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Inquiry into ADAPT's performance

by

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Summary

ADAPT's performance is analysed with a data generator. Once a simulated population is defined, multiple sets of assessment input data are produced at random following some defined criterion. The ability of ADAPT to calculate the original fishing mortality and recruitment is tested in different formulations and various levels of error. Greenland halibut in NAFO Div 2J3*k*LMNO is then analyzed

Introduction

The use of a simulated data generator to analyze properties in both data and population models was considered by the ICES Working Group on Methods on Fish Stock Assessment (ICES 2002), and some specifications where provided for doing it. Those specifications are followed in this paper to analyze the capacity of several ADAPT (Gavaris 1988) formulations to accurately calculate original survivors abundance and fishing mortalities.

The technique of data generation allows producing multiple assessment input data from the same simulated population and so evaluating the goodness of fit with the original values, this is, the exact solution of abundance, fishing mortality and catches linked by the catch equations. Furthermore, replicate assessment input data from the same population allows to explore the effect of accuracy in catch at age data which otherwise need to be assumed as exact figured.

The main objective of this paper is to check two properties the ADAPT routine may have:
- Main population's parameters may be accurately calculated when assessment data have low dispersion from original values.
- Means of estimated main population's parameters may be close to original figures when assessment data have medium or high dispersion from original values.

An additional objective is to explore those properties in different ADAPT formulations.

Material and method

The following general conditions were used to define a simulated population, also referred as original data, which will constitute a case study:

Plus group or not: YES/NO
y1 yn – Years for catch (and abundance)
a1 an – Ages for catch (and abundance)
M – Natural mortality
$spPR_a$ – Partial recruitment at age *a* (values in the interval [0,1])
ns s1 sn – Number of survey indices and years (survey's ages equal catch's ages)
$spQ_{s,a}$ – Survey catchability for each survey *s* at age *a* (values in the interval [0, 1]).

Once original values of the simulated population are calculated, a set of assessment input data (catch in numbers and survey abundance indices at age) are produced using two additional parameters:

sdcc, sdsi – standard deviation for commercial catches and survey indices respectively.

Finally, ADAPT is applied to analyze each assessment input data set. The following diagram trays to explain the different variables involved. A "sp" is included in the symbols of some data to indicate *simulated population*; values for them are initially provided with the only criterion of they are possible figures:

	simulated population	assessment input data	ADAPT ADAPT results
partial recruitment	*spPR*		PR
survey catchability	*spQ*		Q
randomize const.	*sdcc, sdsi*		
fishing mortality	spF		F
abundance	spN		N
Catch in numbers	spCN	CN = spCN * ε	
survey indices		I = spN * spQ * ε	

The following steps were programmed:

a) <u>Define a simulated population</u>: matrices $spF_{a,y}$, $spN_{a,y}$, $spC_{a,y;\ a=a1,an;\ y=y1,yn}$

The basic criteria to prepare these three matrices are: first, that they must be linked by the catch equation, and second, that fishing mortality may not be precisely separable, but as close to it as desired and set in the program as explain in the following development.

a.1- fishing mortality: it is produced at age *a* year *y* by random normal distributed numbers:

$spF_{a,y} = N\ (\mu = spAF_y * spPR_a,\ s.d. = 0.05)$ limited to [0,10]

being

$spAF_y$ = Annual fishing mortality at year *y*

$spAF_y = 0.2 + 0.5 * e$ e = Equal [0,1]

a.2- abundance of each cohort at its first age (inside the margins of the simulated population's case) is produced as follows:

If first cohort's age equal the initial age considered in the case (a1):

$spN_{a1,y}$ = Equal [0,10000] - random equally distributed numbers in the said interval

If first cohort's year equal the initial year considered in the case (y1):

$spN_{a,y1} = e * 0.6^{a-1}$ e = Equal [0,10000]

These magnitudes of recruitment are irrelevant.

a.3- $spN_{a,y}$ for every age *a* and year *y* is calculated using the catch equation.

$$spN_{a+1,\ y+1} = spN_{a,y} / \exp\ (spF_{a,y} + M)$$

a.4- $spC_{a,y}$ = catch in number at age *a* and year *y* is also calculated with the catch equation.

$$spC_{a,y} = (spN_{a,y} - spN_{a+1,\ y+1}) * spF_{a,y} / (spF_{a,y} + M)$$

If last age is a plus group these two previous equations become:

$$spN_{an,y+1} = spN_{an,y} / \exp\ (spF_{an,y} + M) + spN_{an-1,y} / \exp\ (spF_{an-1,y} + M)$$

$$spC_{an-1,y} = spN_{an-1,y} * (1 - spN_{an-1,y} / \exp\ (spF_{an-1,y} + M)) * spF_{an-1,y} / (spF_{an-1,y} + M)$$

$$spC_{an,y} = spN_{an,y} * (1 - spN_{an,y} / \exp\ (spF_{an,y} + M)) * spF_{an,y} / (spF_{an,y} + M)$$

b) Obtain one assessment input data set: matrices $C_{a,y,\ a=a1,an;\ y=y1,yn}$, $I_{s,a,y;\ s=1,ns,\ a=a1,an;\ y=y1,yn}$

b.1- Commercial catches at age ($C_{a,y}$)

$$C_{a,y} = spC_{a,y} * e \qquad e=\log N\ (\mu = 1,\ s.d. = sdcc) \qquad e\in[0, 2]$$

b.2- Survey indices ($I_{s,a,y;\ s=1,ns}$)

$$I_{s,a,y} = spN_{a,y} * spQ_{s,a} * e \qquad e=\log N\ (\mu = 1,\ s.d. = sdsi) \qquad e\in[0.5, 1.5]$$

c) Apply ADAPT on $C_{a,y}$, $I_{s,a,y}$ and M to calculate $N_{a,y}$, $F_{a,y}$, PR_a and $Q_{s,a}$.

$$SS = \sum_{s=1,ns;\ a:=a1,an;\ y=y1,yn} \log\ [I_{say} / (N_{ay} * Q_{sa})]^2$$

d) Repeat b) and c) 10 to 1000 times to produce distribution curves for some ADAPT's results, such as survivors at age, F at age, PR at age.

ADAPT can by formulated in several different ways and this is the reason for several initial option of a case study. They are:

1) How many parameters are calculated

Options:
- survivors of all cohorts occurring in the last year
- survivors of all cohorts occurring in the last year excluding the oldest age
- survivors of all cohorts (both occurring in the last year or elsewhere)

2) What objective function is used

Options:
- sum of squares of [log (I / (Q*N))] (default option)
- sum of squares of [(I – Q*N) / V(N)]

3) How survey's catchability at age (Q_{sa}) is calculated

Options:
- geometric mean with epoch consideration:

$$Q_{s,a} = [\prod_{y=1,ny}(I_{s,a,y} / N_{a,y})]^{1/ny} \qquad \text{(default option)}$$

or

$$Q_{sa} = EXP\ (\text{mean of } \log\ (I_{say} / N_{ay})$$

a log-normal distribution is assumed

- logaritmic: $Q_{sa} = EXP\ (\text{mean of } \log\ (I_{say} / N_{ay}))$
  or: $Q_{s,a} = [\prod_{y=1,ny}(I_{s,a,y} / N_{a,y})]^{1/ny}$
- adjusted with 10% mean values:

$$Q_{sa} = \sum_y [(I_{say} + mI) / \sum_y (N_{ay}+ mN)]$$

$$mI = \text{mean } (I_{say})/10\ ,\ \ mN = \text{mean } (N_{ay})/10$$

- mean of [I/N]

Survey's epoch is always taken into account, so survey's indices (N_{ay}) are transformed to:

$$N_{ay} * EXP\ (-Z * \text{mean epoch of the survey})$$

Survey's catchabilities at age could be included as parameters, but it could be redundant in some cases and, in particular, when the used objective function is the sum of squares of logarithms of quotients (default option) and catchability is calculated as a geometric mean (default option).

4) How partial recruitment is calculated

Options:
- arithmetic mean of Fs (default option)
- arithmetic means of normalized F
- quotients between n(t) and n(t+1)

5) How fishing mortality of the last age is calculated

When intermediate cohorts, those without presence in the last year, are not initialized with a parameter (survivor's abundance), fishing mortality at last age is used to initialize the cohort; it is calculate as a mean of fishing mortalities for younger ages in the same year.

Options: - Heincke method (default option)
- F powered by C
- $F_{year} \times PR$

The first two alternatives include an option on how many younger ages are used

6) Pope's approximation or an exact solution is used. (default option is "exact solution")

7) Plus-group is or not considered. (default option is "not considered")

No references are provided on how biomass or spawning stock biomass is calculated because abundances and catch at age values were only considered in this analysis.

Simulated population for the analysis were prepared according to definitions contained in an ASCII file (Table 1):

Years: 1975-2007
Ages: 1-14
Natural mortality 0.2
Partial recruitment: 0 0 0 0.1 0.2 0.5 1 1 0.75 0.5 0.5 0.5 0.5 0.5
2 survey indices for years: 1990-2007
survey catchability 1: 0.02 0.02 0.03 0.04 0.1 0.2 0.2 0.2 0.1 0.05 0.02 0.02 0.02 0.02
survey catchability 2: 0.3 0.3 0.25 0.25 0.2 0.15 0.15 0.1 0.05 0.02 0.01 0.01 0.01 0.01

Settings of ADAPT routine are also specified in the same ASCII file containing simulated population's definitions. But some characteristics of this analysis were fixed, irrespective of that file content:

- Analyses were repeated in three different ways: one with each options of how many parameters are calculated: 10, 9 or 27.

- Analyses were repeated with four different deviation levels for *sdcc* and *sdsi*: 0.001, 0.01, 0.1 and 0.25. First two levels produce assessment data being very close to the simulated population figures. Last two options try to reproduce more realistic situation.

- Every possible combinations of the above three and four type of analysis were repeated for 10 to 1000 times, according to the following general scheme:

10 parameters sdcc = sdsi = 0.001 10 runs	10 parameters sdcc = sdsi = 0.01 100 runs	10 parameters sdcc = sdsi = 0.1 500 runs	10 parameters sdcc = sdsi = 0.25 1000 runs
9 parameters sdcc = sdsi = 0.001 10 runs	9 parameters sdcc = sdsi = 0.01 100 runs	9 parameters sdcc = sdsi = 0.1 500 runs	9 parameters sdcc = sdsi = 0.25 1000 runs
27 parameters sdcc = sdsi = 0.001 10 runs	27 parameters sdcc = sdsi = 0.01 100 runs	27 parameters sdcc = sdsi = 0.1 500 runs	27 parameters sdcc = sdsi = 0.25 1000 runs

Every run implied in the above scheme is based on a set of assessment input data derived from a unique case study, that is, the same simulated population. Results of all these runs will appear in the same figure: all analysis of each figure will be based on the same simulated population.

Results:

Results are presented in figures 1 to 6 and were prepared with specific ADAPT settings:

Figure 1 and 2: default options
Figure 3: "F last age" = arithmetic mean
Figure 4: "option catchability" = Q=EXP (mean log(Indices/N)) + epoch (NOAA)
Figure 5: "option catchability" = geometric mean + 10% of mean values
Figure 6: "ages for F-last-age" = 5

Each figure contains 12 graphics according to the scheme already described. Each graphic represents the distribution of ADAPT's results, and contains one curve for each calculated parameter. The parameters used are survivors of the every cohort in the last year in the options of 10 or 9 parameters (ages 5 to 14 or 5 to 13 respectively), or survivors for all cohorts with presence in survey indices in the option with 27 parameters. The scale of each distribution curve is transformed for mean to coincide with 1 at abscises axis for easier comparison; maximum deviation is set at 3.

Each figure corresponds to one case study, as it was already said, but different figures came from different simulated populations. Figures 1 and 2 were based on the same ADAPT settings but different simulation populations to illustrate that the observed overestimation or underestimation of several parameters is not a characteristic of the ADAPT formulation (settings) but a consequence of some peculiarities of input data. This is well observed with the 10 or 9 parameters options (rows 1 and 2) at any level of variability in assessment data (columns). Best results are obtaining with the 27 parameters option (row 3), however they show some underestimation to low levels of variability in assessment data (columns 1 and 2) and high dispersion and overestimation for the highest level of variability (column 4). In conclusion, best behaviour is observed for the 27 parameters option at intermediate levels of variability in assessment data (row 3, column 3).

Figure 3 uses an alternative method to calculate F at last age, so it does not affect the 27 parameters option (row 3), which is similar to same option (row 3) in Figures 1 and 2. The effect on the options with 10 or 9 parameters (rows 1 and 2) is unappreciable at low variability in assessment data (columns 1 and 2) when compared with Figures 1 and 2, but the effect on medium-high variability (columns 3 and 4), if any, could be some reduction in dispersion.

Figures 4 and 5 use alternative methods to calculate catchabilities at age, but their behaviour are quite similar to the default option (Figures 1 and 2). Figure 4 shows some overestimation and Figure 5 some underestimation in the options with 10 or 9 parameters (rows 1 and 2) that could be attributed to the assessment data, as in Figures 1 and 2. No other differences are observed in comparison to the default options, but Figure 5 indicates behaviour worsening for the 27 parameters option (row 3).

Figure 6 uses 5 last ages (ages 8-12) to calculate F at the last age instead of 3 (ages 10-12) of the default option (Figures 1 and 2). Ages 10 to 12 have the same partial recruitment (0.5) as age 13, the last true age, so the use of 3 years to calculate F at age 13 is the most appropriate option. But ages 8 and 9 have a different partial recruitment (1.0 and 0.75 respectively), so when F al age 13 is calculated from them its accuracy will be worst. The effect observed in options with 10 and 9 parameters (rows 1 and 2) is a reduction of variability in distribution of estimates but with generalized underestimation. Again, option with 27 parameters (row 3) is unaffected.

In conclusion, best agreement between results and the defined case was achieved when every cohort's survivors are used as parameter (rows 3), even its behaviour get worse with high variability in assessment data (column 4); that worsening implies overestimation of most survivors, and it increases from youngest ages in last year to the oldest ages of former years. That is to say, the overestimation problem increases from present to past and from youngest ages to the oldest ones; in relative terms, this effect also means underestimation of abundance of last year cohorts in comparison to previous ones. Light underestimation is also observed at the most hypothetical case of very low variability in assessment data (columns 1 and 2).

Greenland halibut in NAFO Div. 2+3JKLMNO is analyze with assessment data from 2008 (Healey and Mahé 2008).

The option with a parameter for survivors of every cohort, the 27 parameter option in the simulated exercise, was selected to analyze Greenland halibut data (Table 2, Figures 7 and 8). Retrospective results are presented in Figure 9.

Discussion:

An advantage of ADAPT over other VPA methods is the scarce number of assumptions needed and, in particular, that different options are not data-dependent but are different formulation of the fit method.

There are many sources of variability and skew in both catch at age data and survey results, and it would be too tedious to include in a model all such possible sources. Random variability used to derive assessment data is justified when only the variability due to sampling is considered in defining the simulated population. However systematic skew are common in the real world. On the other hand, sources of error are so numerous in any sampling that results could be considered normally distributed with high probability. However, differences between normal distribution and log normal distribution is low at small standard deviation levels, so the discussion is mainly academics but without a clear effect on these results.

Results with Greenland halibut NAFO Div 3+ indicate a decrease in fishing mortality in recent years that is consistent with the known reduction of fishing effort. The increase of biomass is also consistent with survey results. However the retrospective pattern indicates instability of the solution (Figure 9), so it needs further review.

References:

Gavaris, S.– 1988. An adaptive framework for the estimation of population size. *CAFSAC Res. Doc.* 88/29.

Healey, B.P. and J.-C. Mahé – 2008. An Assessment of Greenland Halibut *(Reinhardtius hippoglossoides)* in NAFO Subarea 2 and Divisions 3KLMNO. *NAFO SCR Doc.* 08/48.

ICES – 2002. Report of the Working Group on Methods on Fish Stock Assessment 2001. *ICES CM* 2002/D:01.

Table 1 – ASCII file with conditions and settings for both simulation of population and ADAPT

```
YES   "plus group"
                                 Simulation conditions
"title" ADAPT test with 2 surveys
1975 2007 "years"
1 14      "age1 ageN"
0.2   "natural mortality"
0 0 0 0.1 0.2 0.5 1 1 0.75 0.5 0.5 0.5 0.5 0.5  "partial R"
2 1990 2007   "survey indices": number, year1, yearN
0.02 0.02 0.03 0.04 0.1 0.2 0.2 0.2 0.1 0.05 0.02 0.02 0.02 0.02
"survey catchability" 1
0.3 0.3 0.25 0.25 0.2 0.15 0.15 0.1 0.05 0.02 0.01 0.01 0.01 0.01
"survey catchability" 2
0.01 "sdcc"   ! 0.25
0.01 "sdsi"   ! 0.1
3 10 "series times"

                                 ADAPT options
3   "parameters" 1=survivors for all cohort in last year
                 2=survivors for all cohort last year except oldest
age
                 3=survivors for all cohorts
                 4=(1) + Qs
                 5=(2) + Qs
                 6=(3) + Qs
1   "option SS"     SS=Sum(z)^2    1: z=ln[I/(N*Q)]
                                   2: z=(I-N*Q)*w     w=1/var(N)
                                          (Catchability option 4)
1   "option catchability" 1= geometric mean
                          2= NOAA: Q=EXP (mean log(Indice/N)) + epoch
                          3= (1) + 10% of mean values
                          4= mean(I/N)
1   "partial recruitment" 1= arithmetic means of F
                          2= arithmetic means of normalized F
                          3= quotients between n(t) and n(t+1)
1   "F last age" 1: Heincke
                 2: F powered by C
                 3: Fyear * PR       (do not work)
3   "ages for F-last-age"
NO  "Pope"
YES "+group removed"

5   "age B plus"
NO  "List data"
YES  "Retrospective"
NO  "Repetition"

words between square brackets are "key words"
```

Table 2 – Greenland halibut results

```
Program : ADAPT.FOR (27)
                                            Date: 12  6 2009   time:11.33
G. halibut SA2+3KLMNO Junio 2008

Data characteristics:
Ages   =     1   14
Years  =  1975 2007
Last age plus-group

RESULTS
number of surveys used    =           3
survey's epoch taken into account
number of data for tuning =         397

ADAPT options:
Plus-group not considered
Number of parameters      =          21
parameters = survivors all cohorts
SS = SS=Sum(z)^2    z=ln[I/(N*Q)]
Catchability = geometric mean
PR = aritmetic mean of F
Catch equation exact solution
Biomass plus  =           5 +


results
parameters = survivors all cohorts

  1:   N- 5 2008        25791.946054
  2:   N- 6 2008        38952.009933
  3:   N- 7 2008        35197.897328
  4:   N- 8 2008        17221.031559
  5:   N- 9 2008         8103.806173
  6:   N-10 2008         2105.286506
  7:   N-11 2008         1116.393407
  8:   N-12 2008          711.638969
  9:   N-13 2008          660.335527
 10:   N-14 2008          306.744971
 11:   N-14 2007          196.540762
 12:   N-14 2006          115.710855
 13:   N-14 2005           67.942734
 14:   N-14 2004           24.751674
 15:   N-14 2003           44.810274
 16:   N-14 2002           94.526645
 17:   N-14 2001            0.826536
 18:   N-14 2000          245.748133
 19:   N-14 1999          258.016999
 20:   N-14 1998          210.951308
 21:   N-14 1997          237.566688
```

Abundances

G. halibut SA2+3KLMNO: abundance

	1	2	3	4	5	6	7	8	9	10	11	12	13
1975	103533.	121208.	105198.	64527.	51349.	31156.	22484.	14135.	9461.	4058.	1508.	415.	721.
1976	107145.	84765.	99236.	86129.	52831.	41740.	22966.	13242.	7131.	4204.	1813.	608.	219.
1977	103322.	87723.	69400.	81248.	70517.	43239.	33623.	15893.	6000.	2481.	1477.	744.	265.
1978	82191.	84593.	71821.	56820.	66520.	57252.	30884.	17844.	6452.	2295.	1125.	1011.	492.
1979	96898.	67293.	69259.	58802.	46520.	51771.	39295.	17234.	7835.	2723.	604.	281.	499.
1980	124495.	79333.	55094.	56704.	48143.	35934.	34530.	20672.	8612.	5362.	1796.	238.	97.
1981	127588.	101928.	64953.	45108.	46426.	39228.	27538.	20052.	8284.	2264.	1012.	570.	81.
1982	126580.	104460.	83452.	53179.	36931.	37231.	28046.	13760.	6235.	2944.	1057.	599.	339.
1983	142969.	103635.	85525.	68324.	43539.	29994.	28408.	17281.	6112.	1955.	913.	335.	261.
1984	150159.	117053.	84849.	70022.	55939.	35014.	21351.	14475.	7432.	2949.	981.	560.	206.
1985	164278.	122940.	95835.	69469.	57329.	44985.	26570.	12233.	5009.	2448.	1289.	439.	330.
1986	183949.	134500.	100655.	78463.	56876.	45147.	32046.	16437.	6873.	2862.	1543.	912.	270.
1987	153384.	150605.	110119.	82409.	64240.	46313.	34942.	20469.	8890.	4306.	1919.	1044.	621.
1988	124436.	125580.	123305.	90158.	67471.	52472.	36201.	18737.	8773.	4736.	2758.	1226.	602.
1989	110207.	101880.	102816.	100954.	73815.	54973.	40085.	22324.	11403.	6023.	3458.	2077.	909.
1990	105652.	90230.	83412.	84179.	82654.	60271.	43214.	26088.	14433.	8001.	4240.	2437.	1460.
1991	92673.	86500.	73874.	68292.	68834.	66676.	43255.	24042.	14576.	8161.	4137.	2391.	1202.
1992	69806.	75874.	70821.	60483.	55714.	53773.	47599.	23613.	10039.	5560.	3358.	1721.	873.
1993	83330.	57152.	62121.	57983.	48558.	41844.	34201.	20523.	8456.	4347.	2971.	1841.	750.
1994	141897.	68225.	46792.	50860.	46560.	31146.	19998.	12214.	6211.	2792.	1918.	1488.	649.
1995	172155.	116175.	55858.	38310.	36777.	23336.	11402.	6460.	4003.	2337.	1298.	845.	839.
1996	152763.	140949.	95116.	45733.	31074.	28890.	16994.	6461.	3379.	2216.	1428.	753.	447.
1997	124210.	125072.	115399.	77875.	37271.	23944.	18976.	8195.	3572.	1909.	1361.	778.	408.
1998	110064.	101695.	102400.	94481.	63456.	28798.	15851.	8785.	3832.	1903.	1019.	737.	416.
1999	115014.	90112.	83261.	83838.	76856.	48727.	18712.	7794.	3926.	1852.	1072.	497.	459.
2000	138755.	94166.	73778.	68168.	68373.	60984.	34825.	7630.	2997.	1731.	958.	570.	135.
2001	138275.	113603.	77096.	60404.	55566.	54147.	38611.	9716.	3298.	1581.	943.	455.	285.
2002	133697.	113210.	93010.	63121.	49050.	43473.	33396.	11944.	3364.	1794.	851.	380.	191.
2003	107716.	109462.	92689.	76151.	51247.	38658.	29075.	11681.	3899.	1640.	879.	375.	112.
2004	57578.	88190.	89620.	75887.	61192.	37907.	22023.	8903.	3880.	1749.	880.	459.	178.
2005	0.	47141.	72204.	73375.	61321.	46435.	23630.	8622.	3605.	2005.	957.	461.	211.
2006	0.	0.	38596.	59116.	59592.	48714.	32612.	10129.	3491.	1689.	1242.	565.	275.
2007	0.	0.	0.	31599.	48205.	47102.	34072.	15825.	3919.	1882.	1048.	895.	420.
2008	0.	0.	0.	0.	25792.	38952.	35198.	17221.	8104.	2105.	1116.	712.	660.

Fishing mortality

G. halibut SA2+3KLMNO: mortalidad pesca

	1	2	3	4	5	6	7	8	9	10	11	12	13
1975	0.000	0.000	0.000	0.000	0.007	0.105	0.329	0.484	0.611	0.606	0.709	0.441	0.550
1976	0.000	0.000	0.000	0.000	0.000	0.016	0.168	0.592	0.856	0.846	0.691	0.629	0.701
1977	0.000	0.000	0.000	0.000	0.008	0.137	0.434	0.701	0.761	0.591	0.179	0.213	0.649
1978	0.000	0.000	0.000	0.000	0.051	0.176	0.383	0.623	0.663	1.135	1.189	0.506	0.678
1979	0.000	0.000	0.000	0.000	0.058	0.205	0.442	0.494	0.179	0.216	0.730	0.861	0.377
1980	0.000	0.000	0.000	0.000	0.005	0.066	0.343	0.715	1.136	1.467	0.948	0.877	0.900
1981	0.000	0.000	0.000	0.000	0.021	0.136	0.494	0.968	0.834	0.562	0.325	0.320	0.858
1982	0.000	0.000	0.000	0.000	0.008	0.070	0.284	0.611	0.960	0.971	0.948	0.629	0.743
1983	0.000	0.000	0.000	0.000	0.018	0.140	0.474	0.644	0.529	0.490	0.289	0.286	0.585
1984	0.000	0.000	0.000	0.000	0.018	0.076	0.357	0.861	0.911	0.628	0.604	0.329	0.820
1985	0.000	0.000	0.000	0.000	0.039	0.139	0.280	0.376	0.360	0.261	0.146	0.285	0.342
1986	0.000	0.000	0.000	0.000	0.005	0.056	0.248	0.415	0.268	0.200	0.191	0.185	0.334
1987	0.000	0.000	0.000	0.000	0.002	0.046	0.423	0.647	0.430	0.245	0.248	0.350	0.505
1988	0.000	0.000	0.000	0.000	0.005	0.069	0.283	0.297	0.176	0.114	0.084	0.099	0.217
1989	0.000	0.000	0.000	0.000	0.003	0.041	0.230	0.236	0.154	0.151	0.150	0.153	0.193
1990	0.000	0.000	0.000	0.001	0.015	0.132	0.386	0.382	0.370	0.460	0.373	0.506	0.394
1991	0.000	0.000	0.000	0.004	0.047	0.137	0.405	0.673	0.764	0.688	0.677	0.807	0.706
1992	0.000	0.000	0.000	0.020	0.086	0.253	0.641	0.827	0.637	0.426	0.401	0.631	0.680
1993	0.000	0.000	0.000	0.019	0.244	0.538	0.830	0.995	0.908	0.619	0.492	0.843	0.872
1994	0.000	0.000	0.000	0.124	0.491	0.805	0.930	0.916	0.777	0.565	0.620	0.373	0.771
1995	0.000	0.000	0.000	0.009	0.041	0.117	0.368	0.448	0.391	0.293	0.345	0.437	0.397
1996	0.000	0.000	0.000	0.005	0.061	0.220	0.529	0.393	0.371	0.287	0.407	0.414	0.432
1997	0.000	0.000	0.000	0.005	0.058	0.212	0.570	0.560	0.430	0.428	0.413	0.425	0.459
1998	0.000	0.000	0.000	0.006	0.064	0.231	0.510	0.606	0.527	0.374	0.519	0.274	0.278
1999	0.000	0.000	0.000	0.004	0.031	0.136	0.697	0.756	0.619	0.459	0.431	1.102	0.425
2000	0.000	0.000	0.000	0.004	0.033	0.257	1.077	0.639	0.439	0.407	0.545	0.494	4.896
2001	0.000	0.000	0.000	0.008	0.045	0.283	0.973	0.861	0.409	0.420	0.708	0.668	0.904
2002	0.000	0.000	0.000	0.008	0.038	0.202	0.850	0.919	0.518	0.514	0.620	1.019	1.250
2003	0.000	0.000	0.000	0.019	0.102	0.363	0.984	0.902	0.602	0.423	0.449	0.545	1.313
2004	0.000	0.000	0.000	0.013	0.076	0.273	0.738	0.704	0.460	0.403	0.446	0.576	0.762
2005	0.000	0.000	0.000	0.008	0.030	0.153	0.647	0.704	0.558	0.279	0.328	0.316	0.403
2006	0.000	0.000	0.000	0.004	0.035	0.157	0.523	0.750	0.418	0.277	0.128	0.096	0.137
2007	0.000	0.000	0.000	0.003	0.013	0.091	0.482	0.469	0.421	0.322	0.188	0.104	0.114

Residuals (N*Q - Indices)   2+3 GHL Tuning data

EU Survey_MNPT

	1	2	3	4	5	6	7	8	9	10	11	12
1995	0.870	0.248	0.370	0.311	-0.338	0.091	0.462	0.646	1.280	0.459	0.428	-0.129
1996	0.237	1.197	-0.082	0.595	0.300	0.067	-0.262	0.343	0.312	-0.597	-0.564	0.519
1997	-0.120	0.569	0.634	0.824	0.642	0.624	0.346	0.484	0.727	0.569	-0.439	-0.100
1998	-0.195	0.206	1.001	1.157	0.664	0.740	0.944	0.636	0.837	0.421	0.103	-1.228
1999	-1.187	-0.788	0.270	1.226	0.539	0.269	0.536	0.475	0.101	-0.152	-1.443	-1.225
2000	-0.111	-1.707	-1.229	-0.142	0.019	0.225	0.097	0.673	0.527	-0.002	0.642	0.000
2001	0.654	-0.303	-0.160	-0.799	-0.700	-0.235	0.140	0.879	-0.483	-0.834	-1.450	0.000
2002	0.011	0.418	0.086	-0.324	-0.273	-0.391	0.073	-0.219	-0.792	-0.621	-0.243	-0.156
2003	-0.392	-0.626	-1.436	-0.603	-0.707	-0.830	-0.804	-1.213	-0.879	-0.081	-0.369	-0.738
2004	0.232	0.780	0.571	-0.339	0.136	0.117	-0.388	-0.727	-0.157	0.147	1.053	1.315
2005	0.000	0.007	0.467	-0.072	0.097	-0.178	-0.369	-0.749	-0.990	-0.169	0.542	0.263
2006	0.000	0.000	-0.493	-0.615	-0.013	-0.242	-0.632	-0.652	-0.351	0.407	1.031	1.090
2007	0.000	0.000	0.000	-1.220	-0.366	-0.256	-0.145	-0.577	-0.131	0.454	0.710	0.389

t SS n V=   1   60.467758   156.00000   0.36711034

CAN 2J3K Fall_MNPT

	1	2	3	4	5	6	7	8	9	10	11	12	13
1996	0.729	0.147	0.465	-0.095	0.100	-0.356	-0.689	-0.916	0.421	-0.169	0.006	-0.010	0.074
1997	-0.322	0.471	0.581	0.168	0.417	0.533	0.109	0.207	0.544	0.450	0.346	0.574	-0.446
1998	-0.384	-0.172	0.365	0.011	-0.063	0.248	0.268	0.053	0.131	0.475	0.597	0.445	-0.262
1999	-0.807	0.266	0.313	0.385	0.328	0.497	0.883	0.526	0.241	0.778	0.180	0.333	0.426
2000	-0.114	-0.228	0.052	-0.170	0.071	0.003	0.036	0.105	-0.442	-0.077	0.058	-0.759	0.000
2001	0.019	-0.381	0.042	0.019	-0.054	0.197	0.294	0.384	0.010	-0.241	0.152	-0.376	0.513
2002	-0.024	-0.319	-0.453	-0.399	-0.418	-1.003	-1.226	-1.062	-0.966	-0.853	-1.077	0.000	-0.075
2003	0.309	-0.184	-0.517	-0.597	-0.347	-0.601	-0.751	-0.711	-1.013	-0.577	-0.347	0.114	0.107
2004	0.594	0.243	-0.310	-0.339	-0.181	-0.496	-0.401	-0.328	-0.406	-0.027	-0.862	-0.468	0.539
2005	0.000	0.157	-0.579	-0.193	-0.049	0.131	0.643	0.318	0.091	-0.214	0.452	0.105	-0.091
2006	0.000	0.000	0.041	0.260	0.156	0.372	0.262	0.751	0.436	-0.239	-0.106	-0.190	0.000
2007	0.000	0.000	0.000	0.950	0.040	0.474	0.572	0.673	0.954	0.693	0.602	0.232	-0.786

t SS n V=   2   31.481607   153.00000   0.19487800

CAN 3LNO Spr_MNPT

	1	2	3	4	5	6	7	8
1996	0.636	1.070	0.987	0.816	0.006	-0.422	-0.722	-2.709
1997	0.510	1.112	0.909	0.675	0.392	0.342	-0.265	-0.319
1998	-1.034	-0.254	0.735	1.133	1.084	1.057	1.084	1.340
1999	-0.794	-0.522	-0.266	0.113	0.500	0.368	0.690	1.152
2000	0.017	0.095	-0.219	0.046	0.067	0.814	1.043	0.651
2001	-0.319	-0.496	-0.631	-0.633	-0.619	-0.102	0.212	0.194
2002	-0.157	-0.714	-1.022	-0.828	-0.767	-1.149	-1.429	-1.334
2003	0.425	0.637	-0.004	-0.019	-0.236	-0.981	-1.200	-1.031
2004	0.716	-0.465	-0.313	-0.299	-0.327	-0.767	-1.233	0.083
2005	0.000	-0.464	-0.177	-0.491	-0.179	0.142	0.277	0.338
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.000	0.000	-0.514	0.079	0.699	1.543	1.634

t SS n V=   3   51.485435   88.000000   0.55411392

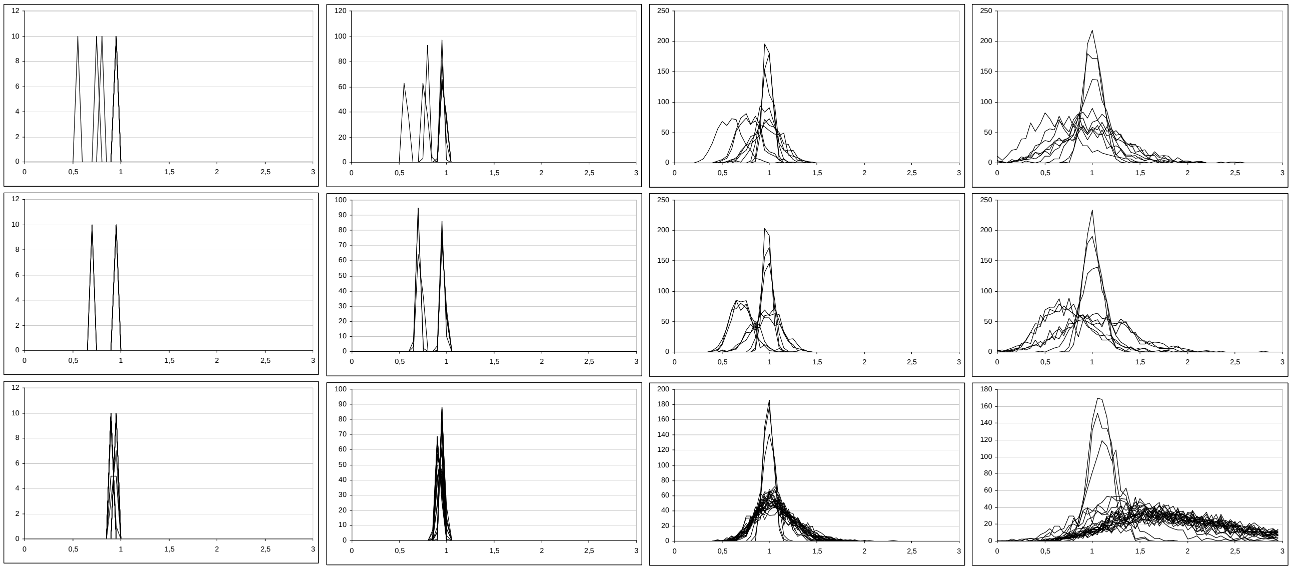

Figure 1 – Default options.

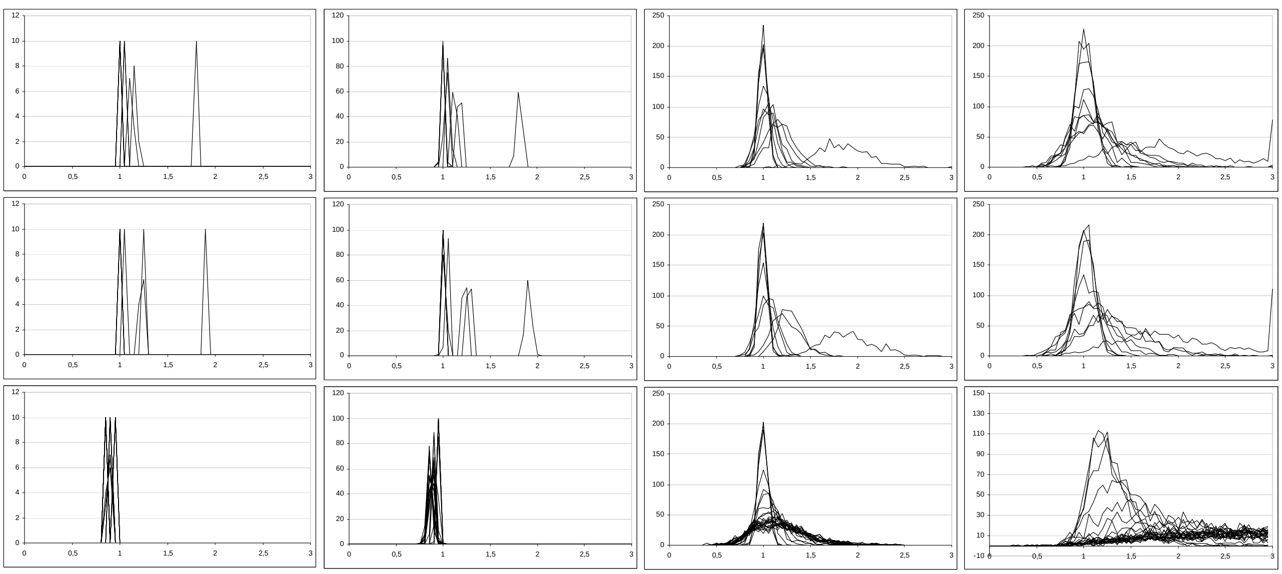

Figure 2 – Default options.

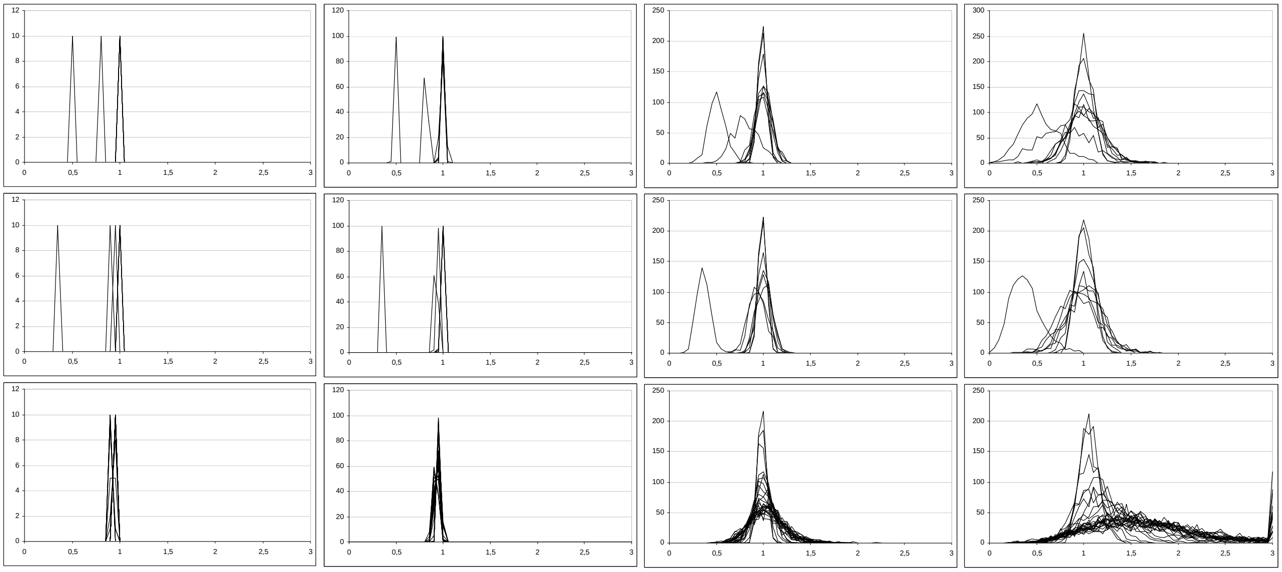

Figure 3 – F last age = arithmetic mean

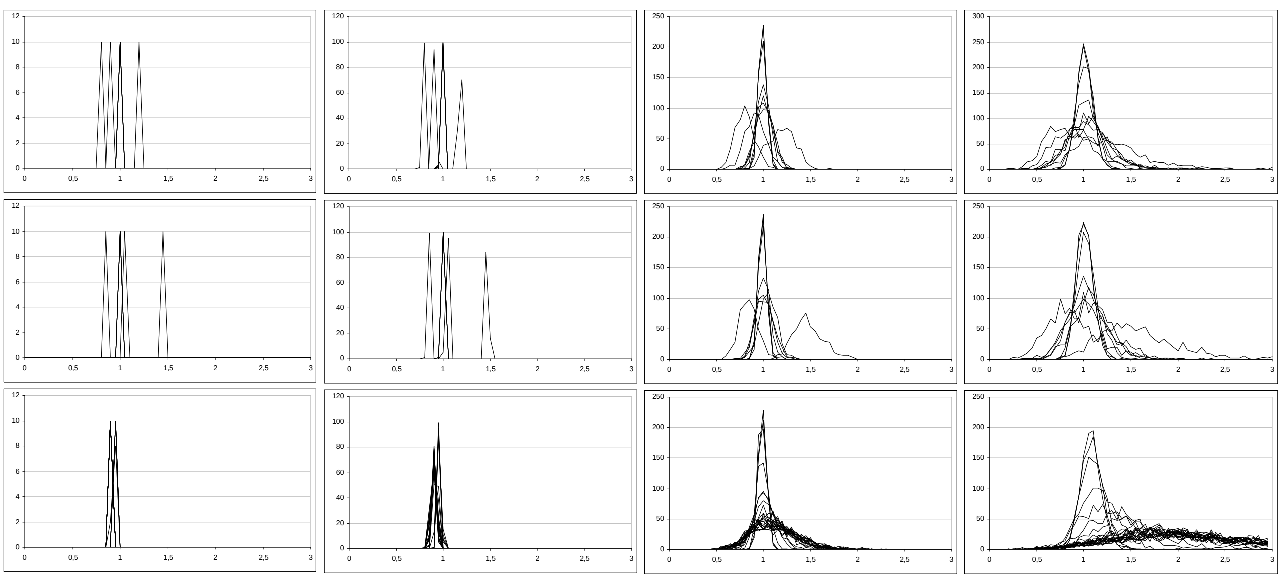

Figure 4 – Catchability option = Q=EXP (mean log(Indice/N)) + epoch (NOAA).

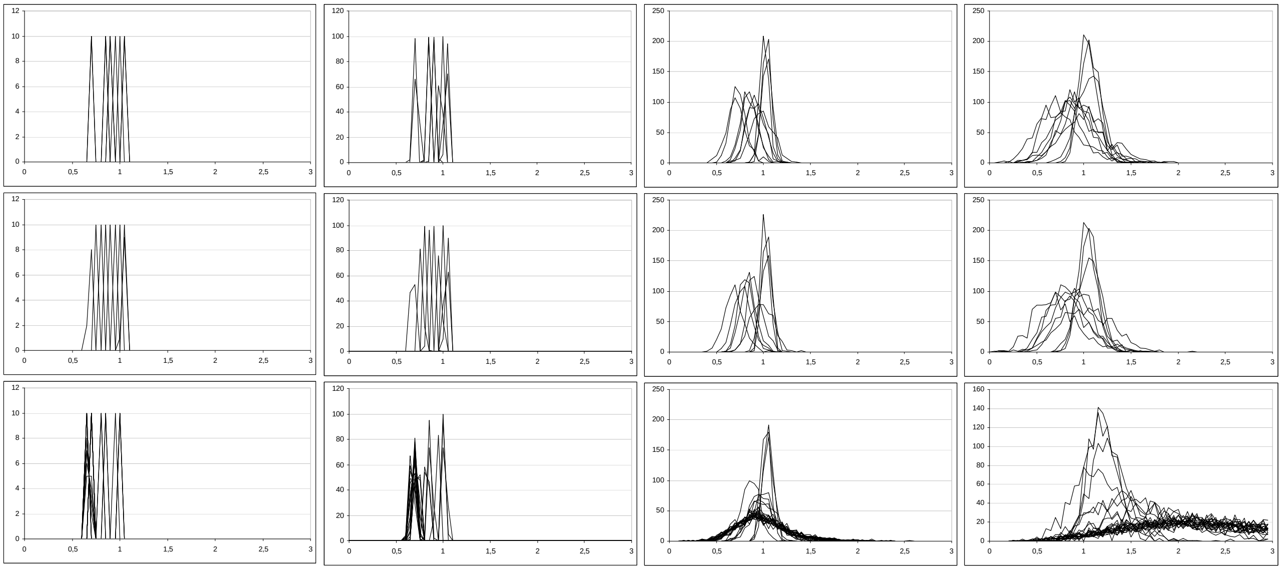

Figure 5 – Catchability option = geometric mean + 10% of mean values

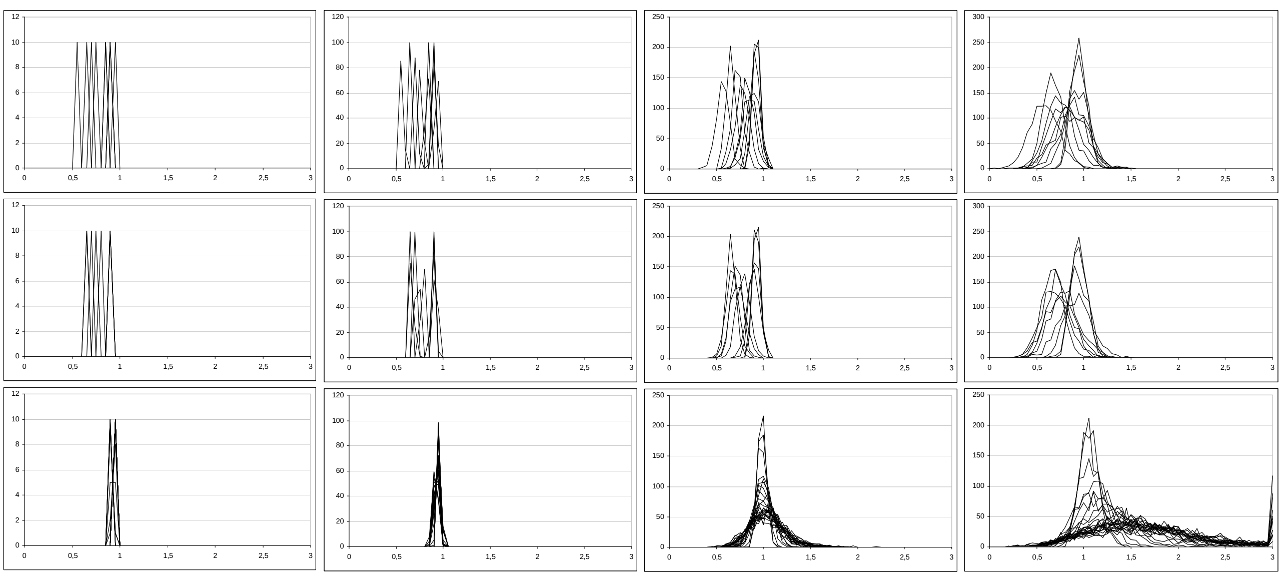

Figure 6 – Ages for F-last-age = 5

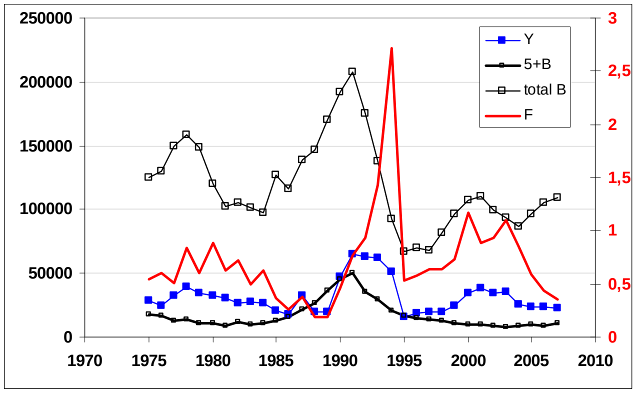

Figure 7- Greenland halibut results.

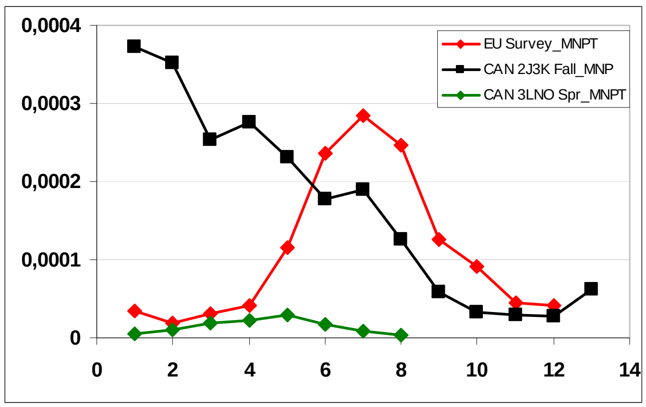

Figure 8 – Catchabilities at age

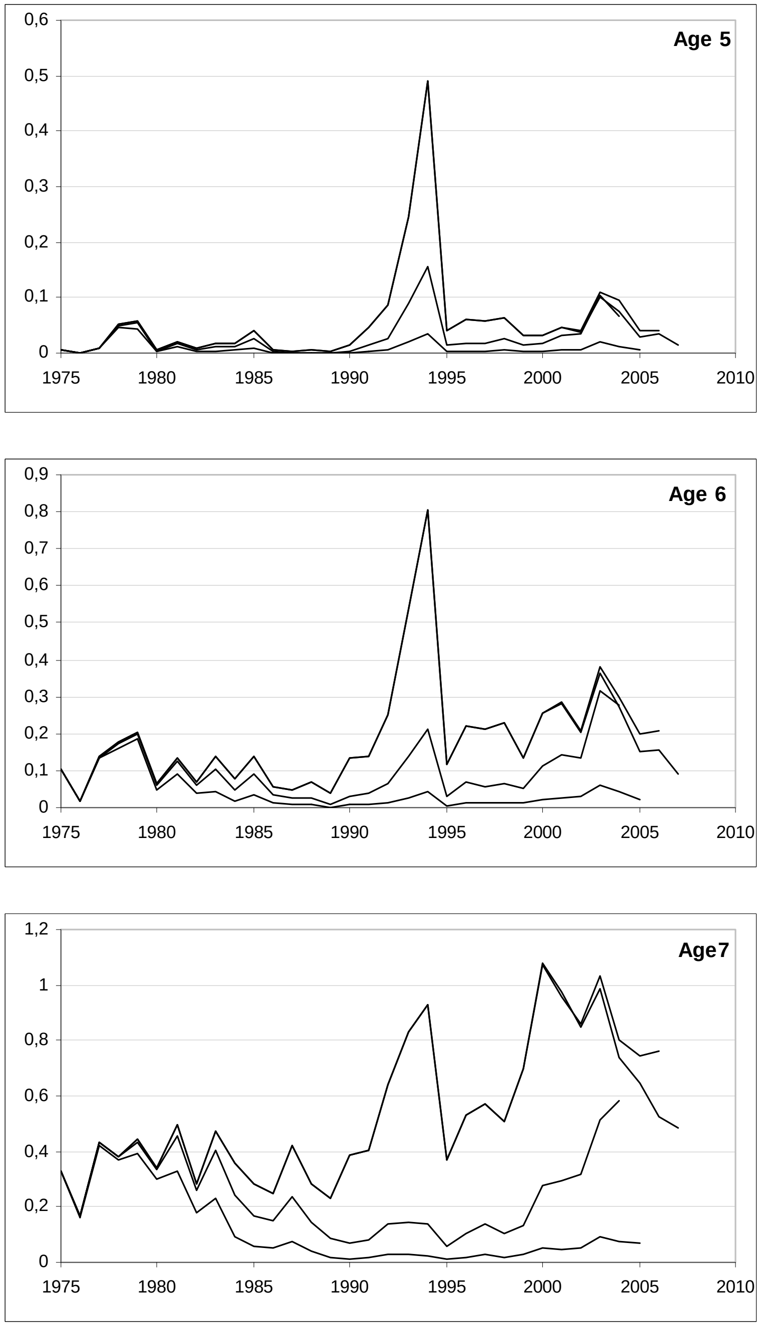

Figure 9 – Retrospective plots