Assessment of Blacknose, Bonnethead, and Atlantic Sharpnose Sharks with a State-Space, Age-Structured Production Model

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SUMMARY:
An age-structured production model was employed to assess the following small coastal sharks: Blacknose (*Carcharhinus acronotus*), Bonnethead (*Sphyrna tiburo*), and Atlantic Sharpnose (*Rhizoprionodon terraenovae*). All models assumed virgin conditions in 1950, and historically reconstructed catches were derived to inform the model on likely levels of removals for the years prior to the start of observed and recorded catches. The base models for all three species applied equal weight to all indices. Base model results for bonnethead shark indicate that the stock is overfished and that there is overfishing. The stock status appears to be quite sensitive to the reconstructed catches, particularly because of some extreme peaks in the bottom longline fishery reports and the shrimp bycatch reports. An initial sensitivity run indicates that the stock depletion decrease when less weight is given to the extreme peaks. Additional sensitivities will be performed at the assessment workshop. The base model results for Blacknose suggest that the stock is overfished and that there is also overfishing. The base model for Atlantic sharpnose assumed a single stock, and results from this model indicate that the stock is not overfished nor is overfishing occurring. A sensitivity analysis where inverse CV weights were applied to the base indices showed very little difference from the base model, and the stock status estimate was no overfishing and the stock is not overfished.

Methods

The age-structured production model (originally derived in Porch 2002) starts from a year when the stock can be considered to be at virgin conditions. Then, assuming that there is some basis for deriving historic removals, one can estimate a population trajectory from virgin conditions through a "historic era," where data are sparse, and a "modern era," where more data are available for model fitting. In all three model applications, virgin conditions were assumed in 1950. The earliest index of abundance (SEAMAP) and the earliest catch series (Shrimp trawl bycatch) begin in 1972, thus the historic model years spanned 1950-1971 (22 years) and the modern model years spanned 1972-2005 (34 years).

Population Dynamics

The dynamics of the model are described below, and are extracted and/or modified from Porch (2002). The model begins with the population at unexploited conditions, where the age structure is given by

$$(1) \qquad N_{a,y=1,m=1} = \begin{cases} R_0 & a = 1 \\ R_0 \exp\left(-\sum_{j=1}^{a-1} M_a\right) & 1 < a < A \\ \dfrac{R_0 \exp\left(-\sum_{j=1}^{A-1} M_a\right)}{1-\exp(-M_A)} & a = A \end{cases} ,$$

where $N_{a,y,1}$ is the number of sharks in each age class in the first model year (y=1), in the first month (m=1), M_a is natural mortality at age, A is the plus-group age, and recruitment (R) is assumed to occur at age 1.

The stock-recruit relationship was assumed to be a Beverton-Holt function, which was parameterized in terms of the maximum lifetime reproductive rate, α:

$$(2) \qquad R = \frac{R_0 S \alpha}{S_0 + (\alpha - 1)S} \quad .$$

In (2), R_0 and S_0 are virgin number of recruits (age-1 pups) and spawners (units are number of mature adult females times pup production at age), respectively. The parameter α is calculated as:

$$(3) \qquad \alpha = e^{-M_0}\left[\left(\sum_{a=1}^{A-1} p_a m_a \prod_{j=1}^{a-1} e^{-M_a}\right) + \frac{p_A m_A}{1-e^{-M_A}} e^{-M_A}\right] = e^{-M_0}\varphi_0 \quad ,$$

where p_a is pup-production at age a, m_a is maturity at age a, and M_a is natural mortality at age a. The first term in (3) is pup survival at low population density (Myers et al. 1999). Thus, α is virgin spawners per recruit (φ_0) scaled by the slope at the origin (pup-survival).

The time period from the first model year (y_1) to the last model year (y_T) is divided into a historic and a modern period, where y_i for i<mod are historic years, and modern years are y_i for which mod ≤ i ≤ T. The historic period is characterized by having relatively less data compared to the modern period. The manner in which effort is estimated depends on the model period. In the historic period, effort is estimated as either a constant (4a) or a linear trend (4b)

(4a) $$f_{y,i} = b_0 \qquad \text{(constant effort)}$$

or

(4b) $$f_{y,i} = b_0 + \frac{(f_{y=\text{mod},i} - b_0)}{(y_{\text{mod}} - 1)} f_{y=\text{mod},i} \qquad \text{(linear effort),}$$

where $f_{y,i}$ is annual fleet-specific effort, b_0 is the intercept, and $f_{y=mod,i}$ is a fleet-specific constant. In the modern period, fleet-specific effort is estimated as a constant with annual deviations, which are assumed to follow a first-order lognormal autoregressive process:

(5) $$\begin{aligned} f_{y=\text{mod},i} &= f_i \exp(\delta_{y,i}) \\ \delta_{y,i} &= \rho_i \delta_{y-1} + \eta_{y,i} \\ \eta_{y,i} &\sim N(0, \sigma_i) \end{aligned} \quad .$$

From the virgin age structure defined in (1), abundance at the beginning of subsequent months (*m*) is calculated by

(6) $$N_{a,y,m+1} = N_{a,y,m} e^{-M_a \delta} - \sum_i C_{a,y,m,i} \quad ,$$

where δ is the fraction of the year (*m*/12) and $C_{a,y,m,i}$ is the catch in numbers of fleet i. The monthly catch by fleet is assumed to occur sequentially as a pulse at the end of the month, after natural mortality:

(7) $$C_{a,y,m,i} = F_{a,y,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad ,$$

where τ_i is the duration of the fishing season for fleet i. Catch in weight is computed by multiplying (7) by $w_{a,y}$, where weight at age for the plus-group is updated based on the average age of the plus-group.

The fishing mortality rate, F, is separated into fleet-specific components representing age-specific relative-vulnerability, v, annual effort expended, f, and an annual catchability coefficient, q:

$$F_{a,y,i} = q_{y,i} f_{y,i} v_{a,i} \quad . \tag{8}$$

Catchability is the fraction of the most vulnerable age class taken per unit of effort. The relative-vulnerability would incorporate such factors as gear selectivity, and the fraction of the stock exposed to the fishery. For this model application to small coastal sharks, both vulnerability and catchability were assumed to be constant over years.

Catch per unit effort (CPUE) or fishery abundance surveys are modeled as though the observations were made just before the catch of the fleet with the corresponding index, i:

$$I_{y,m,i} = q_{y,i} \sum_a v_{a,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad . \tag{9}$$

Equation (9) provides an index in numbers; the corresponding CPUE in weight is computed by multiplying $v_{a,i}$ in (9) by $w_{a,y}$.

State space implementation

In general, process errors in the state variables and observation errors in the data variables can be modeled as a first-order autoregressive model:

$$\begin{aligned} g_{t+1} &= E[g_{t+1}] e^{\varepsilon_{t+1}} \\ \varepsilon_{t+1} &= \rho \varepsilon_t + \eta_{t+1} \end{aligned} \quad . \tag{10}$$

In (10), g is a given state or observation variable, η is a normal-distributed random error with mean 0 and standard deviation σ_g, and ρ is the correlation coefficient. E[g] is the deterministic expectation. When g refers to data, then g_t is the observed quantity, but when g refers to a state variable, then those g terms are estimated parameters. For example, effort in the modern period is treated in this fashion.

The variances for process and observation errors (σ_g) are parameterized as multiples of an overall model coefficient of variation (CV):

(11a) $\sigma_g = \ln\left[(\lambda_g CV)^2 + 1\right]$

(11b) $\sigma_g = \ln\left[(\omega_{i,y}\lambda_g CV)^2 + 1\right]$.

The term λ_g is a variable-specific multiplier of the overall model CV. For catch series and indices (eq 11b), the additional term, $\omega_{i,y}$, is the weight applied to individual points within those series. For instance, because the indices are standardized external to the model, the estimated variance of points within each series is available and could be used to weight the model fit. Given the data workshop decision to use equal weighting between indices for the base model run, all $\omega_{i,y}$ were fixed to 1.0 and the same λ_g was applied to all indices. To evaluate the sensitivity case where indices were weighted by the inverse of their CV, each $\omega_{i,y}$ was fixed to the estimated CV for point *y* in series *i*; an attempt was also made to estimate a separate λ_g for each series, however those multipliers were not estimable and so a single λ was applied to all indices.

Application to Atlantic Sharpnose shark

Sharpnose: Base Model Inputs

Data

Data inputted to the model included maturity at age, fecundity at age (pups per mature female), spawning season, catches, indices, and selectivity functions (Tables AS-1—AS-3; Tables ALL-1 and 2; Figures AS-1—AS-3). Catches were attributed to six different fleets: the commercial bottom long line, the commercial gillnet, the commercial handline, discards from the commercial bottom longline, the recreational sector, and bycatch from the shrimp trawl fishery. Historic catches for each fleet were reconstructed as described in SEDAR13-DW-Final Report. A total of 13 indices were made available after the data workshop.

Parameters

Estimated model parameters were pup survival, virgin recruitment (R0), catchabilities associated with all indices, fleet-specific effort and effort deviations in the modern period.

Sharpnose: Description of Model Runs

Model BASE was the base model, while the S-# configurations were sensitivity runs. Each model is described below.

BASE –all indices were used and given equal weighting; the DW recommended historic catches were used

S1 – all indices were used and given inverse CV weighting; the DW recommended historic catches were used

Sharpnose: Results of Model Runs

The base model results (Table AS-3; Fig. AS-4) indicated that the stock was not overfished nor was overfishing occurring. Although the level of fishing mortality exceeded F_{MSY} in several years, the last three years have all been less than F_{MSY} (Fig. AS-5). Years where $F>F_{MSY}$ generally coincide with peaks in the shrimp landings, most notably in 1981. Examining the pattern in estimated fishing mortality at age for the last decade, it appears that the highest F is occurring on ages 1-3 (Fig. AS-6), i.e. fishing mortality is occurring on fish before they reach maturity (see maturity ogive plotted in Fig. AS-3). The stock is estimated to be at 60-65% of virgin levels (for units of biomass or number, respectively; Fig. AS-7). Catches were fit well in general, although the downweighting of historically reconstructed catches caused them to be fit less closely than data in the modern period, defined as 1972-2005 (Fig. AS-8). Indices were fit assuming lognormal error, and fits to these indices were acceptable (Fig. AS-9).

The base model estimate of MSY is 1.27E+6 kg, or approximately 1.25E+6 sharks, given the selectivities derived for the various catch series. The virgin estimate of sharpnose sharks (in numbers) is about 11 million, while the 2005 population size is estimated to be about 6.2 million.
Results for model S-1, which was configured exactly the same as the base model with the exception that indices were weighted by their inverse CV, were very similar to the base model (Table AS-5).

Table ALL-1. Biological inputs for natural mortality (*M*) and the maturity ogive for all species in the small coastal complex.

	Bonnethead	Blacknose	Sharpnose	Bonnethead	Blacknose	Sharpnose
Age	M at age	M at age	M at age	Female Maturity	Female Maturity	Female Maturity
1	0.41	0.33	0.36	0	0	0
2	0.40	0.28	0.34	0.02	0.10	0.01
3	0.38	0.26	0.33	0.12	0.07	0.28
4	0.37	0.25	0.31	0.48	0.48	0.92
5	0.32	0.25	0.31	0.86	0.92	1
6	0.29	0.24	0.30	0.98	0.99	1
7	0.27	0.24	0.29	1	1	1
8	0.26	0.24	0.27	1	1	1
9	0.25	0.24	0.27	1	1	1
10	0.23	0.24	0.26	1	1	1
11	0.22	0.24	0.25	1	1	1
12	0.21	0.24	0.24	1	1	1
13	na	0.22	na	1	1	1

Table ALL-2. Parameter specifications for vonBertalanffy length at age, length-weight parameters, pup survival, virgin recruitment, and the number of pups per female. for bonnethead, blacknose, and atlantic sharpnose.

Parameter	Bonnethead	Blacknose	Sharpnose
L_∞	113.9 (cm TL)	80.2 (cm FL)	80.2 (cm FL)
K	0.22	0.3	0.61
t0	-1.25	-1.71	-0.84
a	9.52E-11	8.0E-06	5.55519E-6
b	3.59	3.0494	3.07395
Pup Survival	0.66	0.72	0.70
Virgin Recruitment (R0)	[1.0E+4, 1.0E+10]	[1.0E+4, 1.0E+10]	[1.0E+3, 1.0E+10]

Table AS-1. Catches of Atlantic Sharpnose shark by fleet.

Year	Com-BLL	Com-GN	Com-L	BLL-Dis	Rec	Shrimp
1950	*0*	*0*	*0*	*0*	*12,114*	*199,157*
1951	*0*	*0*	*12*	*0*	*13,314*	*255,841*
1952	*0*	*0*	*24*	*0*	*14,514*	*258,937*
1953	*0*	*0*	*36*	*0*	*15,714*	*297,766*
1954	*0*	*0*	*48*	*0*	*16,914*	*307,492*
1955	*0*	*0*	*61*	*0*	*18,114*	*278,697*
1956	*0*	*0*	*73*	*0*	*19,314*	*253,339*
1957	*0*	*0*	*85*	*0*	*20,514*	*227,780*
1958	*0*	*0*	*97*	*0*	*21,714*	*226,216*
1959	*0*	*0*	*109*	*0*	*22,914*	*253,769*
1960	*0*	*0*	*121*	*0*	*24,114*	*271,849*
1961	*0*	*0*	*133*	*0*	*24,815*	*136,426*
1962	*0*	*0*	*145*	*0*	*25,517*	*178,861*
1963	*0*	*0*	*157*	*0*	*26,218*	*269,133*
1964	*0*	*0*	*169*	*0*	*26,920*	*240,757*
1965	*0*	*0*	*182*	*0*	*27,621*	*258,877*
1966	*0*	*0*	*194*	*0*	*28,322*	*244,276*
1967	*0*	*0*	*206*	*0*	*29,024*	*299,894*
1968	*0*	*0*	*218*	*0*	*29,725*	*273,578*
1969	*0*	*0*	*230*	*0*	*30,427*	*286,401*
1970	*0*	*0*	*242*	*0*	*31,128*	*315,416*
1971	*0*	*0*	*254*	*0*	*34,310*	*323,214*
1972	*0*	*0*	*266*	*0*	*34,613*	546,849
1973	*0*	*0*	*278*	*0*	*34,916*	115,836
1974	*0*	*0*	*291*	*0*	*35,220*	208,340
1975	*0*	*0*	*303*	*0*	*35,523*	216,843
1976	*0*	*0*	*315*	*0*	*35,827*	159,043
1977	*0*	*0*	*327*	*0*	*36,130*	560,188
1978	*0*	*0*	*339*	*0*	*36,434*	651,041
1979	*0*	*0*	*351*	*0*	*36,737*	530,051
1980	*0*	*0*	*363*	*0*	41,970	852,586
1981	*1,357*	*0*	*375*	*1,054*	43,490	1,679,872
1982	*2,714*	*0*	*387*	*2,108*	40,656	235,138
1983	*4,072*	*0*	*399*	*3,161*	50,170	386,130
1984	*5,429*	*0*	*412*	*4,215*	37,539	217,712
1985	*6,786*	*0*	*424*	*5,269*	37,994	330,027
1986	*8,143*	*0*	*436*	*6,323*	45,392	228,189
1987	*9,501*	*726*	*448*	*7,377*	46,792	639,555
1988	*10,858*	*1,452*	*460*	*8,430*	103,375	362,917
1989	*12,215*	*2,178*	*472*	*9,484*	65,058	304,957
1990	*13,572*	*2,904*	*484*	*10,538*	45,233	342,124
1991	*14,930*	*3,630*	*496*	*11,592*	134,905	518,206
1992	*16,287*	*4,355*	*508*	*12,645*	85,972	968,330
1993	*17,644*	*5,081*	*521*	*13,699*	67,719	433,492
1994	*19,001*	*5,807*	*533*	*14,753*	101,774	259,349

1995	20,359	6,533	545	16,938	128,478	638,341
1996	12,074	35,721	1,318	5,011	73,114	503,193
1997	6,925	70,619	854	2,631	67,675	329,038
1998	6,580	64,506	1,794	2,711	83,748	512,281
1999	5,248	69,727	1,576	4,561	69,153	311,118
2000	3,951	35,610	1,145	3,564	130,727	539,085
2001	4,787	53,890	1,190	4,782	131,912	318,995
2002	11,635	59,098	819	11,531	88,297	639,044
2003	19,783	15,855	25,773	15,668	85,299	295,059
2004	25,639	47,693	644	24,613	67,870	173,326
2005	24,876	80,539	1,159	21,369	80,761	325,764

Table AS-2a. Base indices available for use in the 2006/2007 Atlantic sharpnose shark assessment. Selectivity series indicated in last row (see Figure AS-3).

Year	PC-LL	PC-GN.a	PC-GN.j	GNOP	BLLOP	SEAMAP-SA	Texas	VA-LL	NMFS-LL SE	SC-GN	SCDNR	SEAMAP-GOM ES	SEAMAP GOM-EF	UNC	MML-GN.a	MML-GN.j
1972	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0.424	-1	-1	-1
1973	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0.455	0.861	-1	-1
1974	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1.38	0.313	-1	-1
1975	-1	-1	-1	-1	-1	-1	1.7	-1	-1	-1	-1	-1	1.193	0.653	-1	-1
1976	-1	-1	-1	-1	-1	-1	0.9	0.036	-1	-1	-1	-1	1.296	0.372	-1	-1
1977	-1	-1	-1	-1	-1	-1	0.8	1.125	-1	-1	-1	-1	0.71	0.739	-1	-1
1978	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0.661	1.366	-1	-1
1979	-1	-1	-1	-1	-1	-1	1.6	-1	-1	-1	-1	-1	0.764	1.166	-1	-1
1980	-1	-1	-1	-1	-1	-1	0.5	3.406	-1	-1	-1	-1	1.263	1.139	-1	-1
1981	-1	-1	-1	-1	-1	-1	0.4	3.703	-1	-1	-1	-1	0.836	0.594	-1	-1
1982	-1	-1	-1	-1	-1	-1	0.3	-1	-1	-1	-1	0.855	0.896	0.34	-1	-1
1983	-1	-1	-1	-1	-1	-1	0.7	3.114	-1	-1	-1	3.329	0.776	1.353	-1	-1
1984	-1	-1	-1	-1	-1	-1	2.1	-1	-1	-1	-1	1.118	0.623	0.922	-1	-1
1985	-1	-1	-1	-1	-1	-1	1.7	-1	-1	-1	-1	1.55	0.941	1.322	-1	-1
1986	-1	-1	-1	-1	-1	-1	4	-1	-1	-1	-1	0.862	0.533	1.15	-1	-1
1987	-1	-1	-1	-1	-1	-1	0.7	5.103	-1	-1	-1	0.705	0.781	1.735	-1	-1
1988	-1	-1	-1	-1	-1	-1	3.4	1.765	-1	-1	-1	0.649	0.443	2.299	-1	-1
1989	-1	-1	-1	-1	-1	-1	1.4	0.946	-1	-1	-1	0.669	0.324	1.265	-1	-1
1990	-1	-1	-1	-1	-1	2.983	1	2.706	-1	-1	-1	0.189	0.474	1.75	-1	-1
1991	-1	-1	-1	-1	-1	3.163	1.7	3.147	-1	-1	-1	0.81	0.244	3.526	-1	-1
1992	-1	-1	-1	-1	-1	2.908	0.9	2.478	-1	-1	-1	0.587	0.237	6.286	-1	-1
1993	0.481	-1	-1	63.769	-1	2.24	0.8	3.154	-1	-1	-1	0.658	0.417	3.141	-1	-1
1994	0.136	-1	-1	520.751	10.534	1.623	1.1	-1	-1	-1	-1	0.232	0.5	2.164	-1	-1
1995	0.301	-1	-1	355.17	118.473	3.052	0.7	2.715	1.982	-1	-1	1.066	0.34	5.698	2.868	0.07
1996	0.951	0.339	1.166	-1	107.619	1.86	3	3.201	1.82	-1	-1	1.057	0.565	3.101	9.14	0.305
1997	0.531	0.679	1.401	-1	157.065	3.855	1.1	2.048	2.426	-1	-1	0.537	0.386	2.898	3.21	2.971
1998	0.38	0.408	1.039	-1	245.823	2.679	1	3.247	-1	8.28	0.154	0.5	0.315	3.78	-1	-1
1999	1.16	0.361	1.514	165.327	760.861	2.734	3.2	6.057	0.627	9.923	0.09	0.484	0.406	2.865	6.522	0.423
2000	0.445	0.616	0.852	27.34	828.94	3.835	2.5	1.156	4.592	5.892	0.148	0.786	0.489	4.001	5.041	0.161
2001	-1	0.706	1.442	634.326	292.945	3.385	0.3	2.55	-1	6.14	0.23	0.351	0.288	-1	32.431	0.505

2002	-1	1.037	1.036	831.673	272.197	5.306	2.6	1.85	14.949	5.182	0.227	0.822	0.286	4.872	13.662	0.897
2003	-1	1.091	1.117	814.365	167.911	5.686	2.9	1.557	-1	14.621	0.195	0.41	0.404	6.899	35.56	0.254
2004	-1	0.659	0.667	278.853	133.011	3.851	2.2	1.833	14.6	3.57	0.075	0.219	0.199	6.449	18.35	0.078
2005	-1	-1	0.339	984.79	148.218	4.969	1.8	7.879	21.693	6.018	0.138	0.359	0.38	8.917	-1	-1
Selectivity series																
	3	5	3	4	1	3	3	2	1	3	2	3	3	2	5	3

Table AS-2b. Sensitivity indices available for use in the 2006/2007 Atlantic sharpnose shark assessment. Selectivity series indicated in last row (see Figure AS-3).

	MS.GN - a	MS.GN - j	Gillnet Logs	NE Exp LL
1979	-1	-1	-1	0.713
1980	-1	-1	-1	-1
1981	-1	-1	-1	-1
1982	-1	-1	-1	-1
1983	-1	-1	-1	1.086
1984	-1	-1	-1	-1
1985	-1	-1	-1	0.115
1986	-1	-1	-1	0.861
1987	-1	-1	-1	-1
1988	-1	-1	-1	-1
1989	-1	-1	-1	0.109
1990	-1	-1	-1	-1
1991	-1	-1	-1	0.273
1992	-1	-1	-1	-1
1993	-1	-1	-1	-1
1994	-1	-1	-1	-1
1995	-1	-1	-1	-1
1996	-1	-1	-1	-1
1997	-1	-1	-1	-1
1998	-1	-1	0.016	-1
1999	-1	-1	0.023	-1
2000	-1	-1	0.018	-1
2001	1.412	0.717	0.017	-1
2002	-1	-1	0.013	-1
2003	0.385	0.153	0.015	-1
2004	0.460	0.109	0.016	-1
2005	0.414	0.199	0.030	-1
Selectivity series				
	5	3	4	2

Table AS-3. Atlantic sharpnose shark assessment model results of the base case (BASE) and sensitivity run (S1 – inverse CV weighting). CVs of model estimates are given in parentheses below each model estimate. SSF is spawning stock fecundity (not spawning stock *biomass*) and is calculated as the sum of the number of mature females multiplied by the number of pups produced per mature female. Parameters N_{2005} and N_{MSY} are calculated mid-year.

Parameter	**BASE** Estimate	**BASE** CV	**S-1** Estimate	**S-1** CV
SSF_{2005}/SSF_{MSY}	1.49	0.45	1.54	0.42
F_{2005}/F_{MSY}	0.70	0.78	0.66	0.76
N_{2005}/N_{MSY}	1.35	--	1.39	
MSY	1.27E+06	--	1.32E+06	
SPR_{MSY}	0.59	0.11	0.59	0.11
F_{MSY}	0.19	0.00	0.19	0.00
SSF_{MSY}	4.59E+06	--	4.77E+06	
N_{MSY}	4.62E+06	--	4.80E+06	
F_{2005}	0.13	0.78	0.12	0.76
SSF_{2005}	6.81E+06	0.65	7.35E+06	0.61
N_{2005}	6.22E+06	--	6.67E+06	
SSF_{2005}/SSF_0	0.56	0.32	0.59	0.29
B_{2005}/B_0	0.49	0.31	0.50	0.27
R0	3.24E+06	0.35	3.36E+06	0.35
Pup-survival	0.76	0.28	0.76	0.28
alpha	2.85	--	2.87	
steepness	0.42	--	0.42	

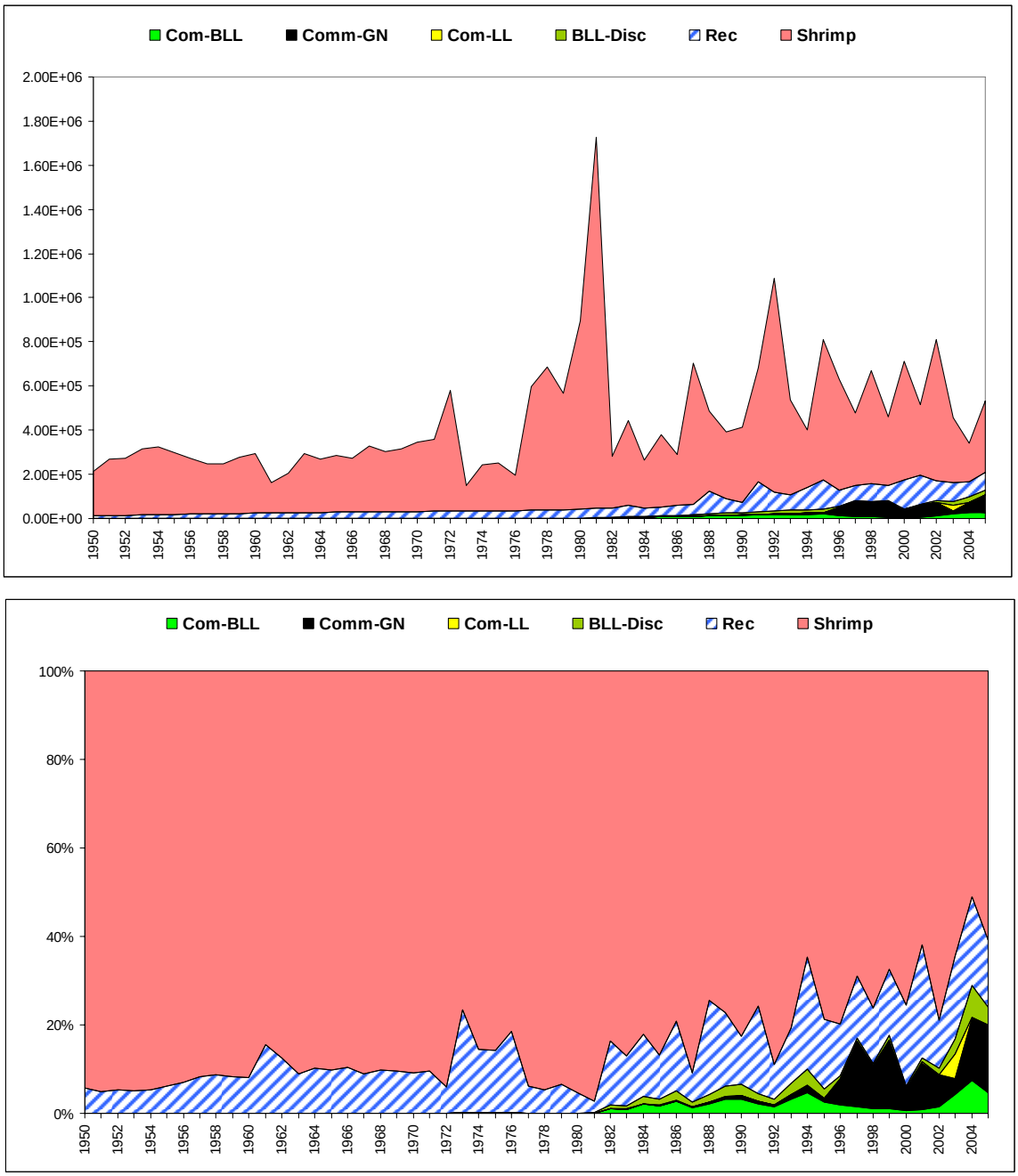
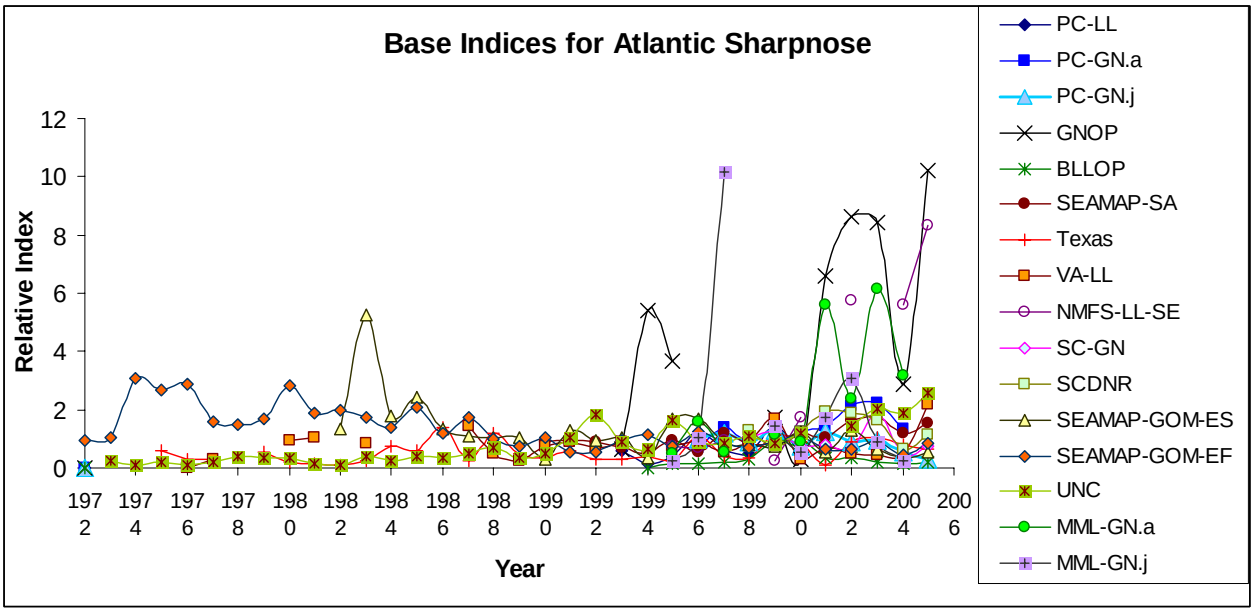


Figure AS-1. Catch of atlantic sharpnose shark by fleet in numbers (top) and by proportion (bottom) from 1950-2005.



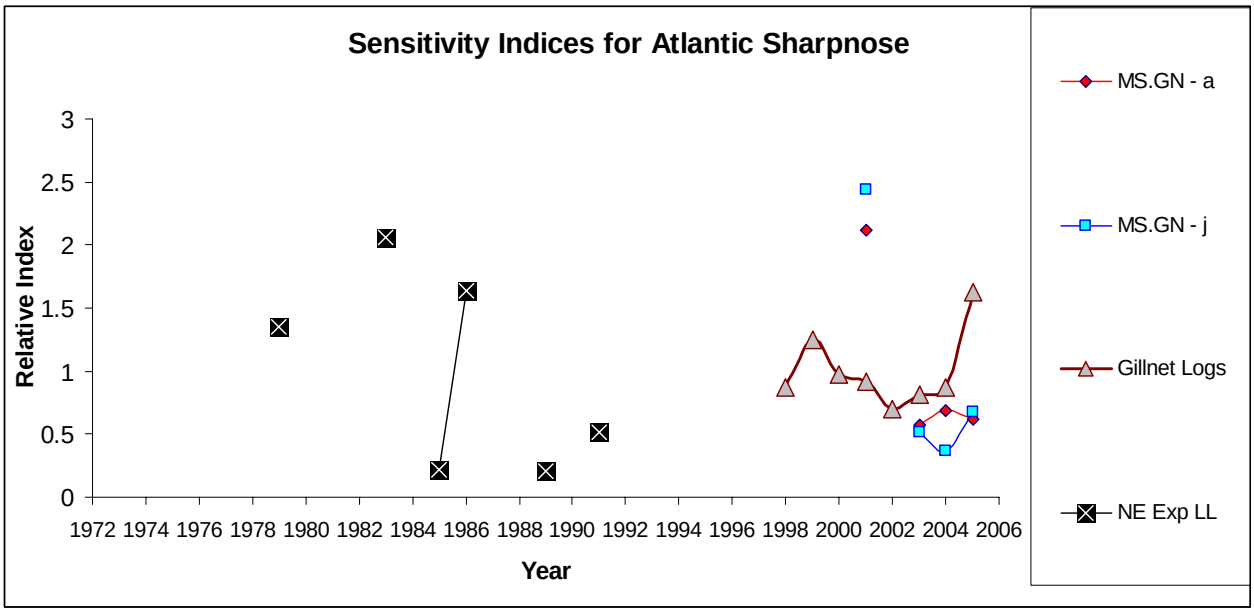


Figure AS-2. Indices for atlantic sharpnose shark. The top panel shows the base indices, the bottom panel shows all indices (base + sensitivity).

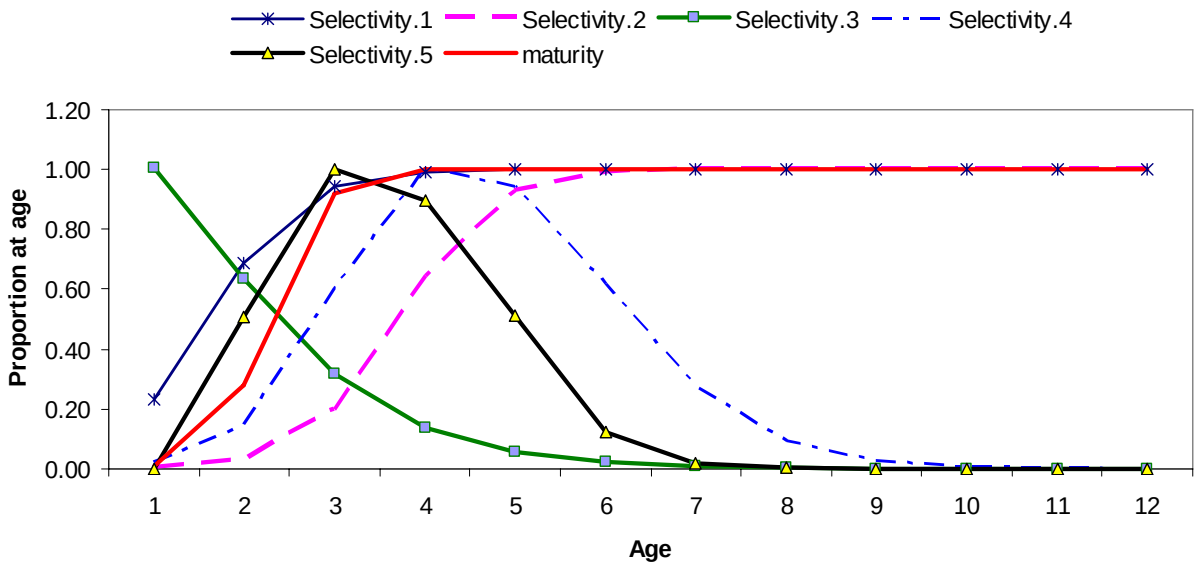


Figure AS-3. Selectivity at age and maturity at age (solid red line). The selectivity assigned to each index is given in the last row of the table of indices (Table AS-2).

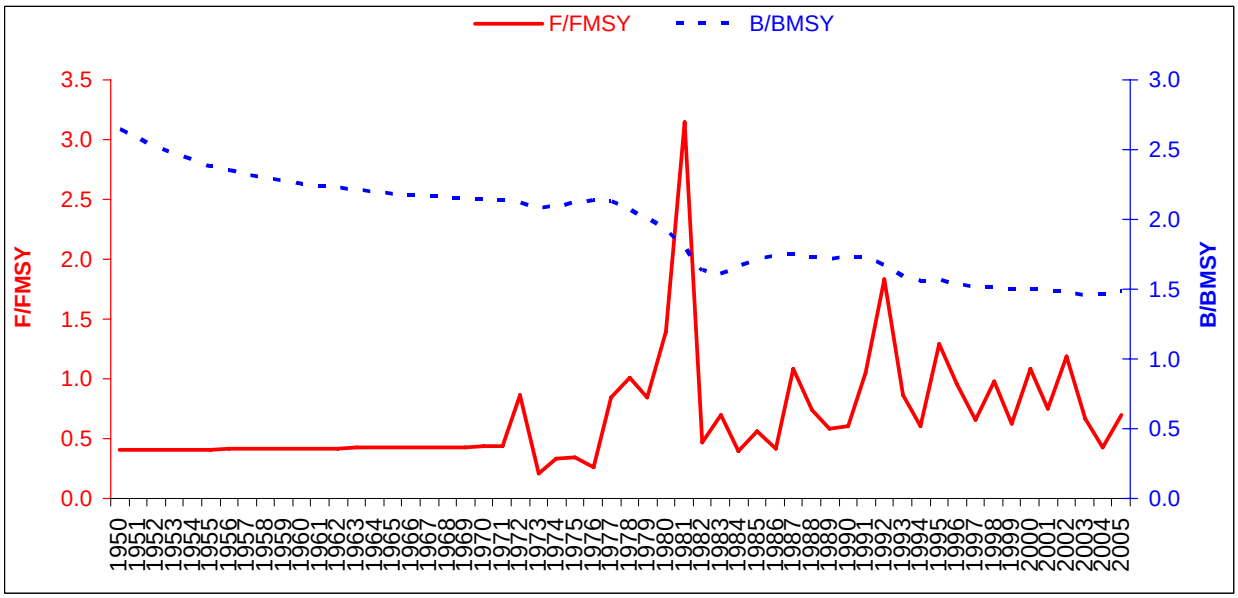


Figure AS-4. Base model estimated relative fishing mortality (solid red) and spawning stock fecundity (dashed blue) for the base case with equal index weighting (top) and inverse CV weighting (bottom).

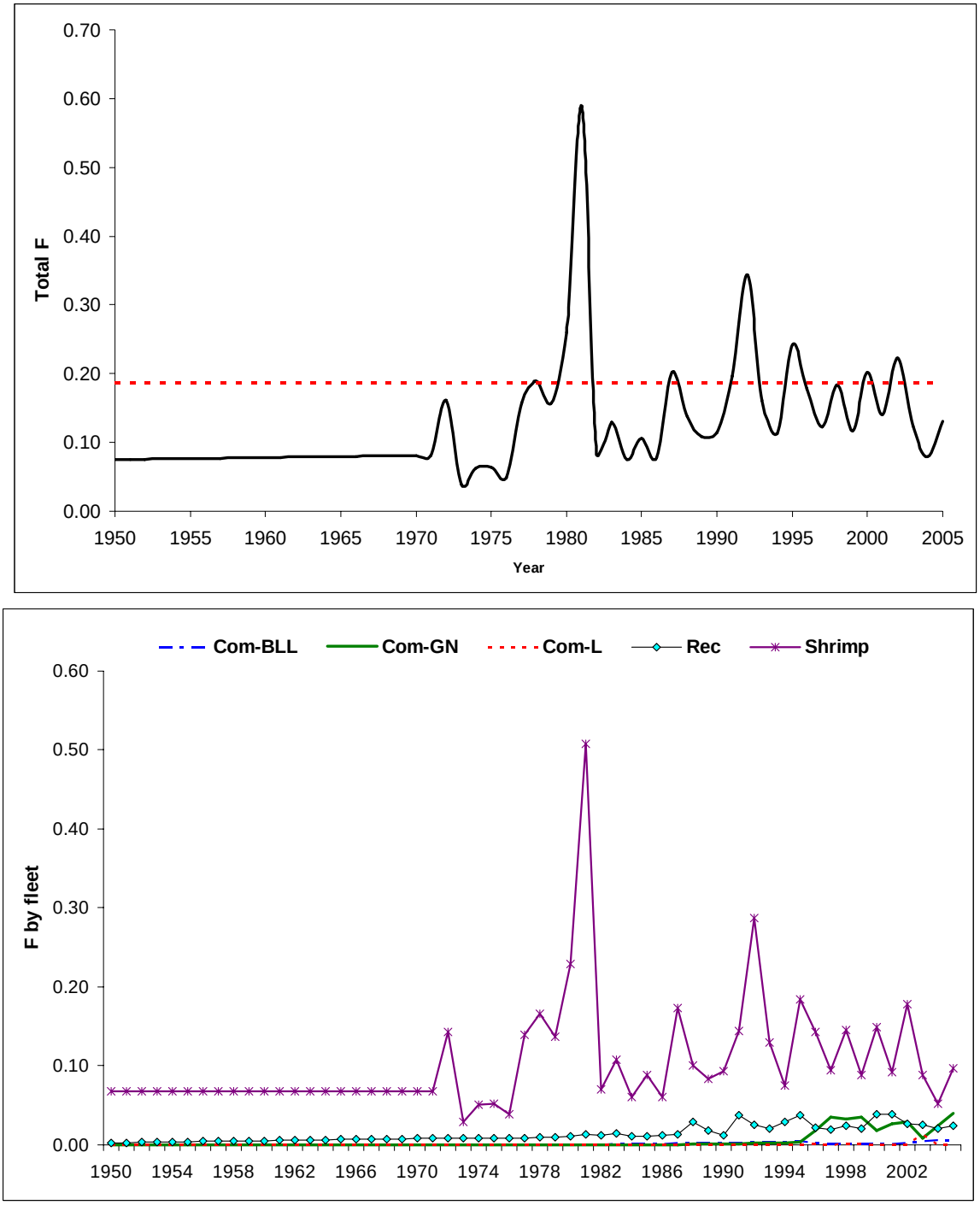


Figure AS-5. Base model estimated total fishing mortality (solid black) and dashed reference line for F_{MSY} (top panel) and fishing mortality by fleet (bottom panel).

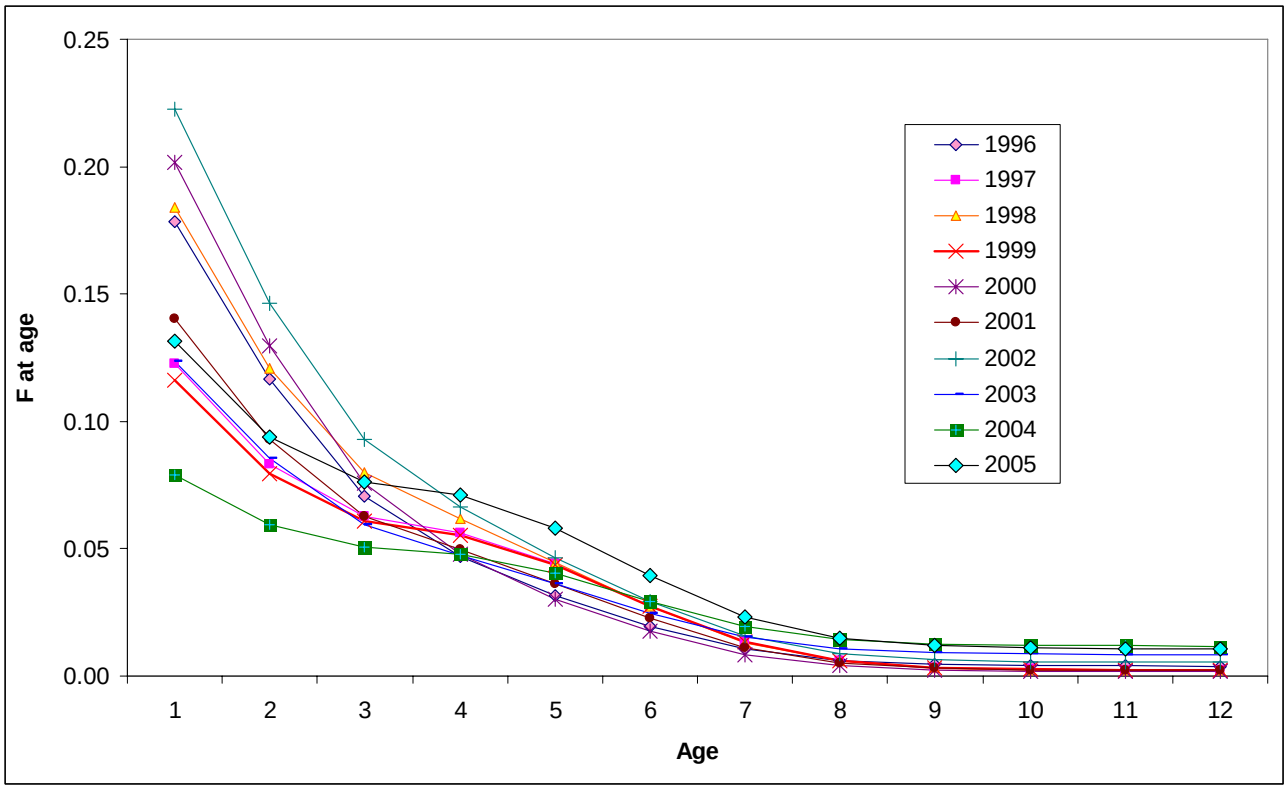


Figure AS-6. Base model estimated fishing mortality at age for years 1996-2005.

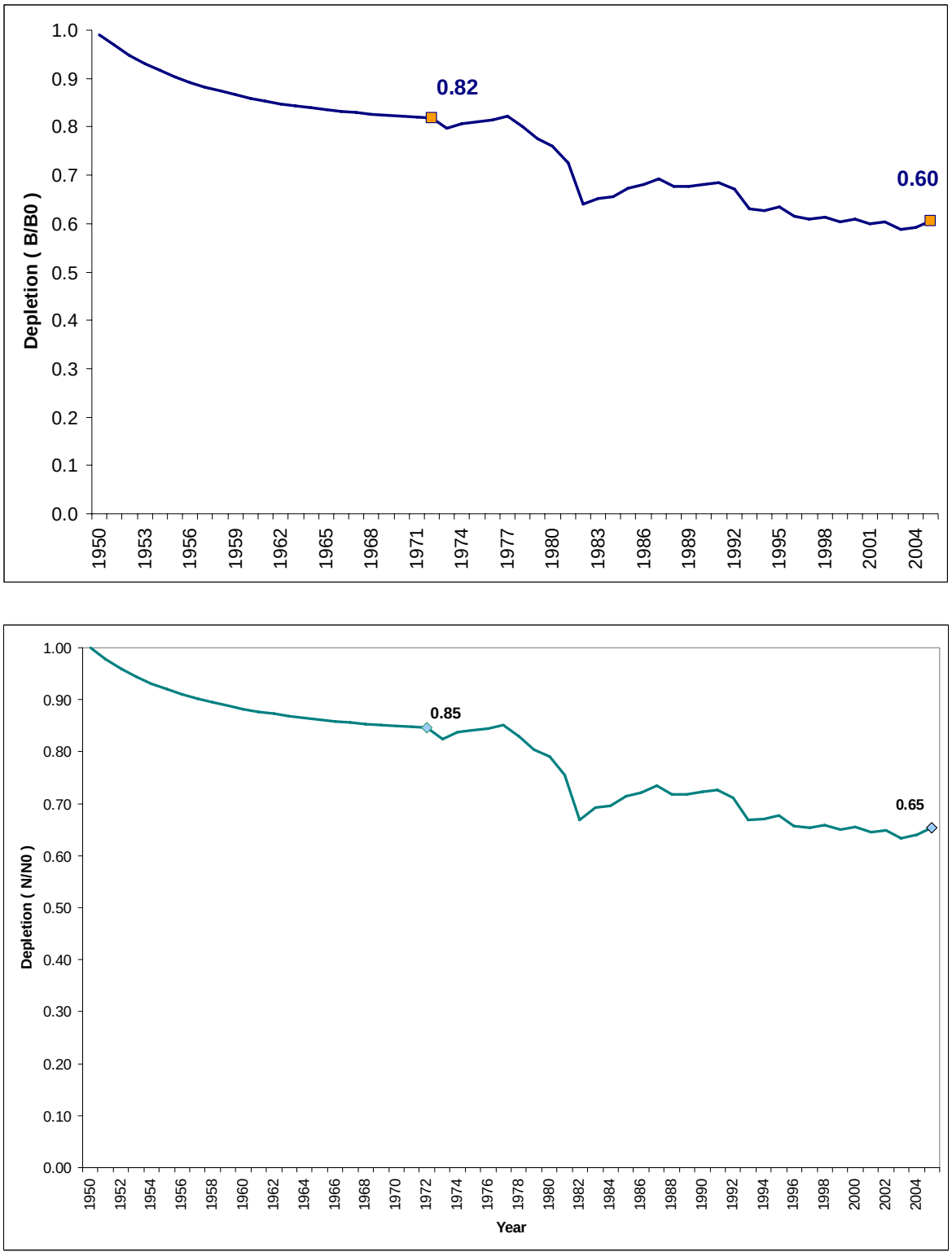
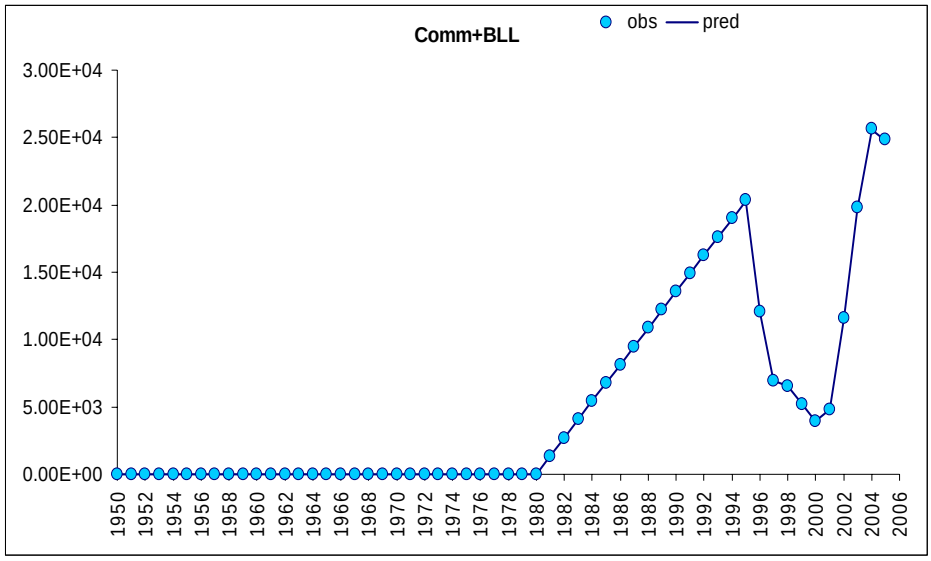
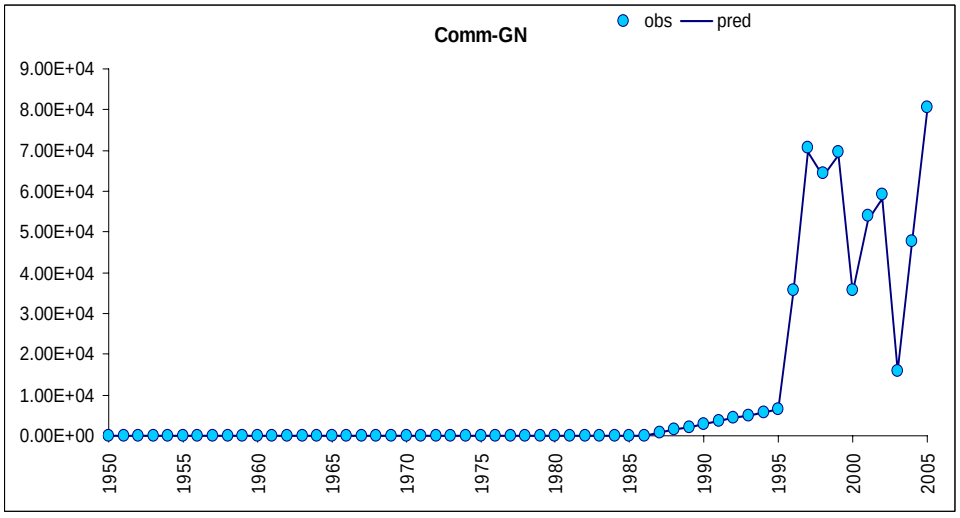


Figure AS-7. Base model estimated depletion of total biomass (top) and total number in the population (bottom). Highlighted values correspond to the year 1972 (first year of 'modern period') and the final assessment year, 2005.





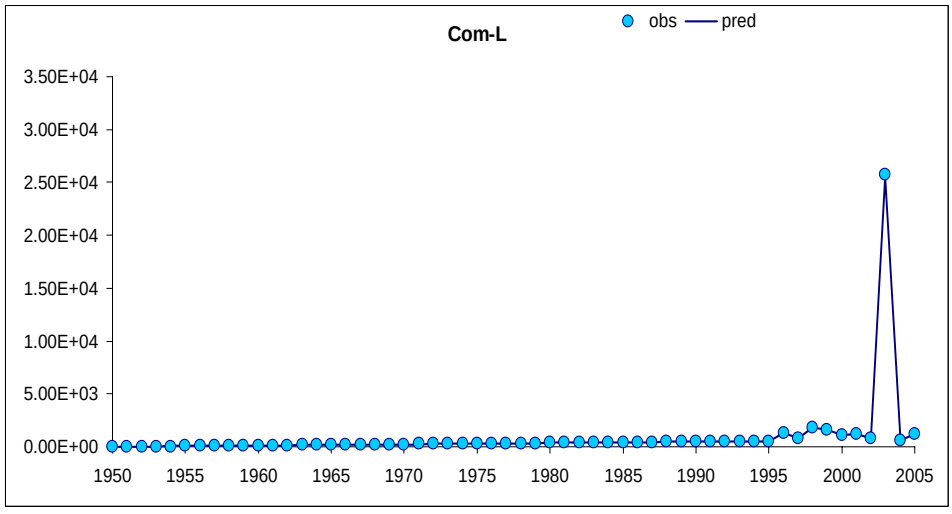
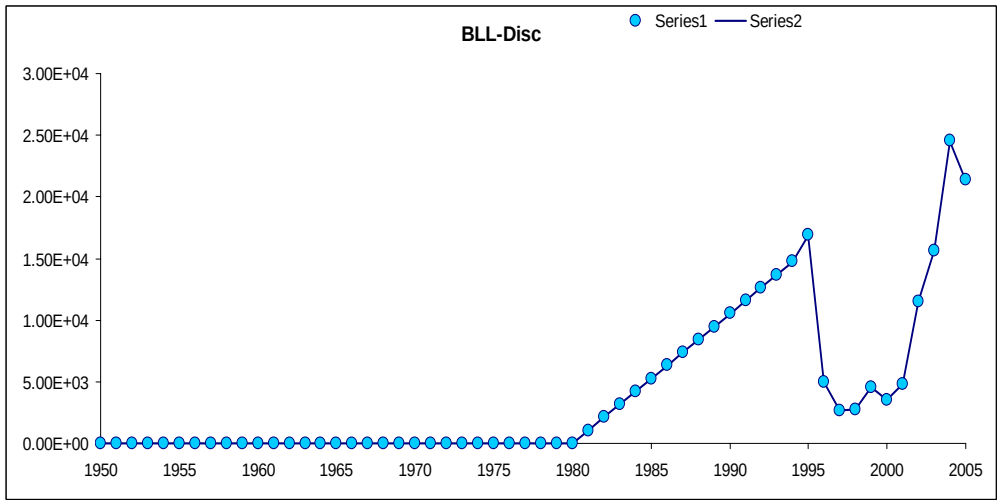
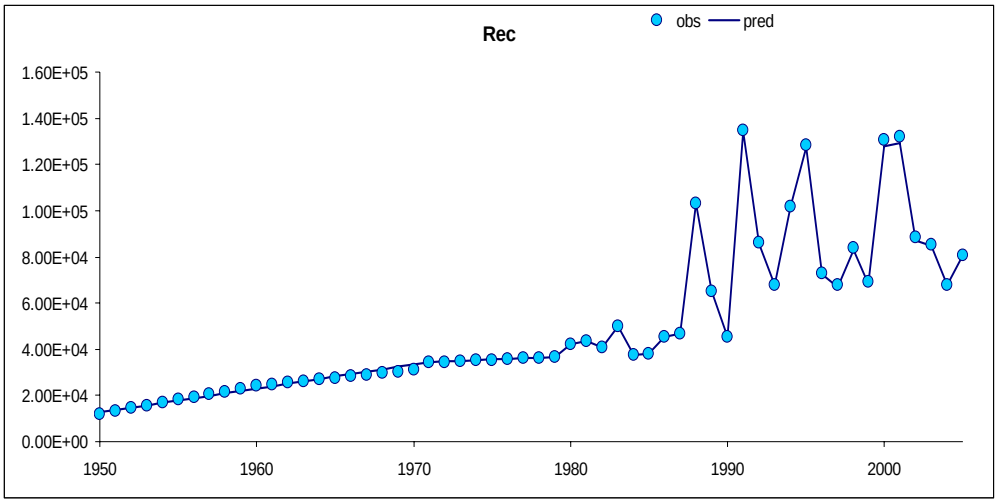


Figure AS-8. Base model estimated catch in number by fleet. The blue dots are observed or reconstructed values, and the solid line is the model fit.





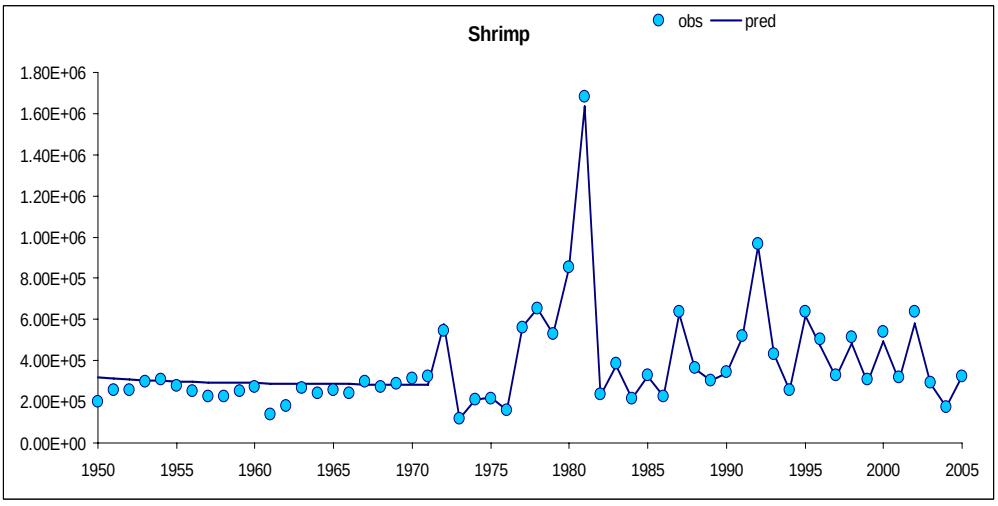


Figure AS-8 continued.

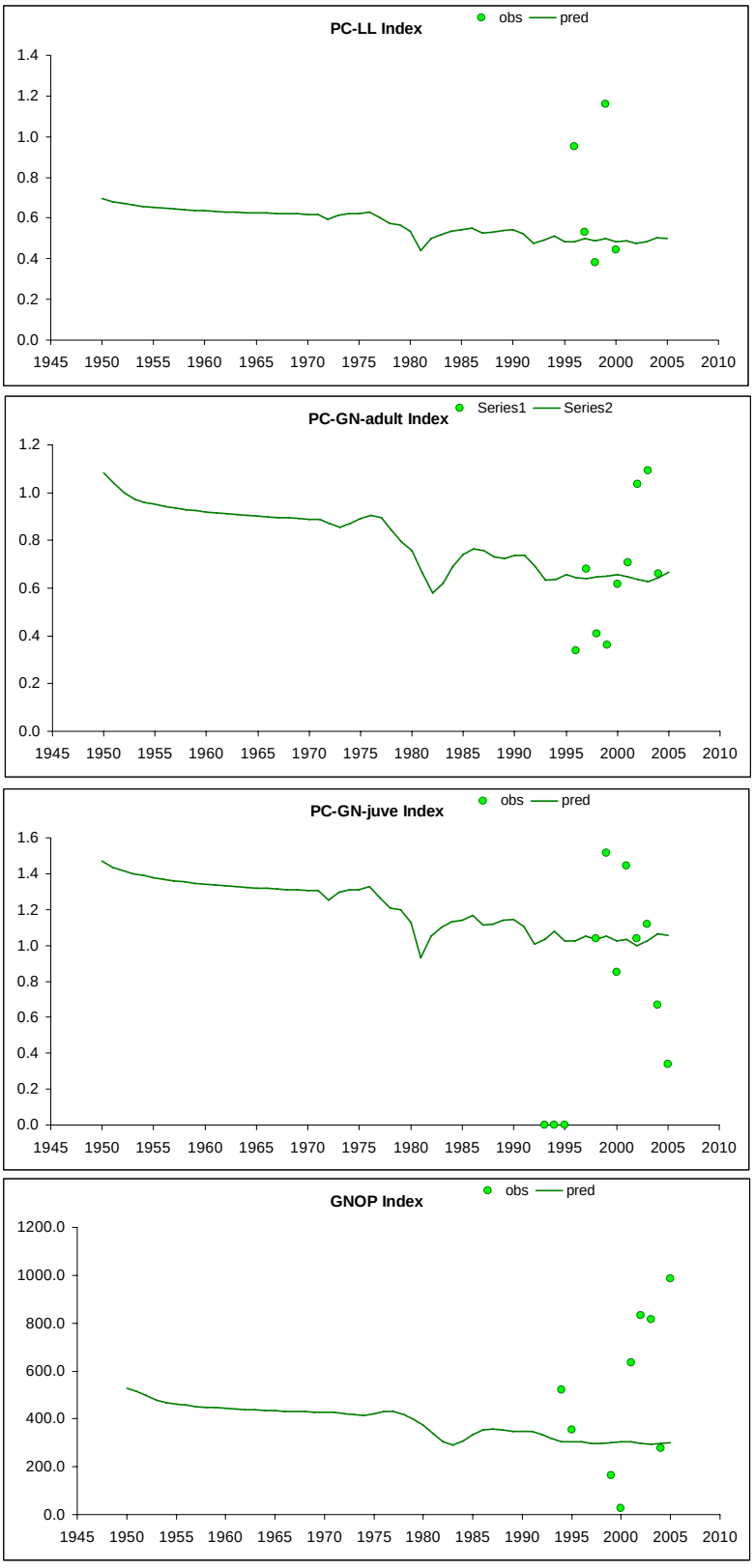
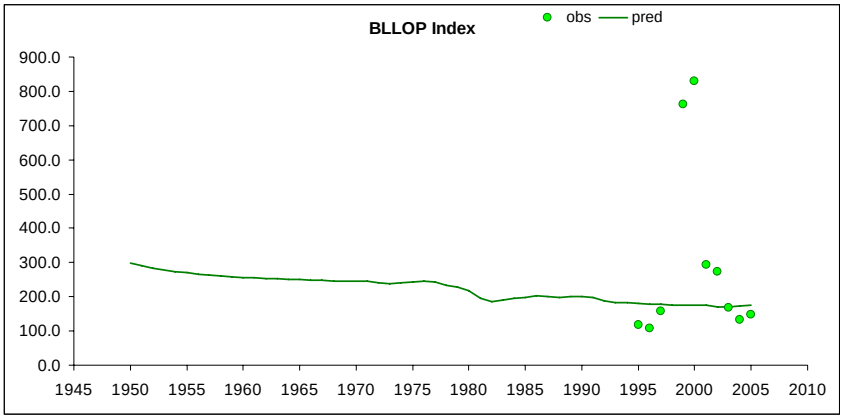
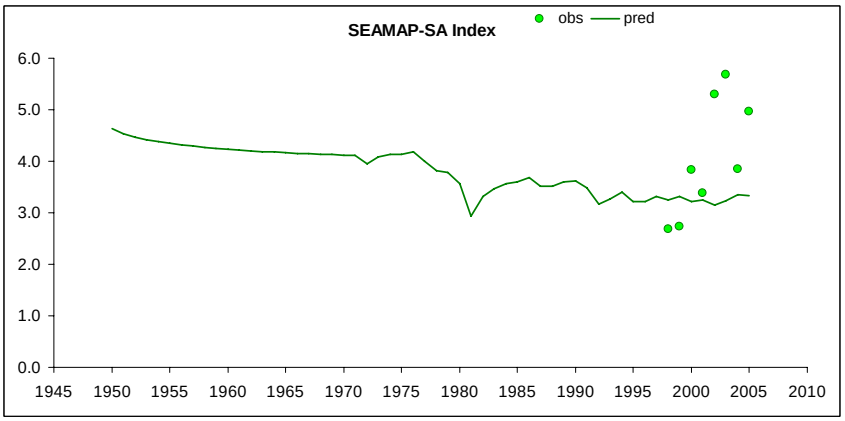
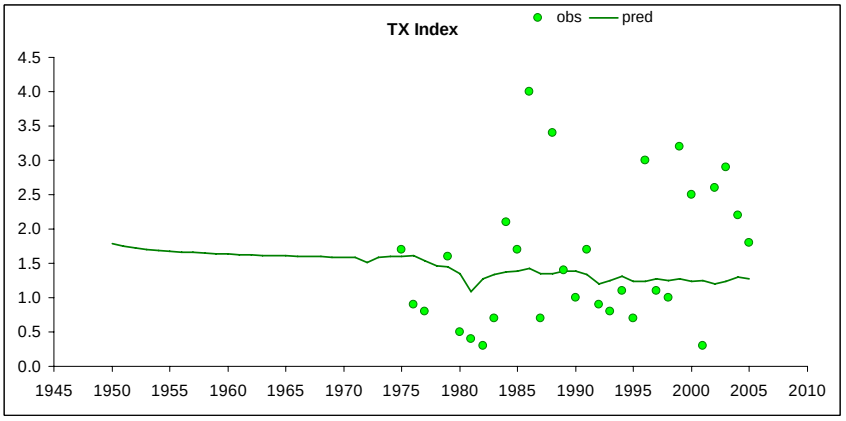


Figure AS-9. Base model estimated fits (solid line) to observed indices (circles).







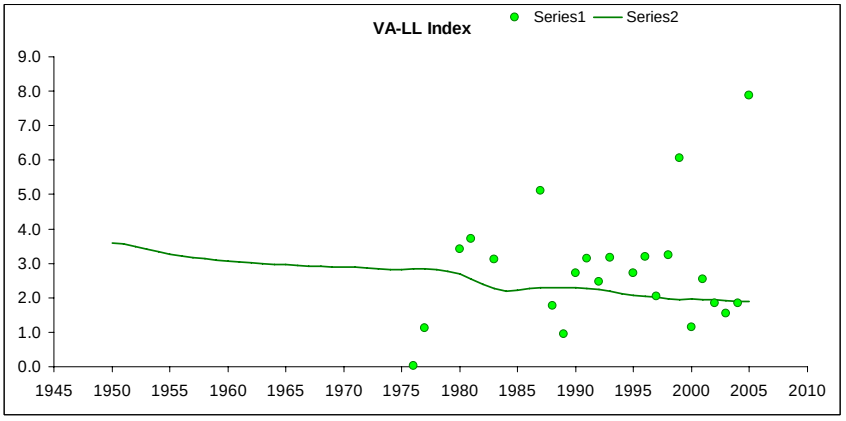


Figure AS-9. (cont).

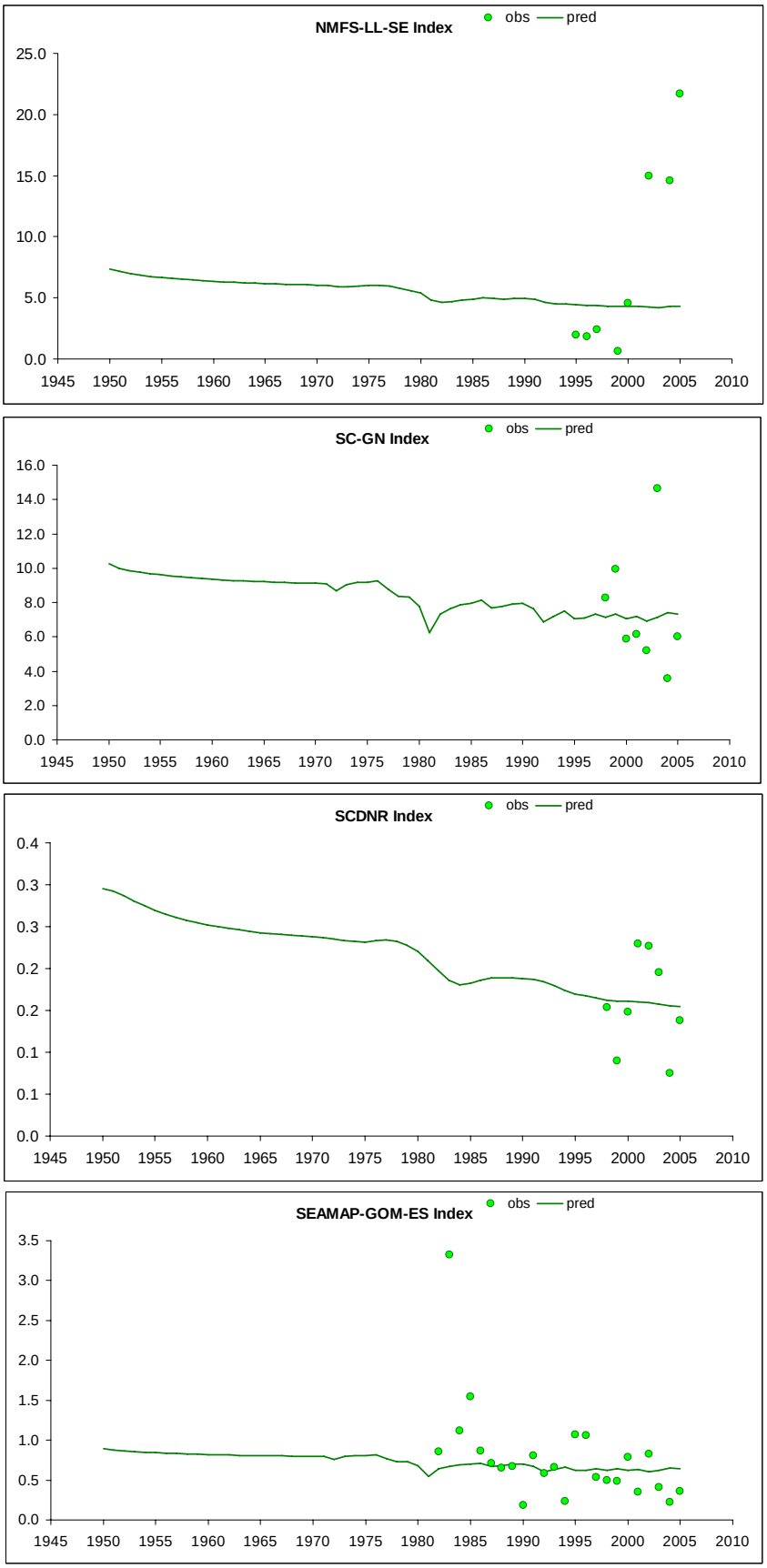


Figure AS-9. (cont).

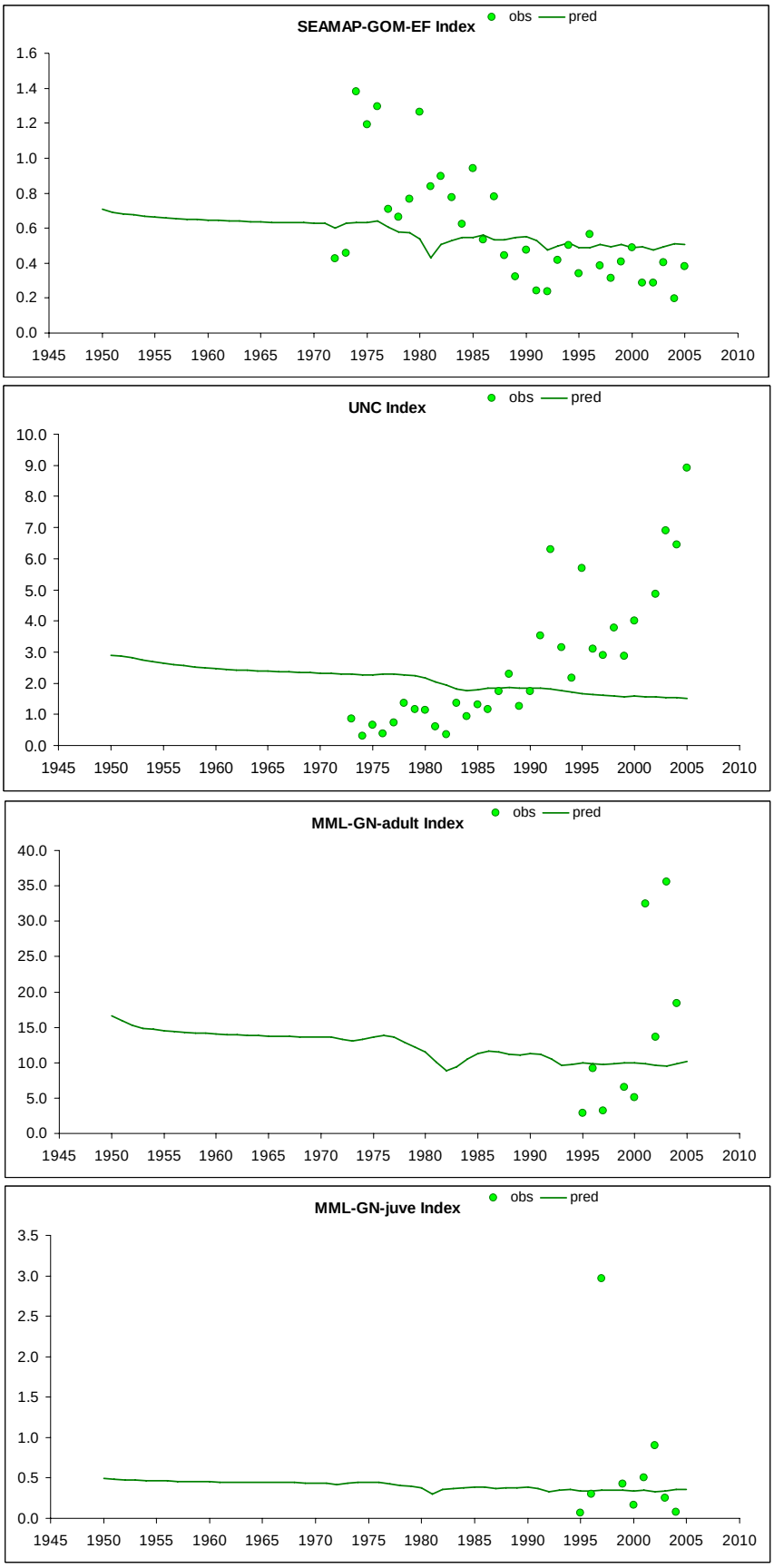


Figure AS-9 continued.

Application to Bonnethead shark

Bonnethead: Base Model Inputs

Data

Data inputted to the model included maturity at age, fecundity at age (pups per mature female), spawning season, catches, indices, and selectivity functions (Tables ALL 1-2, BH 1-3; Figures BH 1-9). Catches were attributed to six different fleets: the commercial bottom longline, the commercial gillnet, the commercial handline, discards from the commercial bottom longline, the recreational sector, and bycatch from the shrimp trawl fishery. Historic catches for each fleet were reconstructed as described in SEDAR13-DW-Final. A total of 12 indices were made available after the data workshop, with 11 recommended as base indices for analysis.

Parameters

Estimated model parameters were pup survival, virgin recruitment (R_0), catchabilities associated with all indices, fleet-specific effort and effort deviations in the modern period.

Bonnethead: Description of Model Runs

The base model was run with the 11 indices recommended as base indices and all six catch series. A sensitivity was recommended using the 12th index, the gillnet logbook series (GN-logs Table BH 2).

BASE –Eleven indices were used and given equal weighting; the DW recommended historic catches were used

S1 – Eleven base indices were used and given equal weighting; alternative historic catches were calculated based on the geometric mean of the first five years for which we have observations rather than the first year alone.

More sensitivities will be carried out during the assessment workshop both as recommended at the data workshop and at the request of assessment workshop participants.

Bonnethead: Results of Model Runs

The base model results (Table BH-3) indicated that the stock was overfished and that there is overfishing occurring. Examination of the implied trend in historic removals suggested that the high level of recorded catches in year 1995 was responsible for implying large removals in the past. However, imputed historic catches are 10 times greater than the recent reported catches. If the high landings reported in year 1995 were uncertain, then that would carry through to the historic catches reconstructed from that value. The first sensitivity run addresses this problem, however, the same conclusion is reach (overfished with overfishing) about the status of the stock.

Table BH-1. Catches of bonnethead shark, including reconstructed catches in the historical period (in italics).

Com-LL	Com-GN	Com-HL	Rec	BLL-bycatch	Shrimp trawl bycatch	Year
0	0	0	*7469*	0	*110474*	1950
0	0	0	*13314*	0	*145665*	1951
0	0	0	*14514*	0	*148416*	1952
0	0	0	*15714*	0	*169773*	1953
0	0	0	*16914*	0	*175887*	1954
0	0	0	*18114*	0	*162257*	1955
0	0	0	*19314*	0	*150330*	1956
0	0	0	*20514*	0	*138437*	1957
0	0	0	*21714*	0	*138692*	1958
0	0	0	*22914*	0	*154162*	1959
0	0	0	*15058*	0	*155729*	1960
0	0	0	*15760*	0	*86447*	1961
0	0	0	*16461*	0	*109139*	1962
0	0	0	*17162*	0	*156196*	1963
0	0	0	*17864*	0	*142327*	1964
0	0	0	*18565*	0	*152585*	1965
0	0	0	*19267*	0	*145649*	1966
0	0	0	*19968*	0	*174969*	1967
0	0	0	*20669*	0	*162205*	1968
0	0	0	*21371*	0	*169588*	1969
0	0	0	*18450*	0	*181440*	1970
0	0	0	*21632*	0	*188879*	1971
0	*0*	*0*	21935	0	281544	**1972**
0	*0*	*0*	22239	0	211509	1973
0	*0*	*0*	22542	0	278285	1974
0	*0*	*0*	22846	0	403227	1975
0	*0*	*0*	23149	0	194922	1976
0	*0*	*0*	23453	0	356130	1977
0	*0*	*0*	23756	0	104896	1978
0	*0*	*0*	24060	0	341781	1979
0	*0*	*0*	25067	0	868578	1980
0	*0*	*0*	39269	*0*	150918	1981
77	*0*	*0*	26115	*61*	220166	1982
155	*0*	*0*	22925	*121*	120628	1983
232	*0*	*0*	15418	*182*	126820	1984
310	*0*	*0*	22607	*242*	133369	1985
387	*0*	*0*	50474	*303*	385713	1986
465	*0*	*0*	26527	*363*	250729	1987
542	*897*	*0*	30986	*424*	240285	1988

620	*1794*	*0*	37901	*485*	192216	1989
697	*2692*	*0*	48317	*545*	361975	1990
775	*3589*	*0*	8837	*606*	162631	1991
852	*4486*	*0*	18692	*666*	230150	1992
930	*5383*	*0*	19798	*727*	227040	1993
1007	*6280*	*0*	20524	*788*	214429	1994
19009	49461	285	32112	19009	361933	1995
7324	5259	209	22519	6350	520695	1996
377	14963	190	14995	34	447804	1997
957	1468	225	29065	957	197545	1998
633	9995	832	37341	0	320631	1999
899	16500	42	56436	899	211940	2000
554	19705	70	59017	0	342877	2001
2344	36840	578	51048	2344	399028	2002
3756	6514	109	40066	3756	270829	2003
924	7063	58	42295	0	504238	2004
2109	9942	224	31215	1757	157434	2005

Table BH-2. Indices available for use in the 2007 bonnethead shark assessment. Sensitivity index in green.

PC-GN adult	PC-GN juvenile	GNOP	ENP	SEAMAP SA	Texas	SC Coastspan GN	SEAMAP GoM EF	SEAMAP GoM ES	MML GN adult	MML GN - juvi	GN-logs	year
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1950
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1951
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1952
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1953
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1954
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1955
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1956
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1957
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1958
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1959
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1960
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1961
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1962
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1963
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1964
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1965
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1966
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1967
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1968
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1969
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1970
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1971
-1	-1	-1	-1	-1	-1	-1	-1	1.69	-1	-1	-1	1972
-1	-1	-1	-1	-1	-1	-1	-1	4.09	-1	-1	-1	1973
-1	-1	-1	-1	-1	-1	-1	-1	2.48	-1	-1	-1	1974
-1	-1	-1	-1	-1	0.16	-1	-1	1.53	-1	-1	-1	1975
-1	-1	-1	-1	-1	1.58	-1	-1	2.75	-1	-1	-1	1976
-1	-1	-1	-1	-1	0.18	-1	-1	2.14	-1	-1	-1	1977
-1	-1	-1	0.44	-1	0.20	-1	-1	0.98	-1	-1	-1	1978
-1	-1	-1	0.55	-1	0.56	-1	-1	1.77	-1	-1	-1	1979
-1	-1	-1	0.15	-1	1.09	-1	-1	1.01	-1	-1	-1	1980
-1	-1	-1	0.40	-1	1.00	-1	-1	0.46	-1	-1	-1	1981
-1	-1	-1	0.29	-1	0.64	-1	0.04	0.48	-1	-1	-1	1982
-1	-1	-1	0.54	-1	1.08	-1	0.05	0.66	-1	-1	-1	1983
-1	-1	-1	0.94	-1	1.40	-1	0.05	0.16	-1	-1	-1	1984
-1	-1	-1	0.63	-1	0.45	-1	0.08	0.65	-1	-1	-1	1985

-1	-1	-1	0.60	-1	0.78	-1	0.04	0.96	-1	-1	-1	1986
-1	-1	-1	0.63	-1	0.09	-1	0.03	0.11	-1	-1	-1	1987
-1	-1	-1	0.71	-1	1.22	-1	0.01	0.10	-1	-1	-1	1988
-1	-1	-1	0.90	0.78	0.59	-1	0.02	0.06	-1	-1	-1	1989
-1	-1	-1	0.82	1.37	1.56	-1	0.03	0.11	-1	-1	-1	1990
-1	-1	-1	0.50	2.10	1.04	-1	0.01	0.12	-1	-1	-1	1991
-1	-1	-1	0.97	1.45	0.40	-1	0.02	0.10	-1	-1	-1	1992
-1	-1	-1	0.93	1.03	0.98	-1	0.03	0.13	-1	-1	-1	1993
-1	-1	196.27	1.03	1.56	0.66	-1	0.01	0.09	-1	-1	-1	1994
-1	-1	12.92	1.14	1.75	0.48	-1	0.06	0.07	0.88	0.49	-1	1995
0.56	1	-1	1.10	0.71	0.56	-1	0.05	0.16	0.60	0.32	-1	1996
0.20	0.83	-1	0.88	1.58	0.49	-1	0.04	0.14	1.18	1.22	-1	1997
0.17	0.62	169.76	0.81	1.25	1.35	5.11	0.01	0.09	-1	-1	0.00	1998
0.37	0.71	102.11	0.94	1.12	0.44	13.23	0.05	0.12	1.41	0.61	0.00	1999
0.05	0.30	431.01	0.89	1.64	1.34	12.37	0.01	0.11	2.48	1.35	0.00	2000
0.62	0.39	133.16	0.97	2.24	1.34	13.09	0.04	0.16	2.73	1.20	0.00	2001
0.50	0.44	67.46	0.88	3.42	1.34	10.32	0.01	0.21	1.69	0.58	0.00	2002
0.69	0.29	29.87	0.80	2.94	0.93	14.30	0.03	0.17	2.35	1.11	0.00	2003
0.30	0.17	8.59	0.78	1.26	1.32	17.23	0.04	0.20	2.81	1.87	0.01	2004
0.07	0.05	163.59	-1	2.73	1.00	16.12	0.04	0.28	-1	-1	0.01	2005

Table BH-3. Bonnethead results of the base case (BASE) and sensitivity run (S1, more sensitivities to follow) with the SPASM model. CVs are given in parentheses below each model estimate. SSF is spawning stock fecundity (not spawning stock *biomass*) and is calculated as the sum of the number of mature females multiplied by the number of pups produced per mature female.

Parameter	**BASE**	**S-1**
SSF_{2005}/SSF_{MSY}	0.58	0.70
F_{2005}/F_{MSY}	1.21	1.04 (1.99)
MSY	496,643	495,849
SPR_{MSY}	2.46	2.5 (0.05)
F_{MSY}	0.19	0.317
SSF_{MSY}	1.89E+06	1.71E+06
F_{2005}	0.39	0.33
SSF_{2005}	4.27E+05	4.64E+05
N_{2005}	1.16E+06	1.18E+06 (0.65)
SSF_{2005}/SSF_{0}	0.21	0.26
B_{2005}/B_{0}	0.26	0.25 (0.59)
R0	1.17E+06	1.05E+06 (0.31)
Pup-survival	0.75	0.68 (0.24)
alpha	1.05	3.25 (0.23)
steepness	0.46	0.45

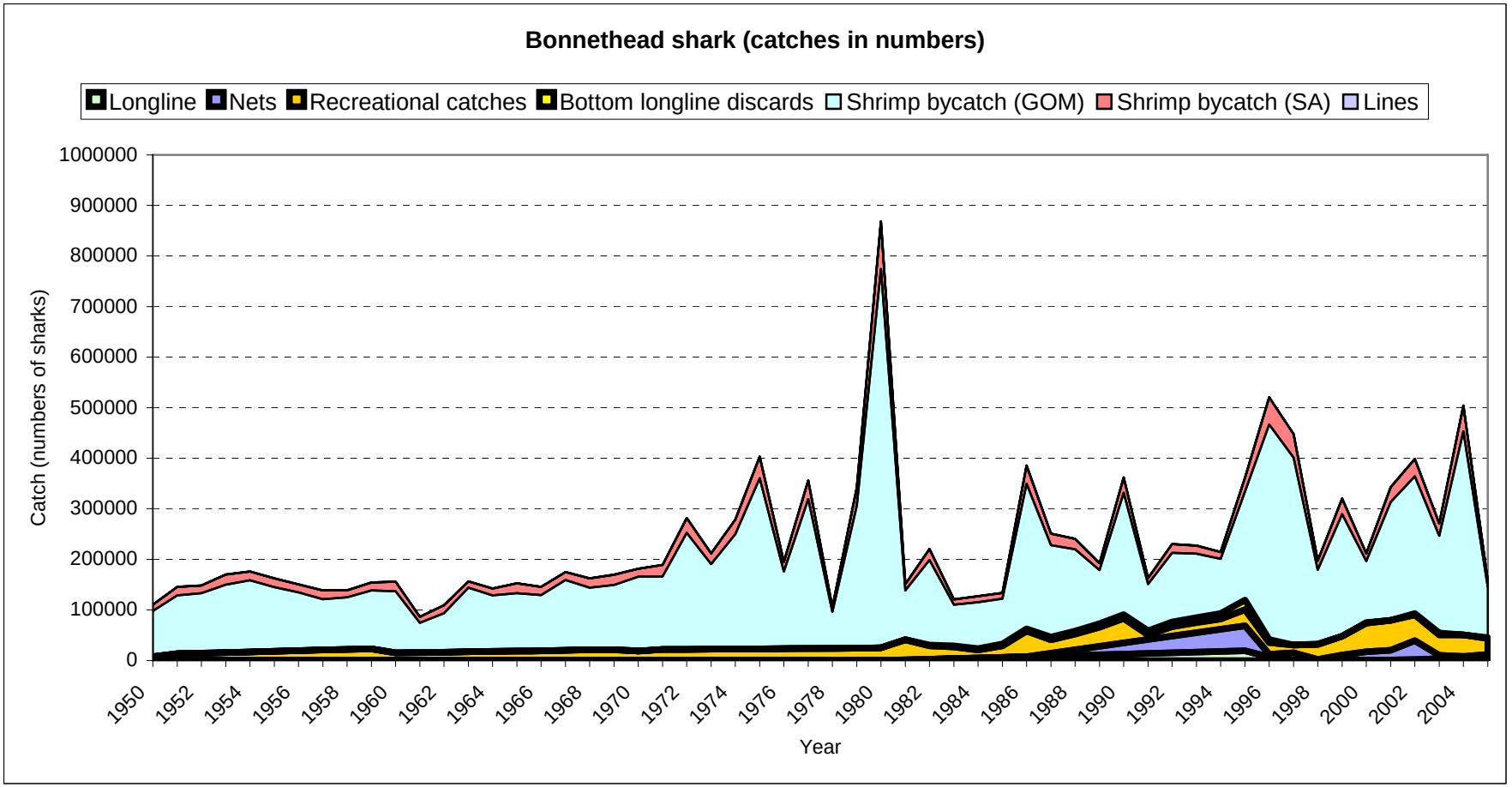


Figure BH-1 The catch series plotted by year. Note that the shrimp bycatch numbers are the largest of all the catch series.

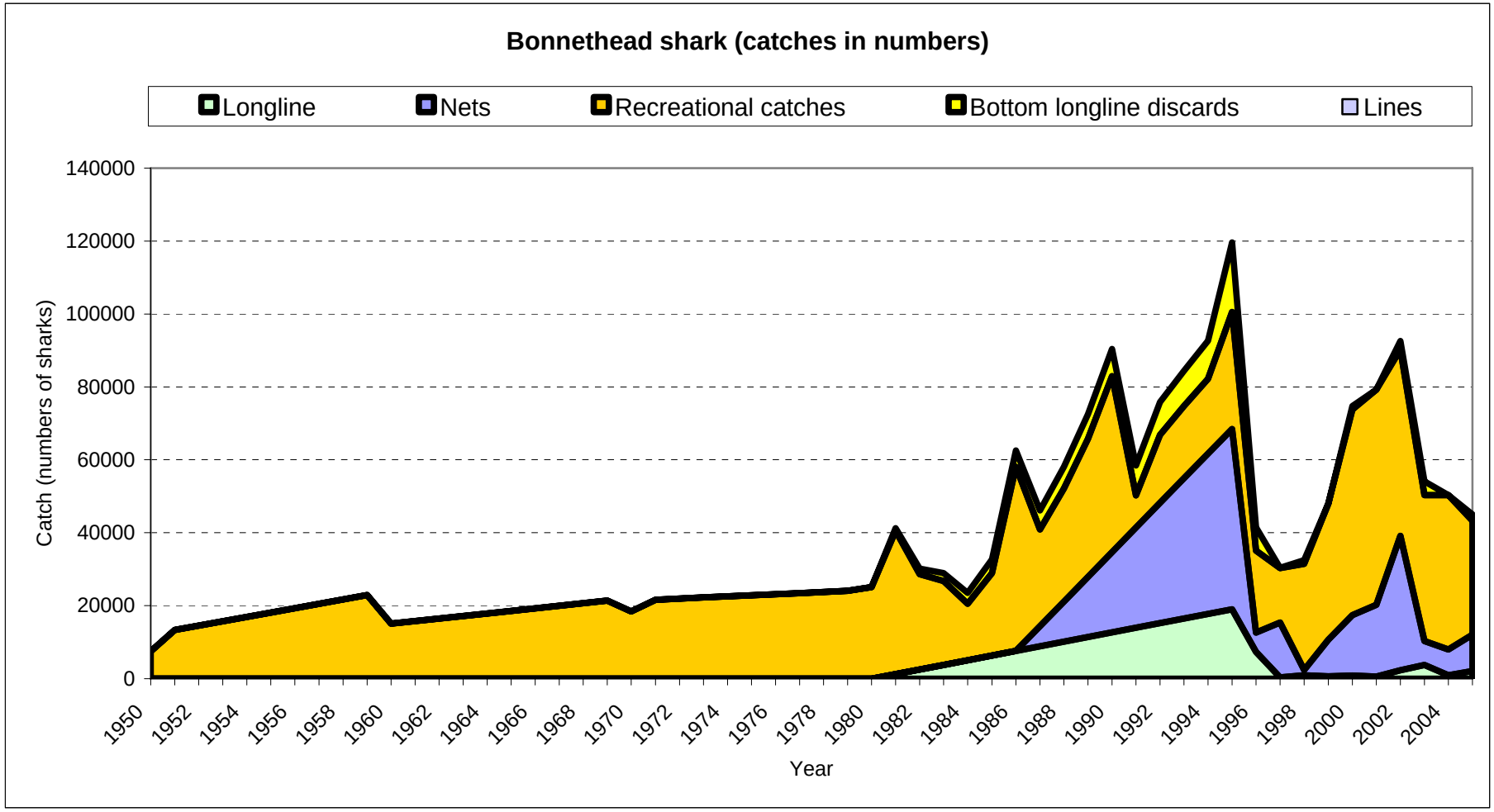


Figure BH-2. The catch series plotted by year without the shrimp bycatch series. The recreational catches are the most significant component.

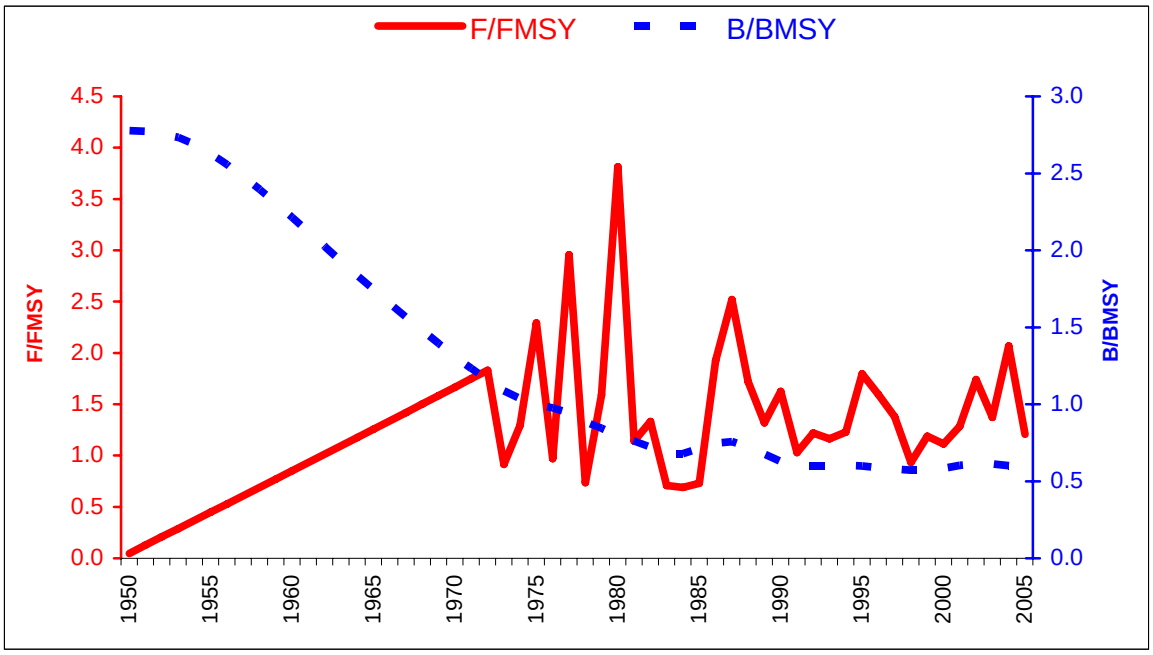
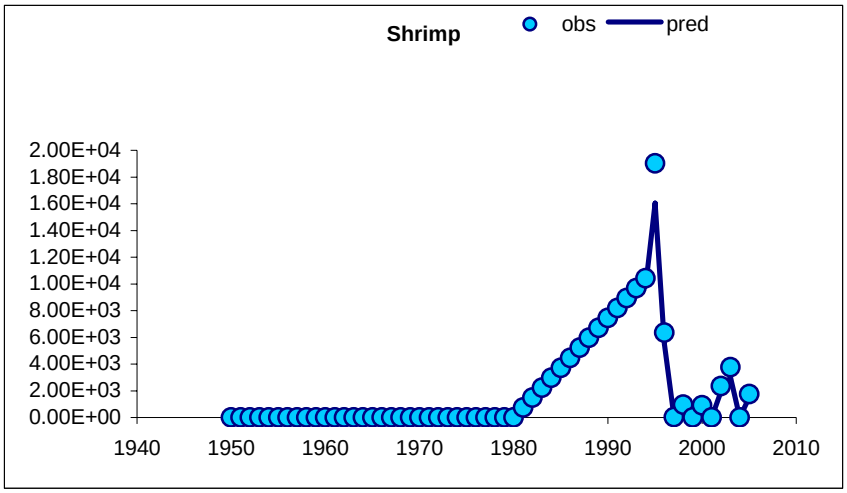
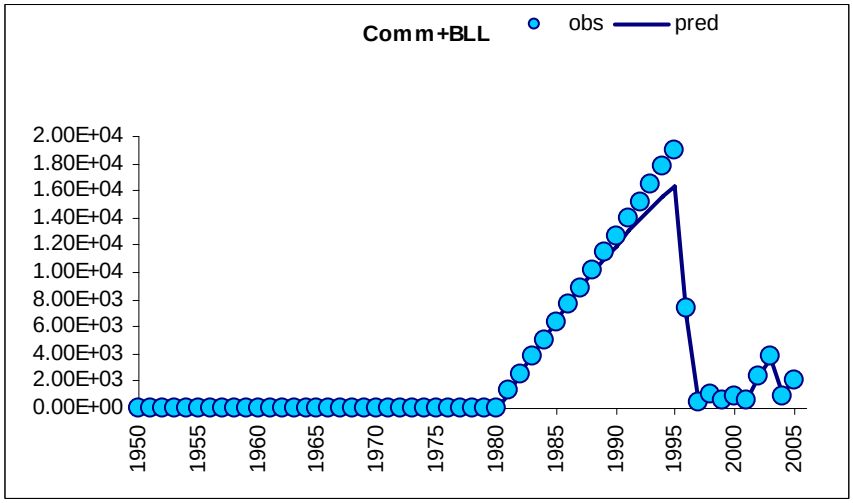


Figure BH-3. Base model estimated relative fishing mortality (solid red) and spawning stock fecundity (dashed blue) for the base case with equal index weighting





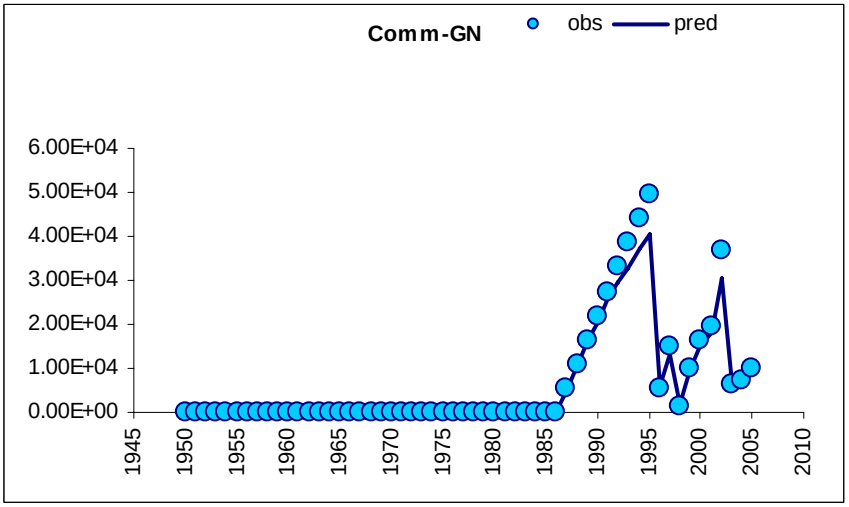


Figure BH-4. Base model fit to base case where reconstructed catches were based on a very large peak in 1995.

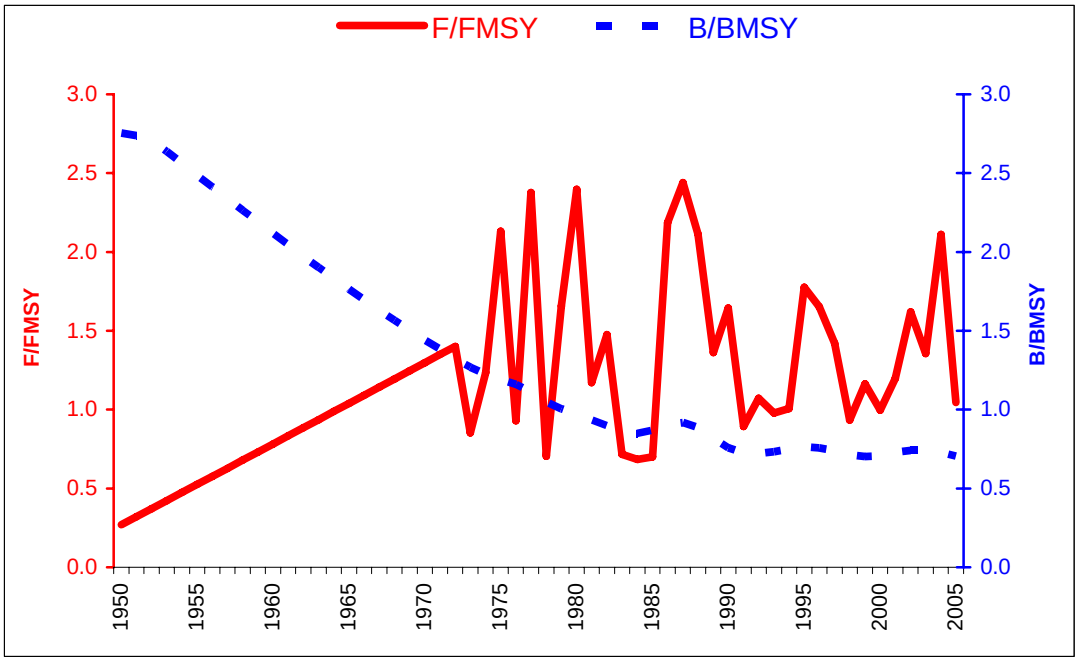


Figure BH-5. Sensitivity model estimated relative fishing mortality (solid red) and spawning stock fecundity (dashed blue) for the base case with equal index weighting

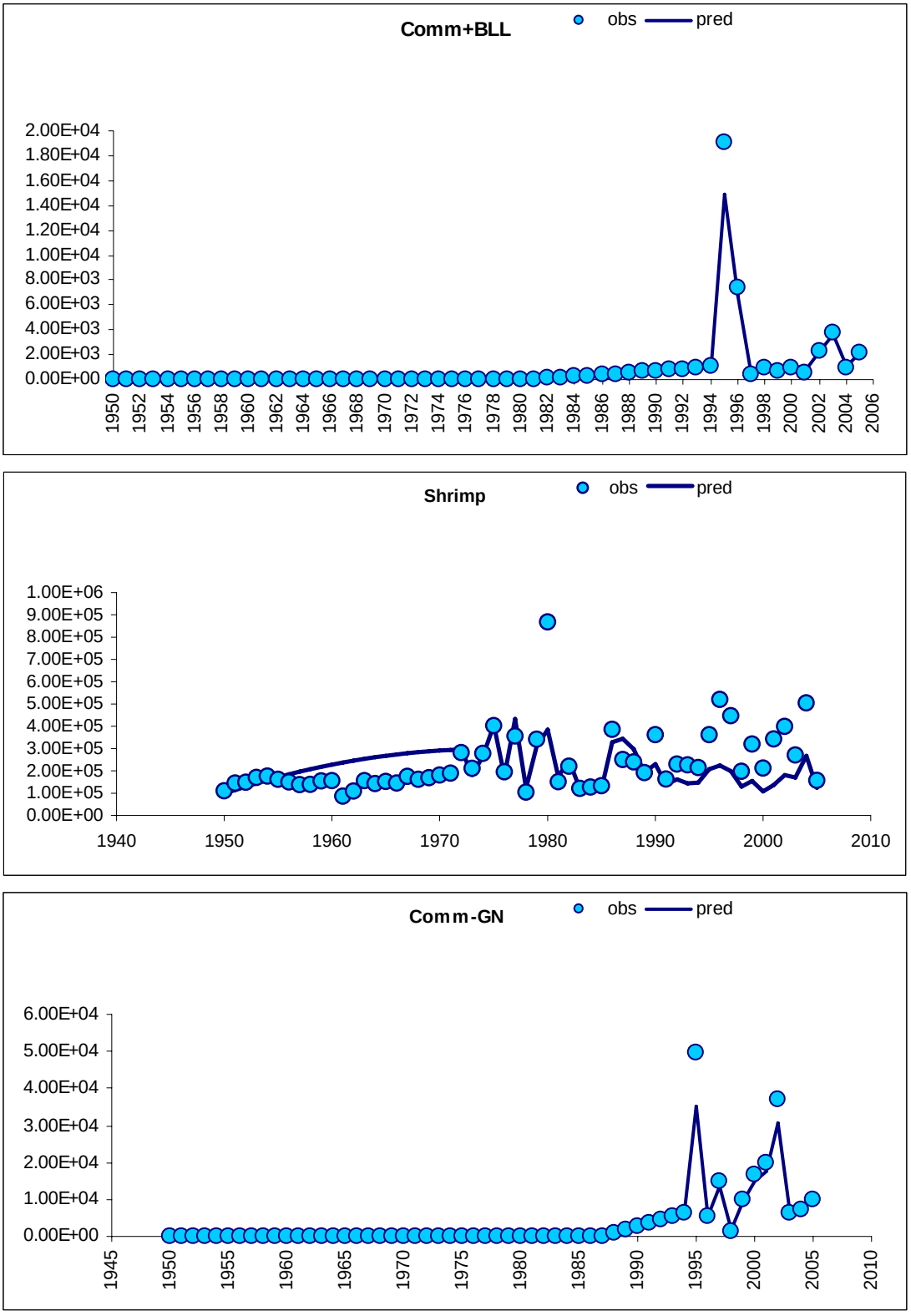


Figure BH-6. Sensitivity model fit where reconstructed catches were based on the geometric mean of the first 5 years of observations.

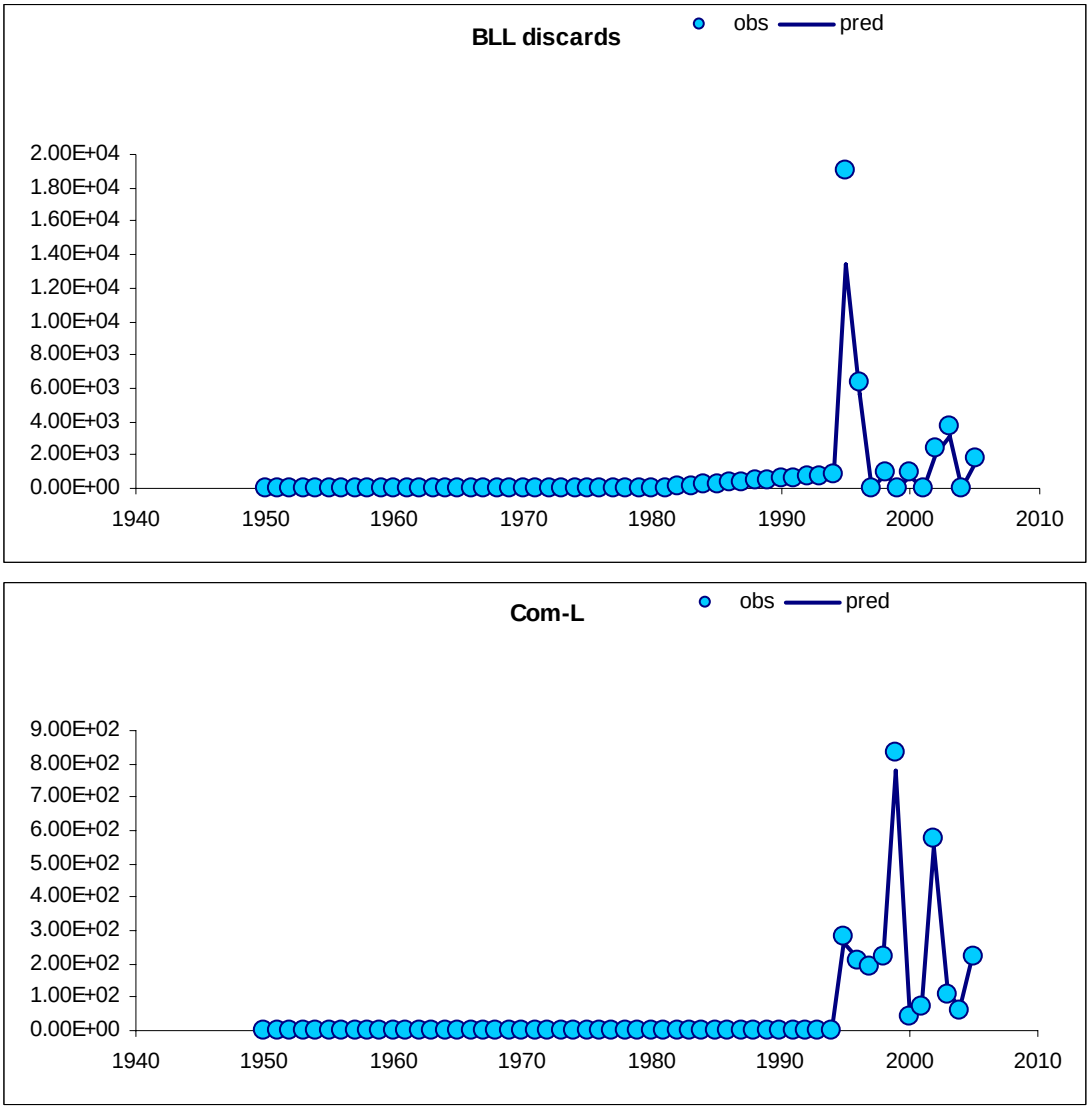


Figure BH-6 continued.

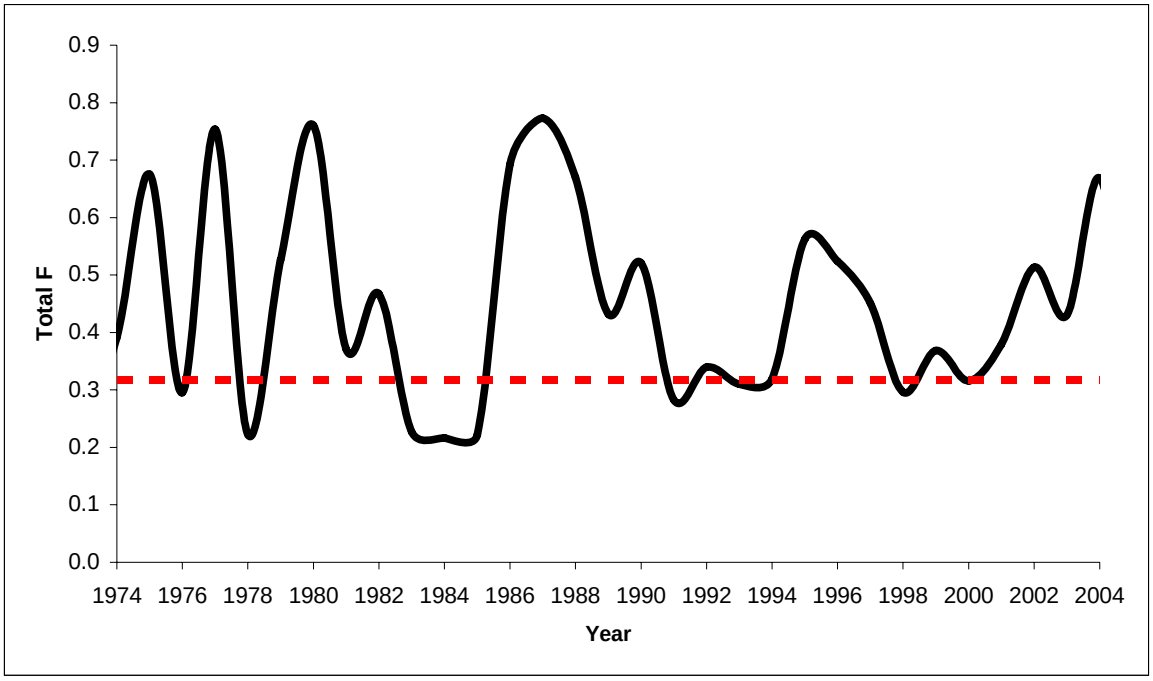


Figure BH-7. Sensitivity model estimates for total fishing mortality (solid black) and dashed reference line for F_{MSY}.

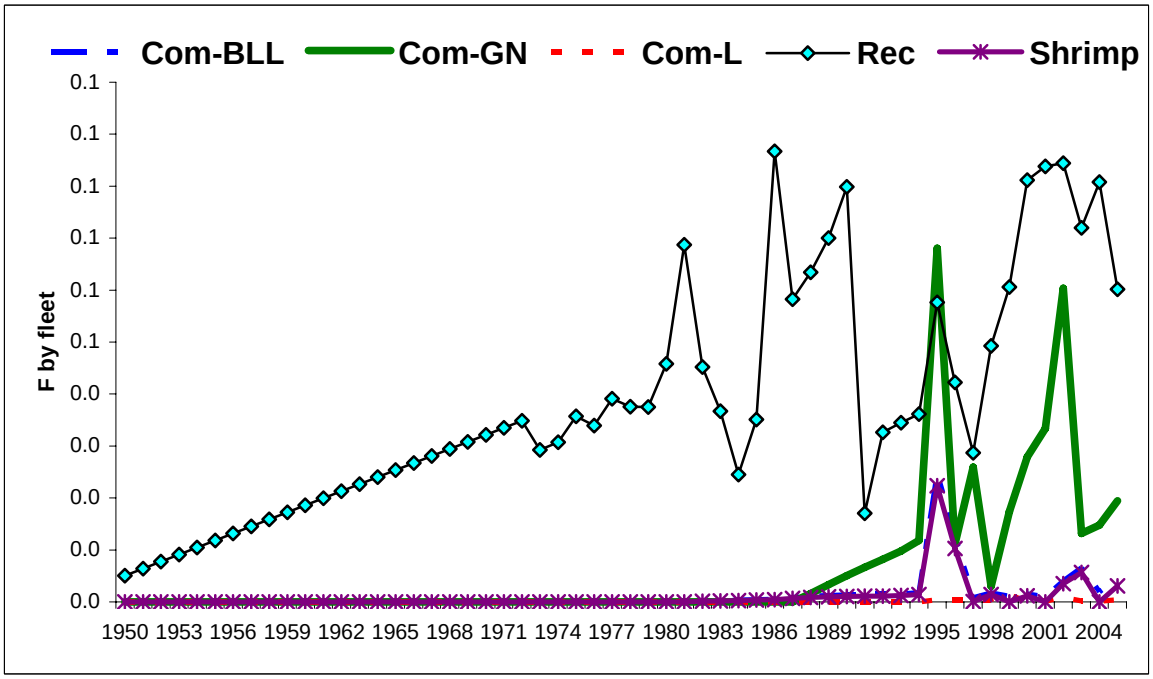


Figure BH- 8. Sensitivity model estimates for and fishing mortality by fleet.

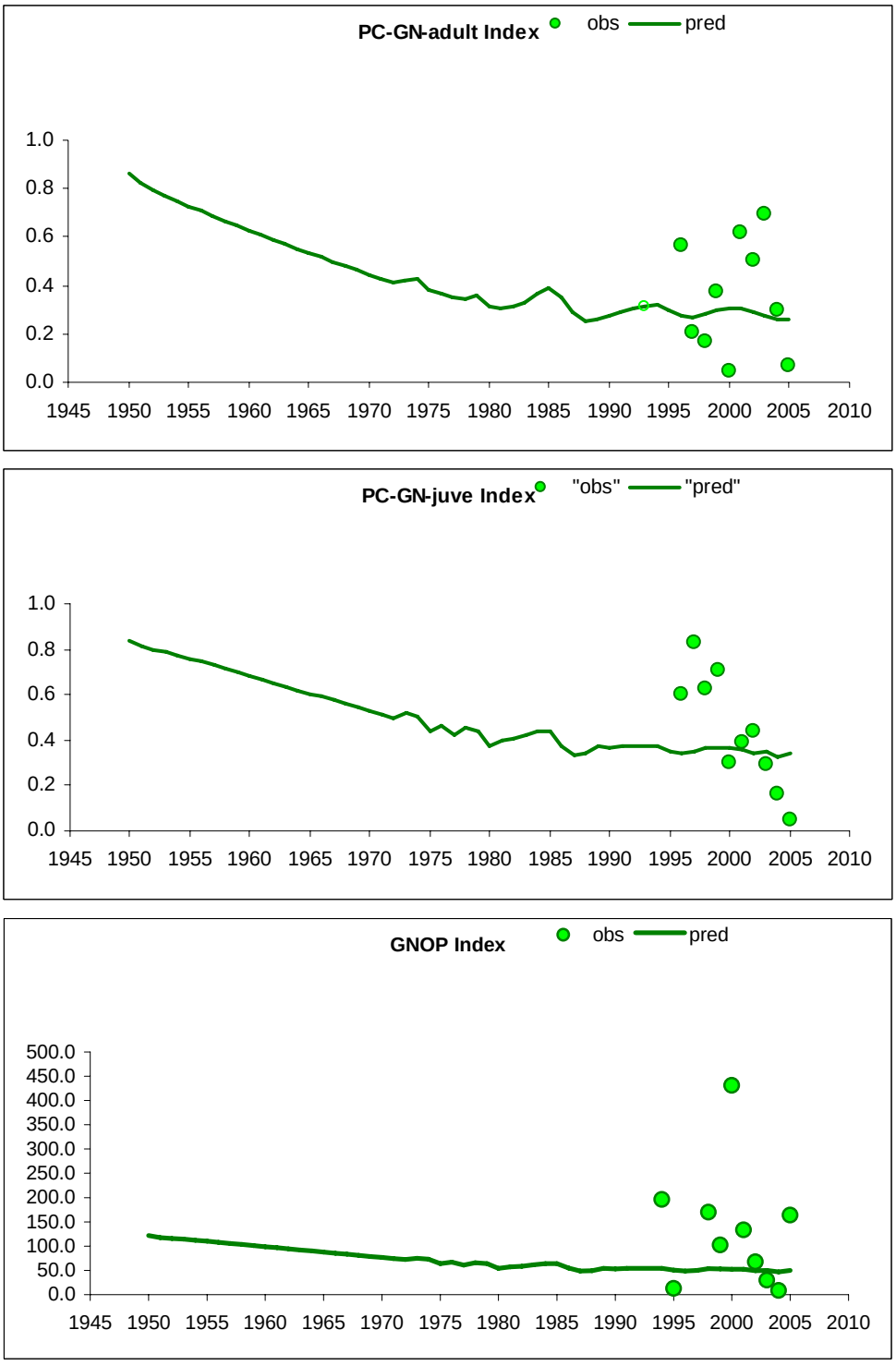


Figure BH-9. Sensitivity model fits to the indices

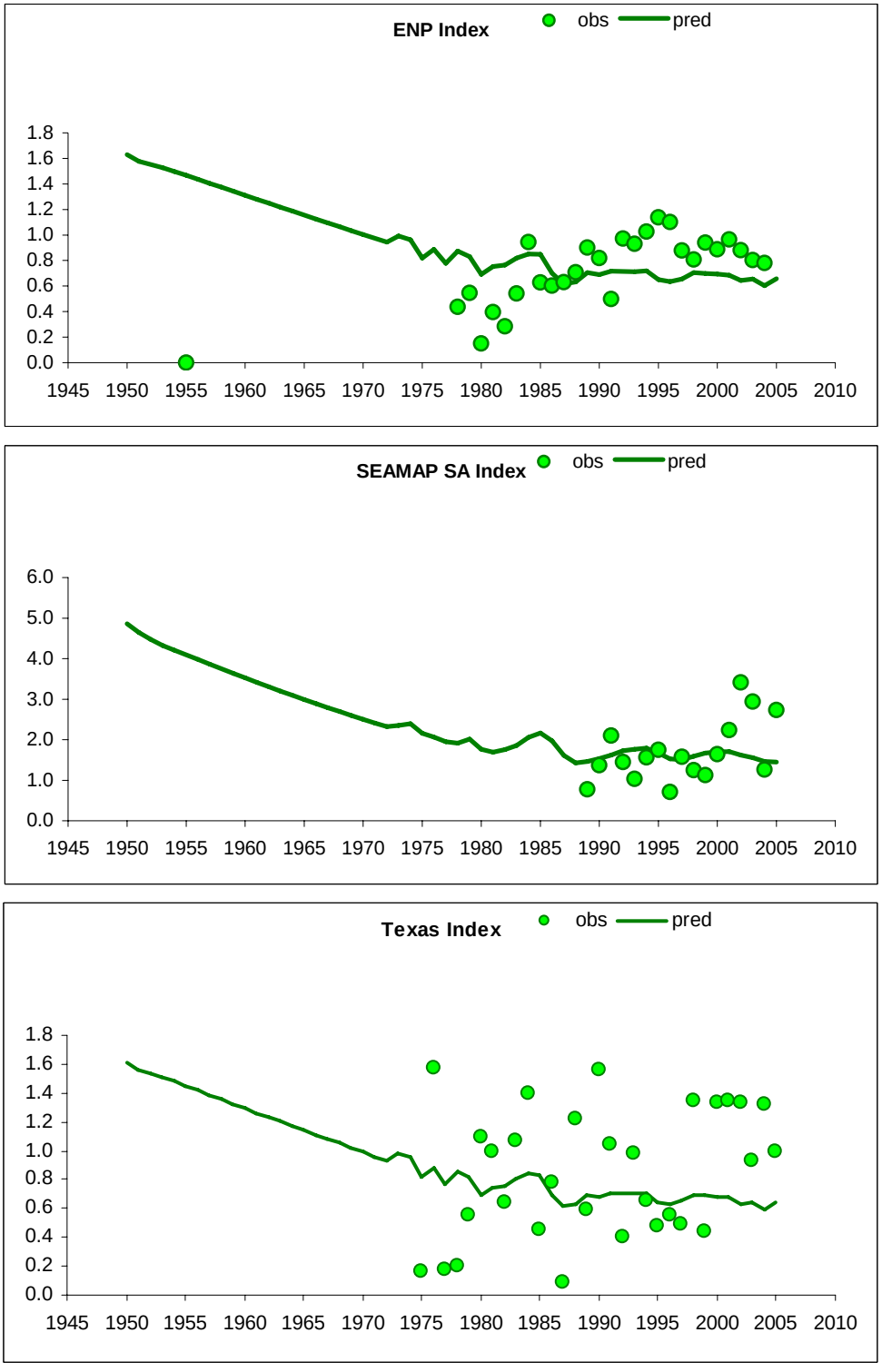
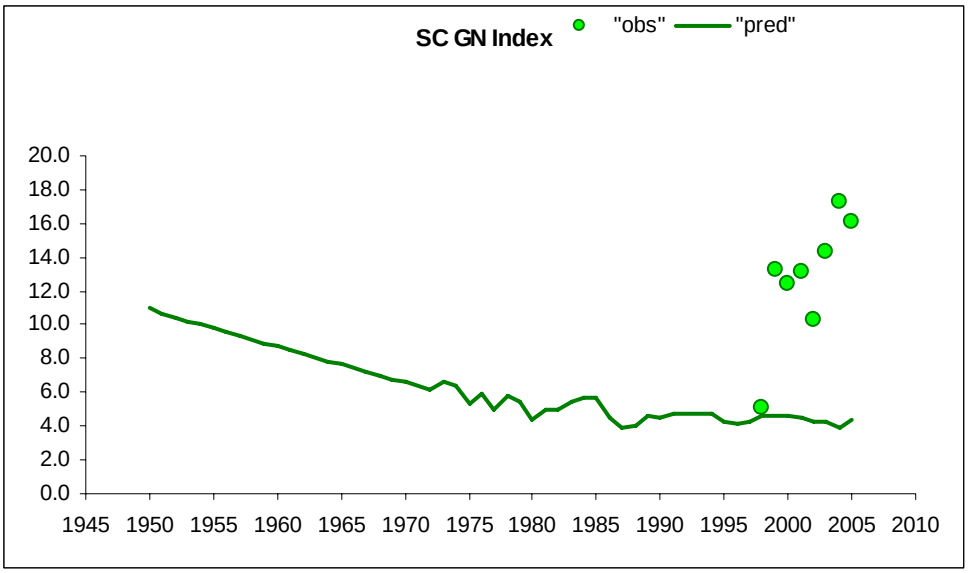


Figure BH-9 continued.



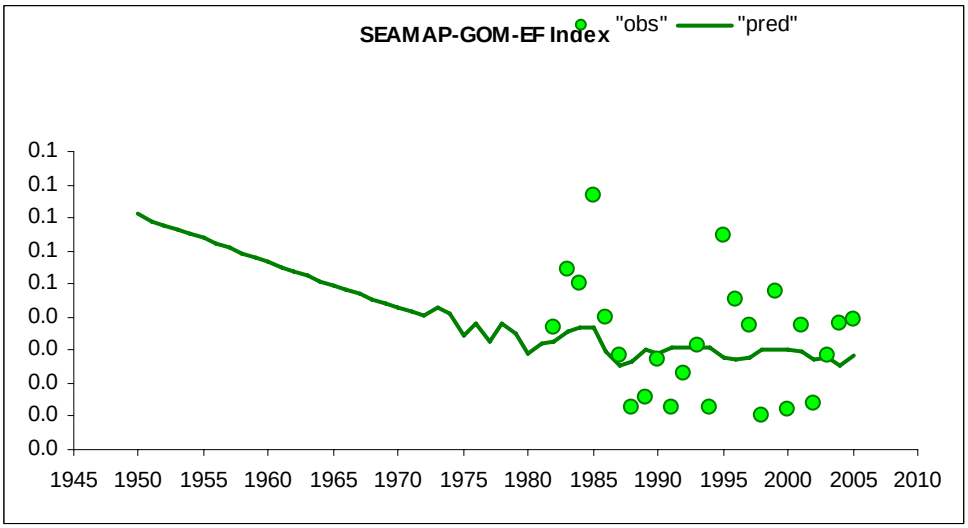


Figure BH-9 continued

Application to Blacknose shark

Blacknose: Base Model Inputs

Data

Data inputted to the model included maturity at age, fecundity at age (pups per mature female), spawning season, catches, indices, and selectivity functions (Tables ALL-1-1; Tables BN-1-3; Figures BN-1-7). Catches were attributed to six different fleets: the commercial bottom long line, the commercial gillnet, the commercial handline, discards from the commercial bottom longline, the recreational sector, and bycatch from the shrimp trawl fishery. Historic catches for each fleet were reconstructed as described in SEDAR13-DW-Final. A total of 10 indices were made available after the data workshop, with eight recommended as a base case.

Parameters

Estimated model parameters were pup survival, virgin recruitment (R0), catchabilities associated with all indices indices, fleet-specific effort and effort deviations in the modern period.

Blacknose: Description of Model Runs

The base model was run with the eight indices recommended as base indices and all six catch series. A sensitivity was recommended using the 9^{th} and 10^{th} indices, the gillnet logbook series and the Panama City longline (GN-logs and PC-LL Table BN- 2).

BASE –Eight indices were used and given equal weighting; the DW recommended historic catches were used.

Sensitivities will be carried out during the assessment workshop both as recommended at the data workshop and at the request of assessment workshop participants.

Blacknose: Results of Model Runs

The base model results (Table BN-3) indicated that the stock was overfished and that there is overfishing occurring. Examination of the implied trend in historic removals suggested that the high level of recorded catches in year 1995 was responsible for implying large removals in the past as well as a large peak in the shrimp bycatch catch series. However, imputed historic catches are 10 times greater than the recent reported catches. If the high landings reported were uncertain, then that would carry through to the historic catches reconstructed from that value. The first sensitivity run addresses this problem, however, the same conclusion is reach (overfished with overfishing) about the status of the stock.

Table BN-1. Catches of blacknose shark including reconstructed catches (in italics).

CATCHES OF BLACKNOSE SHARKS (in numbers)

Year	Commercial				Recreational catches	Bottom longline discards	Shrimp Total
	Total	Longline	Nets	Lines			
1950	*0*	0	0	0	*1826*	0	*11509*
1951	*0*	0	0	0	*2051*	0	*14783*
1952	*1*	0	0	*1*	*2276*	0	*14964*
1953	*1*	0	0	*1*	*2501*	0	*17204*
1954	*2*	0	0	*2*	*2725*	0	*17772*
1955	*2*	0	0	*2*	*2950*	0	*16105*
1956	*3*	0	0	*3*	*3175*	0	*14640*
1957	*3*	0	0	*3*	*3400*	0	*13157*
1958	*4*	0	0	*4*	*3625*	0	*13073*
1959	*4*	0	0	*4*	*3849*	0	*14664*
1960	*4*	0	0	*4*	*4074*	0	*15706*
1961	*5*	0	0	*5*	*4174*	0	*7878*
1962	*5*	0	0	*5*	*4273*	0	*10328*
1963	*6*	0	0	*6*	*4372*	0	*15560*
1964	*6*	0	0	*6*	*4472*	0	*13915*
1965	*7*	0	0	*7*	*4571*	0	*14953*
1966	*7*	0	0	*7*	*4671*	0	*14114*
1967	*8*	0	0	*8*	*4770*	0	*17335*
1968	*8*	0	0	*8*	*4870*	0	*15807*
1969	*8*	0	0	*8*	*4969*	0	*16546*
1970	*9*	0	0	*9*	*5068*	0	*18233*
1971	*9*	0	0	*9*	*4658*	0	*18674*
1972	*10*	0	0	*10*	*4247*	0	16797
1973	*10*	0	0	*10*	*3836*	0	17085
1974	*11*	0	0	*11*	*3425*	0	8716
1975	*11*	0	0	*11*	*3014*	0	22969
1976	*12*	0	0	*12*	*2603*	0	14957

1977	*12*	0	0	*12*	*2193*	0	112863
1978	*12*	0	0	*12*	*1782*	0	24171
1979	*13*	0	0	*13*	*1371*	0	14823
1980	*13*	0	0	*13*	*1183*	0	9759
1981	*1528*	*1043*	0	*14*	0	*470*	11475
1982	*3042*	*2087*	0	*14*	0	*941*	8964
1983	*4556*	*3130*	0	*15*	14233	*1411*	10731
1984	*6071*	*4174*	0	*15*	844	*1882*	8201
1985	*7585*	*5217*	0	*16*	1918	*2352*	11025
1986	*9099*	*6261*	0	*16*	3308	*2822*	22764
1987	*12071*	*7304*	*1457*	*16*	15382	*3293*	13656
1988	*15042*	*8347*	*2915*	*17*	15971	*3763*	12270
1989	*18014*	*9391*	*4372*	*17*	1793	*4234*	29999
1990	*20986*	*10434*	*5829*	*18*	3345	*4704*	22605
1991	*23957*	*11478*	*7286*	*18*	8	*5175*	41979
1992	*26929*	*12521*	*8744*	*19*	5199	*5645*	42999
1993	*29900*	*13565*	*10201*	*19*	2875	*6115*	17464
1994	*32872*	*14608*	*11658*	*20*	14464	*6586*	30789
1995	*33968*	15652	*13116*	20	2954	5181	45384
1996	26176	8641	14573	768	12414	2195	39732
1997	45588	17628	26004	88	11079	1869	65639
1998	25967	7689	15613	43	10523	2622	38367
1999	29221	5968	21812	539	6139	901	30913
2000	57923	13493	32154	956	10410	11321	35523
2001	37766	5732	28549	29	15445	3456	51325
2002	35302	6877	21280	522	11438	6623	28593
2003	28104	10385	12498	90	6615	5130	61079
2004	15930	5889	7942	114	15261	1985	73786
2005	23014	8178	9055	212	7548	5569	23154

Table BN-2. Indices available for use in the 2007 blacknose shark assessment. Sensitivity indices in red.

PC-GN adult	PC-GN juvenile	GNOP	BLLOP	NMFS LL SE	SCDNR	UNC	MML	PC-LL	GN logs	Year
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1950
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1951
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1952
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1953
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1954
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1955
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1956
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1957
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1958
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1959
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1960
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1961
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1962
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1963
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1964
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1965
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1966
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1967
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1968
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1969
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1970
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1971
-1	-1	-1	-1	-1	-1	3.9673	-1	-1	-1	1972
-1	-1	-1	-1	-1	-1	4.2333	-1	-1	-1	1973
-1	-1	-1	-1	-1	-1	1.6003	-1	-1	-1	1974

-1	-1	-1	-1	-1	-1	3.3256	-1	-1	-1	1975
-1	-1	-1	-1	-1	-1	2.4895	-1	-1	-1	1976
-1	-1	-1	-1	-1	-1	6.2761	-1	-1	-1	1977
-1	-1	-1	-1	-1	-1	4.0479	-1	-1	-1	1978
-1	-1	-1	-1	-1	-1	3.1151	-1	-1	-1	1979
-1	-1	-1	-1	-1	-1	1.8658	-1	-1	-1	1980
-1	-1	-1	-1	-1	-1	0.7275	-1	-1	-1	1981
-1	-1	-1	-1	-1	-1	1.5026	-1	-1	-1	1982
-1	-1	-1	-1	-1	-1	0.8487	-1	-1	-1	1983
-1	-1	-1	-1	-1	-1	1.8139	-1	-1	-1	1984
-1	-1	-1	-1	-1	-1	0.9533	-1	-1	-1	1985
-1	-1	-1	-1	-1	-1	0.5945	-1	-1	-1	1986
-1	-1	-1	-1	-1	-1	1.099	-1	-1	-1	1987
-1	-1	-1	-1	-1	-1	2.1347	-1	-1	-1	1988
-1	-1	-1	-1	-1	-1	0.8117	-1	-1	-1	1989
-1	-1	-1	-1	-1	-1	0.5648	-1	-1	-1	1990
-1	-1	-1	-1	-1	-1	1.0523	-1	-1	-1	1991
-1	-1	-1	-1	-1	-1	2.3154	-1	-1	-1	1992
-1	-1	12.832	-1	-1	-1	1.3813	-1	0.008	-1	1993
-1	-1	110.912	17.126	-1	-1	0.8185	-1	0.076	-1	1994
-1	-1	14.734	41.156	0.06576	-1	1.0115	-1	0.021	-1	1995
0.446	0.168	-1	35.776	0.1774	-1	1.3957	-1	-1	-1	1996
0.161	0.082	-1	13.373	0.12944	-1	0.4191	-1	0.017	-1	1997
0.156	0.069	39.207	37.706	-1	0.0155	0.1894	-1	0.032	0.001	1998
0.308	0.086	55.567	44.055	0.13907	0.0077	0.1309	-1	0.052	0.001	1999
0.025	0.105	96.643	130.194	0.13907	0.0334	0.1936	-1	0.096	0.001	2000
0.157	0.114	40.011	14.477	0.25082	0.0162	0.5966	-1	-1	0.004	2001
0.242	0.124	143.84	67.202	0.21501	0.0347	0.2429	-1	-1	0.011	2002

0.216	0.117	63.992	34.63	0.48306	0.0226	0.1	0.988	-1	0.015	2003
0.232	0.131	46.179	28.78	0.34725	0.0152	0.3869	2.5482	-1	0.014	2004
0.118	0.119	251.732	130.604	0.20378	0.0343	0.4054	1.7171	-1	0.026	2005

Table BN-3. Blacknose results of the base case with the SPASM model. CVs are given in parentheses below each model estimate. SSF is spawning stock fecundity (not spawning stock *biomass*) and is calculated as the sum of the number of mature females multiplied by the number of pups producd per mature female.

Parameter	**BASE**
SSF_{2005}/SSF_{MSY}	0.83 (0.55)
F_{2005}/F_{MSY}	2.12 (1.55)
MSY	1.26E+05
SPR_{MSY}	1.40 (0.04)
F_{MSY}	0.06 (0.00)
SSF_{MSY}	3.99E+05
F_{2005}	0.13
SSF_{2005}	0.35 (0.32)
N_{2005}	5.28E+05
SSF_{2005}/SSF_0	0.35 (0.32)
B_{2005}/B_0	0.31 (0.56)
R0	3.64E+05 (0.28)
Pup-survival	0.764
alpha	1.981
steepness	0.331

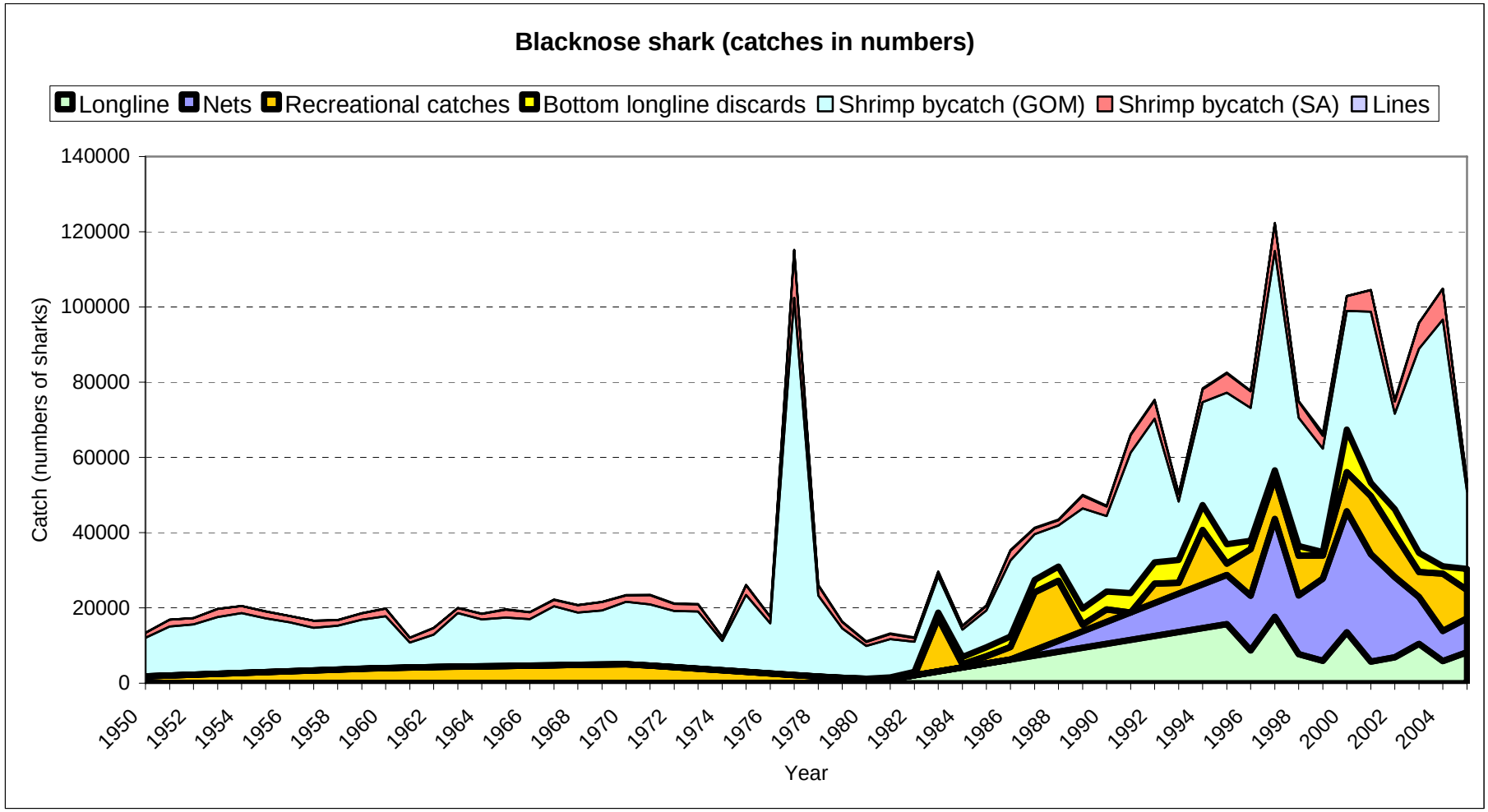


Figure BN-1. The catch series plotted by year. The shrimp bycatch series is by far the largest contributor to the catch estimates.

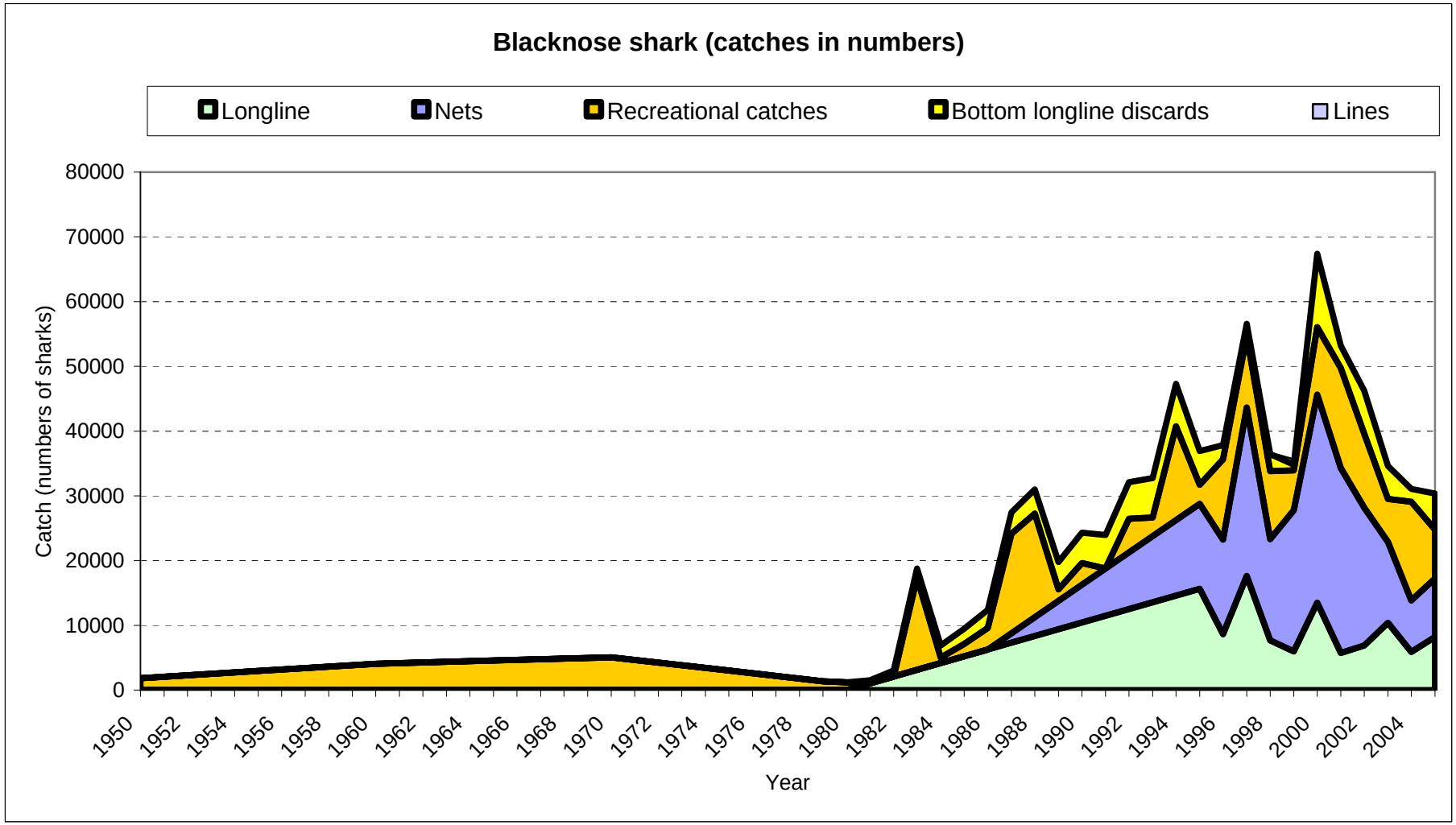


Figure BN-2 The catch series plotted by year without the shrimp bycatch series.

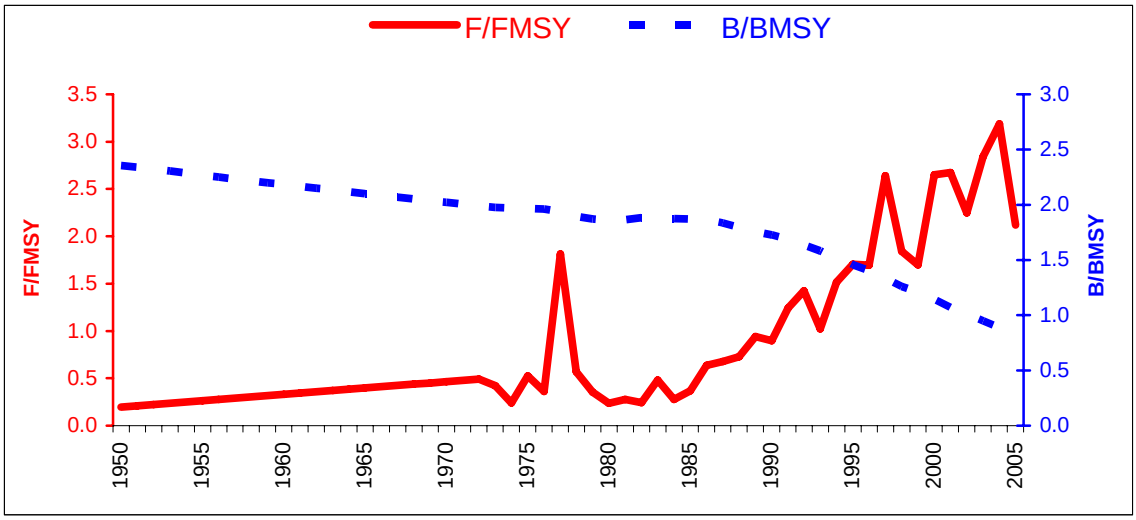


Figure BN-3. Base model estimated relative fishing mortality (solid red) and spawning stock fecundity (dashed blue) for the base case with equal index weighting

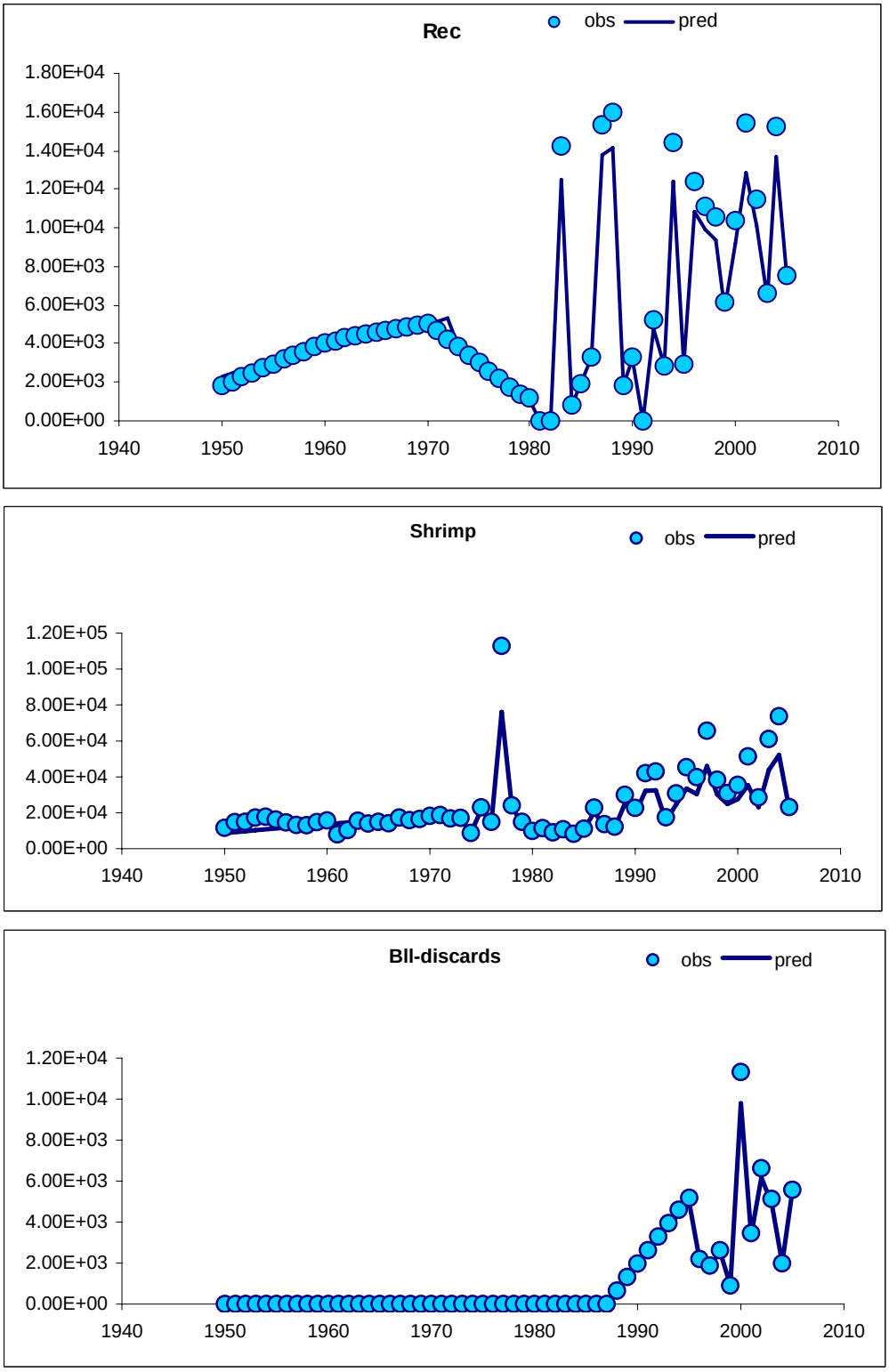
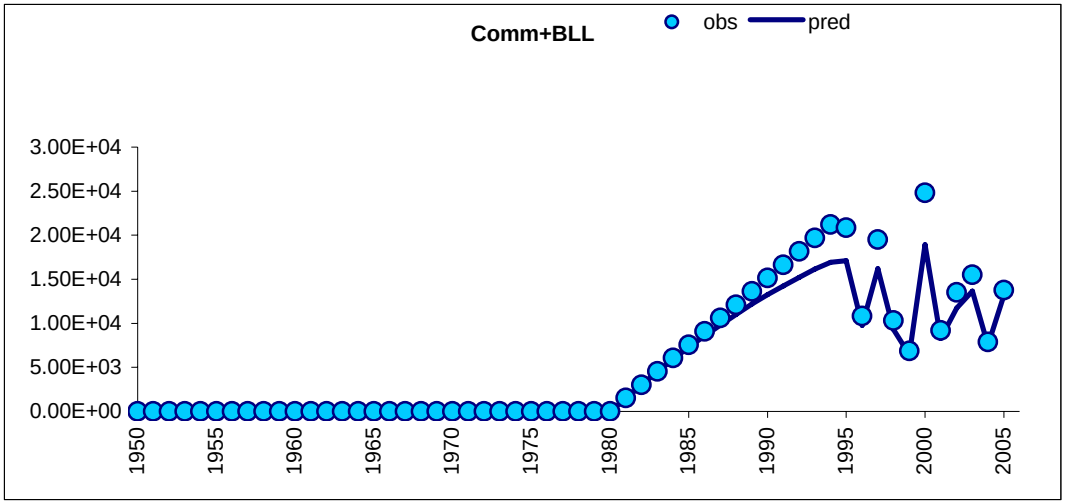
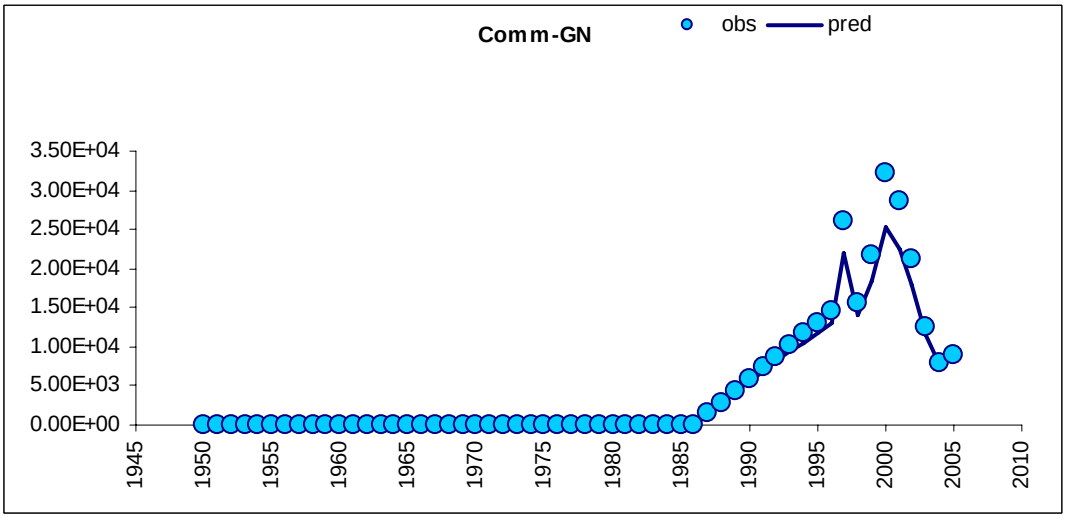


Figure BN-4. Base model estimates of the fit to the indices.





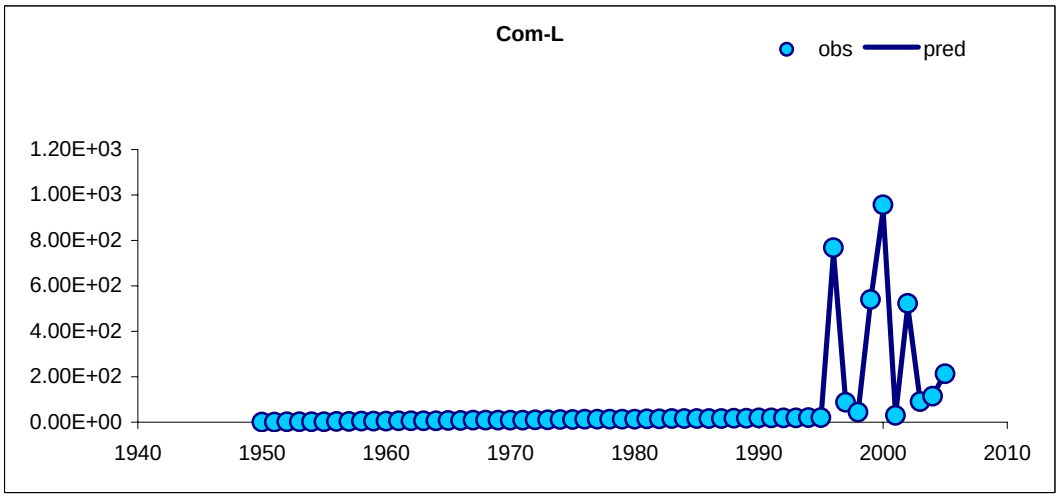


Figure BN-4. continued

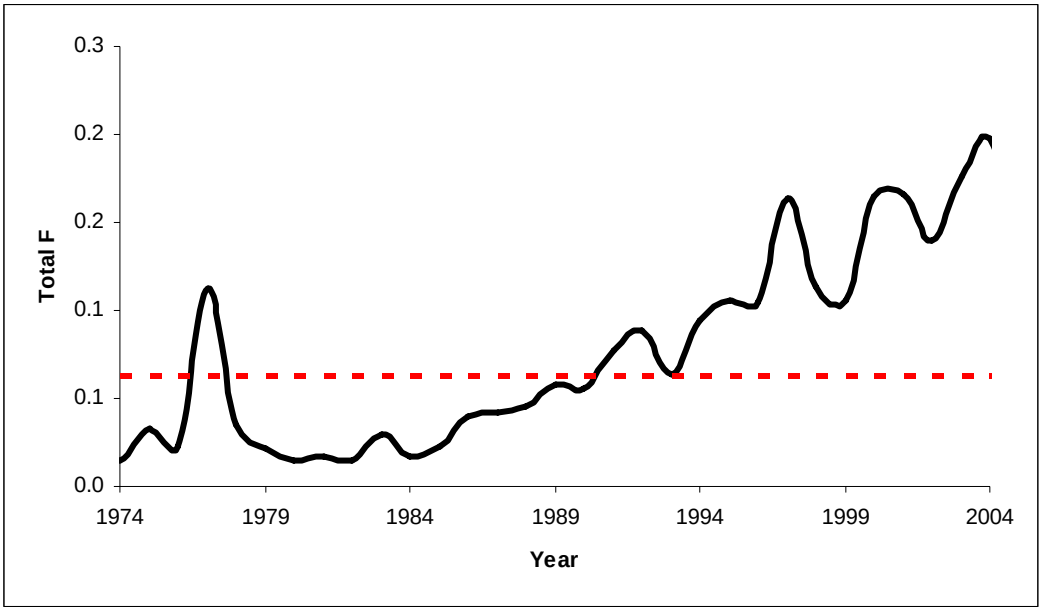


Figure BN-5. Base model estimates for total fishing mortality (solid black) and dashed reference line for F_{MSY}

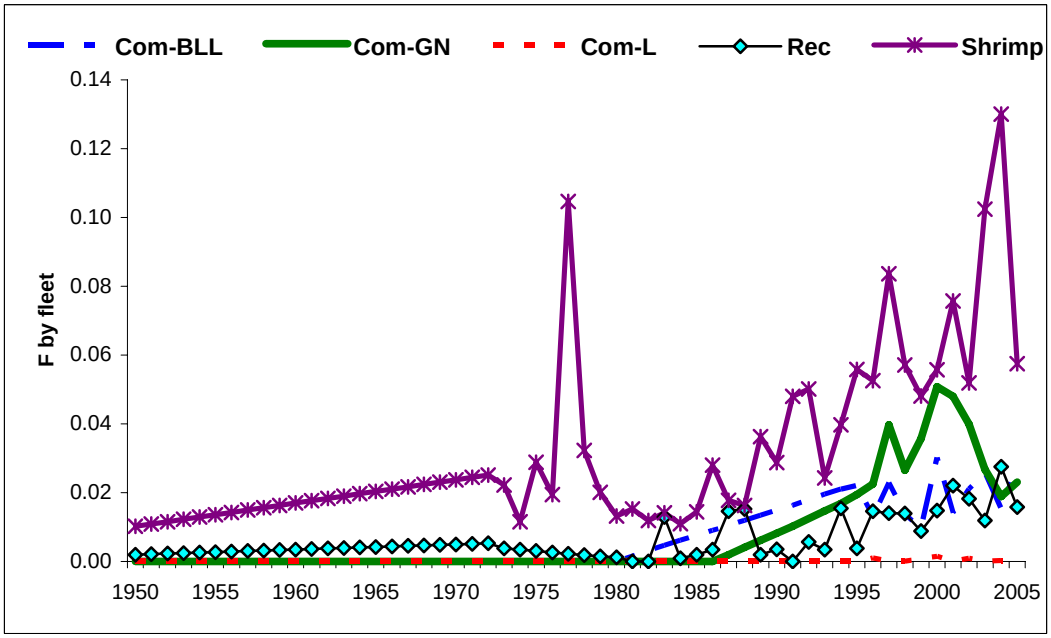


Figure BN-6. Base model estimates for and fishing mortality by fleet.

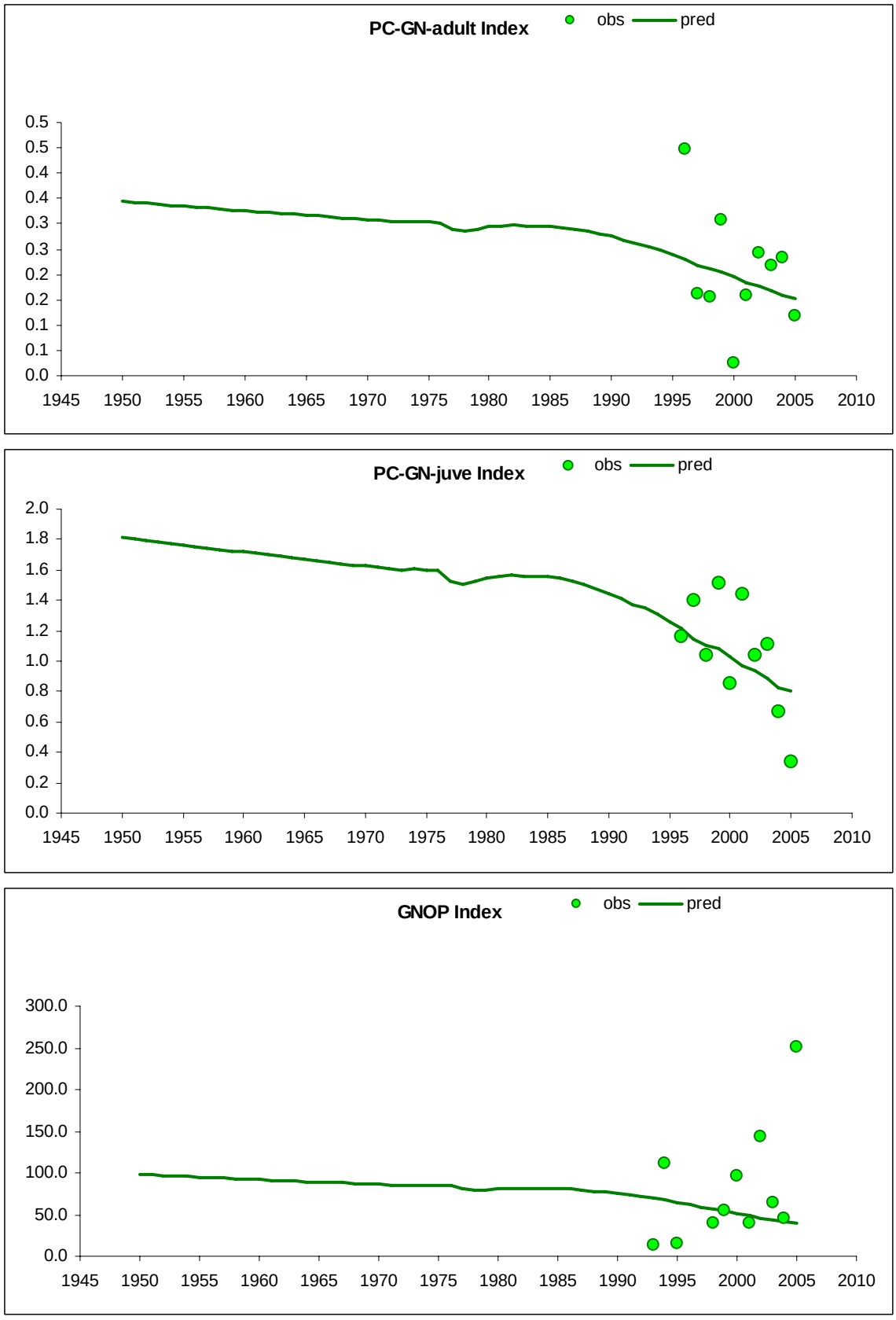


Figure BN-7. The Base model fits to the indices.

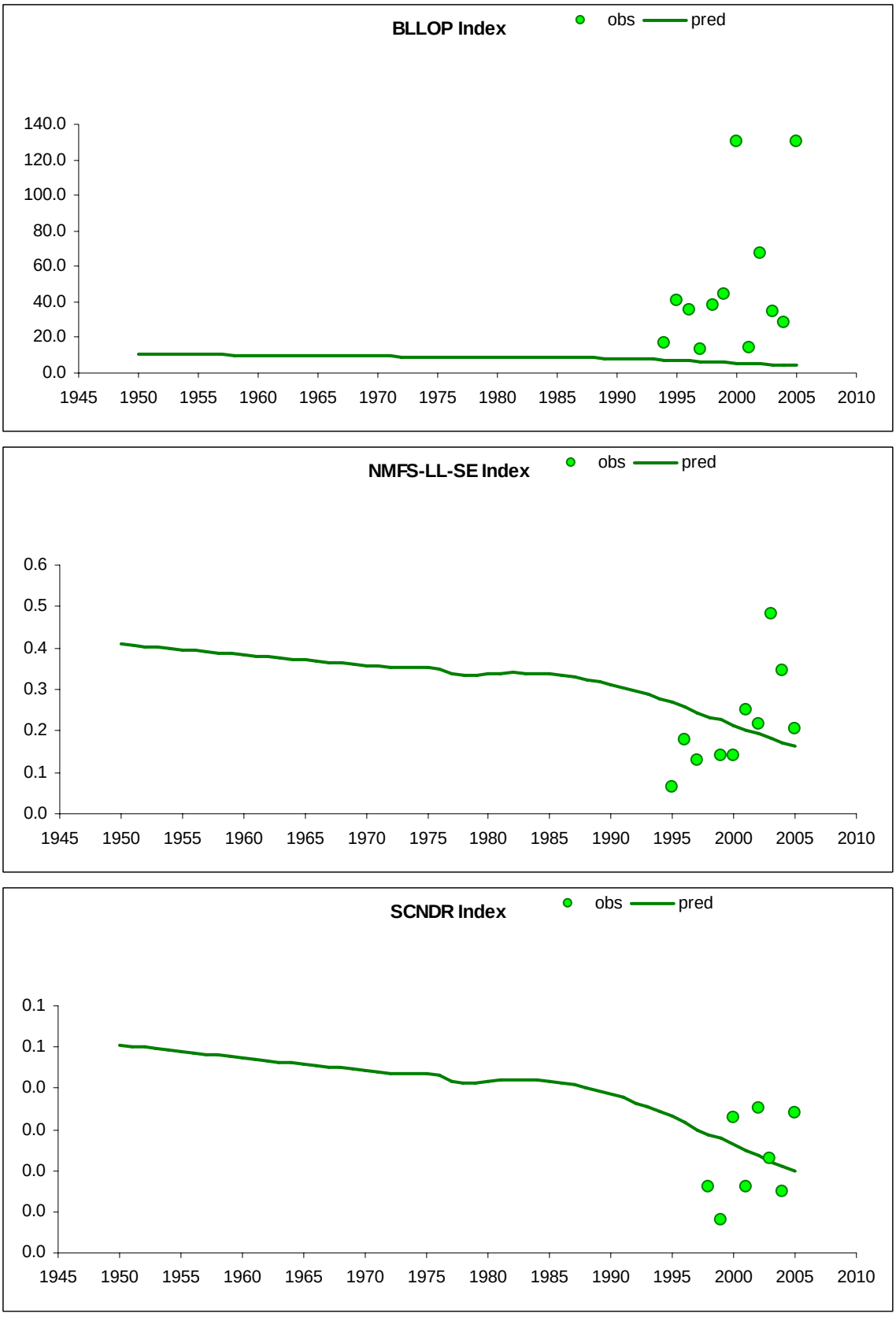


Figure BN-7. continued

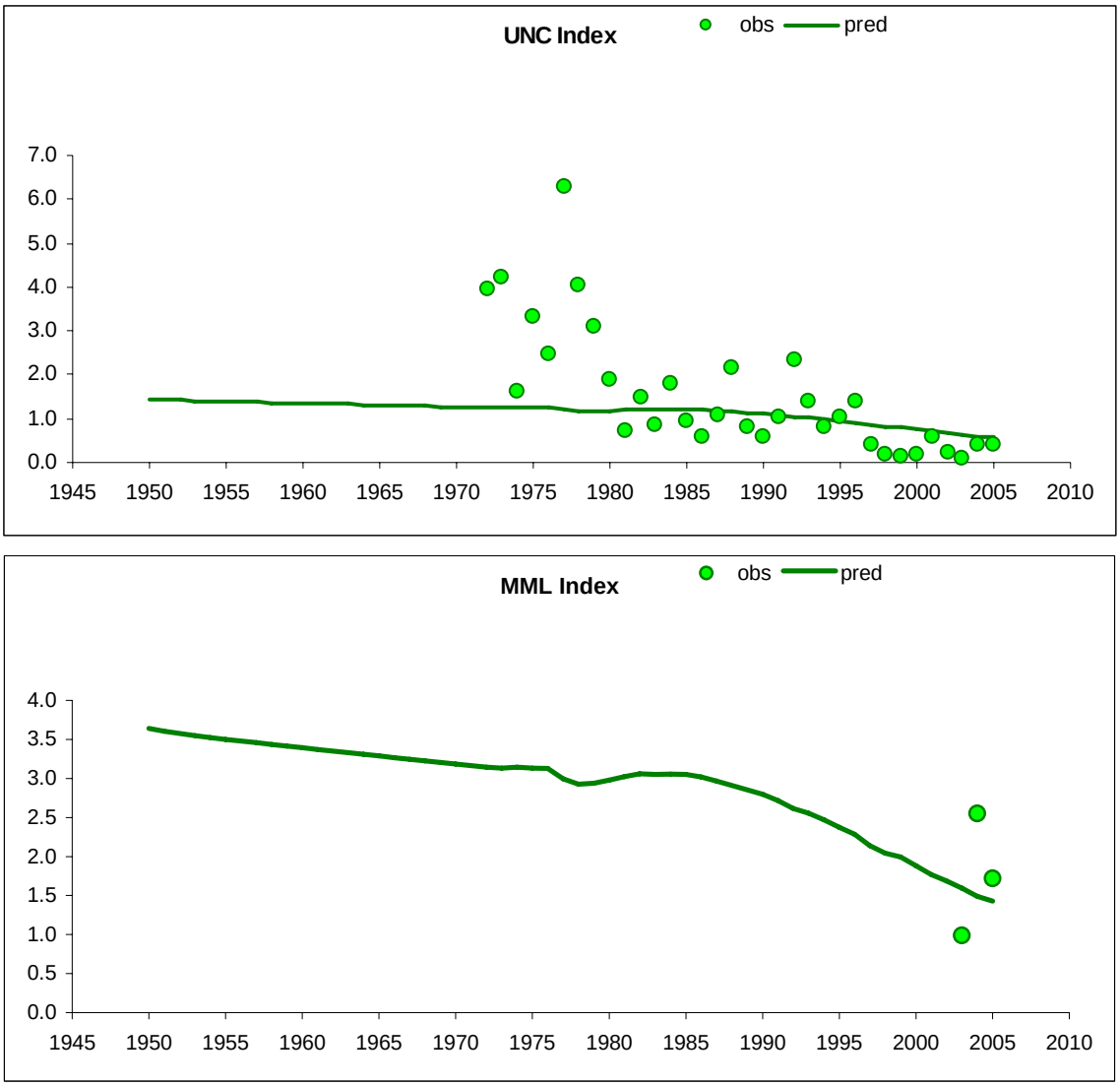


Figure BN-7. continued