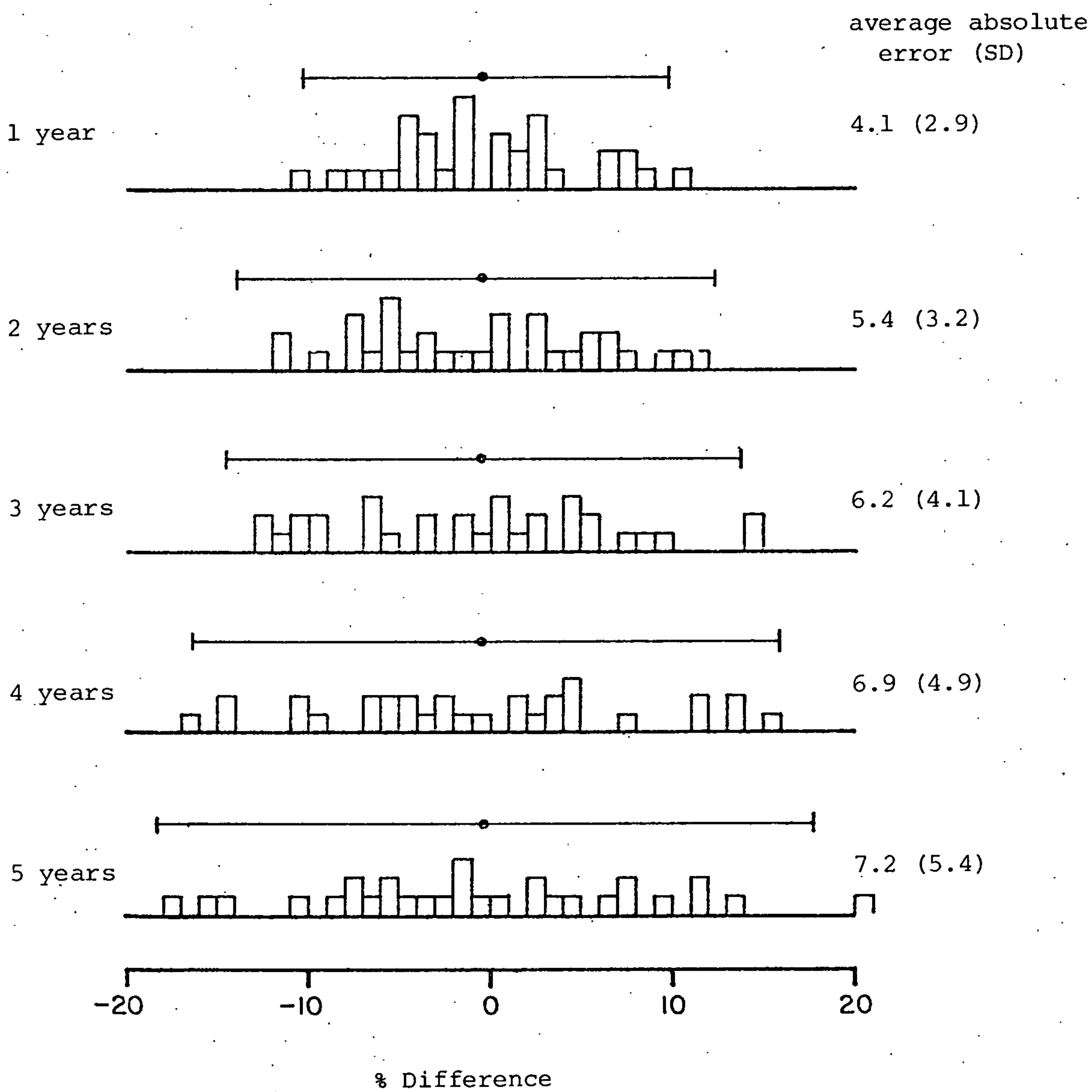
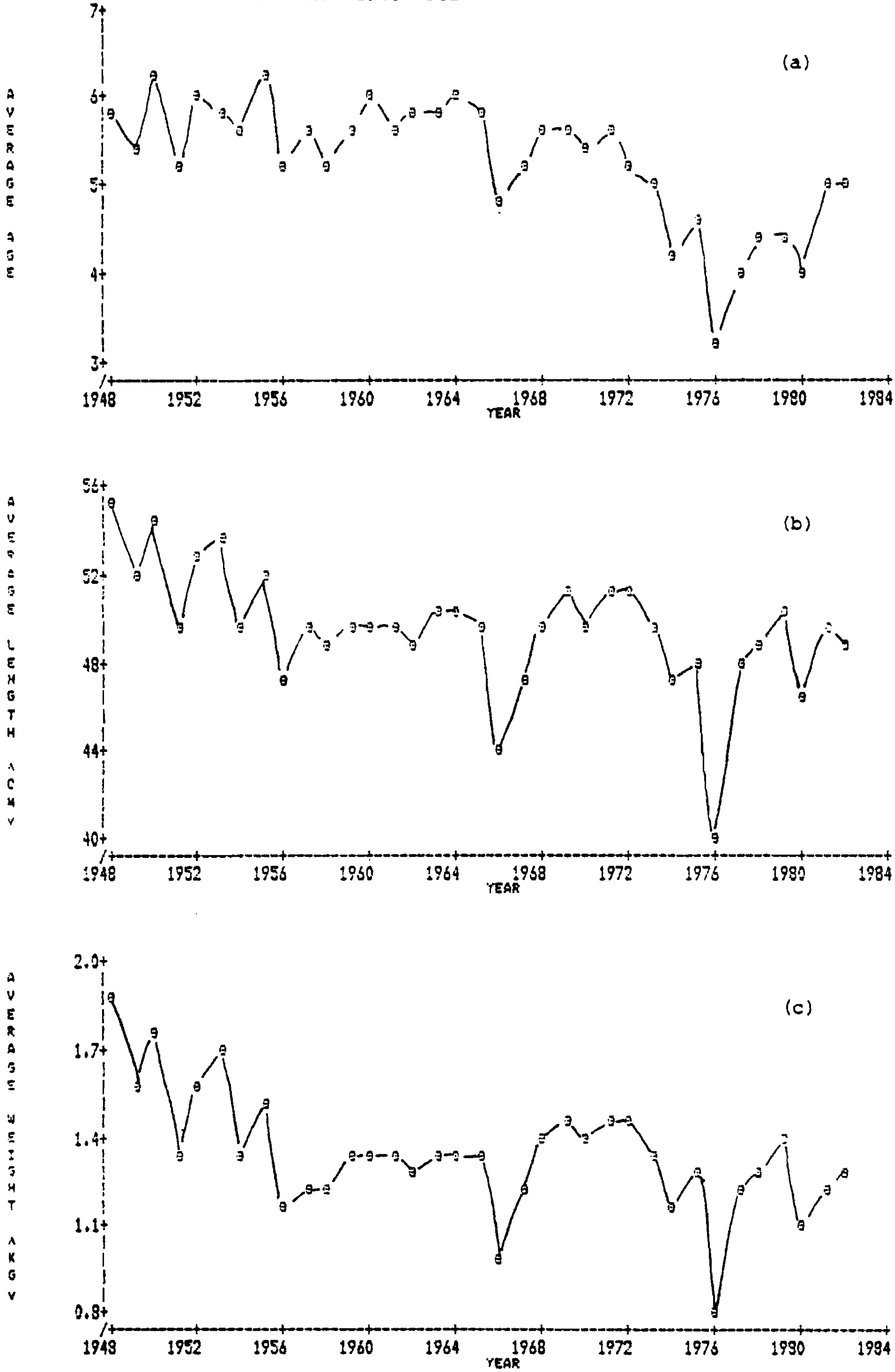


Figure 4. The percent difference between the observed and predicted $F_{0.1}$ for 4VW haddock 1948-1982.

Figure 5. Average age (a) weight (b) and length (c) of 4VW haddock in otter trawl catches 1948-1982



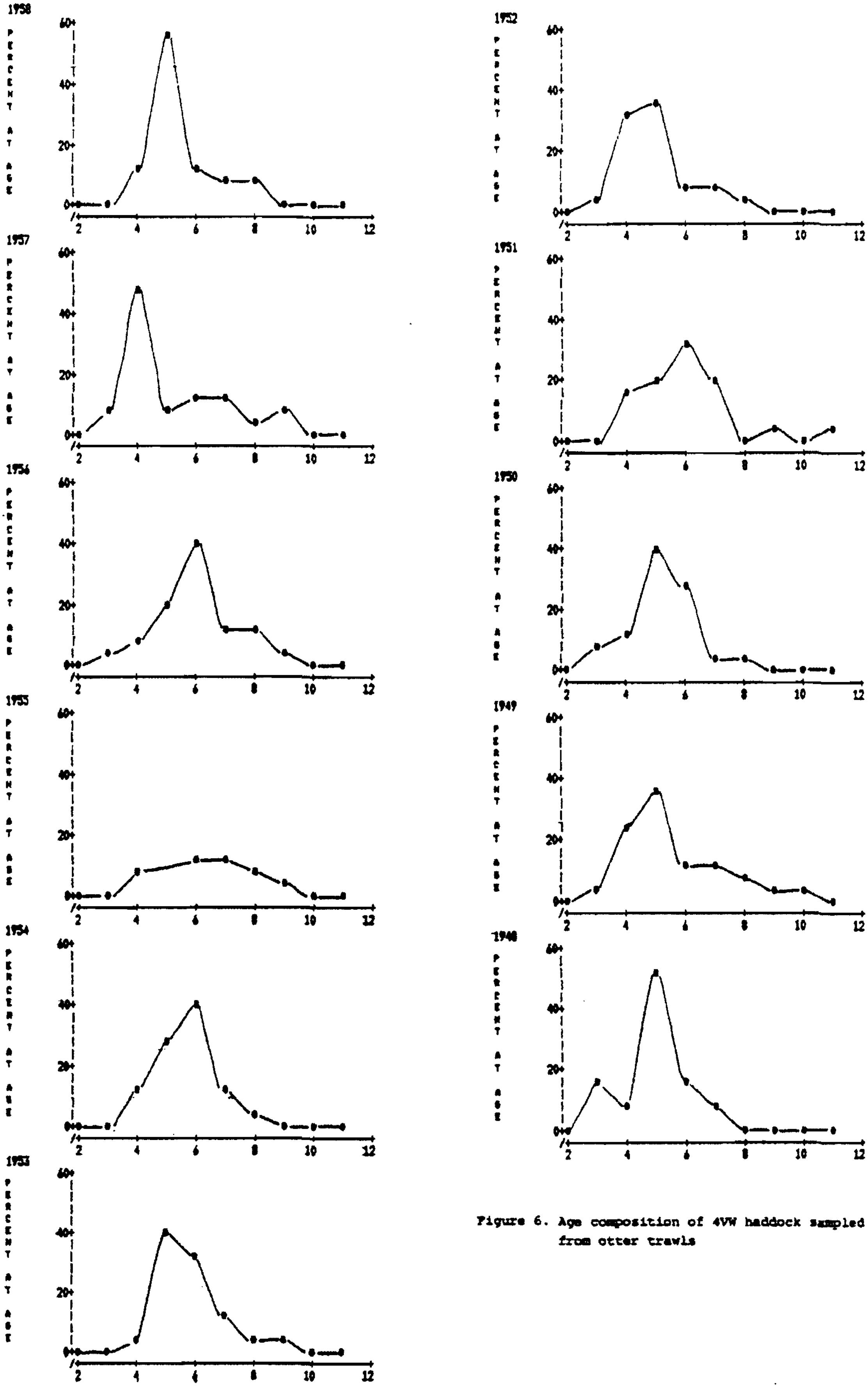


Figure 6. Age composition of 4VW haddock sampled from otter trawls

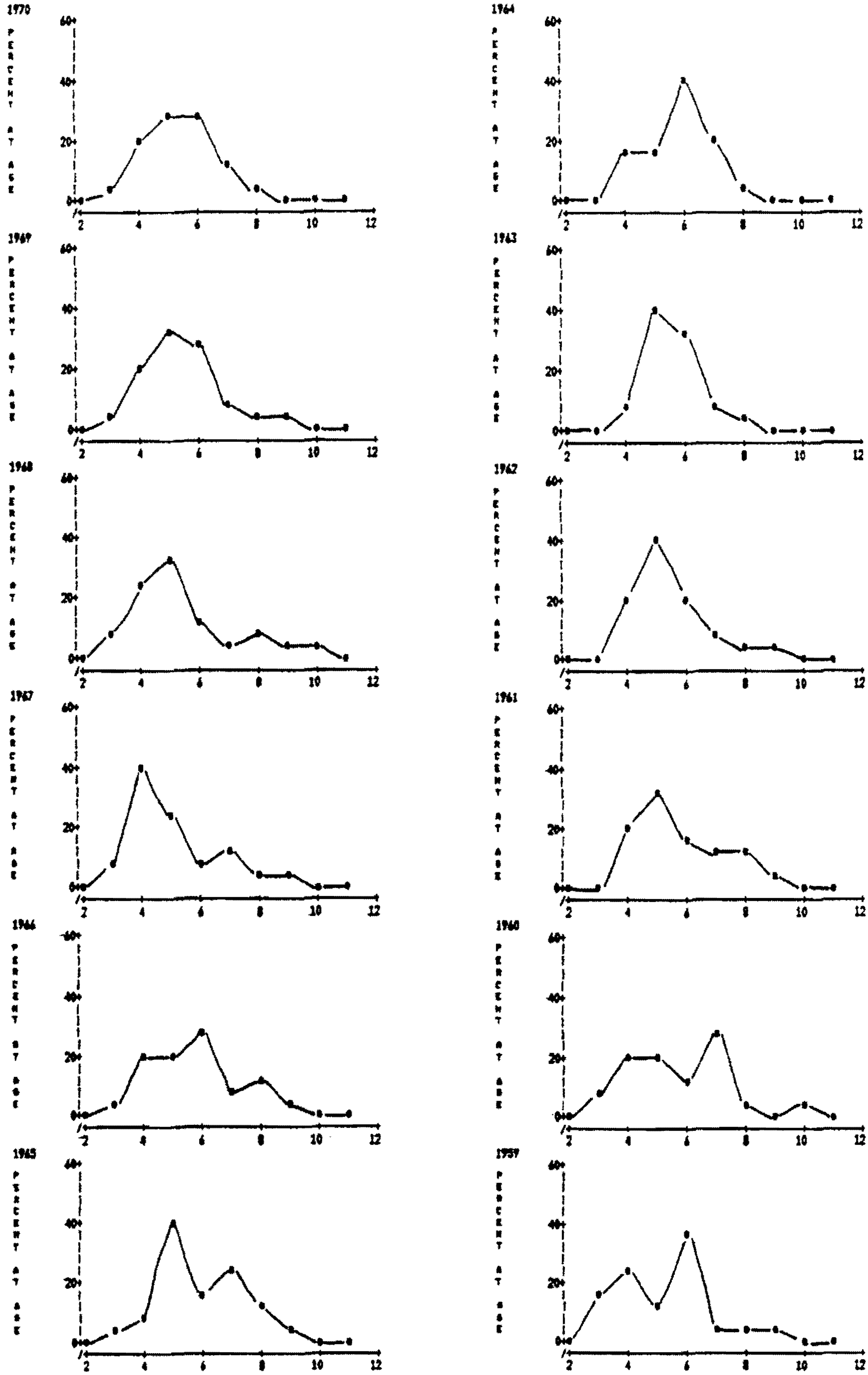


Figure 6 continued.

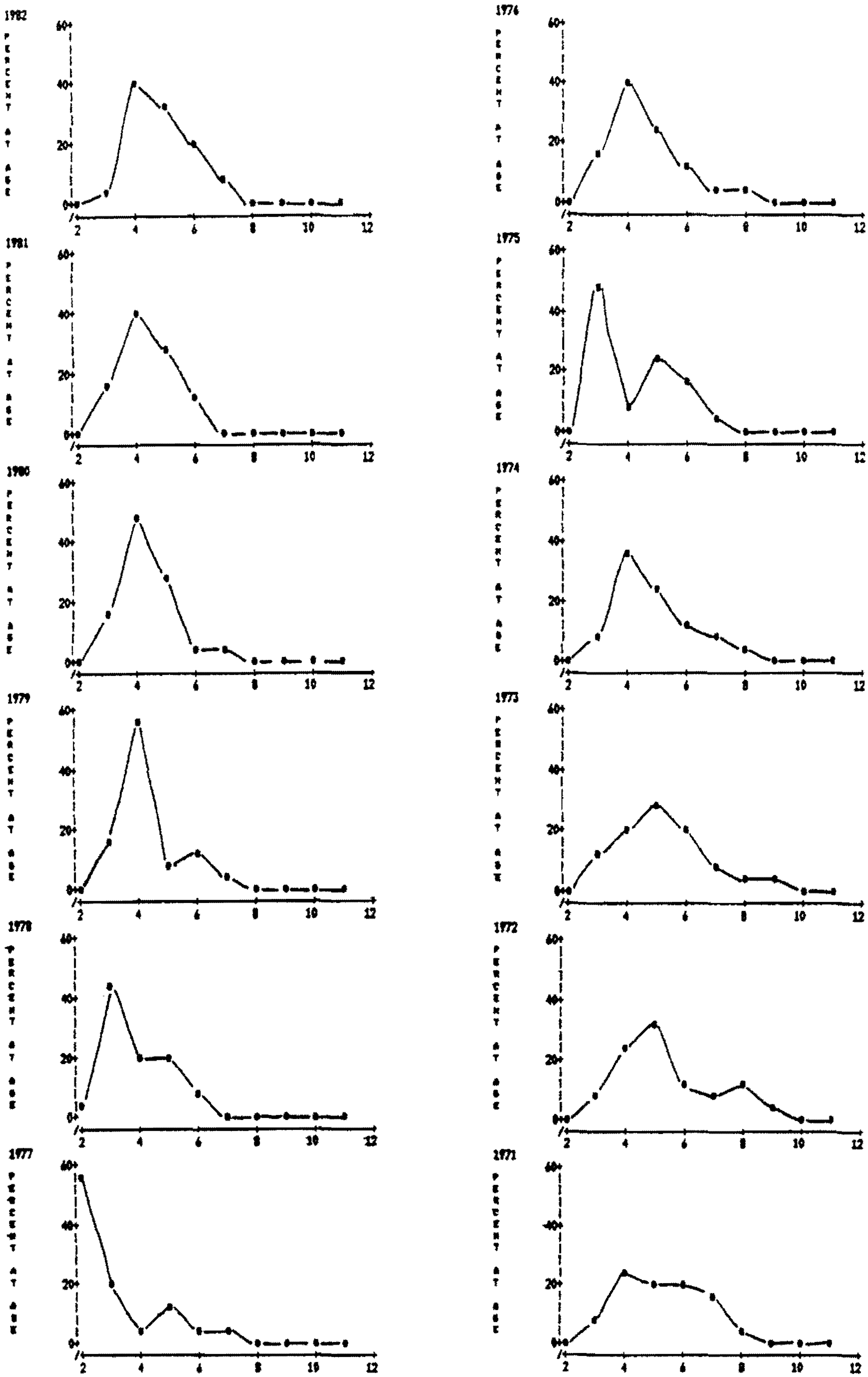


Figure 6 continued.

Appendix 1. Calculation details

The calculations were performed using the APL functions which appear below, running under the CDC APL Version 2 interpreter on a CDC Cyber 171 located at the Bedford Institute of Oceanography. The values for the global variables used in the analysis were:

EPS = 7.071×10^{-6}

K = 8

MAXF = 1

MISS = -1×10^{322}

TOL = 5×10^{-5}

```
∇ DESCRIBE;VERSION
  VERSION←'TTYPRWS,DESCRIBE,0'⍝ G ,WHITE ,83/2/6
  'MAIN FUNCTIONS:'
  '---- ---------'
  ''
  'RESULT← YEAR DOFOR WT'
  ''
  '  YEAR := YEAR IN WHICH THE MEAN WEIGHT AT AGE VECTOR WAS "WT",'
  '  WT   := WEIGHTS IN KG,'
  '  RESULT := VECTOR := YEAR, F0.1, FMAX'
  ''
  '  REQUIRED GLOBAL VARIABLES FOR "DOFOR" ARE:'
  ''
  '     EPS := INCREMENT FOR FINITE DIFFERENCE DERIVATIVES'
  '            (A VALUE OF AROUND 1E¯6 IS SUGGESTED),'
  '     K := NUMBER OF DIVISIONS USED BY "KSECT"'
  '          (SUGGESTED VALUE IS 8),'
  '     MAXF := UPPER BOUND ON THE FULLY RECRUITED FISHING MORTALITY'
  '             (A VALUE OF AROUND 1.0 IS SUGGESTED, BUT IN SOME'
  '              CASES, E.G., FLAT TOPPED YIELD CURVE, A LARGER'
  '              VALUE MAY BE REQUIRED),'
  '     MISS := VALUE TO BE USED IF FMAX OR F0.1 CANNOT BE DETERMINED
  '             (A NUMBER SUCH AS ¯1E320 IS SUGGESTED),
  '     TOL := TOLERANCE FOR THE ESTIMATION OF FMAX AND F0.1'
  '            (A VALUE OF 0.5E¯5 IS SUGGESTED),'
  ''
  '  NOTE:'
  '  -----'
  '  "DOFOR" CONTAINS SEVERAL PARAMETERS WHICH MUST BE DEFINED BEFORE'
  '  IT IS USED.  THESE ARE THE FIRST AND LAST AGE, THE VALUE OF THE'
  '  NATURAL MORTALITY PARAMETER, M, AND THE PARTIAL RECRUITMENT'
  '  VECTOR.  THEY ARE SET BY EDITING "DOFOR",'
  ''
  'SAVE RESULT'
  ''
  '     ADDS A RESULT VECTOR TO A GLOBAL ARRAY "STORE",'
  ''
  '     STORE := ARRAY WITH 4 COLUMNS:'
  '              YEAR, F0.1, FMAX, CYCLE'
  '              (CYCLE IS USED TO DISTINGUISH DUPLICATE ENTRIES FOR THE'
  '               SAME YEAR),'
  ''
  'SUGGESTED USAGE:'
  '--------- -----'
  ' ASSUME THAT "WT" CONTAINS WEIGHT DATA FOR THE YEAR 2001'
  ''
  'THE COMMAND: "SAVE 2001 DOFOR WT" WILL PERFORM THE CALCULATIONS'
  'AND SAVE THE RESULT IN THE GLOBAL ARRAY "STORE",'
  ''
  '                                                    ',VERSION
∇
```

```
∇ F←YLD∆FIND DATA;SLOPE;VERSION;AI
   ⍝ FIND F←F0.1,FMAX, YIELDWS,
   VERSION←'YIELDWS,YLD∆FIND,0'⍝ G, WHITE, 83/01/30.
  STRT:⍝ CHECK GLOBAL VARIABLES
   →(2≠⎕NC'EPS')/ERR1
   →(2≠⎕NC'MAXF')/ERR2
   →(2≠⎕NC'MISS')/ERR3
   →(2≠⎕NC'K')/ERR4
   →(2≠⎕NC'TOL')/ERR5
   AI←⎕AI
   F←2⍴MISS
   SLOPE←0.1×(+/,1 0↓DATA YPR 0,EPS)÷EPS ⍝ TO FIND F0.1
   F[1]←TOL KSECT 0,MAXF
   SLOPE←0 ⍝ TO FIND FMAX
   F[2]←TOL KSECT(0⌈F[1]),MAXF
   ⎕←PRTAI ⎕AI-AI
   ⎕←''
   →0,0↑⍞←'                                        ,VERSION
   ⍝============= ERROR RECOVERY ==================
  ERR1:EPS←'(0<X)∧X<1,E¯4'INPUT'FINITE DIFFERENCE STEP, EPS←'
   →STRT
  ERR2: MAXF←'(0<X)∧X<10'INPUT'MAXIMUM VALUE FOR FULLY RECRUITED F, MAXF←'
   →STRT
  ERR3: MISS←'0)X'INPUT'MISSING VALUE CODE, MISS←'
   →STRT
  ERR4:K←'3<X'INPUT'NUMBER OF SECTIONS, K←'
   →STRT
  ERR5:TOL←'(0<X)∧X<1E¯4'INPUT'TOLERANCE FOR ANSWERS, TOL←'
   →STRT
```

```
    ∇ RESULT←YEAR DOFOR WT;A;DATA;LEN;VERSION;F;M;PR;YRS
[1]   ⍝ DO YIELD PER RECRUIT CALCULATIONS FOR WEIGHT VECTOR WT, TTYPRWS,
[2]   VERSION←'TTYPRWS,DOFOR,0'⍝ G, WHITE, 83/02/06.
[3]   ''⍝ SET PROBLEM-SPECIFIC PARAMETERS A,M,PR,YRS
[4]   ⍝ VERSION ,0 PARAMETERS FOR THE EXAMPLE IN RIVARD FASTR 1091.
[5]   A←2 11 ⍝ FIRST AND LAST AGES
[6]   M←0.2 ⍝ NATURAL MORTALITY
[7]   PR←0.474 0.632 0.737 0.895 0.947 0.947 1 1 1 1 ⍝ PARTIAL RECRUITMENT
[8]   YRS←1948 1981 ⍝ FIRST AND LAST YEARS OF THE DATA SET
[9]   ⍝ BEGIN INITIALIZATIONS
[10]  LEN←1+-/A ⍝ NUMBER OF AGES (AND LENGTH OF WT)
[11]  'DOFOR; LEFT ARGUMENT'ERROR(YEAR≠⌈YEAR)∨(YRS[2]<YEAR)∨YEAR<YRS[1]
[12]  'DOFOR; RIGHT ARGUMENT'ERROR(LEN≠⍴WT)∨∨/WT≤0
[13]  DATA←(4,LEN)⍴M ⍝ DATA ARRAY, LAST ROW WILL BE NATURAL MORTALITY
[14]  DATA[1;]←¯1+A[1]+⍳LEN
[15]  DATA[2;]←WT
[16]  DATA[3;]←PR ⍝ PARTIAL RECRUITMENT
[17]  ⍝ CALCULATIONS
[18]  ' INPUT ARRAY "DATA" FOR YIELD CALCULATIONS;'
[19]  ''
[20]  10 4 ⍕ DATA
[21]  ''
[22]  RESULT←YEAR,F←YLDΔFIND DATA
[23]  ''⍝ OUTPUT
[24]  ' GLOBAL VARIABLES EPS, K, MAXF, MISS, TOL: ';EPS,K,MAXF,MISS,TOL
[25]  ' YEAR, F0.1, FMAX: ';10 0 10 4 10 4⍕RESULT
[26]  '                                                      ',VERSION
[27]  →0
[28]  ⍝ ORIGINALLY DESIGNED TO EXAMINE THE EFFECTS OF CHANGES IN GROWTH, AS
[29]  ⍝ REFLECTED IN CHANGES IN THE WEIGHT AT AGE, IN 4VW HADDOCK,
[30]  ⍝ REQUIRED GLOBAL VARIABLES ARE;
[31]  ⍝   EPS, K, MAXF, MISS, AND TOL (USED IN "YLDΔFIND"),
[32]  ⍝    SEE "DESCRIBE" FOR SUGGESTED VALUES.
    ∇

    ∇ SAVE RESULT;VERSION;INDEX;CYCLE;HITS
[1]   ⍝ SAVES RESULT IN THE ARRAY "STORE", TTYPRWS,
[2]   VERSION←'TTYPRWS,SAVE,0'⍝ G, WHITE, 83/02/06.
[3]   'SAVE; RIGHT ARGUMENT'ERROR 3≠⍴RESULT
[4]   ''⍝ TEST FOR PRESENCE OF STORE
[5]   →(2≠⎕NC'STORE')/NEW
[6]   INDEX←1↑RESULT
[7]   HITS←INDEX=STORE[;1]
[8]   CYCLE←1+⌈/¯1,STORE[HITS/⍳1↑⍴STORE;4]
[9]   'SAVE; ADDING TO EXISTING "STORE"                    ',VERSION
[10]  ' YEAR AND CYCLE; ';INDEX,CYCLE
[11]  STORE←STORE,RESULT,CYCLE
[12]  →0
[13] NEW:'SAVE; CREATING NEW GLOBAL VARIABLE "STORE"           ',VERSION
[14]  ' YEAR AND CYCLE; ';(1↑RESULT),0
[15]  STORE←1 4⍴RESULT,0
[16]  →0
[17]  ⍝ THE GLOBAL VARIABLE "STORE" HAS 4 COLUMNS;
[18]  ⍝   YEAR, F0.1, FMAX, CYCLE
[19]  ⍝
[20]  ⍝ EACH RESULT IS A VECTOR WITH ENTRIES;
[21]  ⍝   YEAR, F0.1, FMAX
    ∇

    ∇ YLD←DATA YPR FRF;C;F;R;Z

[1]   ⍝ YIELD-PER-RECRUIT FUNCTION, YIELDWS;
[2]   ⍝ VERSION←'YIELDWS,YPR,0' ⍝ G, WHITE, 83/01/30.
[3]   ⍝ YLD - ARRAY WITH ROWS;
[4]   ⍝       1; CATCH NUMBERS
[5]   ⍝       2; CATCH BIOMASS (KG)
[6]   ⍝ DATA - ARRAY WITH ROWS;
[7]   ⍝        1; AGES
[8]   ⍝        2; WEIGHT AT AGE (KG)
[9]   ⍝        3; PARTIAL RECRUITMENT VALUES
[10]  ⍝        4; NATURAL MORTALITY RATES
[11]  ⍝ FRF - FULLY RECRUITED FISHING MORTALITIES (VECTOR)
[12]  ⍝
[13]  F←FRF∘.×DATA[3;]
[14]  R←⍴F
[15]  Z←(R⍴DATA[4;])+F ⍝ TOTAL MORTALITY, ONE ROW FOR EACH VALUE IN "FRF"
[16]  ⍝ N←*-+\Z ⍝ STABLE AGE COMPOSITION FOR EACH VALUE OF "FRF"
[17]  YLD←+/C←(*-+\Z)×F×(¯1+*Z)÷Z ⍝ CATCH EQUATION
[18]  YLD←YLD,[0.5]+/C×R⍴DATA[2;]
    ∇
```