Preliminary Runs of a State-Space, Age-Structured Production Model for Blacktip Shark

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SUMMARY:
An age-structured production model was used to assess blacktip shark, the same that was used in the 2002 assessment. A continuity run was made using the 2002 assessment decisions about biology and stock structure. Base models for the 2006 assessment were then run for the Gulf of Mexico and the Atlantic Ocean separately, using decisions made at the data workshop. All runs reached the same conclusion that the stock is not overfished nor, for the most recent years, is overfishing occurring. A number of adjustments to biological inputs were necessary to achieve model convergence, and this point warrants further discussion at the assessment workshop.

Model Description – Age-structured production model

The model used in the 2002 Large Coastal Shark assessment was a state space, age structured production model (SSASPM, Porch 2002). Unlike a production model, the SSASPM can incorporate age-specific differences in model parameters such as growth, fecundity, and gear vulnerability (selectivity). In the case of long-lived, late-maturing fish or when there are multiple fisheries that exploit different age classes, having the flexibility to incorporate age-specific information could lead to a better fit to observed data. Age-specific vectors for fecundity, maturity, and selectivity are specified by the user, and length and weight at age are calculated within the model based on user-specified growth functions. Natural mortality at age and a stock recruitment function are additional model parameters. The stock recruit function is parameterized in terms of virgin recruitment (R0) and pup survival. To derive the initial age structure for the first year that data is available, the model estimates a level of historic fishing (F_{hist}) and calculates the corresponding equilibrium population age structure. A historic selectivity vector is specified by the user, which is multiplied by F_{hist} to arrive at the historic age-specific fishing mortality rate. A historic selectivity vector of 1 for all ages was assumed.

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 1-3; Figures 1-5). Catches were made by the commercial sector, the recreational sector, and the Mexican fishery. In addition, unreported commercial catches were estimated, as were menhaden discards. Because of similar selectivity functions, the commercial and unreported catches were combined, and recreational catches were combined with Mexican catches, yielding a model with 3 distinct "fleets". A total of 9 indices were available for the continuity model, 10 for the Gulf of Mexico runs (of which 7 were used for the base case), and 7 indices for the Atlantic runs (of which 4 were used for the base case). None of the indices designated as sampling only "age 0" were used, as this model began with age class 1, which means that the stock recruitment relationship governed the number of one year olds to survive from the initial number of pups produced in a given year.

Catch data and indices begin in 1981. The base case in 2002 attempted to estimate a level of historic F, so that estimated for the base run. Initial model runs found that F_{hist} was difficult to estimate or it converged to near 0. Therefore, for all runs presented here, F_{hist} was fixed to 0, which implies that the stock was unexploited prior to 1981.

Parameters

Estimated model parameters were pup survival, virgin recruitment (R0), catchabilities associated with catches and indices, and fleet-specific effort. Although the continuity model attempted to estimate an age-constant M for ages 1^+, the model had difficulty converging on a value that satisfied a mathematical lower limit on steepness, which must be >0.2. Therefore, M was fixed in the continuity model at 0.22, the best estimate recommended by the 2002 workshop. There were also issues with steepness in the 2006 base models, so despite the fact that the data workshop recommended a fixed vector of

age-specific M, that parameter was instead fixed at the age constant value of 0.19. Values higher than this led to steepness values <0.2.

Description of Model Runs

Continuity – F_{hist} was fixed at 0, all indices were used and given equal weighting; M=0.22 (fixed); catches and indices were for Gulf and Atlantic combined; 2002 biological parameters used; 10 pups per mature female
Gulf of Mexico stock – F_{hist} was fixed at 0, BASE indices were used and given equal weighting, M=0.19 (fixed); 6.6 pups per female
Atlantic stock – F_{hist} was fixed at 0, BASE indices were used and given equal weighting, M=0.19 (fixed); 6.6 pups per female

Results
As alluded to in the discussion of model inputs, the life-history parameters agreed upon by the data workshop participants needed to be altered in order to satisfy a lower bound on steepness. M at age was fixed to an age-constant value. In addition, the number of pups per mature female was increased from the best value recommended at the data workshop to the upper range of expected values (Table 3). Given these adjustments, it was possible to obtain results with steepness in the range of 0.21-0.31, with the continuity case producing the largest steepness. Estimates of MSY ranged from 1.2E5 kg for the Gulf of Mexico, to 2.2E6 kg with the continuity one-stock model (Table 4). The model estimate of MSY for the Atlantic stock is about 100 kg, which seems unrealistically low. Depletion ranged from 55% of virgin levels to 96% of virgin levels. In all model runs, the blacktip shark was not estimated to be (or ever have been) overfished, and in recent years it is no longer being overfished.

A sensitivity case was run that assumed one stock, no historic fishing, the average of Gulf and Atlantic 2006 maturity, M fixed at 0.19, and 6.6 pups per female (basically the continuity model with 2006 biological parameters). The results were extremely similar to the continuity case. By lowering the number of pups from 10 to 6.6, the model responded by estimating a higher pup survival (0.75 instead of 0.68), but steepness was still 0.31. Time did not permit a full suite of sensitivity runs to the indices included nor to alternative weighting schemes.

Discussion
Given the manipulations of biological inputs required to achieve convergence, these results should be regarded as preliminary. A fuller discussion about where to incorporate uncertainty in these parameters should take place at the assessment workshop.

No projections were done at this point.

References

Porch, C. E. 2002. A preliminary assessment of Atlantic white marlin (*Tetrapturus albidus*) using a state-space implementation of an age-structured model. SCRS/02/68 23pp.

Table 1. Catches in number of Blacktip shark in the Gulf of Mexico and the Atlantic Ocean. For the continuity model, which assumed one stock, values for the Gulf and Atlantic were added together.

	Gulf of Mexico			Atlantic	
Year	Commercial +Unreported	Recreational + Mexican	Menhaden	Commercial +Unreported	Recreational + Mexican
1981	7,261	161,954	17,495	551	4,498
1982	7,261	124,603	17,933	551	28,050
1983	7,844	88,980	17,714	595	29,299
1984	10,712	131,959	17,714	813	16,100
1985	9,950	132,272	15,964	755	53,267
1986	71,435	224,930	15,746	4,172	13,626
1987	98,806	156,674	16,402	8,573	46,660
1988	174,842	207,083	15,964	4,025	19,662
1989	190,962	192,279	16,839	3,872	21,793
1990	115,002	199,323	16,402	4,896	7,174
1991	46,484	200,210	12,684	75,319	40,614
1992	53,236	232,849	11,153	97,190	19,627
1993	57,102	210,606	11,372	71,522	12,824
1994	120,028	154,194	12,200	81,244	15,941
1995	84,862	134,884	11,200	66,295	19,431
1996	58,666	154,722	11,153	41,901	27,867
1997	45,221	132,184	11,372	36,023	16,336
1998	62,486	125,280	10,935	32,418	21,499
1999	52,304	72,013	12,028	6,807	8,850
2000	42,131	112,581	10,279	9,667	6,753
2001	39,397	80,034	9,622	9,654	14,945
2002	30,040	79,944	9,404	20,634	5,277
2003	71,540	55,778	9,185	18,355	30,063
2004	44,174	72,734	9,404	13,397	4,278

Table 2. Maturity and natural mortality at age for the Continuity, Gulf, and Atlantic Blacktip models.

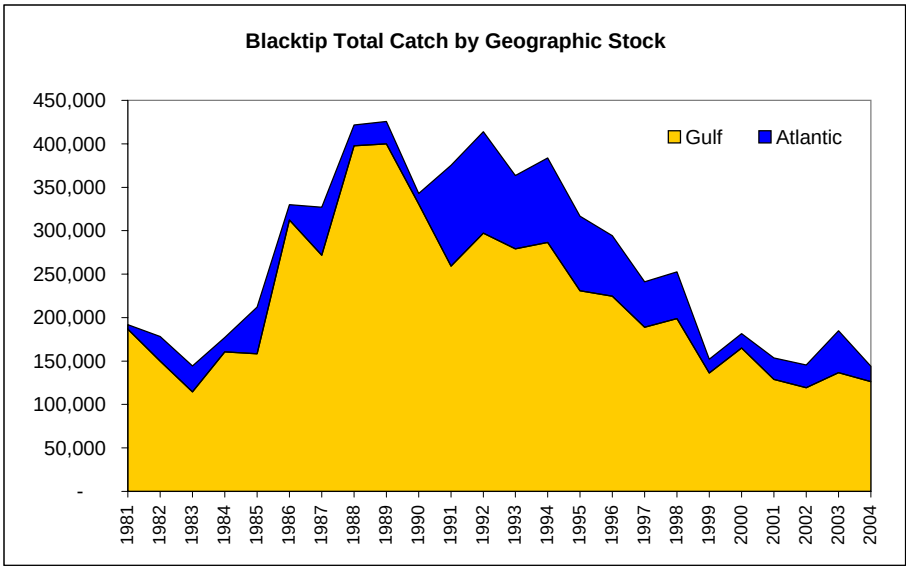
	Maturity			Natural Mortality	
Age	2002	2006 Gulf	2006 Atlantic	2002	2006 Gulf	2006 Atlantic
1	0	0.002	0	0.22	0.358	0.287
2	0	0.006	0.001	0.22	0.303	0.252
3	0.02	0.019	0.004	0.22	0.271	0.229
4	0.09	0.059	0.02	0.22	0.250	0.212
5	0.35	0.166	0.095	0.22	0.235	0.199
6	0.74	0.387	0.354	0.22	0.225	0.190
7	0.94	0.667	0.741	0.22	0.218	0.182
8	0.9	0.865	0.937	0.22	0.212	0.177
9	1	0.953	0.987	0.22	0.208	0.172
10	1	0.985	0.998	0.22	0.205	0.168
11	1	0.996	1	0.22	0.203	0.165
12	1	0.999	1	0.22	0.201	0.162
13	1	1	1	0.22	0.200	0.160
14	1	1	1	0.22	0.198	0.159
15	1	1	1	0.22	0.198	0.157

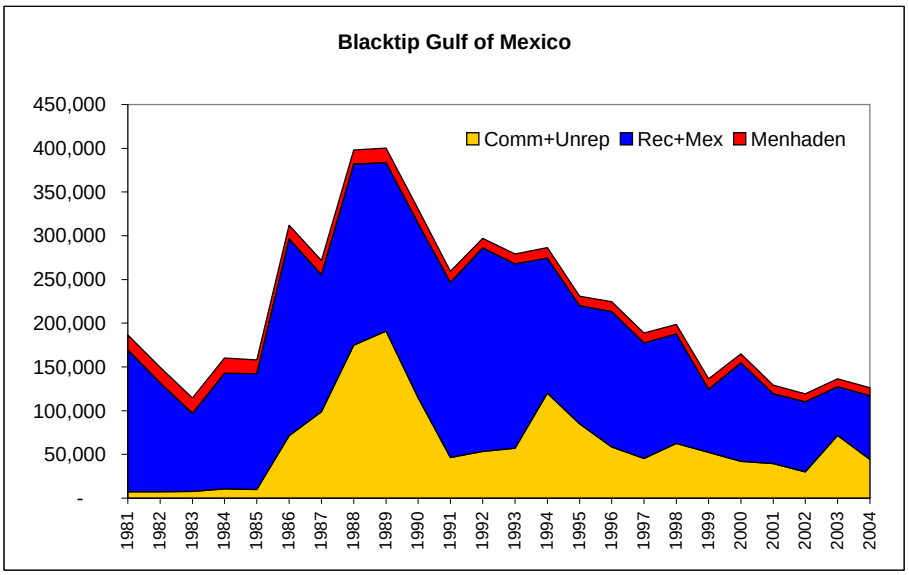
Table 3. Additional parameter specifications. For the continuity model, a value of 10 pups per mature females was used, while for the 2006 base models, 6.6 was used.

Parameter	Value	Prior
L_∞	164	*constant*
K	0.089	*constant*
t0	-3.8	*constant*
a	1.09E-5	*constant*
b	3.012	*constant*
F_{hist}	0.0	*constant*
Historic Selectivity	1 for all ages	*constant*
M (continuity)	0.22	*constant*
M (Gulf and Atlantic)	0.19	*constant*
Pups-per-mature female	10, 6.6	*constant*
Pup Survival	0.52	~LN with CV=0.45
Virgin Recruitment (R0)	1.0E+6	~U on [1.0E+4, 1.0E+9]

Table 4. Results from the continuity, Gulf, and Atlantic Blacktip assessment model runs.

	Model Run		
	Continuity	**Gulf**	**Atlantic**
Parameter	**Est**	**Est**	**Est**
R0	1.78E+06	2.62E+06	3.92E+06
MSY	2.20E+06	1.19E+05	9.92E+01
B2004/B0	0.59	0.82	0.96
SSF2004/SSF0	0.55	0.82	0.96
SSFMSY	1.95E+06	2.43E+06	3.37E+06
SSF2004/SSFMSY	1.30	1.80	2.30
SPRMSY	0.75	0.88	0.95
F2004	0.06	0.03	0.001
FMSY	0.06	0.05	0.004
F2004/FMSY	0.91	0.65	0.25
Pup-survival	0.68	0.63	0.53
alpha	1.77	1.28	1.10
steepness	0.31	0.24	0.21
BMSY/B0	0.42	0.46	0.42





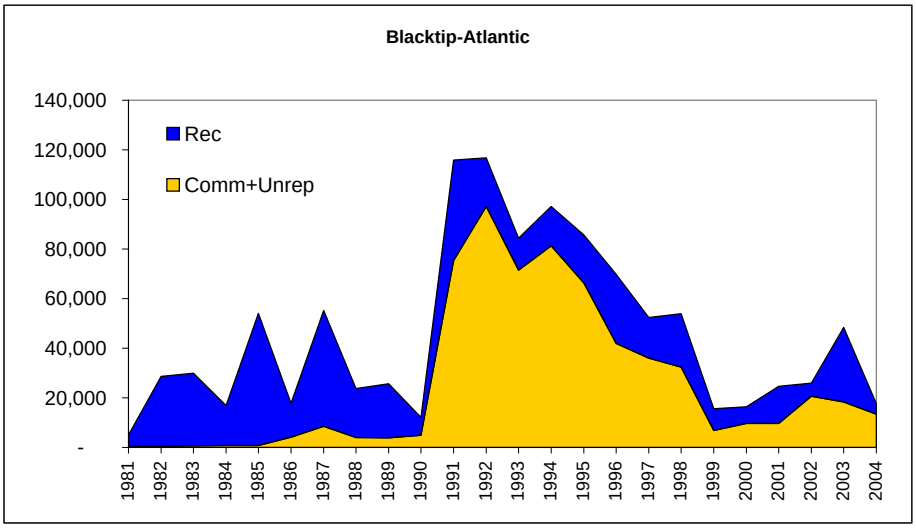
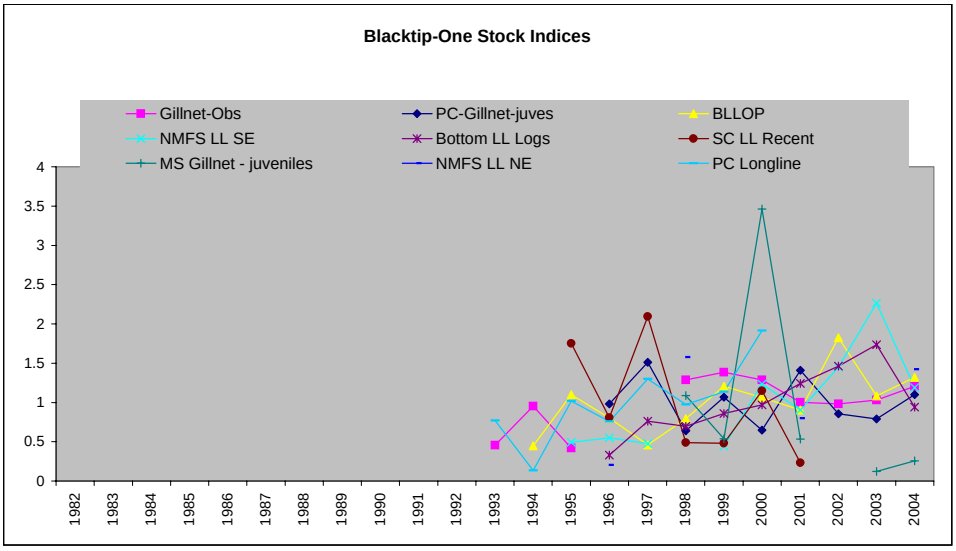
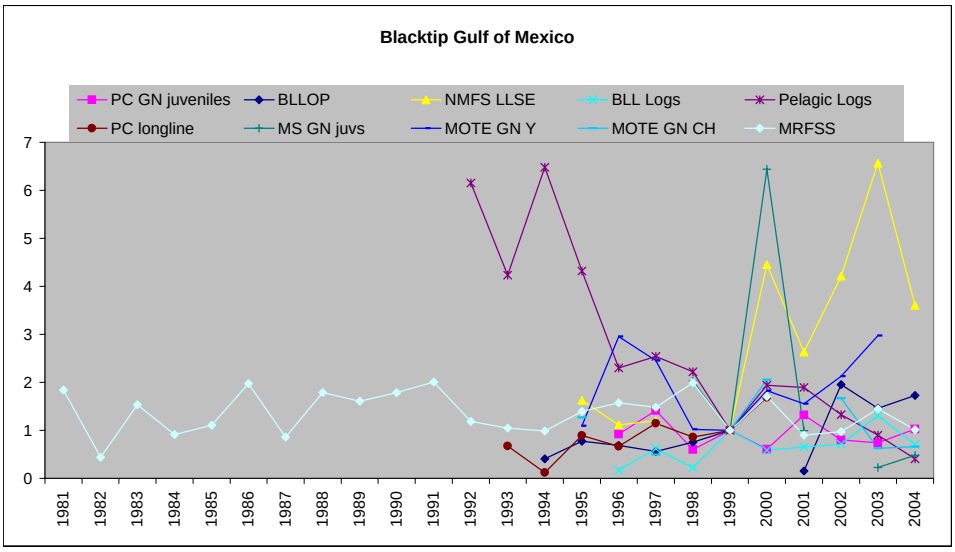


Figure 1. Total catch of Blacktip (top), and fleet specific catch in the Gulf of Mexico (middle) and Atlantic Ocean (bottom).





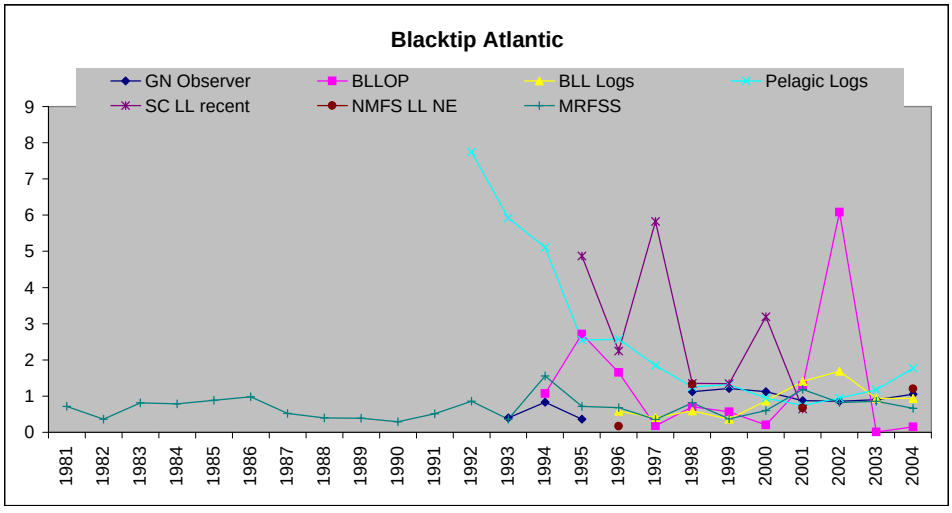


Figure 2. All available indices for Blacktip assessments for one stock (top), Gulf of Mexico stock (middle), and Atlantic Ocean stock (bottom) In the top figure, there were no years where all indices had observations, so they are not standardized to each other. In the middle, all indices are standardized to the 1999 value (only year of overlap). In the bottom plot, indices are standardized to the average of 1998, 2000.

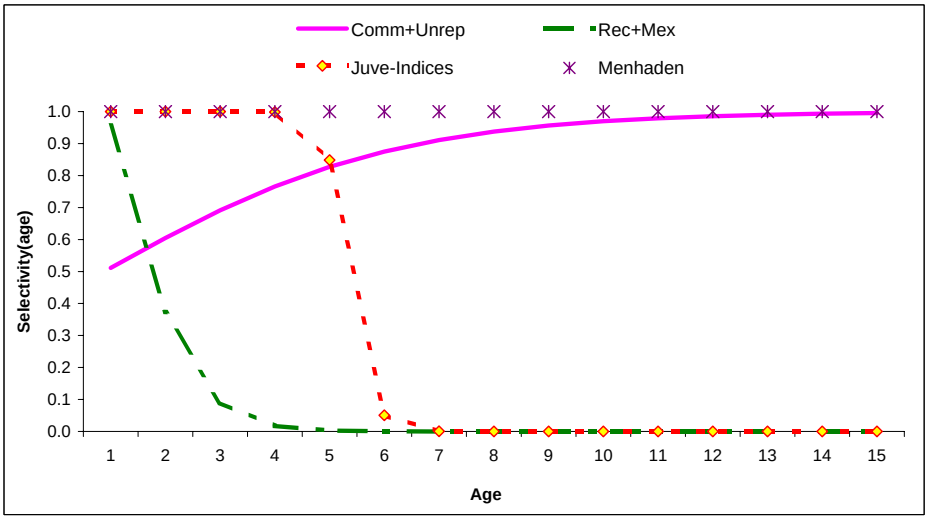


Figure 3. Selectivities applied to Blacktip catches and catch rates.

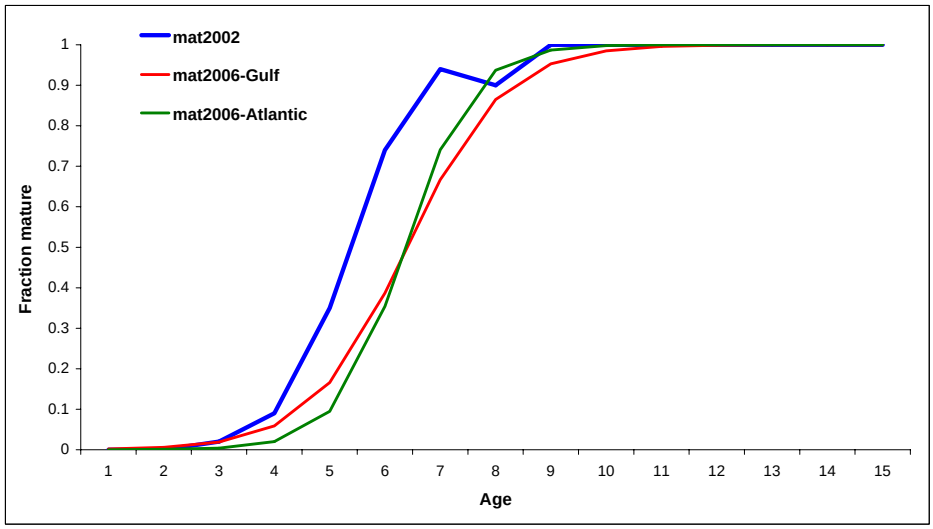


Figure 4. Maturity ogives for Blacktip.

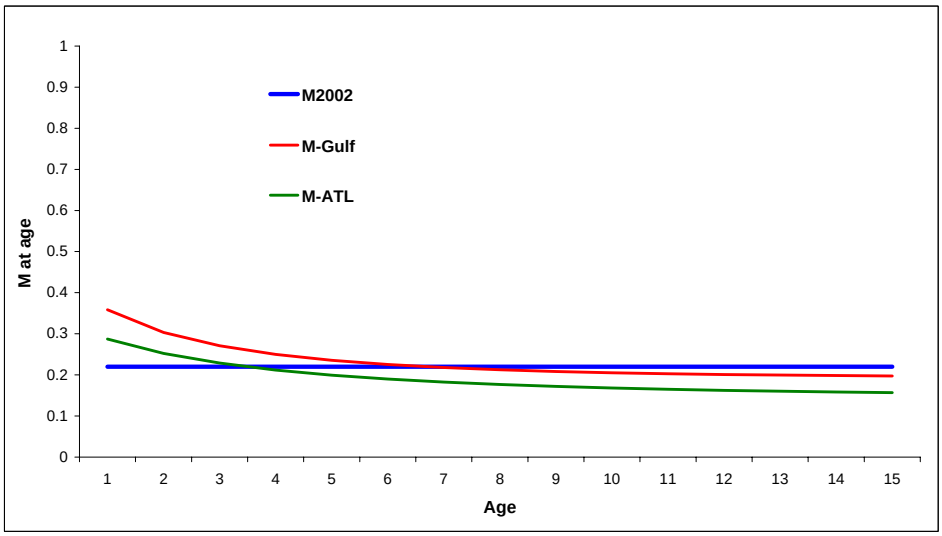


Figure 5. Natural mortality at age for Blacktip shark.

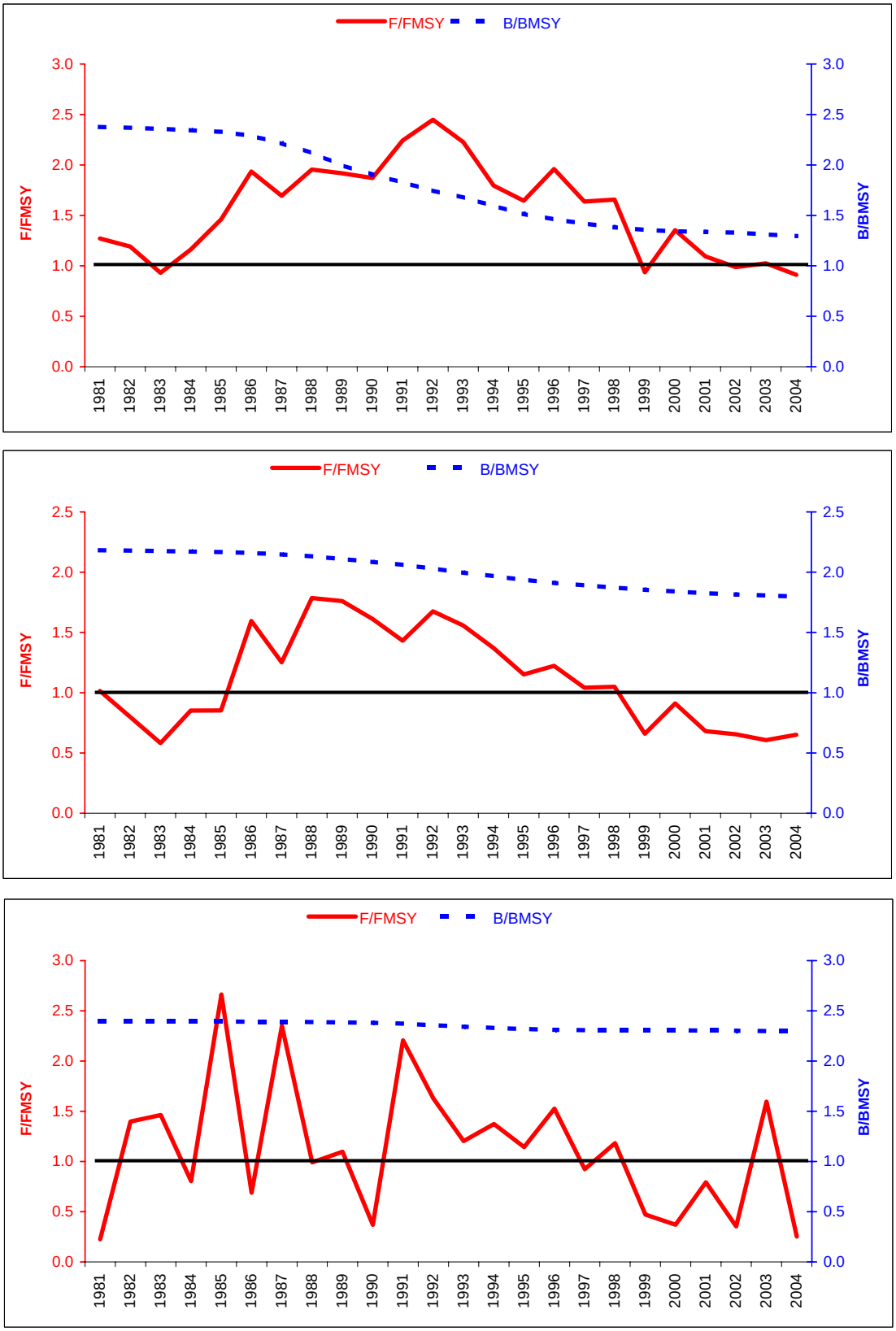


Figure 6. Estimates of Blacktip stock status for the continuity model (one stock, top), Gulf of Mexico stock (middle), and the Atlantic Ocean stock (bottom).

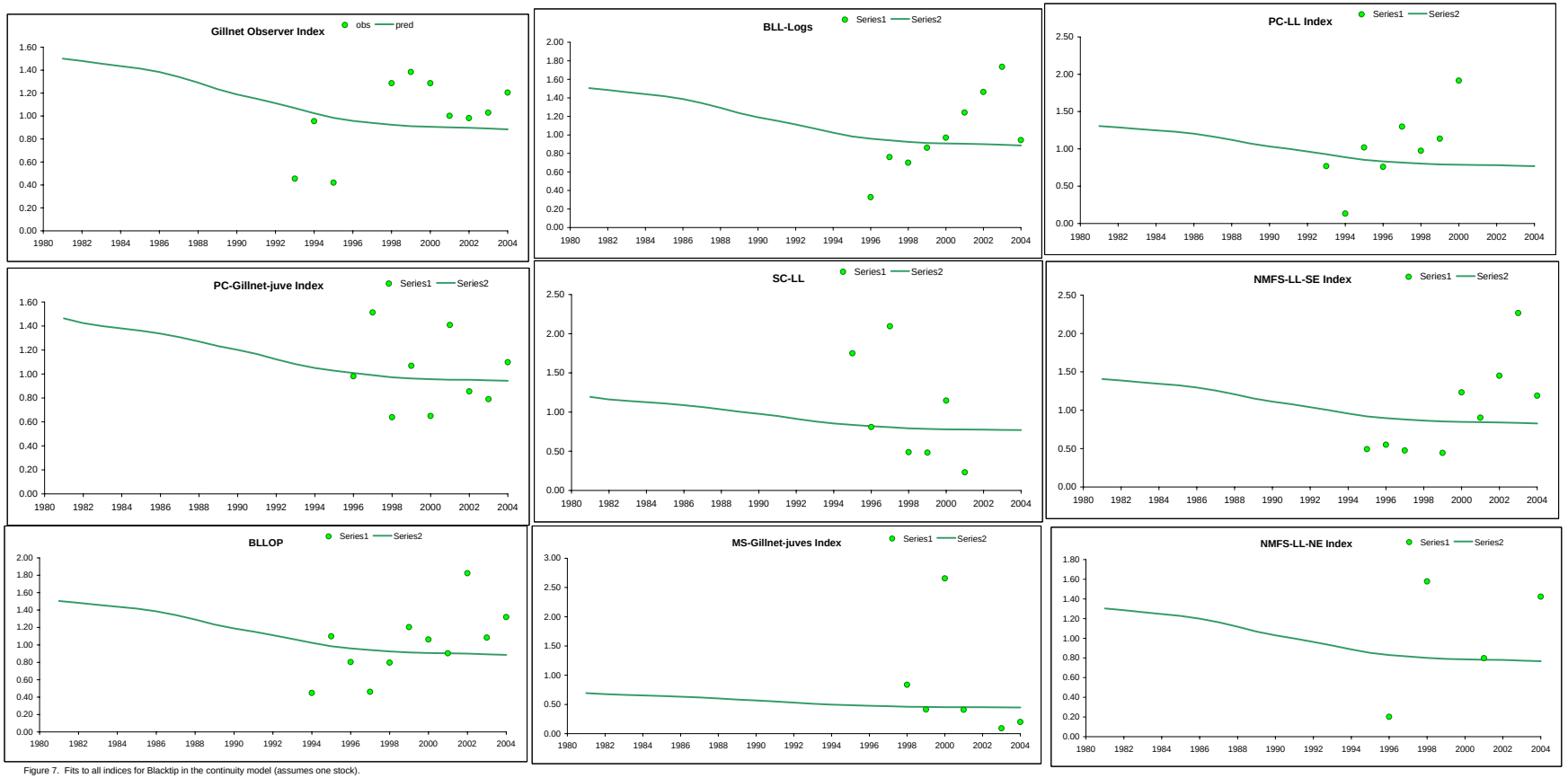
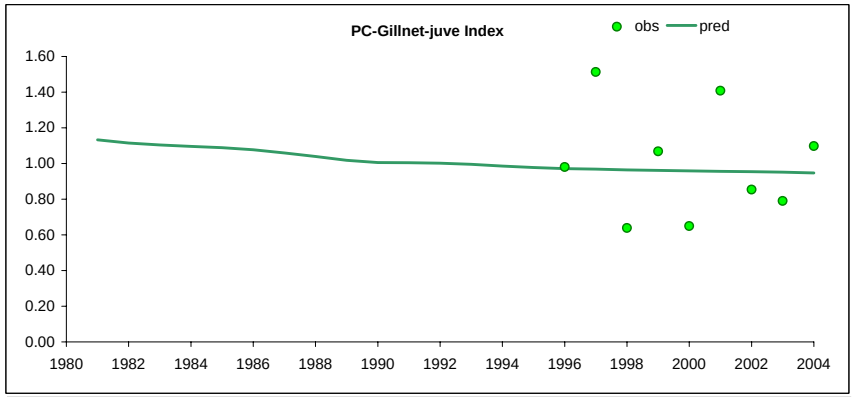
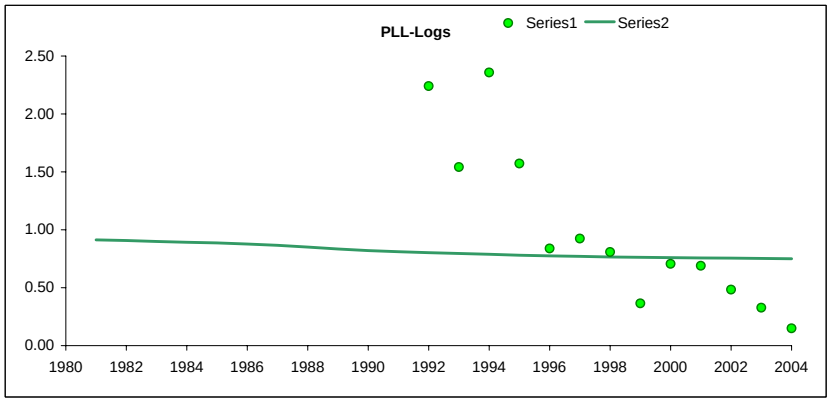
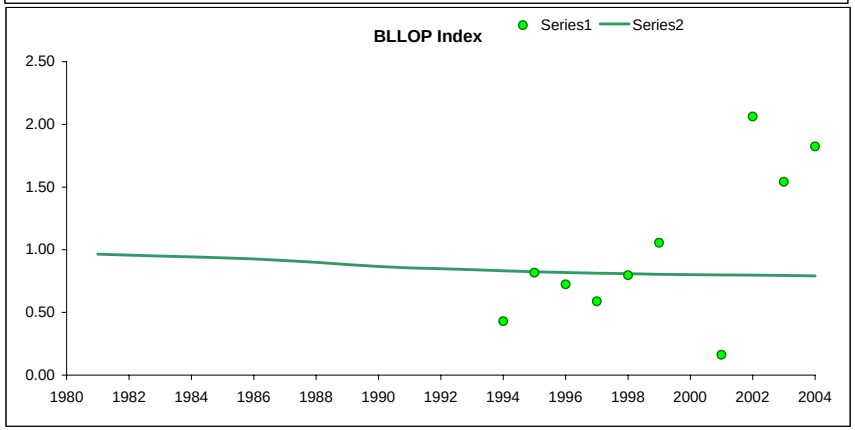
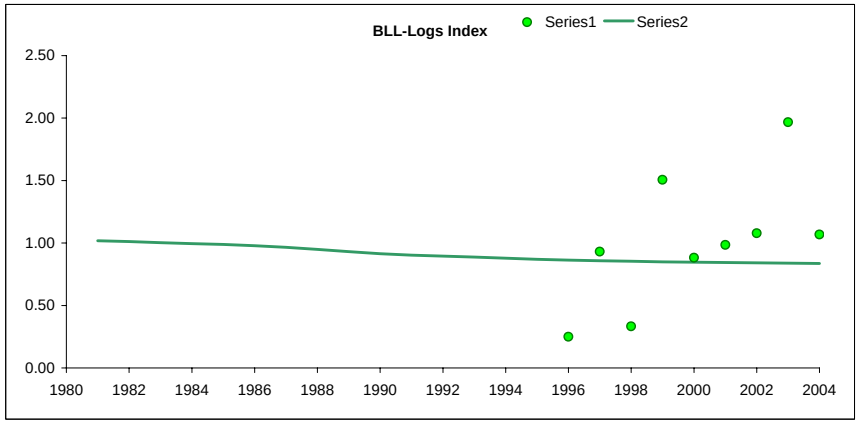


Figure 7. Fits to all indices for Blacktip in the continuity model (assumes one stock).









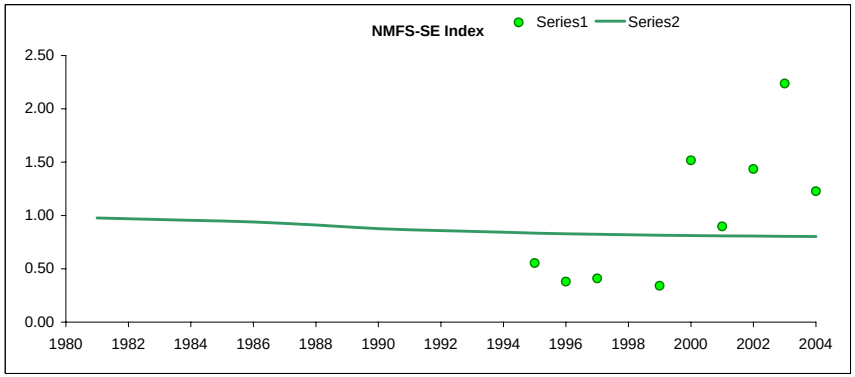
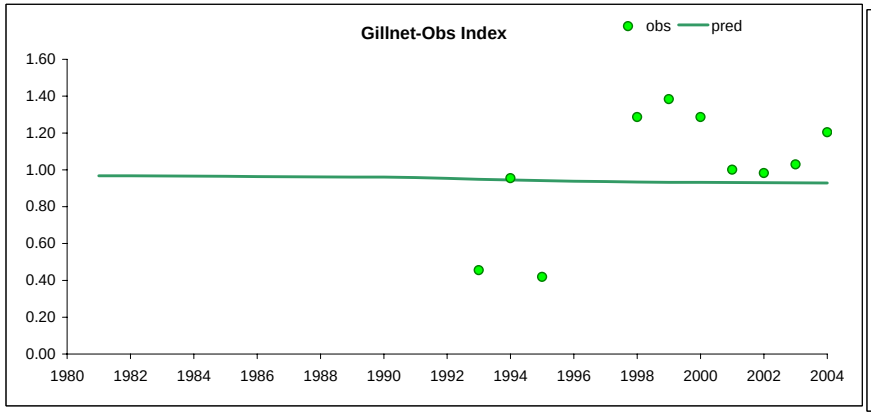
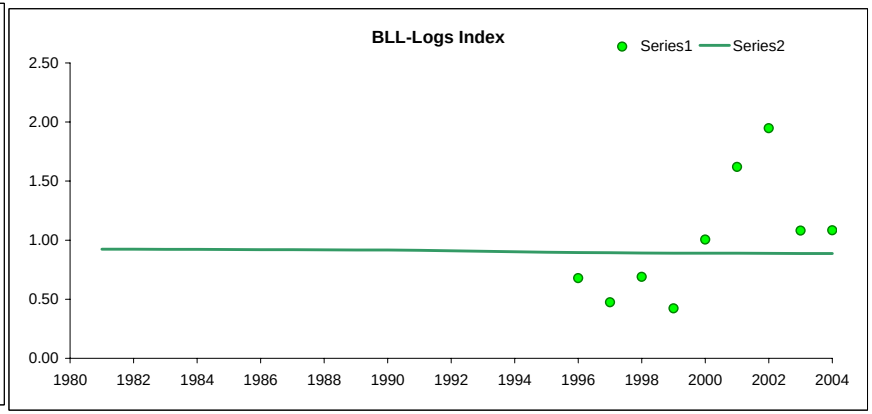
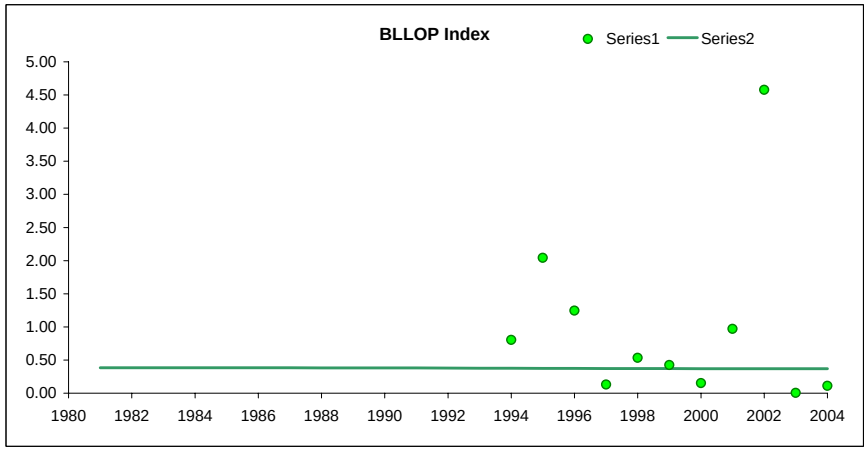


Figure 8. Fits to base indices for Blacktip in the Gulf of Mexico.







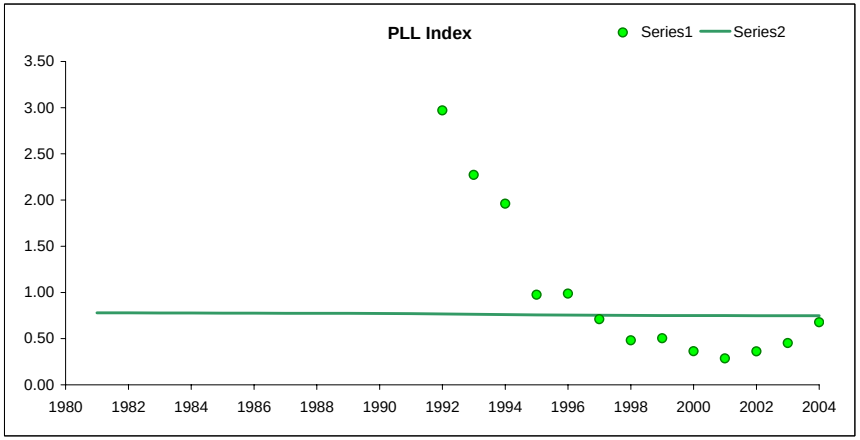
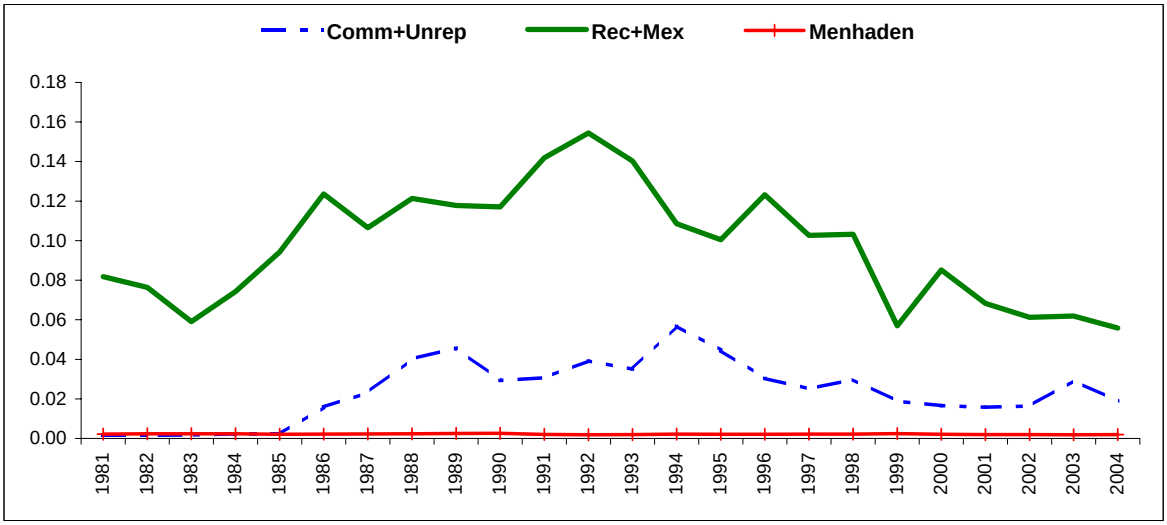
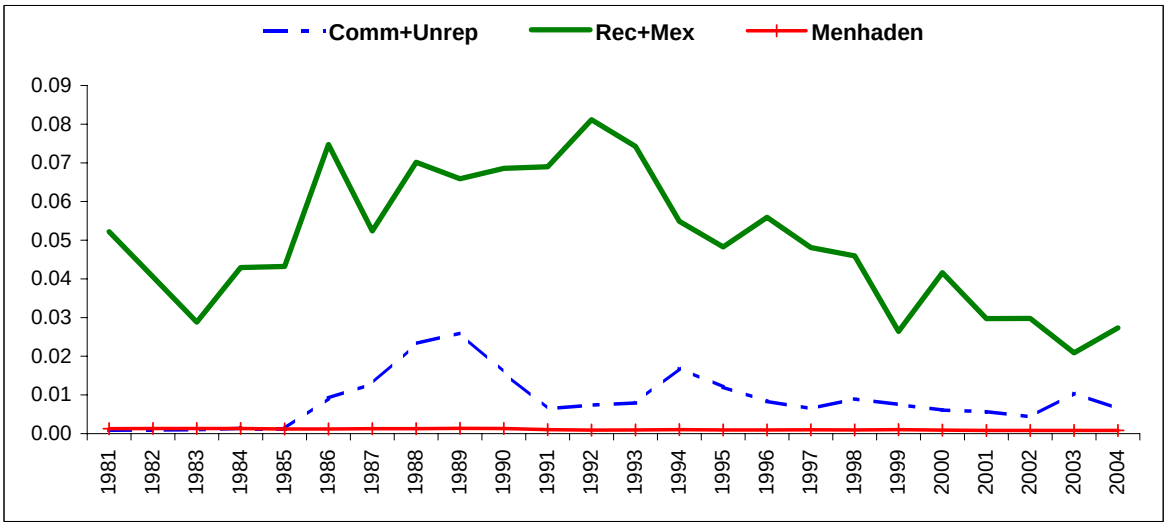


Figure 9. Fits to base indices for Blacktip in the Atlantic Ocean.





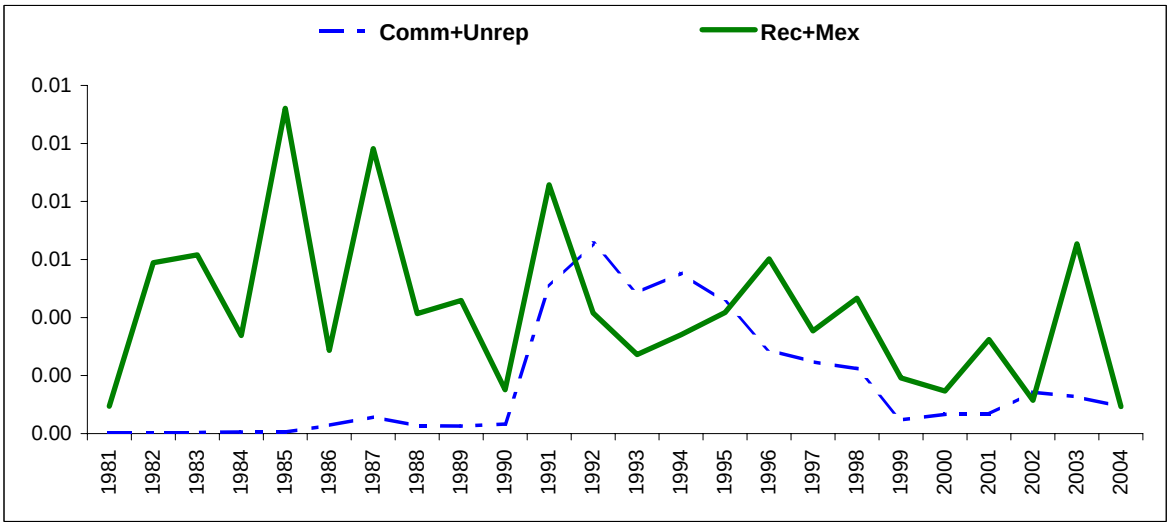
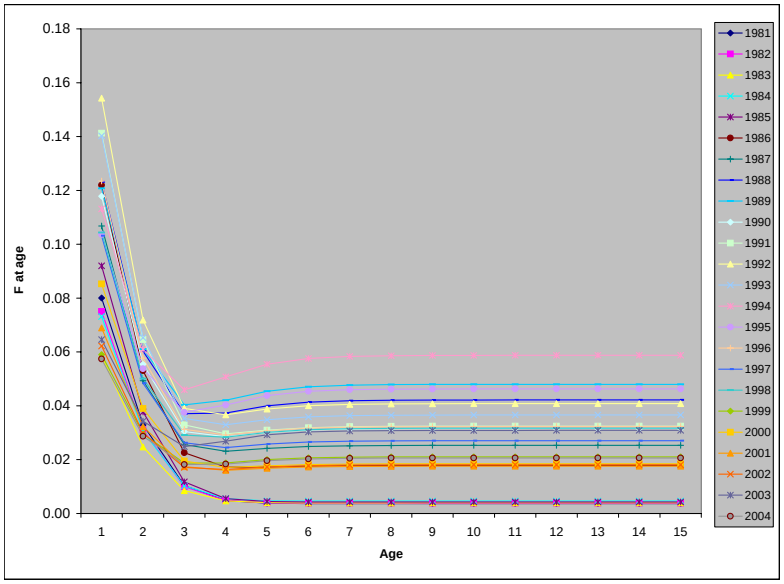
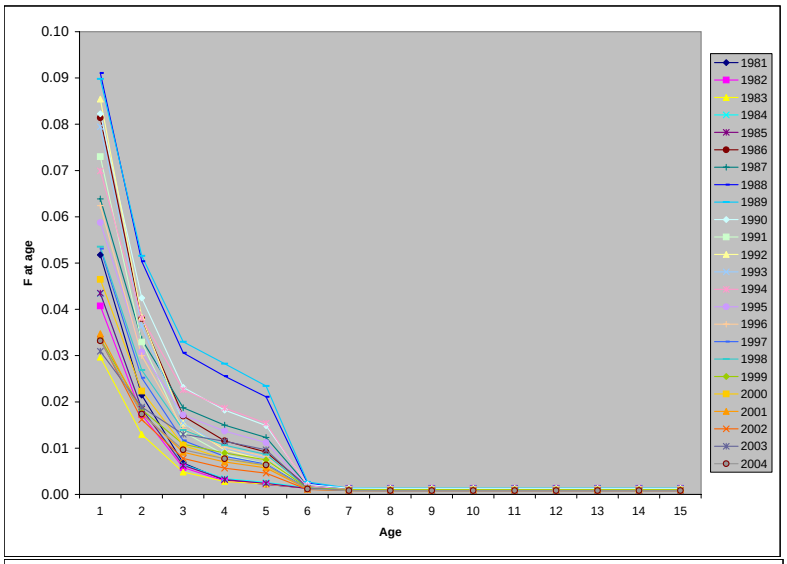


Figure 10. Estimates of fleet specific F for Blacktip in the continuity model (top, one stock), Gulf of Mexico (middle), and the Atlantic Ocean (bottom).





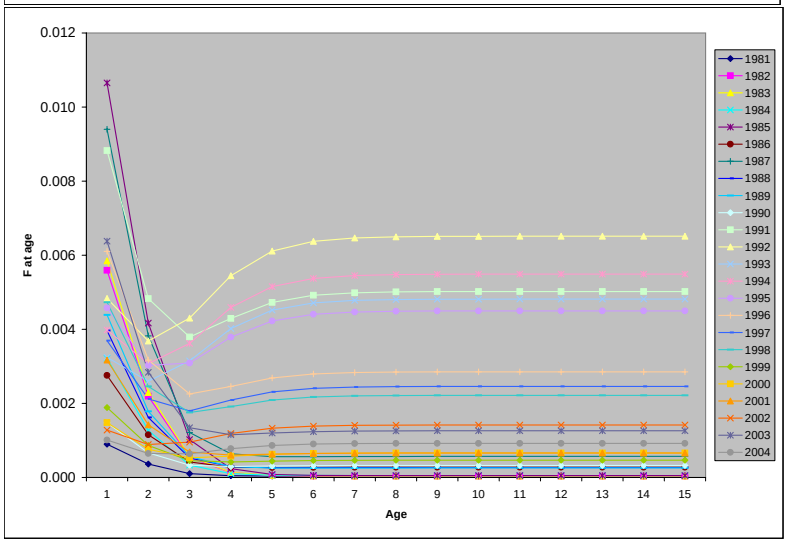


Figure 11. F at agefor Blacktip in the continuity model (top, one stock), Gulf of Mexico (middle), and the Atlantic Ocean (bottom).

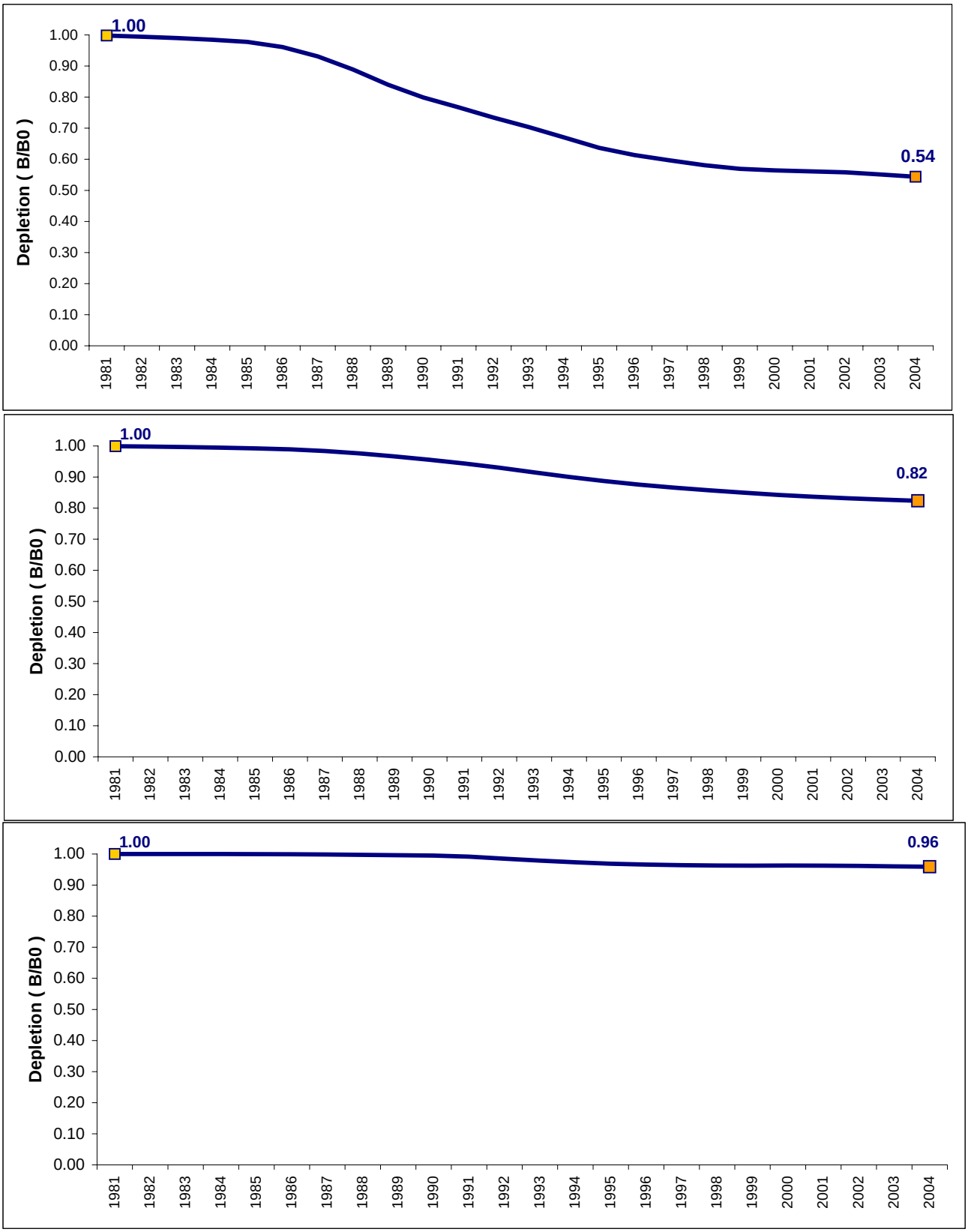


Figure 12. Estimates of stock depletion for Blacktip in the continuity model (top, one stock), Gulf of Mexico (middle), and the Atlantic Ocean (bottom).