APPENDIX C1: Black sea bass Length Tuned Model (LTM)

Introduction

Incomplete age information on catch and survey indices, often limits the application of full age-structured assessment models tuned with age specific data (e.g. Virtual Population Analysis). Knowledge of a species growth and lifespan, along with total catch data, size composition of the removals, recruitment indices and indices on numbers and size composition of the large fish in a survey can provide insights on population status using a simple model framework.

Herein we used a simple forward projecting age-based model tuned with total catch, catch at length, age-1 recruitment (estimated from first length mode in the survey), and survey numbers and length frequency of the larger fish sizes. The Length Tuned Model (LTM) was developed in the AD model builder framework. The model estimates fishing mortality and recruitment in each year, fishing mortality to produce the initial population (Fstart), and Qs for each survey index.

Methods

Model configuration

The LTM model assumes growth follows the mean input length at age with predetermined input error in length at age. Therefore a growth model or estimates of the average mean lengths at age is essential for reliable results. The LTM model uses an input partial recruitment (pr) vector at length in each year for the calculation of population and catch age-length matrices. A starting population is computed for year one in the model. First the estimated populations numbers at age starting with age-1 recruitment get normally distributed at one cm length intervals using the mean length at age with the assumed standard deviation. Next the initial population numbers at age are calculated from the previous age at length abundance using the survival equation. An estimated fishing mortality (Fstart) is also used to produce the initial population. This F can be thought of as the average fishing mortality that occurred before the first year in the model. Now the process repeats itself with the total of the estimated abundance at age getting redistributed according to the mean length at age and standard deviation in the next age (age+1).

This two step process is used to incorporate the effects of length specific selectivities and fishing mortality. The initial population length and age distribution is constructed by assuming that the population is at equilibrium with an initial value of F, say F_{start}. Length specific mortality is estimated as a two step process in which the population is first decremented for the length specific effects of mortality as follows:

$$N^{*}_{a,len,y_1} = N_{a-1,len,y_1} e^{-\left(PR_{len}F_{start}+M\right)}$$

In the second step, the total population of survivors is then redistributed over the lengths at age *a* by assuming that the proportions of numbers at length at age *a* follow a normal distribution with a mean length derived from the von Bertalanffy growth function.

$$N_{a,len,y_1} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y_1}$$

where

$$\pi_{len,a} = \Phi\left(len+1 \mid \mu_a, \sigma_a^2\right) - \Phi\left(len \mid \mu_a, \sigma_a^2\right)$$

where

$$\mu_a = L_\infty\left(1 - e^{-K(a-t_0)}\right)$$

For black sea bass the variance of length at age a = σ_s^2 was estimated from the NEFSC survey age data (standard deviation of 4.2 from ages 4+).

This model formulation does not explicitly track the dynamics of length groups across age because the consequences of differential survival at length at age a do not alter the mean length of fish at age a+1. However, it does more realistically account for the variations in age specific partial recruitment patterns by incorporating the expected distribution of lengths at age.

In the next step the population numbers at age and length for years after the calculation of the initial population use the previous age and year for the estimate of abundance. Here the calculations are done on a cohort basis. Like in the previous initial population survival equation the partial recruitment is taken from the input length vector.

$$N^*_{a,len,y} = N_{a-1,len,y-1} e^{-(PR_{len} F_{start} + M)}$$

second stage

$$N_{a,len,y} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y}$$

Constant M is assumed along with an estimated length-weight relationship to convert estimated catch in numbers to landings in weight. The best available estimate of partial recruitment at length is used as input to the model from knowledge of landings size distribution, fishing practice, regulations, and discarding. The standard Baranov's catch equation is used to remove the catch from the population in estimating fishing mortality.

$$C_{y,a,len} = \frac{N_{y,a,len} F_y \left(1 - e^{-\left(F_y PR_{len} + M\right)}\right)}{(F_y \ \ PR_{len}) + M}$$

Catch is converted to yield by assuming a time invariant average weight at length

$$Y_{y,a,len} = C_{y,a,len} W_{len}$$

The LTM model results in the calculation of population and catch age-length matrices for the starting population and then for each year thereafter. The model is programmed to estimate recruitment in year 1 and estimate variation in recruitment relative to recruitment in year 1 for each year thereafter. Estimated recruitment in year one can be thought of as the estimated average long term recruitment in the population since it produces the initial population. The residual sum of squares of the variation in recruitment $\sum(\mathrm{Vrec})^2$ is than used as a component of the total objective junction. The weight on the recruitment variation component of the objective junction (Vrec) can be used to penalize the model for estimating large changes in recruitment relative to estimated recruitment in year one.

The model requires an age-1 recruitment index for tuning or the user can assume relatively constant recruitment over time by putting a high weight on Vrec. Usually there is little overlap in ages at length for fish that are one and/or two years of age in a survey of abundance. The first mode in a survey can generally index age-1 recruitment using length slicing. In addition numbers and the length frequency of the larger fish in a survey where overlap in ages at a particular length occurs can be used for tuning population abundance. The model tunes to the catch and survey length frequency data using a multinomial distribution. The user specifies the minimum size (cm) for the model to fit. Different minimum sizes can be fit for the catch and survey data length frequency.

The number of parameters estimated is equal to the number of years in estimating F and recruitment plus one for the F to produce the initial population (Fstart) and for each survey Q. The total likelihood function to be minimized is made up of 10 likelihood components:

$$\mathrm{L}_1 = \sum_{years} \left(l\,\mathrm{n}(Y_{\mathrm{obs,y}} + 1) - \ln\left(\sum_a \sum_{len} \mathrm{Y}_{\mathrm{pred,len,a,y}} + 1 \right) \right)^2$$

$$L_2 = -N_{eff} \sum_y \left(\sum_{len=30}^{L_\infty} \left(\left(C_{y,len} + 1\right) \ln\left(1 + \sum_a C_{pred,y,a,len} \right) - \ln\left(C_{y,len} + 1\right) \right) \right)$$

$$L_3 = \sum_{y=2}^{Nyears} \left(Vrec_y\right)^2 = \sum_{y=2}^{Nyears} \left(R_1 - R_y\right)^2$$

$$L_4 = \sum_{y}^{Nyears} \left(\ln\left(I_{FALL,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{FALL} \right)^2$$

$$L_5 = \sum_{y=1992}^{Nyears} \left(\ln\left(I_{WINTER,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{WINTER} \right)^2$$

$$L_6 = \sum_{y}^{Nyears} \left(\ln\left(I_{SPRING,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{SPRING} \right)^2$$

$$L_7 = \sum_{y=1992}^{Nyears} \left(\ln\left(I_{WINTER,22+,y} + 1\right) - \ln\left(\sum_{a} \sum_{len=22}^{L_\infty} \ln\left(N_{pred,y,a,len} + 1\right) q_{WINTER,22+} \right) \right)^2$$

$$L_8 = -N_{eff} \sum_{y=1992}^{Nyears} \left(\sum_{len=22}^{L_\infty} \left(\left(I_{WINTER,y,len} + 1\right) \ln\left(1 + \sum_{a} N_{pred,y,a,len}\right) - \ln\left(I_{WINTER,y,len} + 1\right) \right) \right)$$

$$L_9 = \sum_{y}^{Nyears} \left(\ln\left(I_{SPRING,22+,y} + 1\right) - \ln\left(\sum_{a} \sum_{len=22}^{L_\infty} \ln\left(N_{pred,y,a,len} + 1\right) q_{SPRING,22+} \right) \right)^2$$

$$L_{10} = -N_{eff} \sum_{y} \left(\sum_{len=22}^{L_\infty} \left(\left(I_{SPRING,y,len} + 1\right) \ln\left(1 + \sum_{a} N_{pred,y,a,len}\right) - \ln\left(I_{SPRING,y,len} + 1\right) \right) \right)$$

In equation L_2 calculations of the sum of length is made from the user input catch length to the maximum length for fitting the catch. In equation L_7 through L_{10} the survey length up to the maximum length is used in the calculation.

$$Obj\ \ fcn = \sum_{i=1}^{10} \lambda_i L_i$$

Lambdas represent the weights to be set by the user for each likelihood component in the total objective function.

Black Sea Bass LTM Model Results

Black sea bass natural mortality was assumed to be 0.2 with a fifteen year lifespan. Estimates of commercial discard were not available. B2 estimates were relatively small when reduced by a 15 % mortality rate and are not used in the model. The catch length frequency were fit to 30+ cm fish and the survey numbers and survey length frequency were fit to 22+ cm fish. Surveys were standardized by dividing each survey by its mean and multiplying by 1 million. An approximation of the partial recruitment vector at length was developed by shifting the partial recruitment curve to larger fish as minimum size limits and mesh size increases occurred in the recreational and commercial fisheries (Fig 1). The shift to larger fish can be observed in the landings length frequency.

All black sea bass LTM model runs estimated high F start values. The model predicts a truncated distribution at the beginning of the model in 1981. The fishery landings history supports the presence of an exploited population before 1981.

The working group reviewed the effects of using different growth estimates in runs 1 to 3 (Fig 2 and 3). The three different growth estimates tend to produce changes in the fishing mortality estimates in the past with the terminal year estimates being very similar among the runs. However the changes in growth resulted in a shift in the recruitment/biomass estimates among the three runs. The survey growth model was used for all subsequent model runs and comparisons.

In general all three recruitment indices showed increases in recruitment between 2000 and 2002. The recreational B2 estimates were also higher during the early 2000s which suggests higher recruitment. Runs with different assumptions on the variation in recruitment (Vrec = 1, 1000, 0.1) showed different trends in F and biomass depending on how closely the model is allowed to fit the increases in recruitment in the surveys from 2000-2002 (Table 1, Fig 4). However all the black sea bass LTM model runs could not match the decrease in the 22+ index. Given that the catch has decreased and strong recruitment occurred during the early 2000s, the effect should be reflected in both the adult index (22+) and the exploitable length frequency in the terminal year of the model. Both the winter and spring survey show a substantial decrease in numbers of 22+ fish from 2004 to 2006. The model predicts a greater amount of larger fish than observed in the catch and surveys for the terminal year especially as the model is allowed to fit the high recruitment in the surveys. The working group was not confident in the LTM model results for stock status determination given the differences in trends between the predicted and observed 22+ cm indices in the last three years. The working group could not determine if this mismatch was due to a survey availability event and/or an unaccounted source of mortality such as commercial and recreational discards.

The working group questioned the large increases in recreational catch in 1982 and 1986. These large increases were not realistic and the average of adjacent years was used for the recreational catch estimate in these two years. Results did not change greatly when the actual reported recreational landings were used in run 7 (Fig 5). All of the resulting output graphs are shown for run 3 which uses the survey growth curve and a Vrec weight of 5 in figures 6-11. Using the Lower or Upper 95% confidence intervals for the MRFSS catch did not produce different trends in the LTM model results (Table 3, Fig 12).

APPENDIX C1

Table 1. Black Sea Bass LTM runs of residual sum of squares, input weights, estimated Qs, estimated Fstart, and age 1 recruitment in year 1.

run number	1	2	3	4	5	6	7
Landings makeup	avg rec 82 & 86	avg rec 82 & 86	avg rec 82 & 86	avg rec 82 & 86	avg rec 82 & 86	avg rec 82 & 86	MRFSS landings
growth	Shepherd	Caruso	NEFSC survey	NEFSC survey	NEFSC survey	NEFSC survey	NEFSC survey
total objective function	181.00	206.14	184.28	165.93	172.80	202.53	187.24
total catch	0.04	0.23	0.14	0.14	0.13	0.17	0.18
catch len freq 80+	10.31	17.51	9.17	10.39	9.98	9.96	10.13
Vrec	1.98	1.60	1.62	12.07	5.46	0.0002	1.61
Fall age 1	11.62	13.11	13.41	12.94	12.67	16.77	13.61
Spring age 1	40.16	41.78	42.32	33.47	36.26	52.86	43.22
Winter age 1	16.75	16.45	15.83	10.00	11.84	22.35	15.55
Winter 80+ len freq	17.81	21.94	18.84	20.73	20.13	19.07	18.96
Winter 80+ numbers	6.46	6.06	5.95	5.67	5.55	7.06	5.81
Spring 80+ len freq	58.19	69.93	60.57	61.94	61.49	62.37	61.10
Spring 80+ numbers	9.37	9.04	8.69	8.22	8.08	10.17	9.04
wt total catch	10	10	10	10	10	10	10
effective sample size wt catch len freq 80+	200	200	200	200	200	200	200
wt Vrec	5	5	5	0.1	1	1000	5
wt Fall age 1	1	1	1	1	1	1	1
wt Spring age 1	1	1	1	1	1	1	1
wt Winter age 1	1	1	1	1	1	1	1
effective sample size wt Winter 80+ len freq	200	200	200	200	200	200	200
wt Winter 80+ numbers	1	1	1	1	1	1	1
effective sample size Spring 80+ len freq	200	200	200	200	200	200	200
wt Spring 80+ numbers	1	1	1	1	1	1	1
Q Fall age 1	0.80	0.83	0.82	0.81	0.82	0.82	0.82
Q Spring age 1	0.77	0.80	0.79	0.78	0.79	0.79	0.79
Q Winter age 1	0.77	0.80	0.79	0.77	0.78	0.80	0.79
Q Winter 80+ numbers	0.77	0.81	0.80	0.78	0.79	0.81	0.80
Q Spring 80+ numbers	0.79	0.82	0.81	0.80	0.81	0.82	0.81
Fstart	0.75	1.72	1.40	1.08	1.43	1.36	0.89
recruitment year 1	21.9	12.0	14.0	12.4	14.5	13.6	15.4

Table 2. Black Sea Bass LTM run 3 F-mult, age 1 recruitment and 22+ population biomass.

year	F Fmult	age 1 recruitment millions	population 22+ biomass metric tons
1981	0.83	14.0	3,520
1982	0.78	12.4	4,589
1983	0.93	10.2	5,230
1984	0.78	10.7	4,753
1985	0.79	13.1	4,725
1986	0.96	15.1	4,885
1987	1.24	12.2	4,909
1988	1.54	18.3	4,881
1989	1.39	10.8	4,575
1990	1.23	15.0	4,846
1991	1.56	15.1	4,707
1992	1.35	16.6	4,553
1993	1.45	9.9	5,024
1994	0.77	11.8	4,650
1995	1.17	14.3	5,293
1996	1.32	13.4	4,954
1997	1.34	11.9	4,795
1998	0.57	9.8	4,492
1999	0.60	16.4	5,821
2000	0.82	24.6	7,199
2001	0.72	13.3	8,879
2002	0.80	25.2	11,567
2003	0.42	21.6	13,601
2004	0.20	15.4	17,882
2005	0.13	16.6	23,359

Table 3. Black Sea Bass LTM runs 8 and 9 which used the MRFSS 95% upper and lower CI bounds. The residual sum of squares, input weights, estimated Qs, estimated Fstart, and age 1 recruitment in year 1 are shown.

run number	8	9
Landings makeup	MRFSS lower CI landings	MRFSS upper CI landings
growth	NEFSC survey	NEFSC survey
total objective function	183.00	185.81
total catch	0.12	0.16
catch len freq 80+	8.98	9.20
Vrec	1.66	1.72
Fall age 1	13.32	13.61
Spring age 1	41.92	41.94
Winter age 1	15.74	15.93
Winter 80+ len freq	18.65	19.01
Winter 80+ numbers	5.88	6.05
Spring 80+ len freq	60.33	60.99
Spring 80+ numbers	8.67	8.90
wt total catch	10	10
effective sample size wt catch len freq 80+	200	200
wt Vrec	5	5
wt Fall age 1	1	1
wt Spring age 1	1	1
wt Winter age 1	1	1
effective sample size wt Winter 80+ len freq	200	200
wt Winter 80+ numbers	1	1
effective sample size Spring 80+ len freq	200	200
wt Spring 80+ numbers	1	1
Q Fall age 1	0.82	0.81
Q Spring age 1	0.79	0.78
Q Winter age 1	0.79	0.78
Q Winter 80+ numbers	0.80	0.79
Q Spring 80+ numbers	0.82	0.80
Fstart	1.51	1.40
recruitment year 1	13.3	17.1

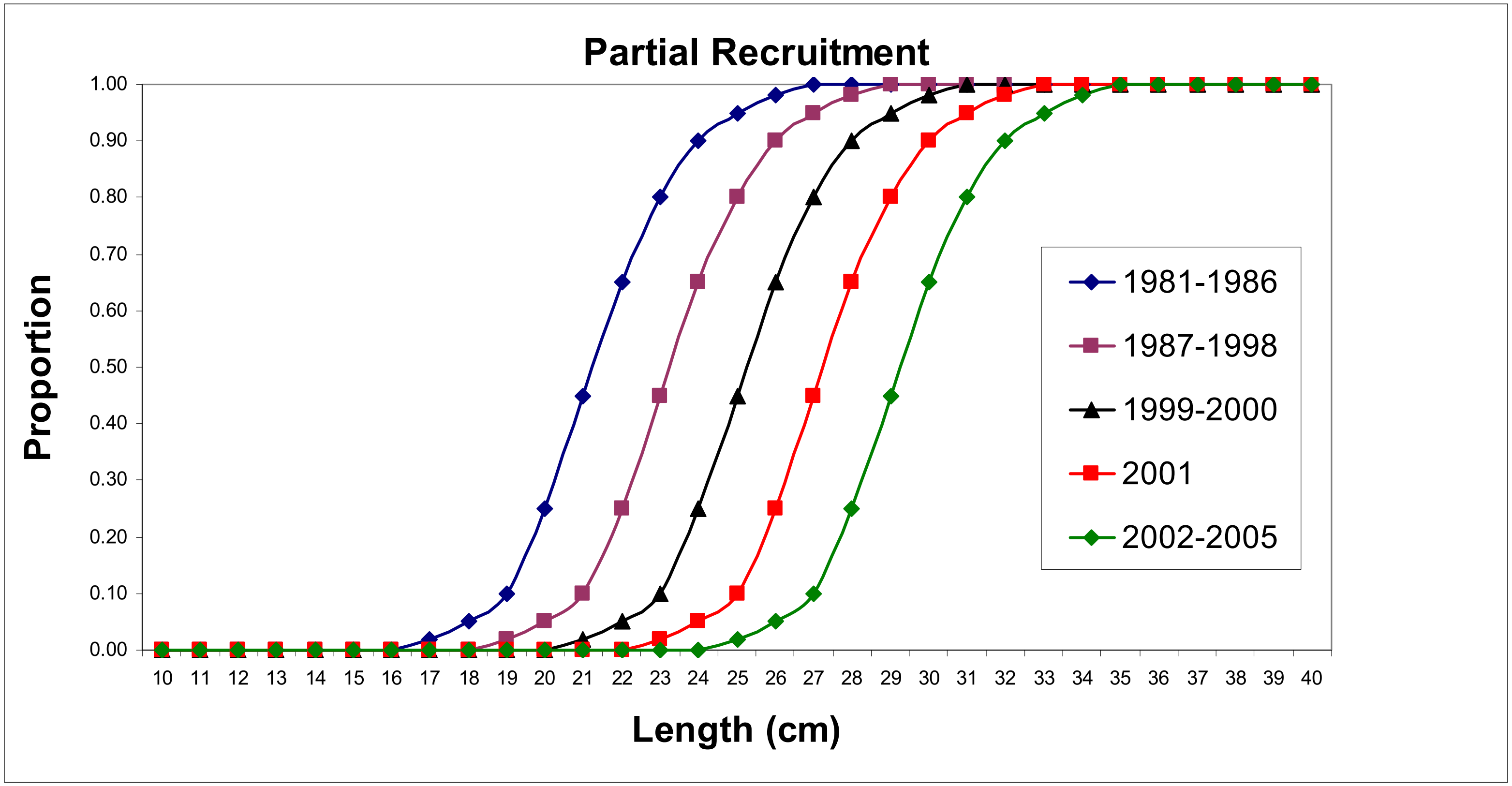

Figure 1 (Appendix C1). Input partial recruitment vector at length used in the black sea bass LTM model.

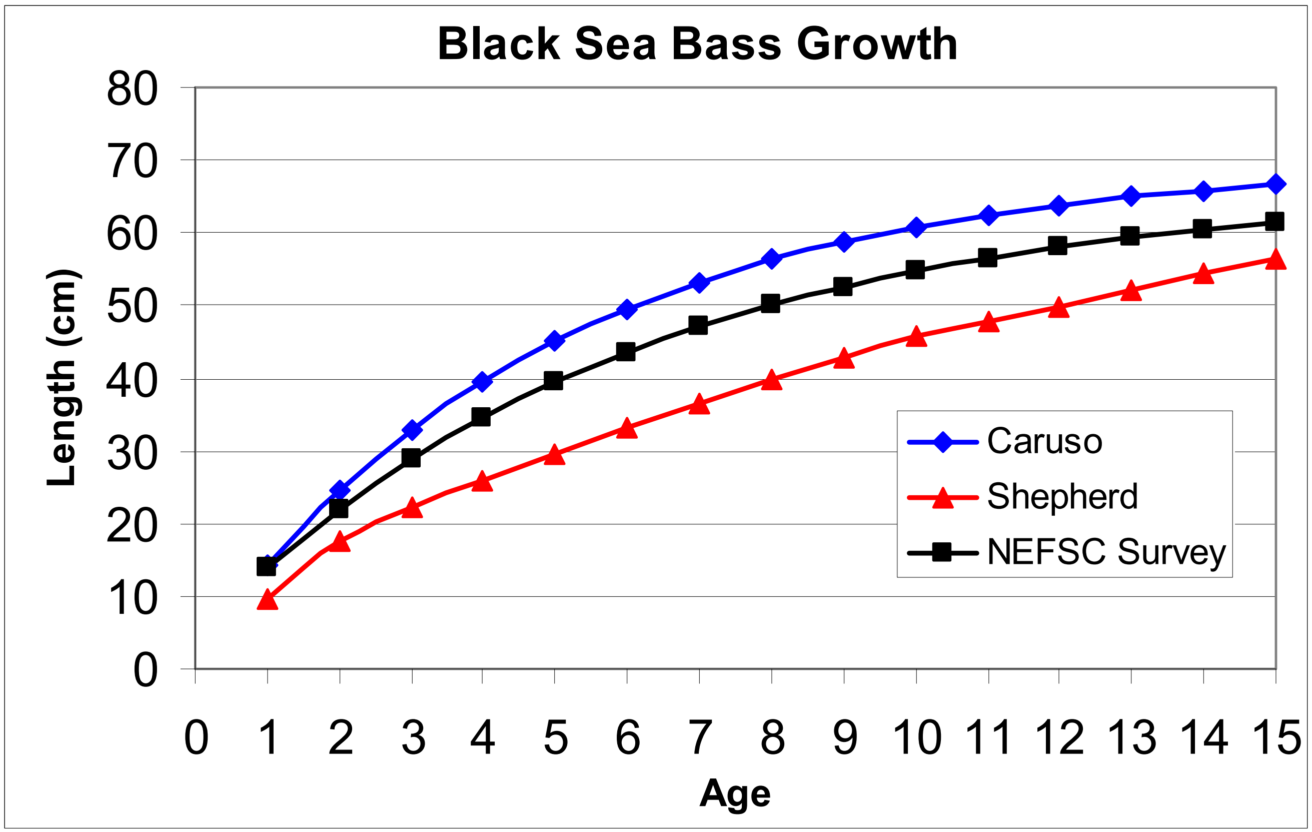

Figure 2 (Appendix C1). Three different growth models used in Black Sea Bass LTM runs 1 to 3.

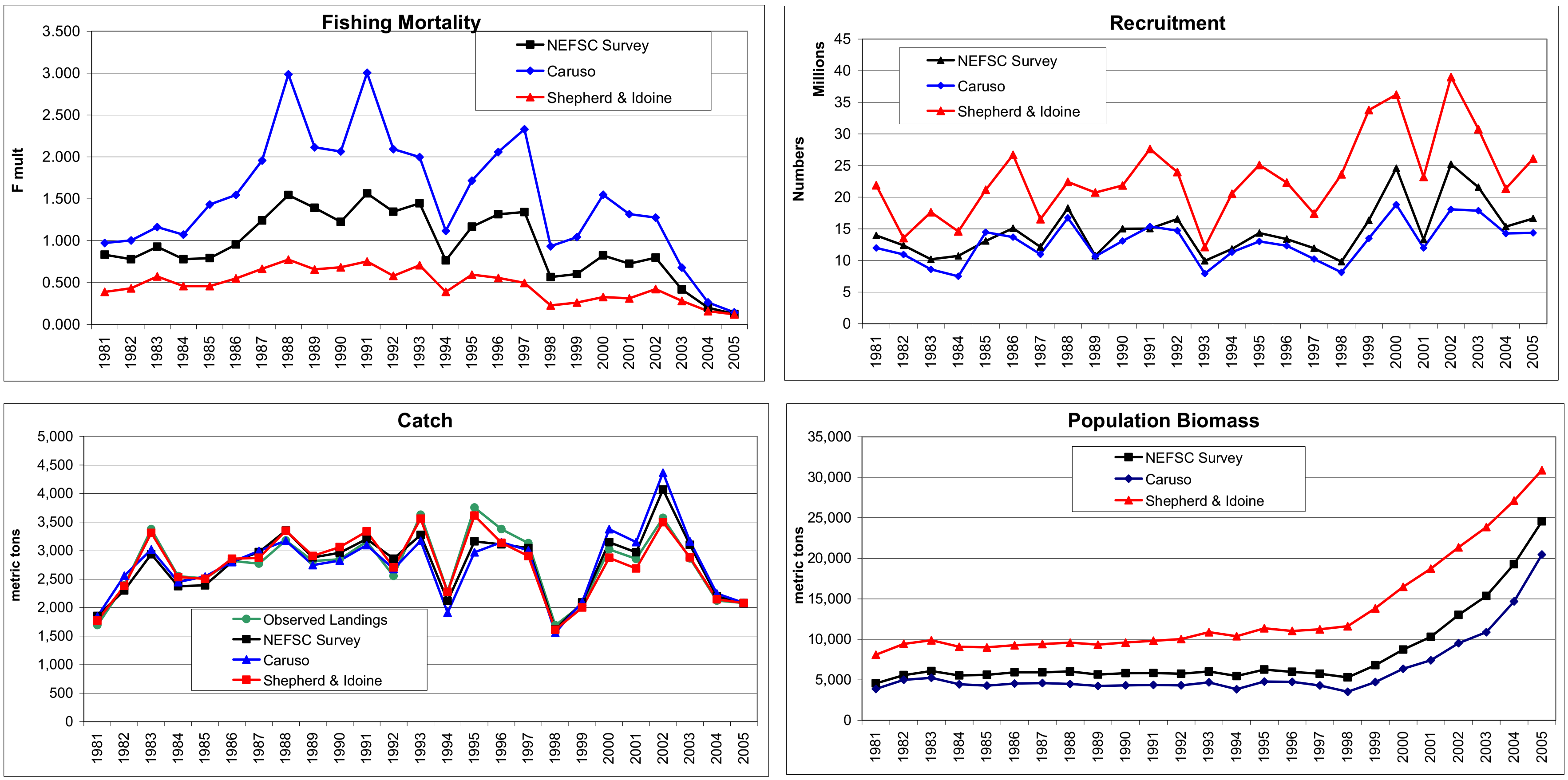

Figure 3 (Appendix C1). Black Sea Bass LTM runs 1 to 3 using three different growth models with a Vrec weight of 5 and average 82 and 86 recreational landings.

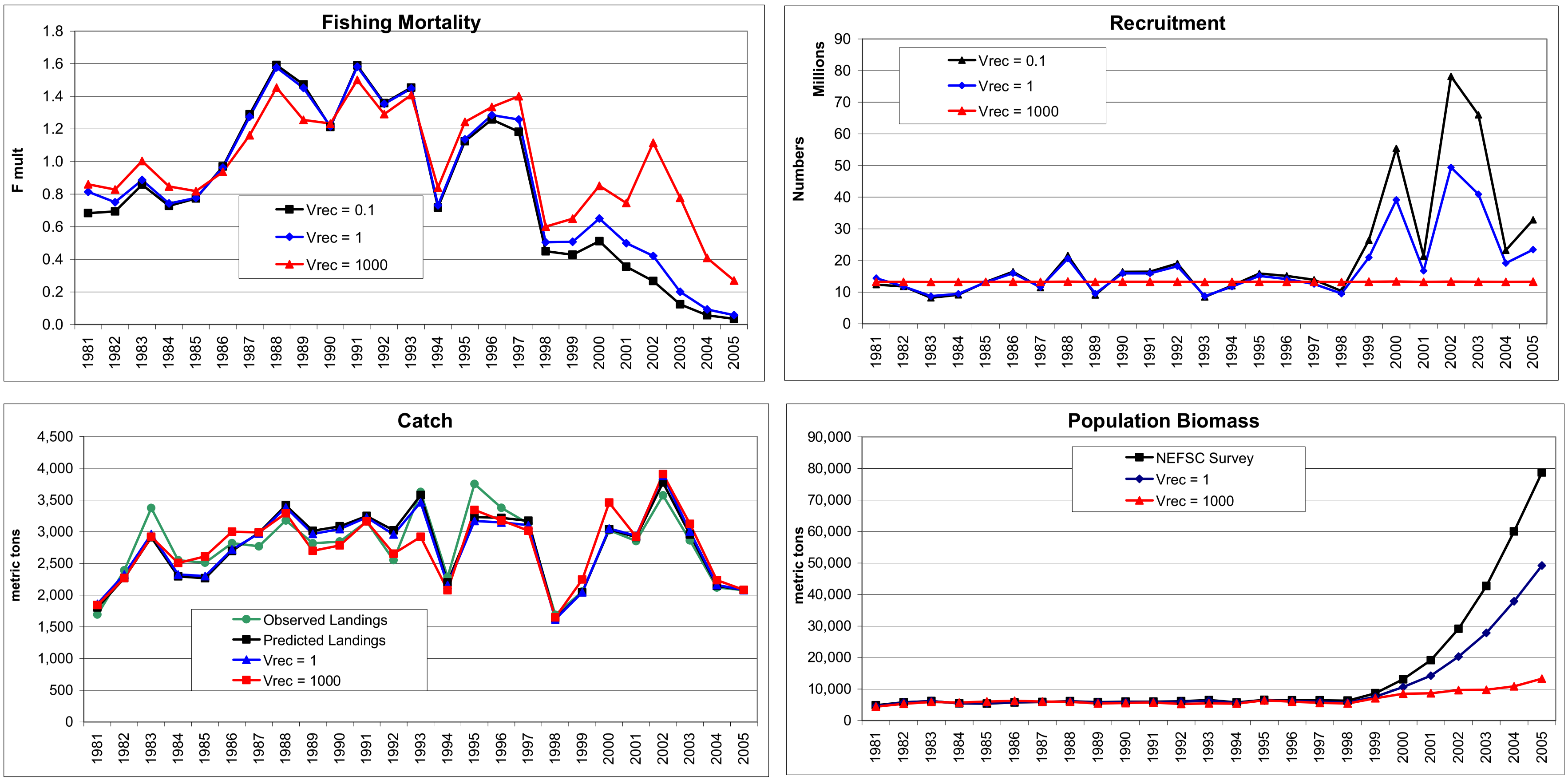

Figure 4 (Appendix C1). Black Sea Bass LTM runs 4 to 6 using three different Vrec weights (0.1,1,1000) and average 82 and 86 recreational landings.

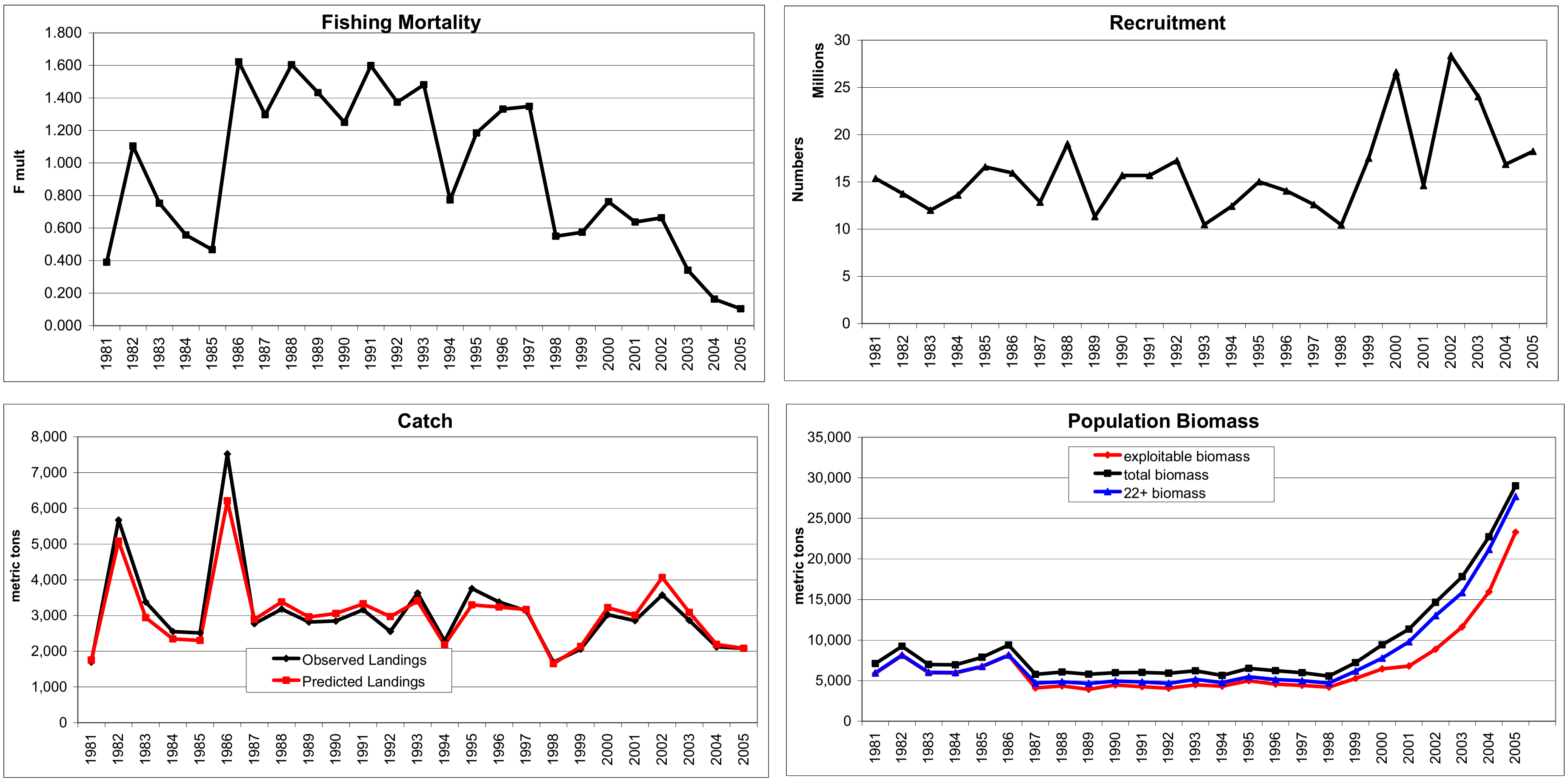

Figure 5 (Appendix C1). Black Sea Bass LTM run 7 using Vrec weight of 5 and the reported recreational landings for 1982 and 1986

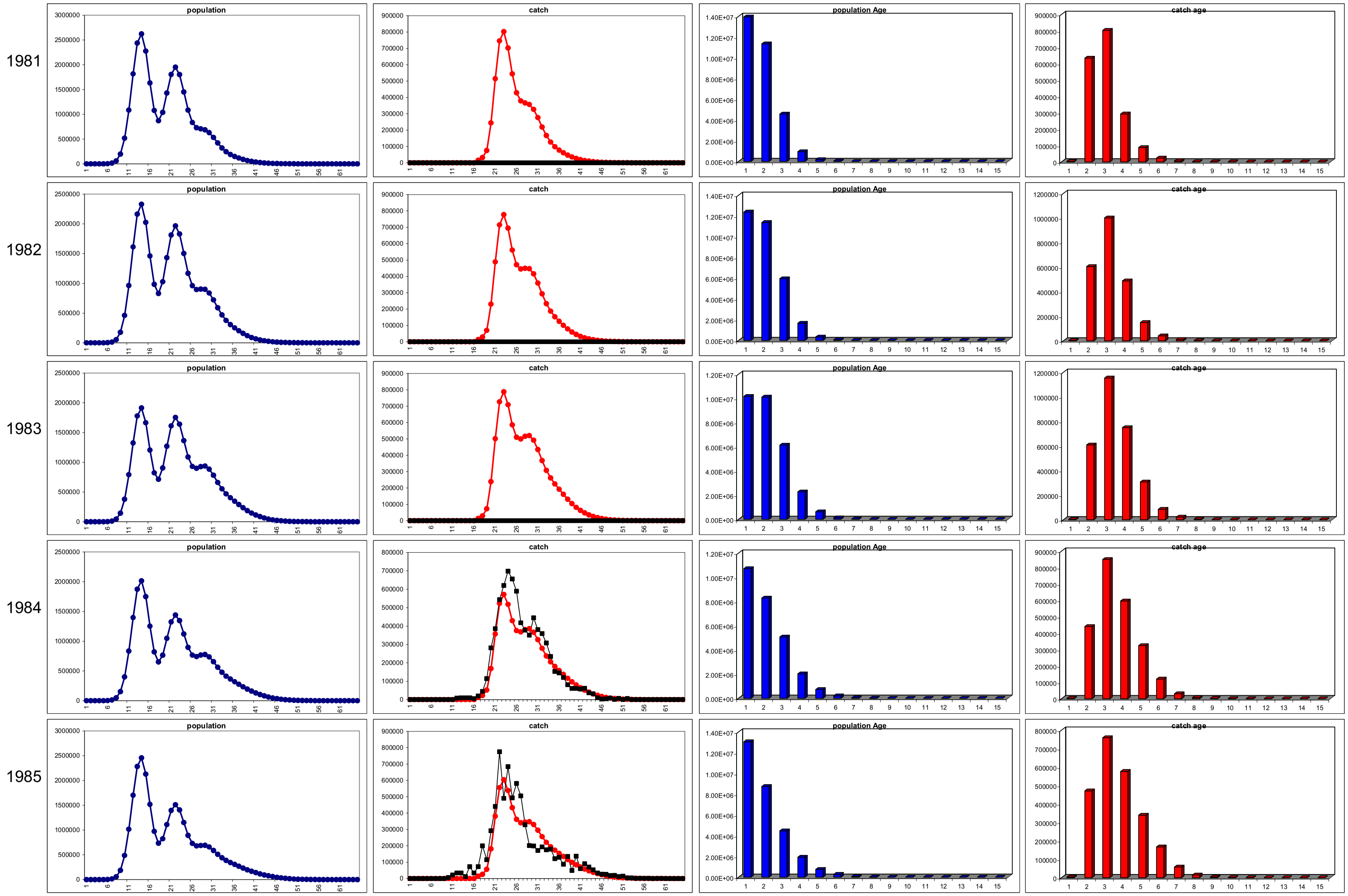

Figure 6 (Appendix C1). Black Sea Bass LTM run 3 population length frequency, observed (squares) and predicted (dots) catch length frequency, population age frequency and catch frequency from 1981-2005.

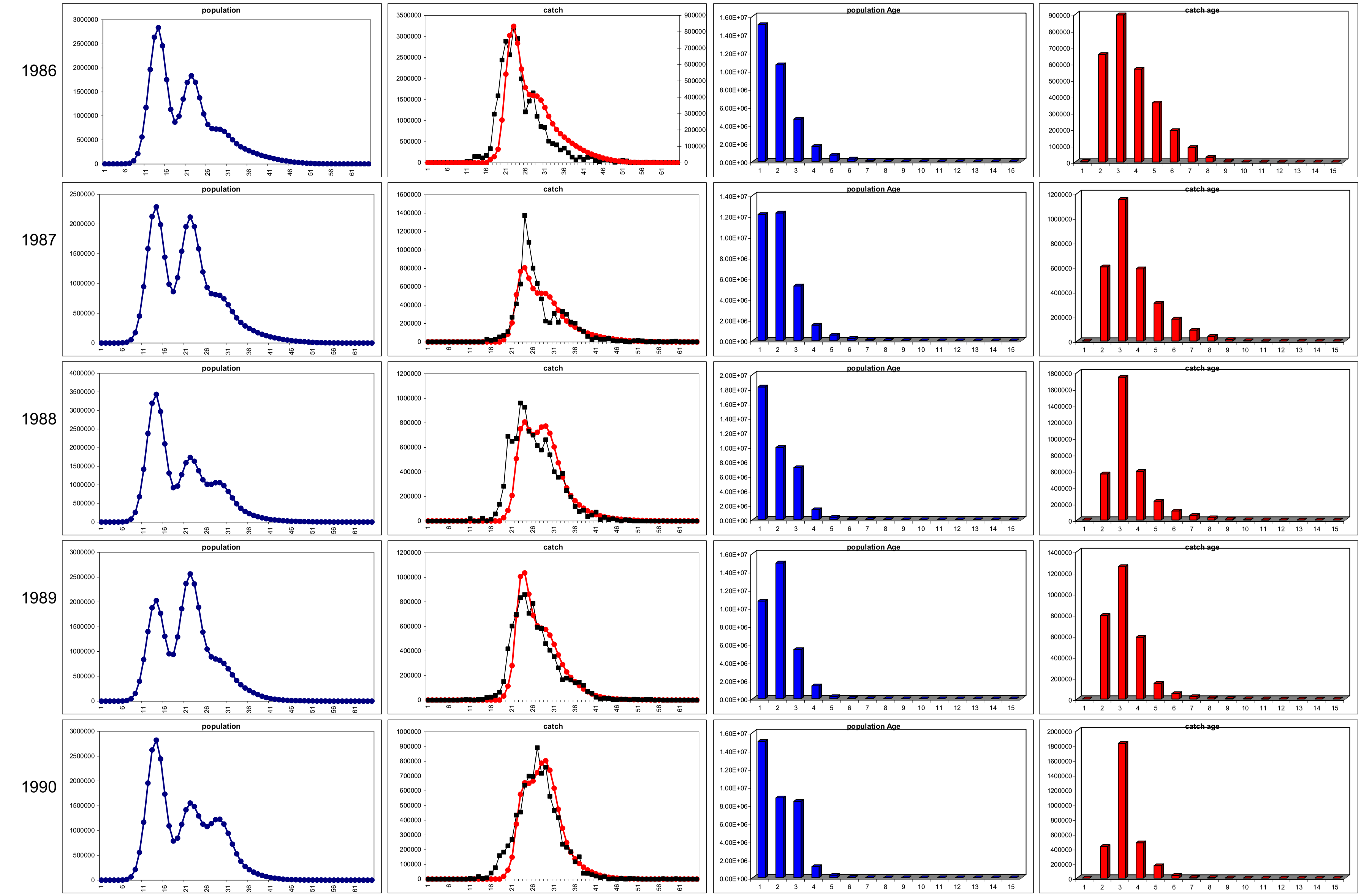
1986
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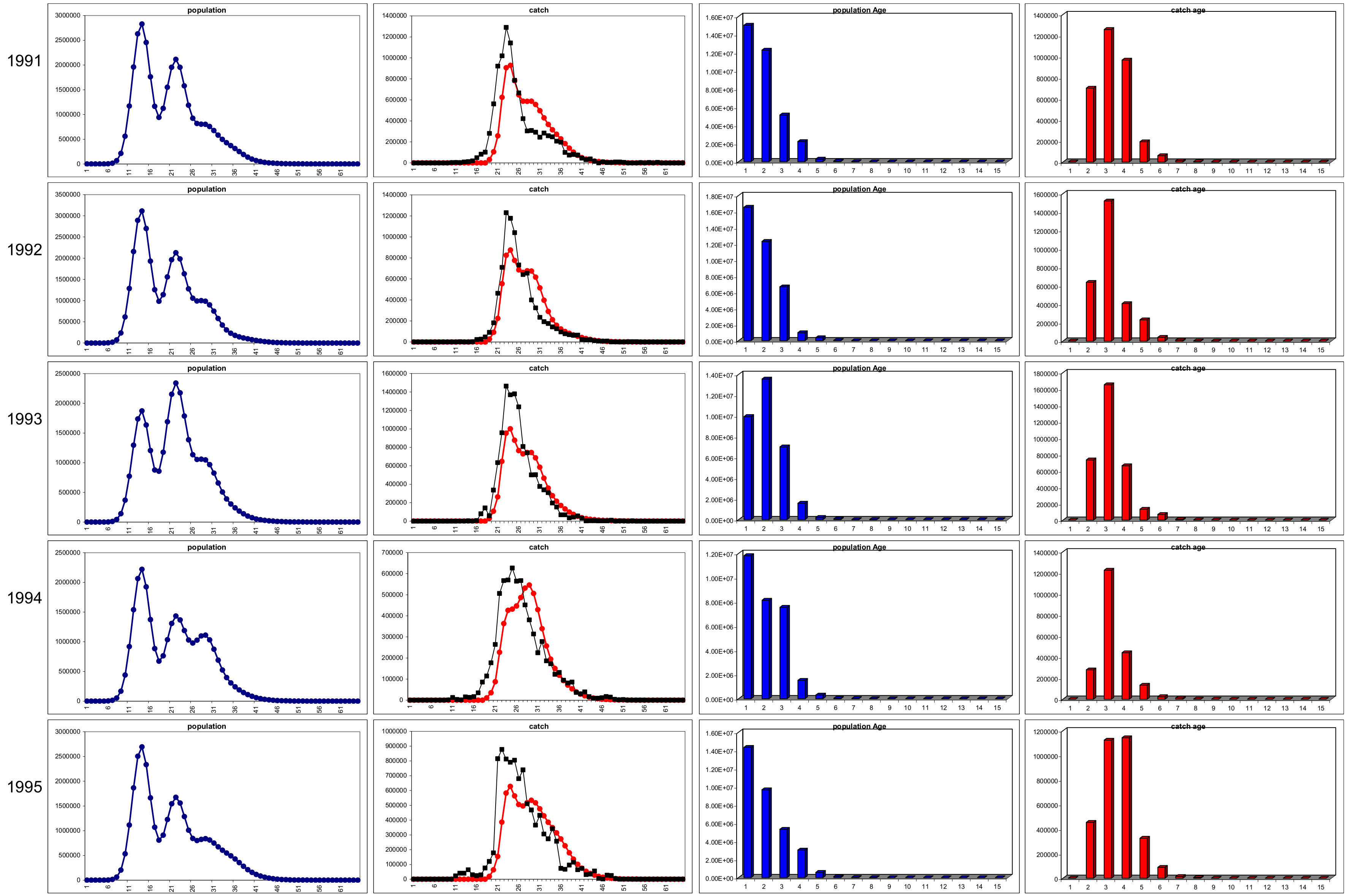
Fig. 6. cont.


1991
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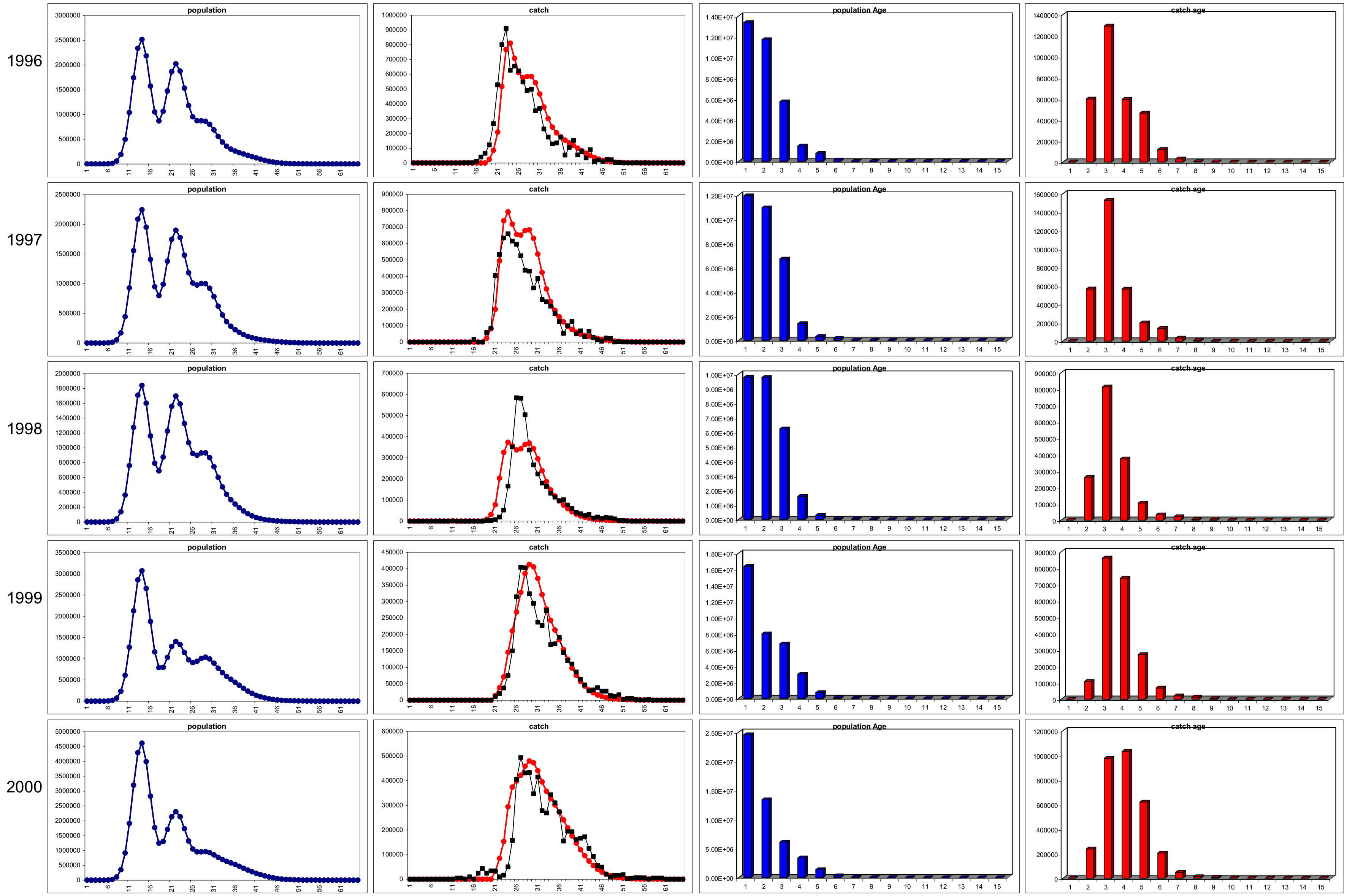
population
catch
population Age
catch age

Fig. 6. cont.



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population
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Fig. 6. cont.

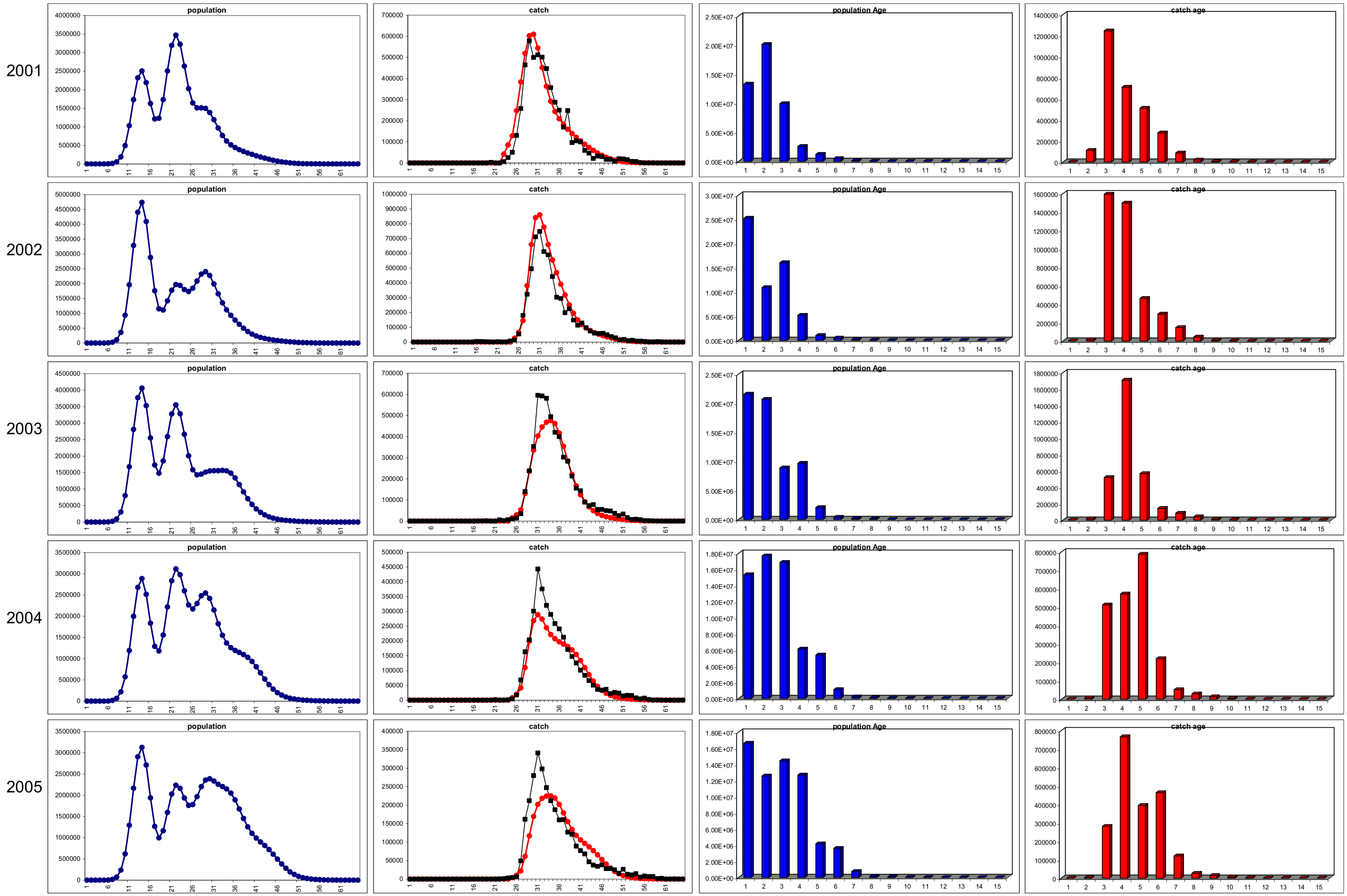
2001
2002
2003
2004
2005
population
catch
population Age
catch age

Fig. 6. cont.

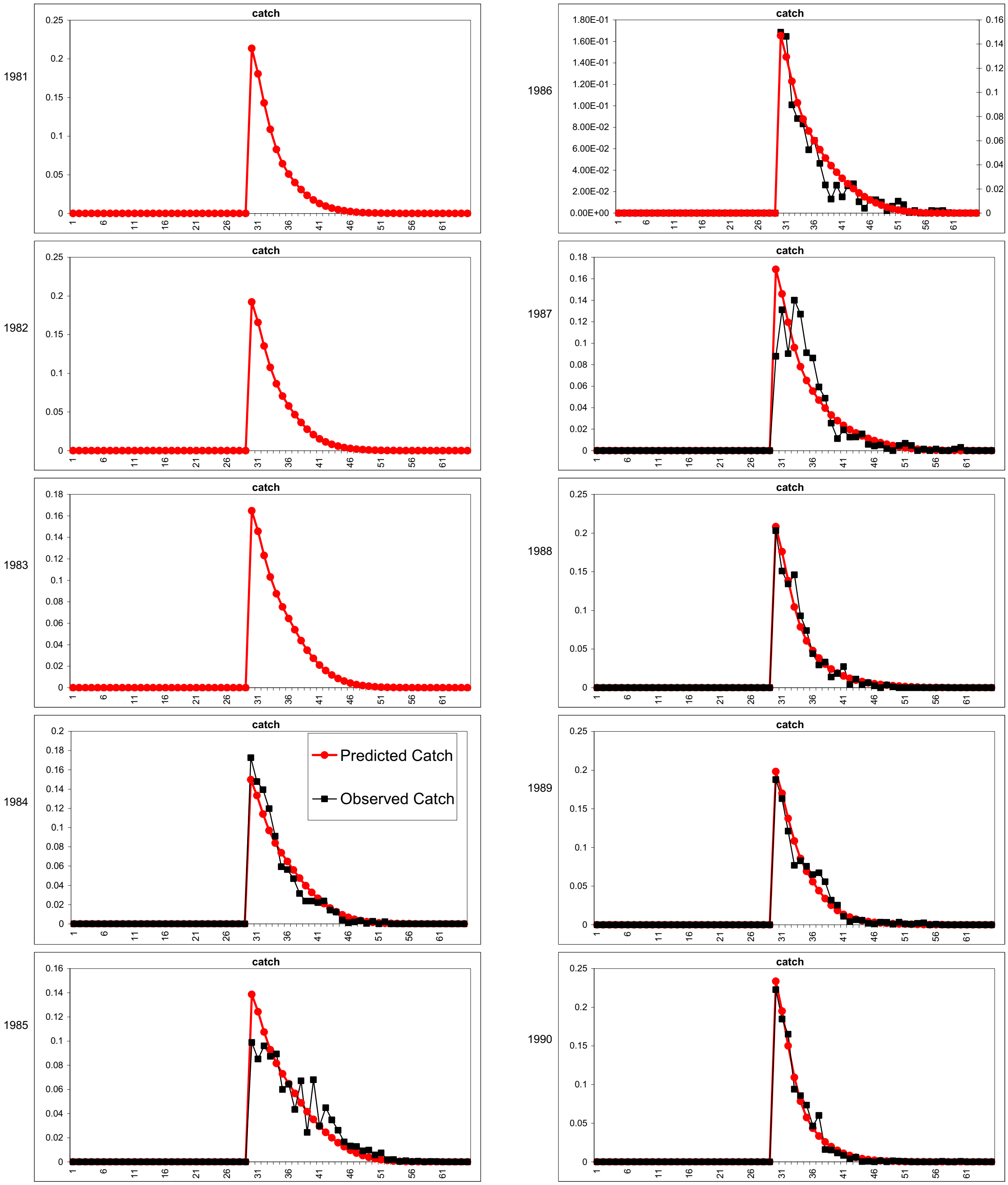

Figure 7 (Appendix C1). Black sea bass LTM run 3 observed and predicted fitted catch length frequency for 22+ cm fish from 1981-2005.

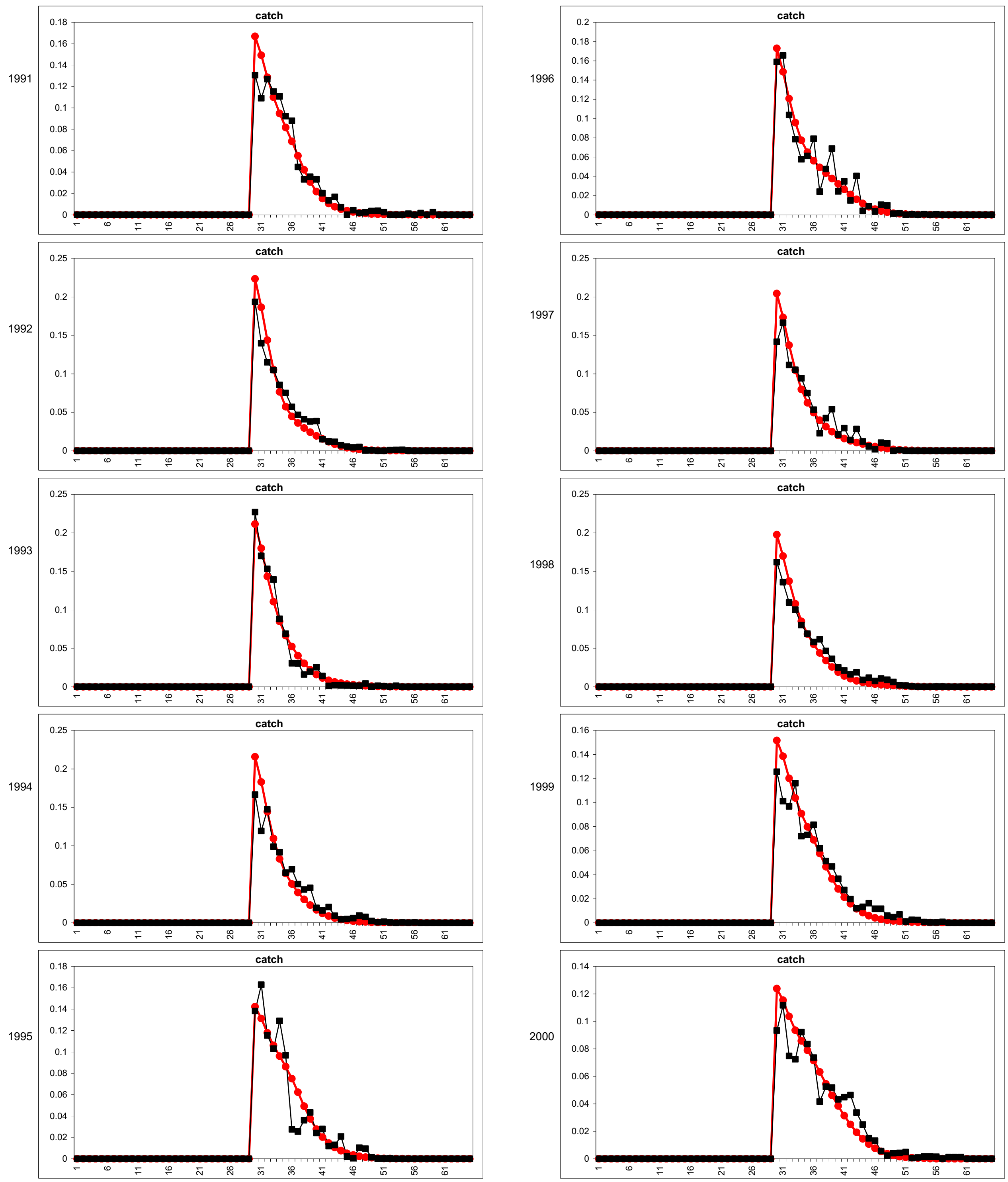
1991
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Fig 7. cont.

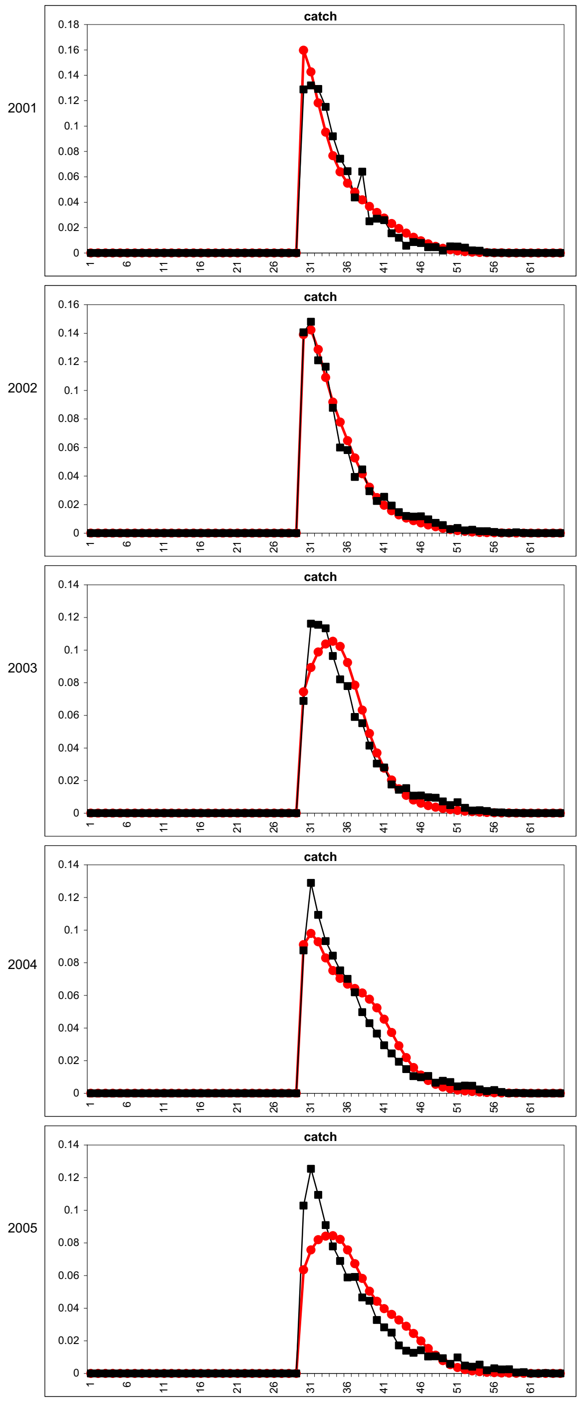

Fig 7. cont.

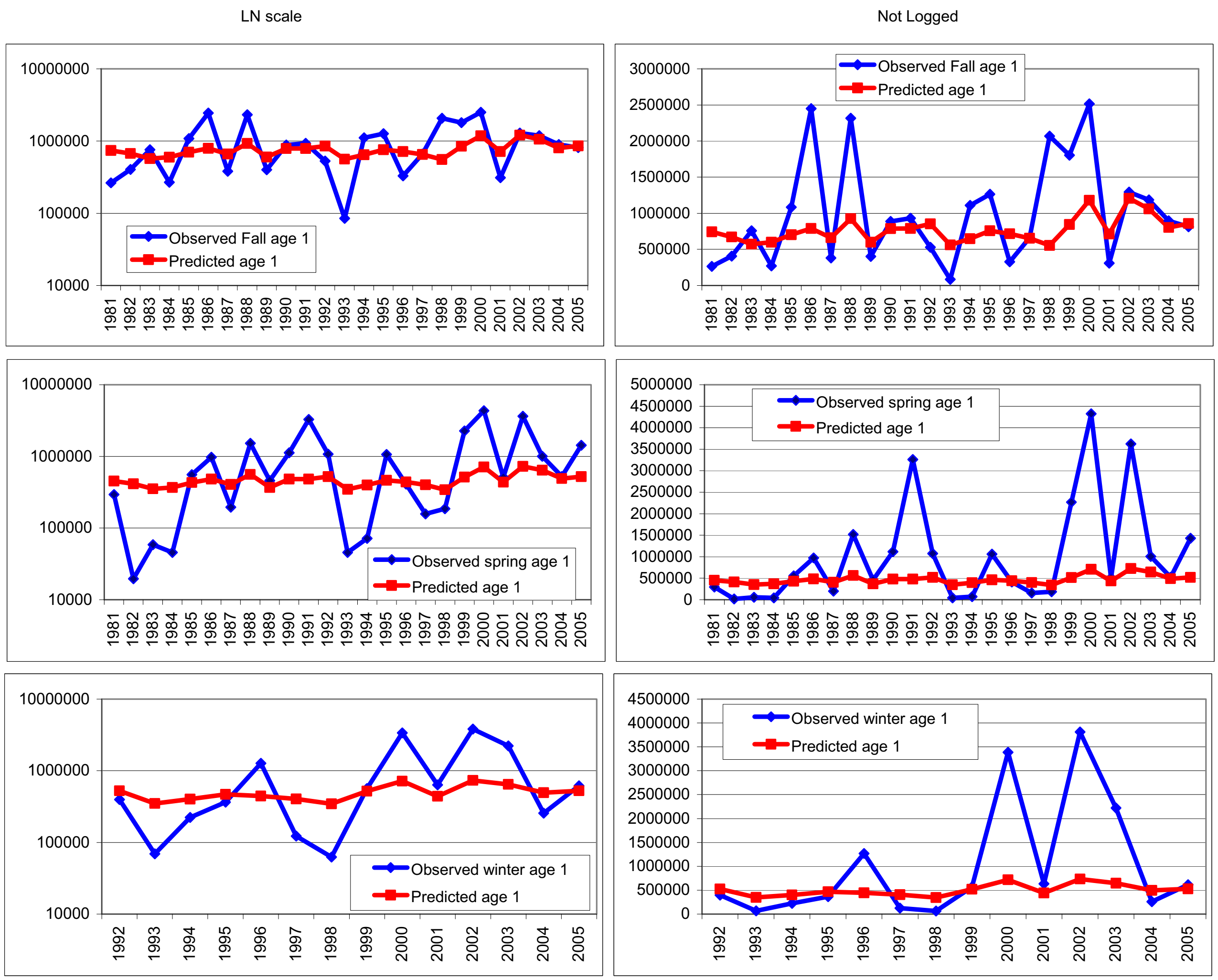

Figure 8 (Appendix C1). Black sea bass run 3 ln and nominal observed and predicted age 1 recruitment indices for the Fall, Spring, and winter NEFSC surveys.

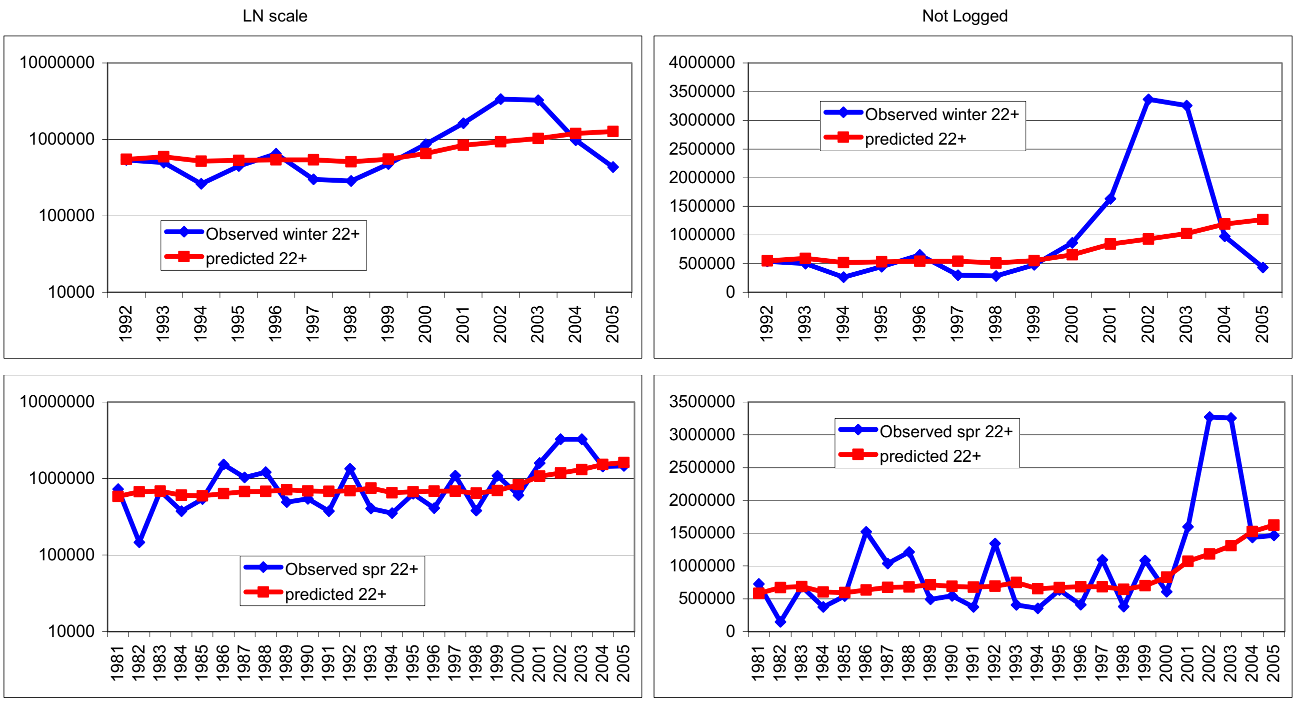

Figure 9 (Appendix C1). Black sea bass run 3 ln and nominal observed and predicted 22+ cm number indices for the NEFSC winter and spring surveys.

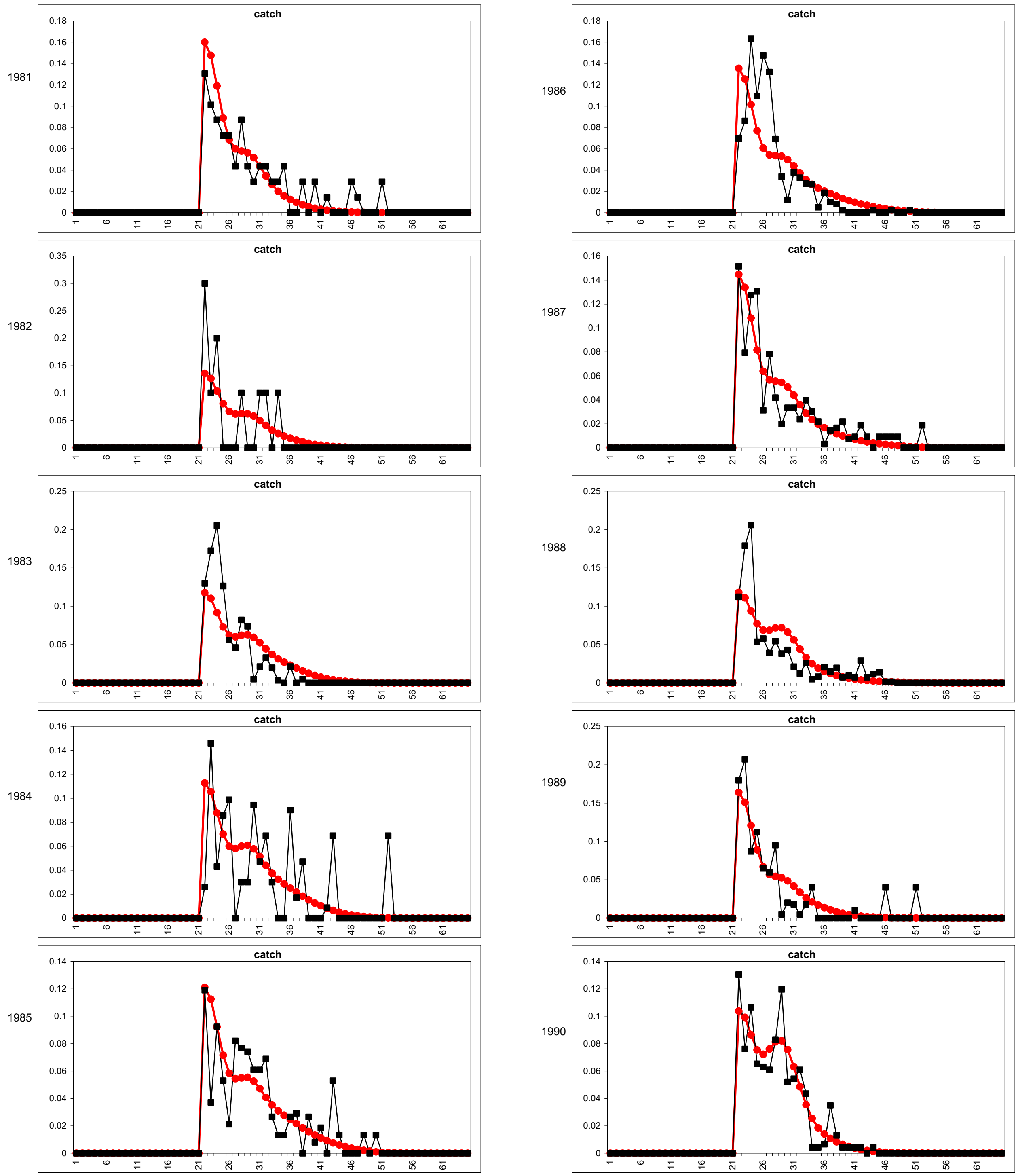

Figure 10 (Appendix C1). Black sea bass LTM run 3 observed (squares) and predicted (dots) fitted length frequency for 22+ cm fish for the NEFSC Spring survey from 1981-2005.

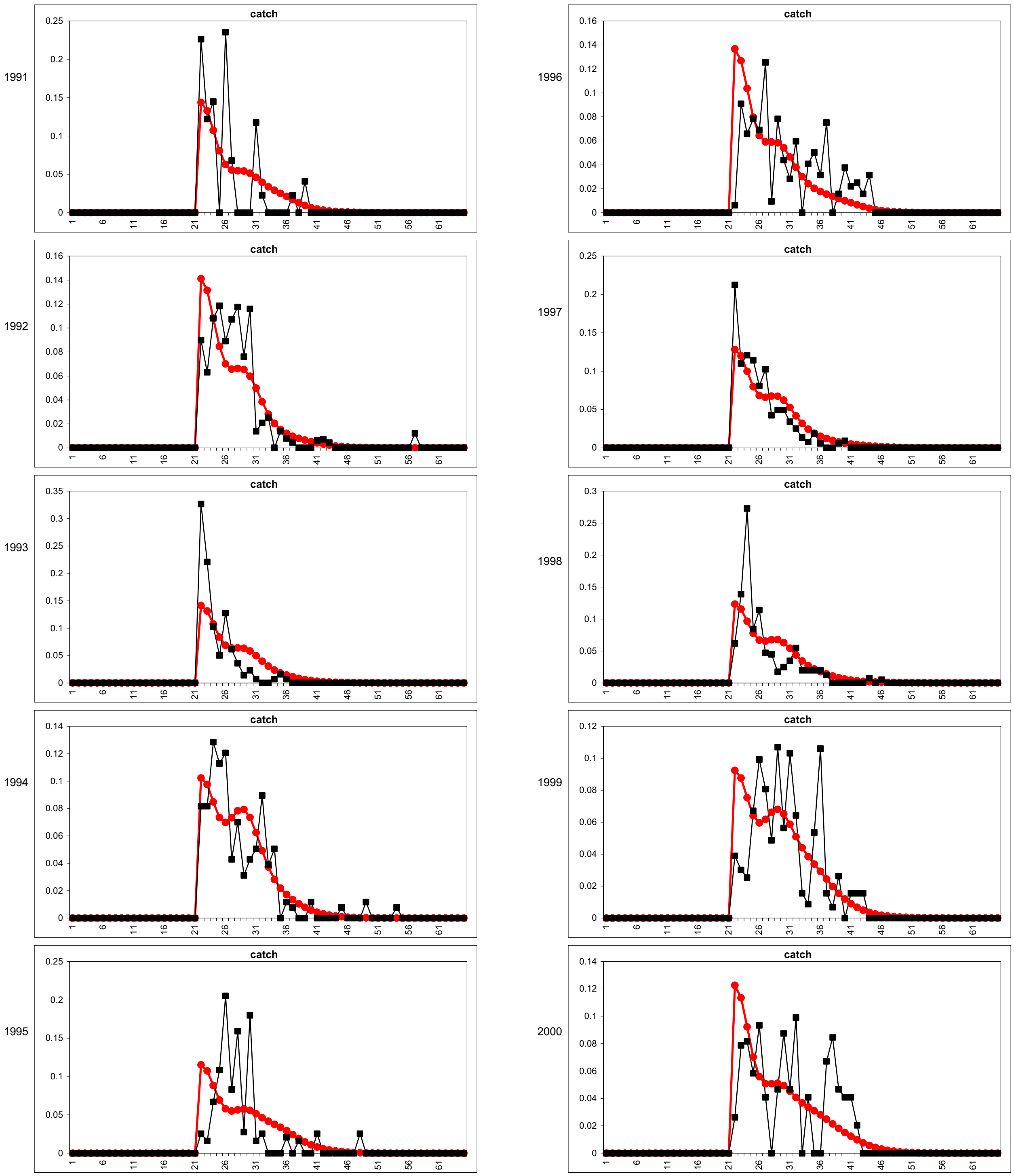
1991
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Fig 10. cont.

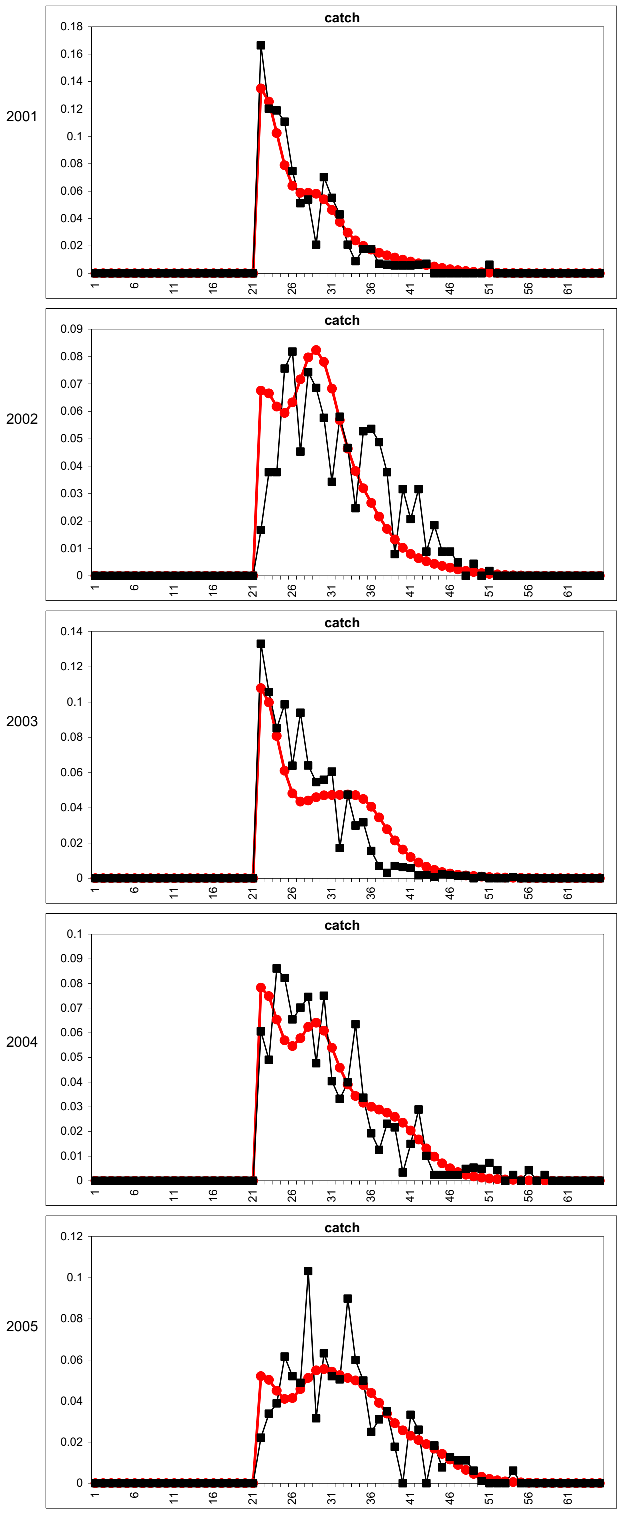

Fig 10. cont.

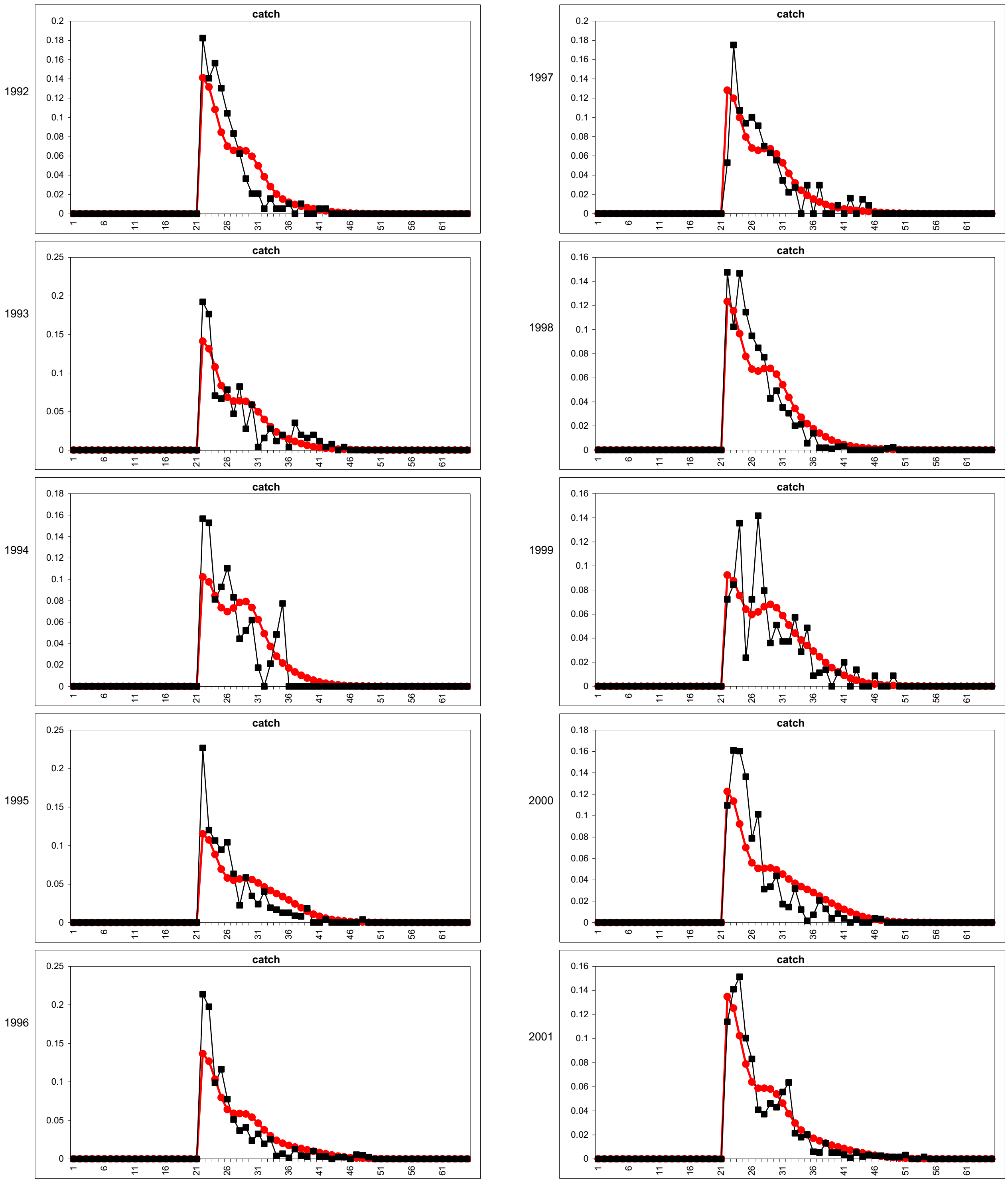

Figure 11 (Appendix C1). Black sea bass LTM run 3 observed (squares) and predicted (dots) fitted length frequency for 22+ cm fish for the NEFSC Winter survey from 1992-2005.

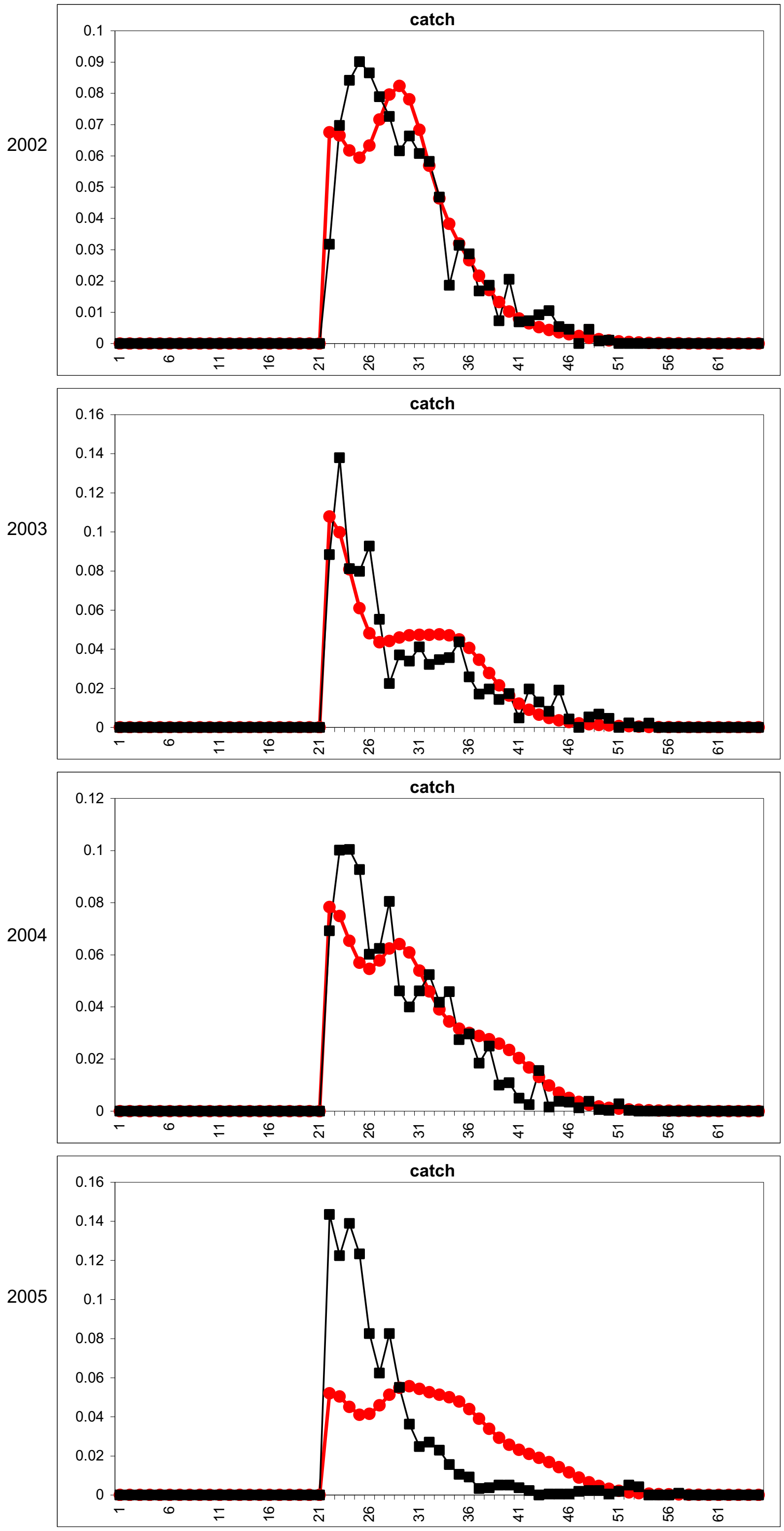
2002
catch
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1 6 11 16 21 26 31 36 41 46 51 56 61
2003
catch
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1 6 11 16 21 26 31 36 41 46 51 56 61
2004
catch
0.12
0.1
0.08
0.06
0.04
0.02
0
1 6 11 16 21 26 31 36 41 46 51 56 61
2005
catch
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1 6 11 16 21 26 31 36 41 46 51 56 61

Fig 11. cont.

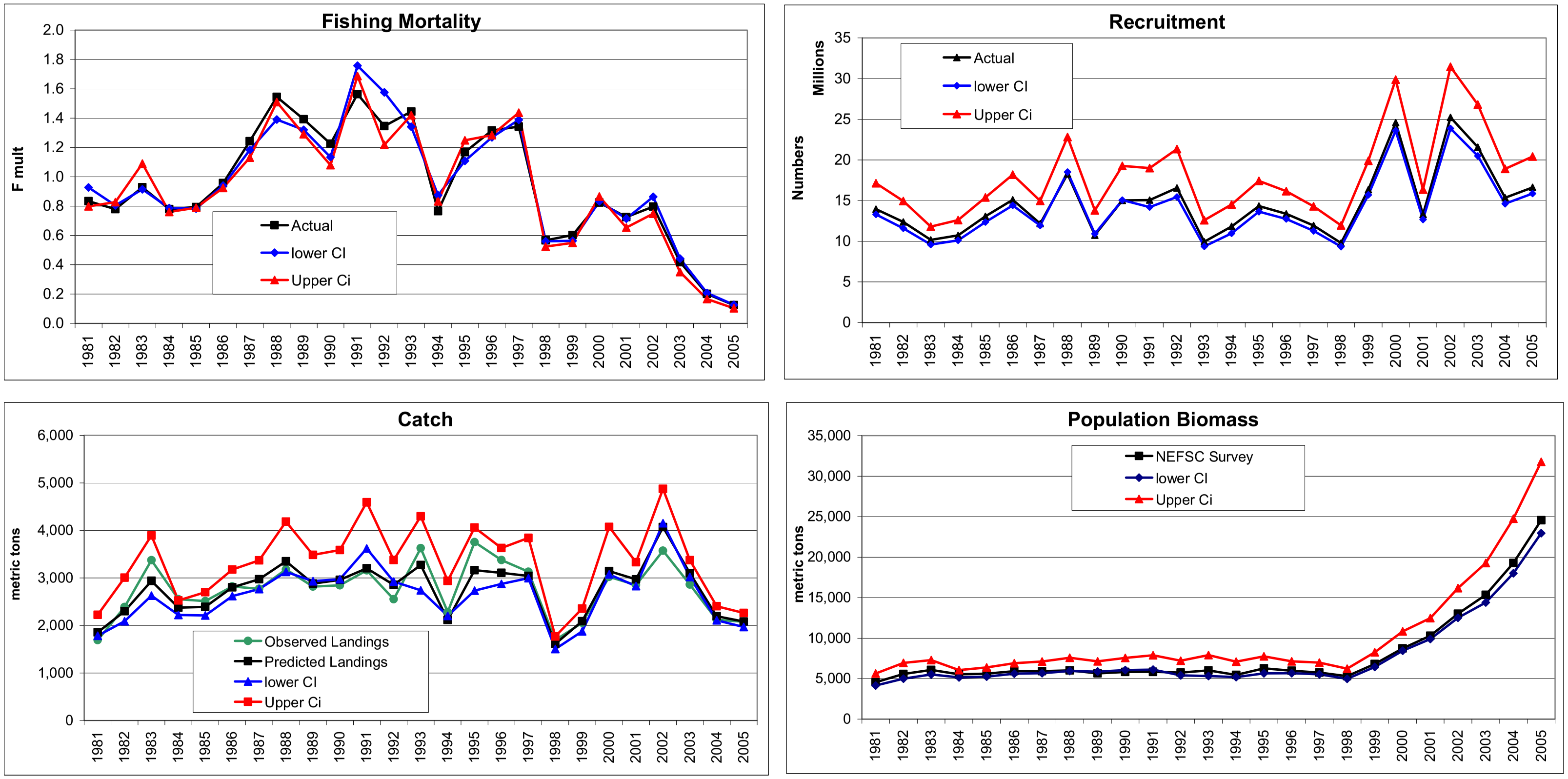

Figure 12 (Appendix C1). Black Sea Bass LTM runs 3, 8, and 9 using MRFSS median, 95% lower and upper confidence interval as the catch with a Vrec weight of 5 and average 82 and 86 recreational landings.