APPENDIX C: CALIBRATING THE GENERAL BIOECONOMIC GENERAL SIMULATION MODELS (GBFSM)

Two models were calibrated for this research. There is the large version of GBFSM used to examine fractional license and fractional gear as well as other policies such as size limits, bag limits, etc. Then there is the small version of the model used for dynamic optimization to determine the optimal TAC over time. Shrimp and red snapper are included in both models and therefore both models must be calibrated for shrimp and red snapper. The large model had been used by Griffin and Samonte-Tan (1999) to evaluate the impact of bycatch reduction devices on the harvesting and consumer sectors of the Gulf of Mexico shrimp fishery. The large model was calibrated for shrimp at that time and is reported in Griffin and Samonte-Tan and can be found at http://gbfsm.tamu.edu. It will not be repeated here. Griffin, Gillig and Ozuna (1999) used the version by Griffin and Samonte-Tan and added red snapper. With both shrimp and red snapper in the large version of GBFSM, they were able to assess the Gulf of Mexico red snapper management policies and there interaction with the shrimp fishery and the mandatory use of BRDs. Calibration of the red snapper fishery is reported in Griffin, Gillig, and Ozuna. (1999) and can be found at http://gbfsm.tamu.edu. The Ricker stock-recruitment relationship was used to calibrate the model for red snapper.

In this research the original intent was to use the Griffin, Gillig and Ozuna's version of the model to analyze fractional license and fractional gear. Given that we had a calibrated version of the larger model, we tuned the smaller version of the dynamic optimization model using the Ricker stock-recruitment relationship. However, given the nature of the dynamic optimization, the model did not perform well and so we tuned it with the Beverton and Holt (1957) stock-recruitment relationship, which did perform satisfactorily. As a result, we determined that is was best to have both the large and small models tuned with the same stock-recruitment relationship. Therefore, we calibrated the red snapper in the large model using the Beverton and Holt stock-recruitment relationship. The shrimp in the large model did not have to be recalibrated.

Coefficients in both the large and small versions of GBFSM were derived from information in the literature and/or data from federal/state management agencies whenever possible. When data is not available, or when there is a wide range of estimated values, these coefficients were determined from subjective estimation using an iterative simulation procedure. Calibrating the models involves matching simulation results to a historical data set.

We calibrated the small model for the red snapper stock first because is had fewer dimensions and would be easier. Given that our recreational red snapper data was from 1995, we calibrated the small model so that we get approximately the age structure in 1995 as shown in Table 28 of Schirripa and Legault (1997). We then allow the small model to simulate effort and stock to the end of 2000 where we store the data. This allows the dynamic analysis to begin in 2001 since our only concern is determining the optimum TAC over time.

Once the small red snapper model was tuned, we calibrated the large red snapper model. In this case however, we want the model to begin in 1998 since this is the first year BRDs were required and our intent was to compare the fractional license and fractional gear policies with other policies, especially BRDs.

Simulation models are only as good as the input data. In the case of red snapper the stocks are considered low and that they can be rebuilt a much larger amount. In the "Regulatory Amendment to the Reef Fish Fishery Management Plan to Set a Red Snapper Rebuilding Plan Through 2032" (Gulf of Mexico Fishery Management Council, Feb. 2001) it states that "…analysis suggested a high degree of uncertainty about the stock. Estimates of maximum sustainable yield (MSY) range from 22 to 205 mp…." Figure C.1 shows the historical commercial red snapper landings in the Gulf of Mexico from 1948 to 1998 and recreational red snapper landings from 1981 to 1998. Since it is very time consuming to calibrate GBFSM to different MSY, we will only calibrate it to one level. Therefore, based on the historical landing we will calibrate GBFSM so that it will attain about 22 mp of landings by the year 2032 using a variable TAC that remains proportional to pounds of spawners beginning in 2001. We began with a 9.12 million pound TAC in 2001. Both the large and small models were calibrated in the way.

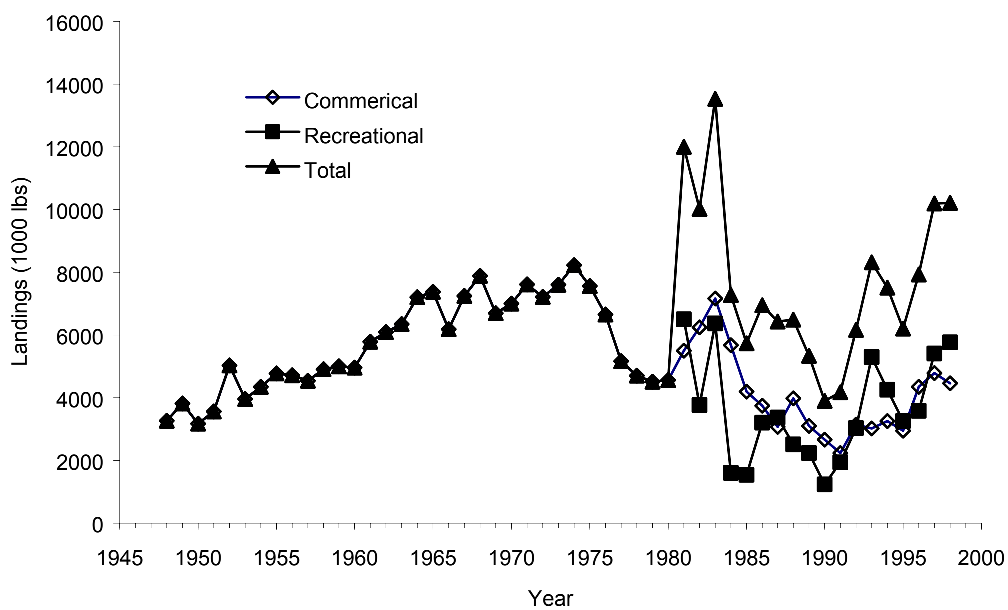

Figure C.1. Red snapper commercial and recreational landings in the Gulf of Mexico for the period 1948 to 1998. Source: Schirripa and Legault (1997)

In the following discussion we will first describe the dimensions of both the large an small models. Next, the results of calibrating shrimp for the small model will be presented. This will be followed by the results of calibrating the red snapper for the small model using a Beverton and Holt stock-recruitment relationship. Finally, we will present the results of calibrating the large model also using a Beverton and Holt stock-recruitment relationship.

Model Dimensions

Small (Dynamic) model

The dimensions of the small (dynamic)model in GBFSM for this study are as follows:

Two species of fish:

Species 1: Shrimp (Brown (*Penaeus aztecus*), Pink shrimp (*P. duorarum*), and White shrimp (*P. setiferus*)
Species 2: Red snapper (*Lutjanus campechanus*)

Three size classes of fish (value indicates lower size limit):

Species	Size 1	Size 2	Size 3
Shrimp (mm)	142.0	112.0	80.0
Red snapper (cm)	35.3	14.8	1.0

The sizes of shrimp represent the following tail count per pound:

Size	Tail count/pound
1	30-larger
2	31-67
3	68-smaller

The sizes of red snapper represent the following age classes:

Size	Age class
1	3 +
2	1-2
3	0

One regions where landings occur:

Region 1: Gulf of Mexico

One area fished:

Area 1: Gulf of Mexico

Four vessel classes:

Vessel class 1: Shrimp vessels $\leq$ 60 ft
Vessel class 2: Shrimp vessels > 60 ft
Vessel class 3: Commercial red snapper vessels
Vessel class 4: Recreational red snapper vessels

Three depths fished:

Inshore/bay
1-5 fathoms
> 6 fathoms

Number of cohorts:

Red snapper are allowed to live up to 40 years in the model; therefore, since there are 12 time steps per year, there are 480 cohorts.

Large Model

The dimensions of the large model in GBFSM for this study are as follows:

Four species of fish:

Species 1: Brown shrimp (*Penaeus aztecus*)
Species 2: Pink shrimp (*P. duorarum*)
Species 3: White shrimp (*P. setiferus*)
Species 4: Red snapper (*Lutjanus campechanus*)

Six size classes of fish (value indicates lower size limit):

Species	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6
Brown (mm)	166.5	145.5	123.0	111.3	92.5	80.0
Pink (mm)	158.0	138.5	117.5	106.8	89.3	80.0
White (mm)	166.0	147.0	125.8	115.0	97.5	80.0
Red snapper (cm)	69.1	37. 7	28.7	18.2	10.0	1.7

The sizes of shrimp represent the following tail count per pound:

Size	Tail count/pound
1	20-up
2	21-30
3	31-50
4	51-67
5	68-116
6	> 117

The sizes of red snapper represent the following age classes:

Size	Age class
1	9 +
2	4
3	2
4	1
5	5-12 months
6	0-4 months

Five regions where landings occur:

Region 1: Florida
Region 2: Alabama
Region 3: Mississippi
Region 4: Louisiana
Region 5: Texas

Six areas fished:

Area 1: Lower Florida (Statistical grids 1-3)
Area 2: Upper Florida (Statistical grids 4-9)
Area 3: Alabama, Mississippi, E. Louisiana (Statistical grids 10-12)
Area 4: W. Louisiana (Statistical grids 13-17)
Area 5: Upper Texas (Statistical grids 18-19)
Area 6: Lower Texas (Statistical grids 20-21)

Four vessel classes:

Vessel class 1: Shrimp vessels $\leq$ 60 ft
Vessel class 2: Shrimp vessels > 60 ft
Vessel class 3: Commercial red snapper vessels
Vessel class 4: Recreational red snapper vessels

Five depths fished:

Inshore/bay
1-5 fathoms
6-10 fathoms
11-20 fathoms
> 20 fathoms

Number of cohorts:

Red snapper are allowed to live up to 50 years in the model. Therefore, since there are 48 time steps per year, there are 2400 cohorts.

Calibration of Shrimp for Dynamic GBFSM

The model was calibrated to the 1991-1995 period since TEDs were in use during that time and, therefore, the impact of the BRD with the TED already factored into landing patterns could be measured. To calibrate GBFSM, effort data for the 1991-1995 period is exogenous to the model and the model coefficients are tweak so that the simulated landings predict as close as possible the actual landings for 1991-1995. To aid this process of calibrating, GBFSM reads in the actual data and compare it to the simulated data. The comparisons are by depth fished, size class of fish, and month.

Figure C.2 shows how well the simulation model predicts landings by depth fished. Figure C.3 shows how well the simulation model predicts landings by size class of shrimp. Figure C.4 shows how well the simulation model predicts landings by months. An examination of the figures shows that the model did very well in all three categories.

Figure C.5 shows a comparison of actual and simulated data for the period 1965-1998 where landings are plotted against days fished. The model was tuned to 1991-1995 data and these actual years are plotted with a black "o" ring. The simulated data will pass through the average of the 1991-1995 data. This means that the simulated data may not look like a good fit to the actual data for the year 1965-1990 and 1996-1998. The simulated data lies at the bottom half of the actual data. This would be expected since in 1987 total Florida landings of pink shrimp dropped from around 10-13 million pounds annually to 5-7 million pounds annually due to the environment in the inshore area.

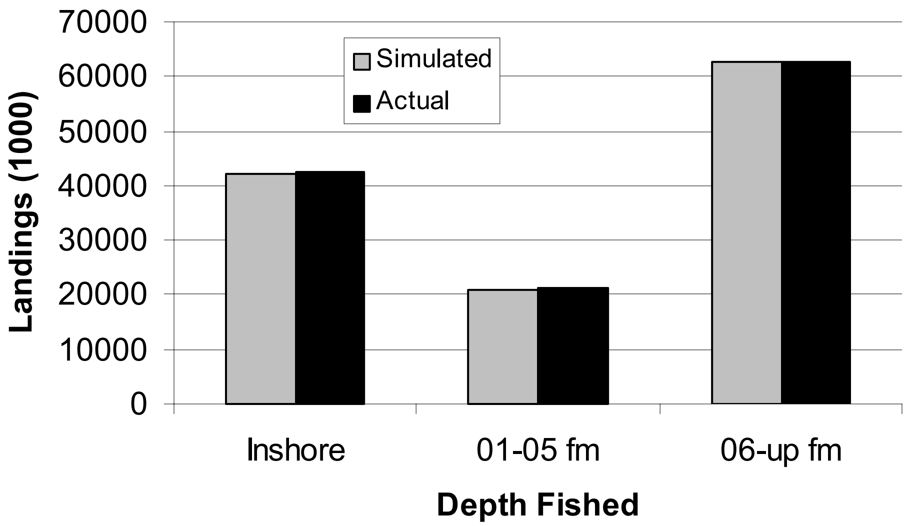

Figure C.2. Comparison of actual and simulated shrimp landings by depth fished in the US Gulf of Mexico, 1991-1995

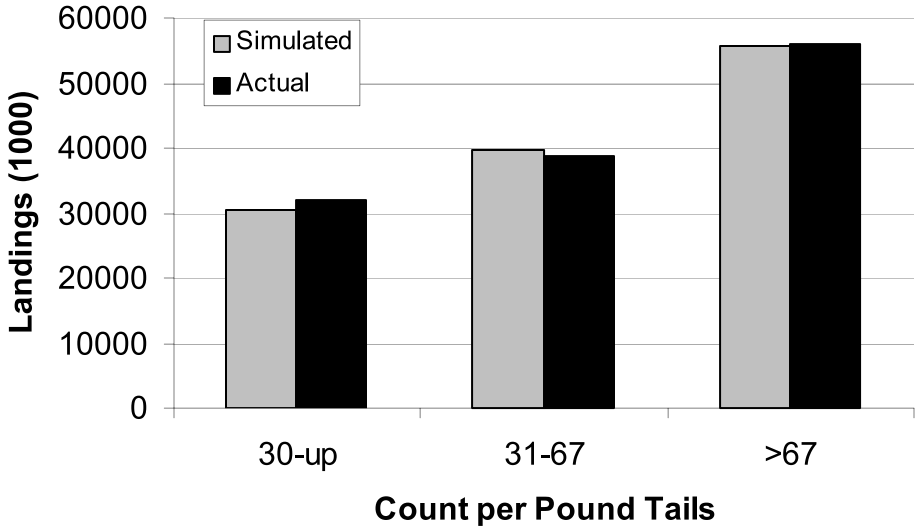

Figure C.3. Comparison for actual and simulated shrimp landings by size class of shrimp in the US Gulf of Mexico

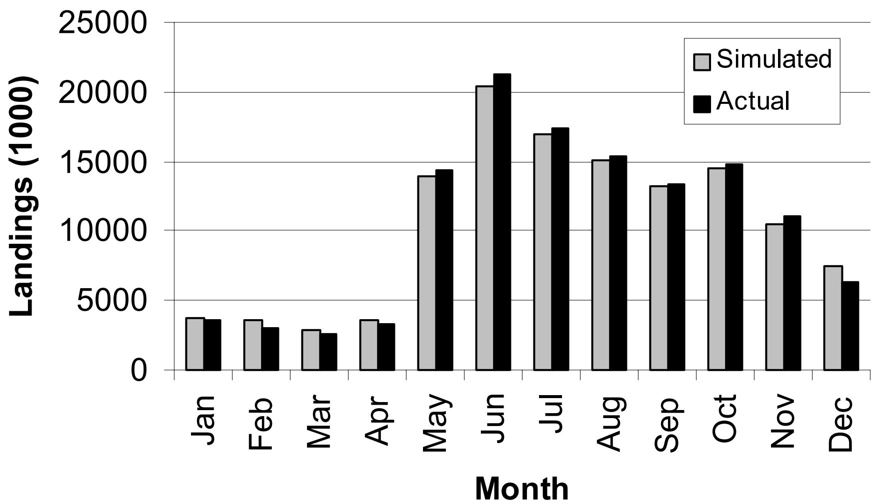

Figure C.4. Comparison of actual and simulated shrimp landings by month in the US Gulf of Mexico, 1991-1995

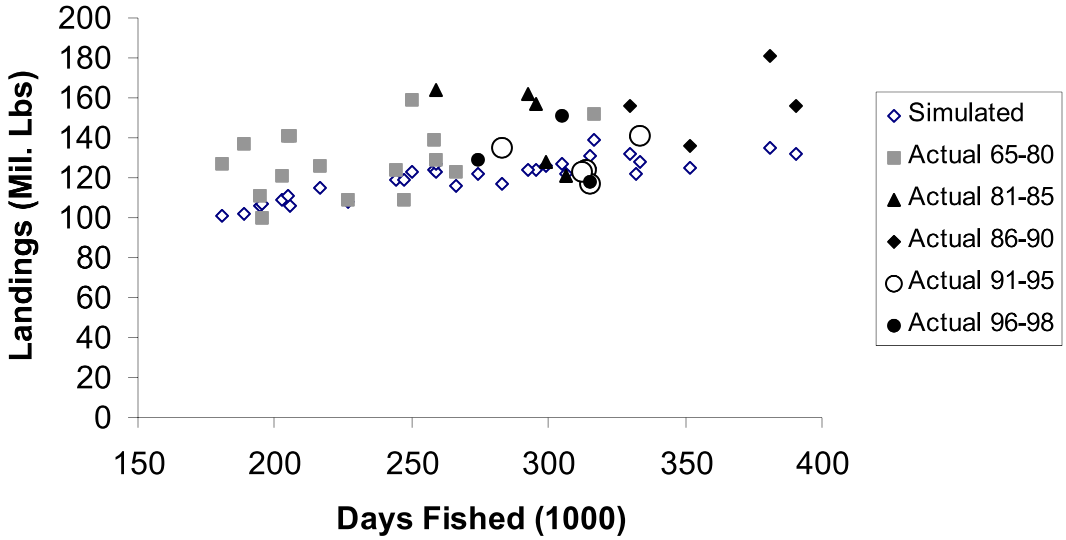

Figure C.5. Comparison of actual and simulation shrimp landings for the years 1965-1998 where the model was calibrated to the 1991-1995 data

Calibration of Red Snapper for Dynamic GBFSM

The red snapper biological model was calibrated to reflect the average fish stock in a given year rather then to replicate specific year classes. Since the major concern in policy analysis is with the optimum TAC over time, all other things are held constant so as to isolate the impact of the TAC policy change. While having historical year class strengths in the model may be beneficial, it will add very little to the outcome of the analysis when projecting to year 2032 in the future.

The biological red snapper model was tuned using 1995 data. The model was calibrated using several different indicators. One of the first steps in calibrating the model was to determine the growth curve. The von Bertelanffy growth equation is used to calculate the growth of fish and is represented by the following equation:

$$L_t = L_{t-1} + \mathrm{k}\,(L_\infty - L_{t-1})$$

where L_t is the length of fish in the current time step, L_{t-1} is the length of fish in the previous time step, L_∞ is the asymptotic length of fish and k is the growth coefficient. Figure C.6 shows the plot of our simulated curve and that of Goodyear's simulated curve (Table 5, page 61, 1995).

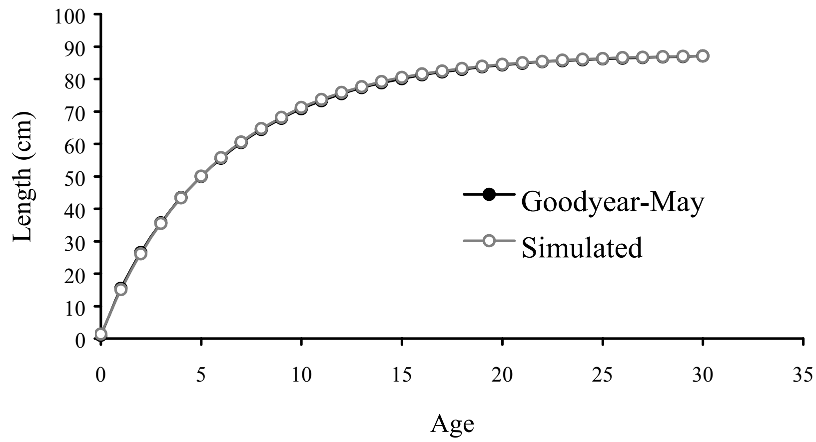

Figure C.6. Estimated growth relationship used in the GBFSM compared with Goodyear's (1995) growth relationship

The fishing mortality was determined as part of the calibration process. Fishing mortality F in the GBFSM is a function the catchability coefficient and effort. The catchability coefficients are assigned so as to generate the actual level of landings observed in 1995 by the recreational and commercial fisheries. Figure C.7 shows the calibration results for commercial red snapper fishery (hand line only) by depth zones for the US Gulf of Mexico. Figure C.8 shows the results for the recreational red snapper fishery.

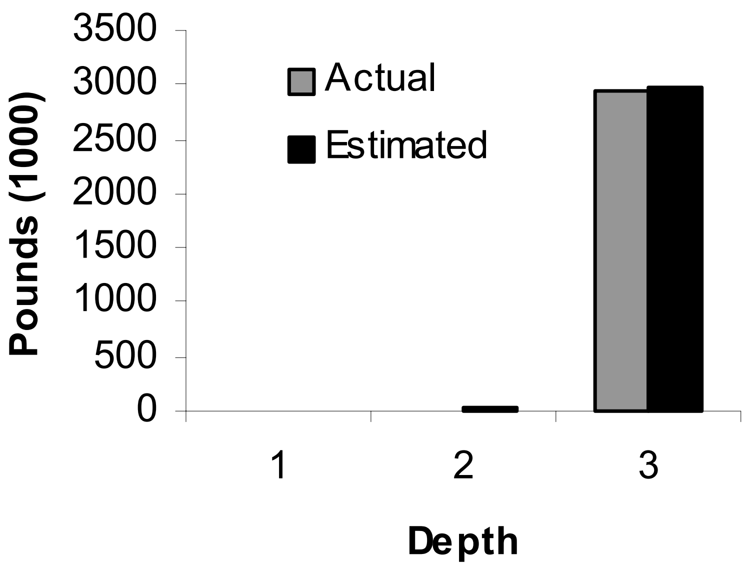

Figure C.7. Actual versus simulated landings by depth zone for US Gulf of Mexico commercial red snapper fishermen

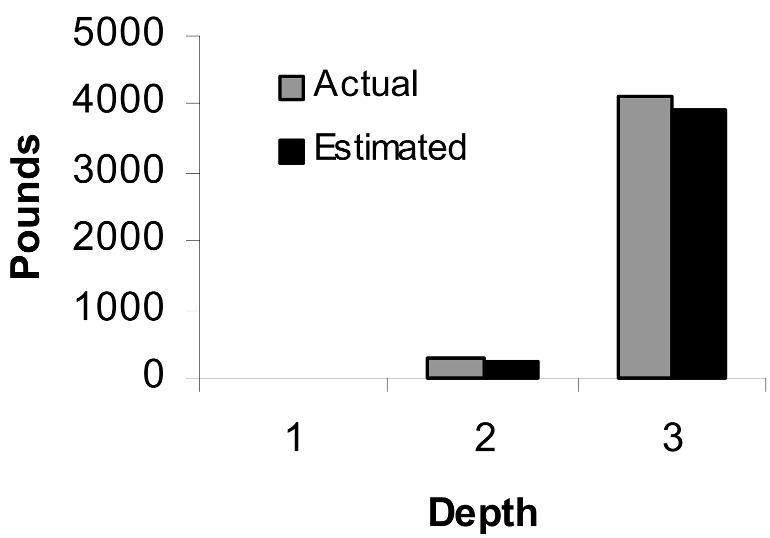

Figure C.8. Actual versus simulated landings by depth zone for US Gulf of Mexico recreational red snapper fishermen

In Figure C.9 the recreational landings in inches were compared to the actual recreation data from the NMFS. This comparison is made in inches instead of age since this is the only way the actual data could be categorized. The size frequency was generated from the actual recreational data and then the total number of fish in each size category was calculated. The GBFSM was then calibrated so that it generated as close as possible the same number of fish in each size category. Wilson has determined the age distribution of commercially caught red snapper fishery. The GBFSM was tuned so that it matched that same distribution as close as possible (Figure C.10).

From the onboard observer data, the distribution of juvenile red snapper bycatch by shrimp vessels in inches was determined. This was then compared to the simulated data and the results are shown in Figure C.11 for the US Gulf of Mexico. Also from the observer data, the catch per unit effort (CPUE) of juvenile red snapper by a single shrimp trawl for vessels greater then 60 feet in length was calculated. Then the average CPUE of juvenile red snapper was multiplied by the average number of nets pulled by a shrimp vessel to determine the CPUE by a shrimp vessel greater then 60 feet in length. The average number of nets pulled by vessels greater then 60 feet in length is approximately 3.5. The GBFSM was then calibrated to generate as close as possible that same CPUE of juvenile red snapper. The results are shown in Figure C.11.

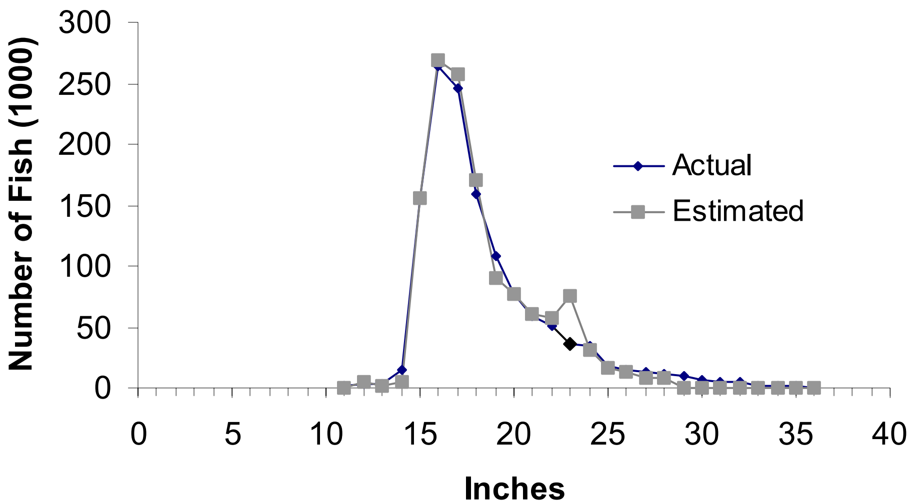

Figure C.9. Estimated number of red snapper landed compared to actual for Gulf of Mexico recreational red snapper fishermen

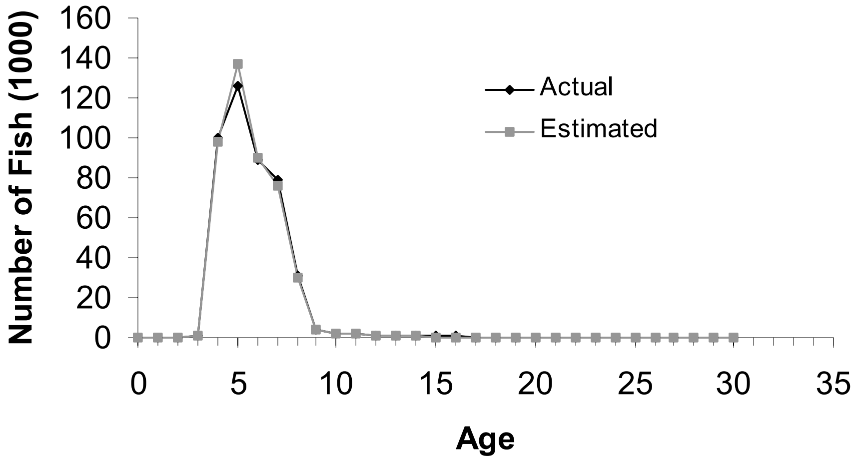

Figure C.10. Estimated number of red snapper landed compared to distribution of commercial landings in a study by Wilson.

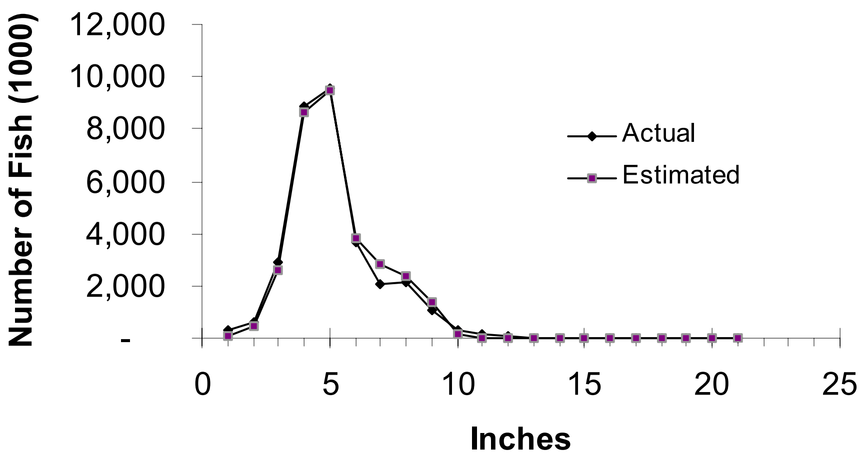

Figure C.11. Estimated number of red snapper discarded bycatch by shrimp fishermen compared to distribution of on board observer data

Finally, 1995 simulated data are compared to the population abundance in numbers of fish at the start of the year in the stock assessment by the NMFS (Schirripa and Legault 1997) as shown Figure C.12. Then GBFSM was then used to project the population abundance for 1996 through 1998 and compared to the NMFS stock assessment (Figures D.13 through D.15). The GBFSM simulated results are in actual age of the fish, not age by year class.

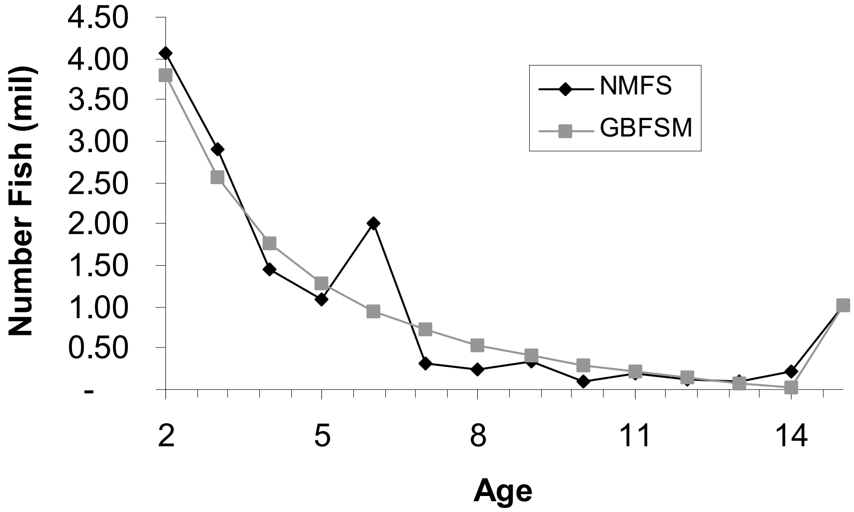

Figure C.12. Simulates versus NMFS (Schirripa and Legault between pages 83 and 84) population abundance at the start of the year for ages 2 and higher in 1995

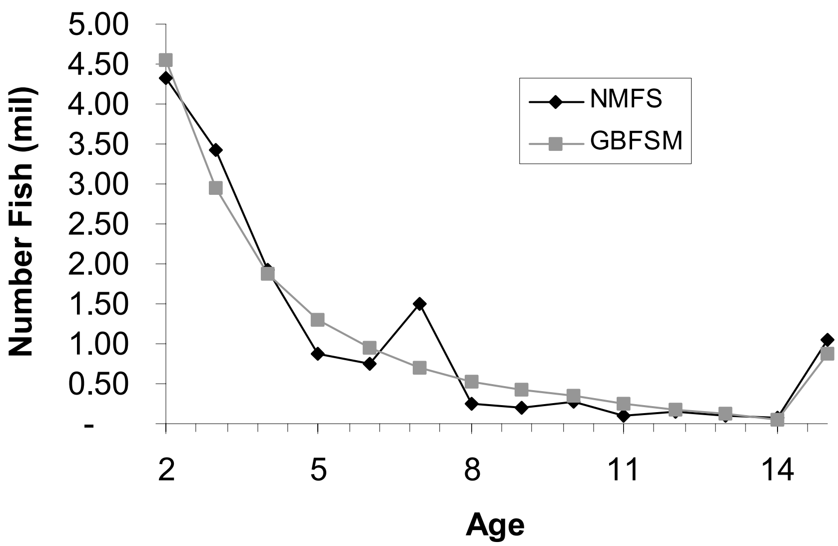

Figure C.13. Simulates versus NMFS (Schirripa and Legault between pages 83 and 84) population abundance at the start of the year for ages 2 and higher in 1996

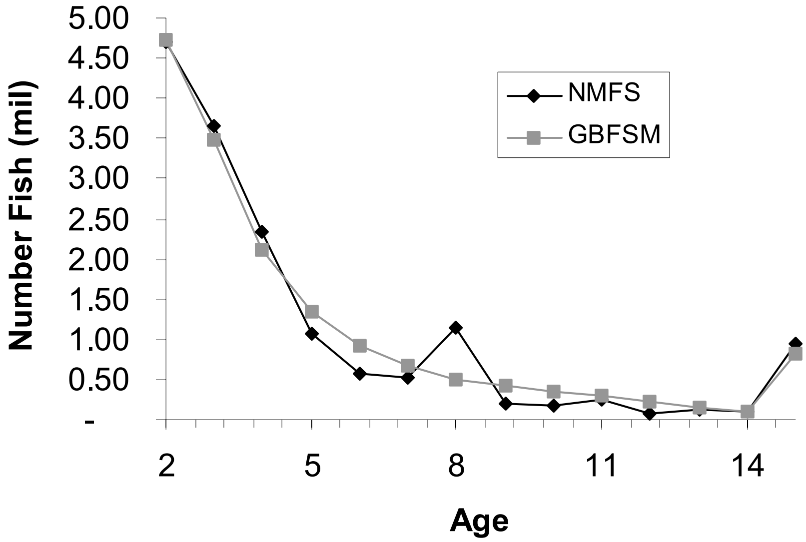

Figure C.14. Simulates versus NMFS (Schirripa and Legault between pages 83 and 84) population abundance at the start of the year for ages 2 and higher in 1997

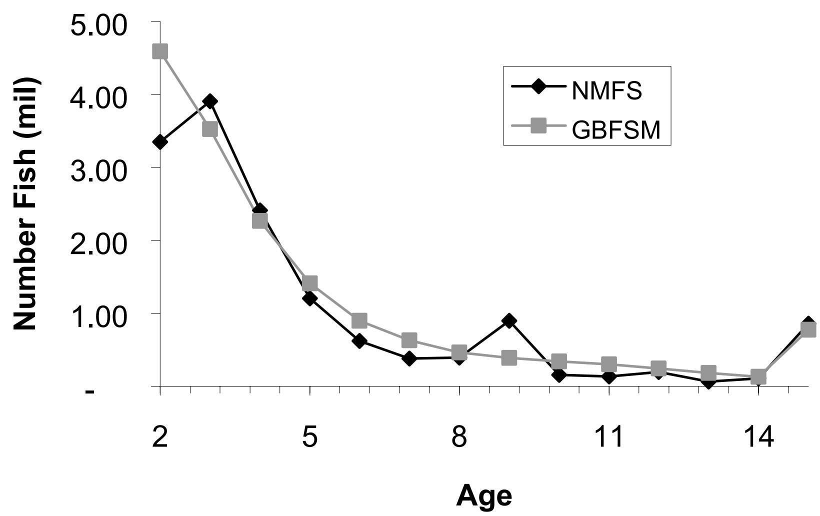

Figure C.15. Simulates versus NMFS (Schirripa and Legault between pages 83 and 84) population abundance at the start of the year for ages 2 and higher in 1998

Calibration of Red Snapper for the Large GBFSM

As with the dynamic model, the large red snapper biological model was calibrated to reflect the average fish stock in a given year rather than to replicate specific year classes. The concern in this analysis is the relative difference between different policies. While having historical year class strengths in the model may be beneficial, it will add very little to the outcome of the analysis when projecting to year 2032 in the future.

The large biological red snapper model was tuned using 1995 data. The model was calibrated using several different indicators. The fishing mortality was determined as part of the calibration process. Fishing mortality F in the GBFSM is a function the catchability coefficient and effort. The catchability coefficients are assigned so as to generate the actual level of landings observed in 1995 by the recreational and commercial fisheries.

Figure C.16 shows the actual versus simulated landings by depth zone and area fished, for the Gulf of Mexico recreational red snapper fishermen. There are no landings for Area 1, which are the first three statistical zones of Florida. Figure C.17 shows the actual versus simulated landings by depth zone and area fished, for the Gulf of Mexico commercial red snapper fishermen.

In Figure C.18 the recreational landings, in inches, were compared to the actual recreation data from the NMFS. This comparison is made in inches instead of age since this is the only way the actual data could be categorized. The size frequency was generated from the actual recreational data and then the total number of fish in each size category was calculated. The GBFSM was then tuned so that it generated, as closely as possible, the same number of fish in each size category.

Wilson has determined the age distribution of commercially caught red snapper. The GBFSM was tuned so that it matched that same distribution as close as possible (Figure C.19). From the onboard observer data, the distribution of juvenile red snapper bycatch by shrimp vessels, in inches, was determined. This was then compared to the simulated data. The results are shown in Figure C.20 for the entire Gulf of Mexico. Also, from the observer data, the catch per unit effort (CPUE) of juvenile red snapper by a single shrimp trawl for vessels greater than 60 feet in length was calculated.

Finally, 1998 simulated data are compared to the population abundance in numbers of fish at the start of the year in the stock assessment by the NMFS (Schirripa and Legult, 1997) as shown in Figure C.21. The year 1998 is the beginning year of the policy simulation runs for Chapter 2.

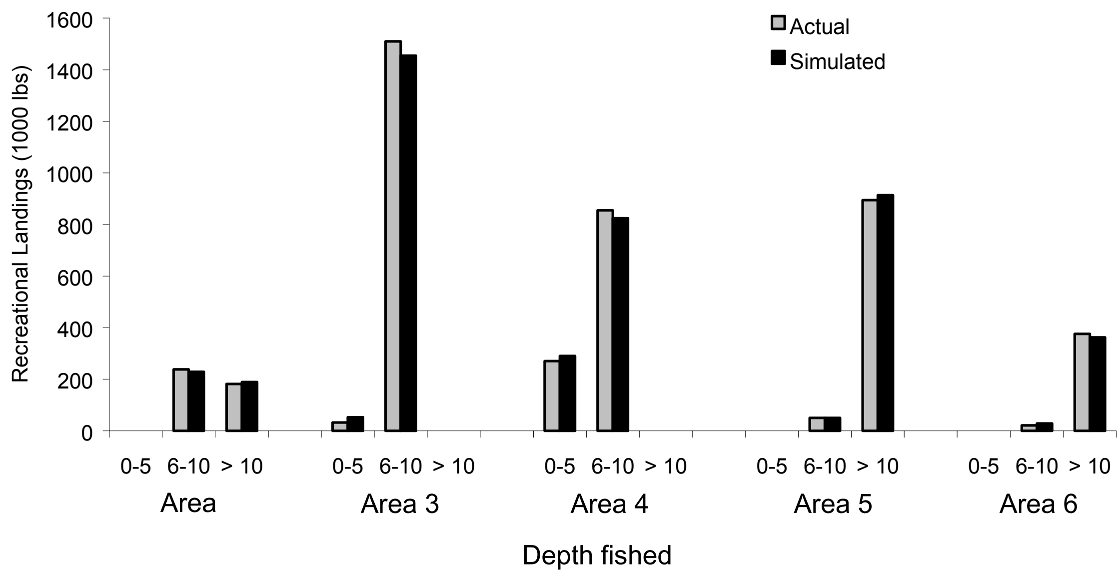

Figure C.16. Actual versus simulated landings by depth zone and area fished, for the Gulf of Mexico Recreational red snapper fishermen

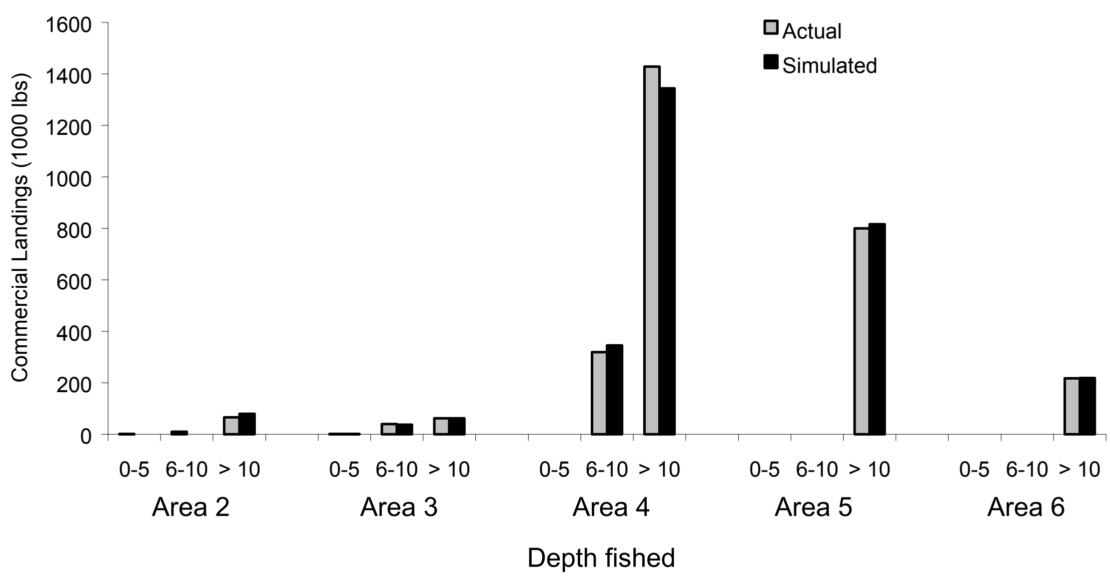

Figure C.17. Actual versus simulated landings by depth zone and area fished, for the Gulf of Mexico Commercial red snapper fishermen.

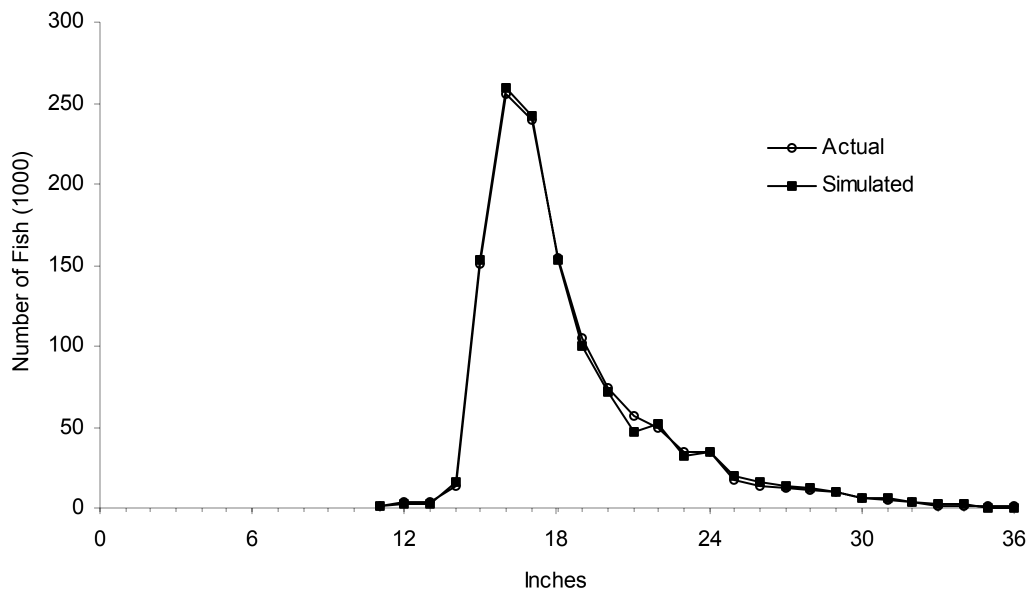

Figure C.18. Simulated number of red snapper landed compared to actual for the Gulf of Mexico recreational red snapper fishermen

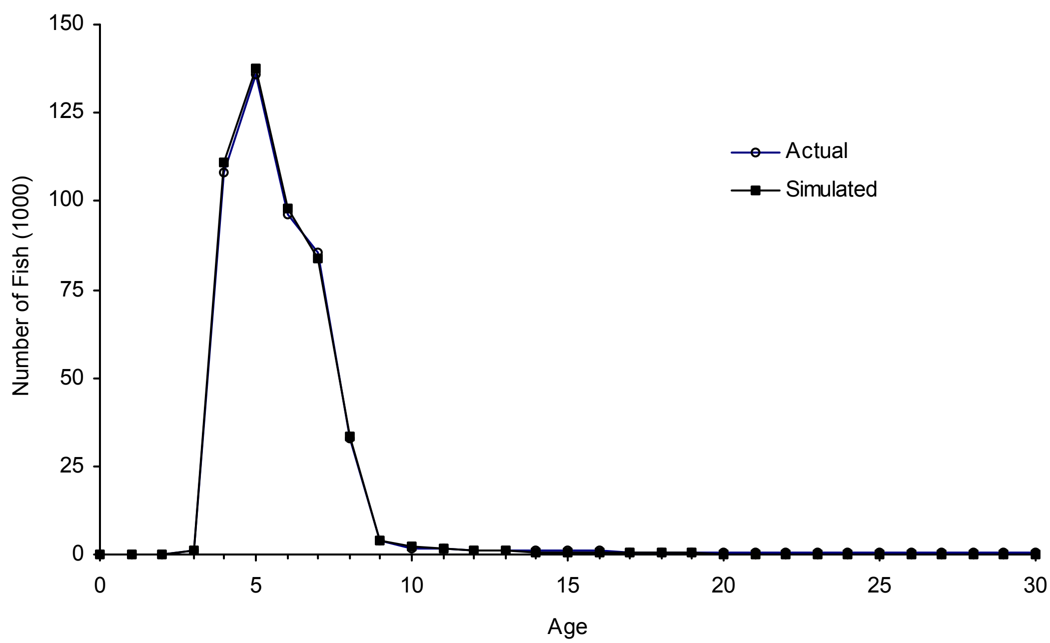

Figure C.19. Simulated number of red snapper landed compared to the distribution of commercial landings in a study by Wilson

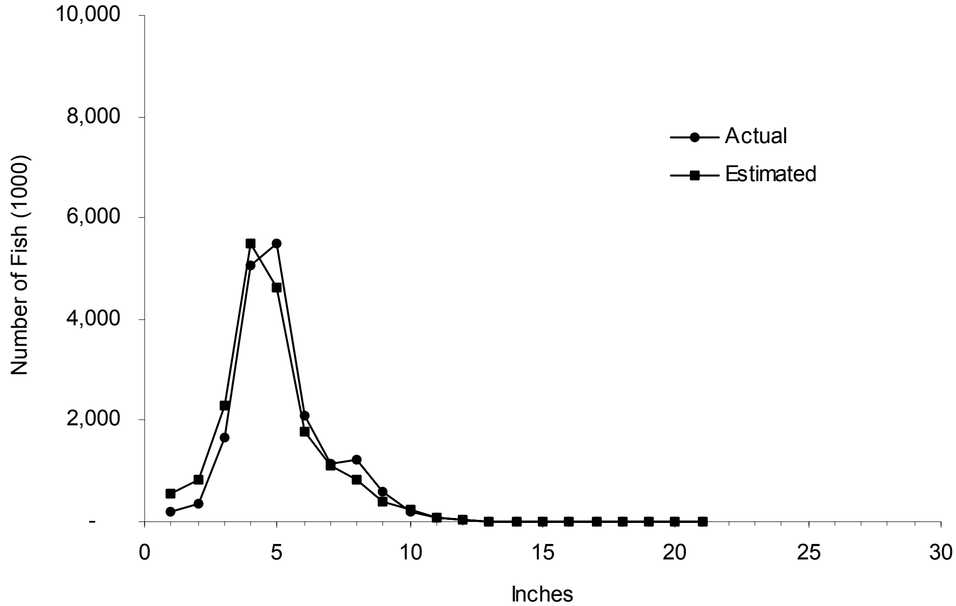

Figure C.20. Simulated number of red snapper discarded bycatch by the shrimp fishery compared to the distribution of on board observer data in the Gulf of Mexico.

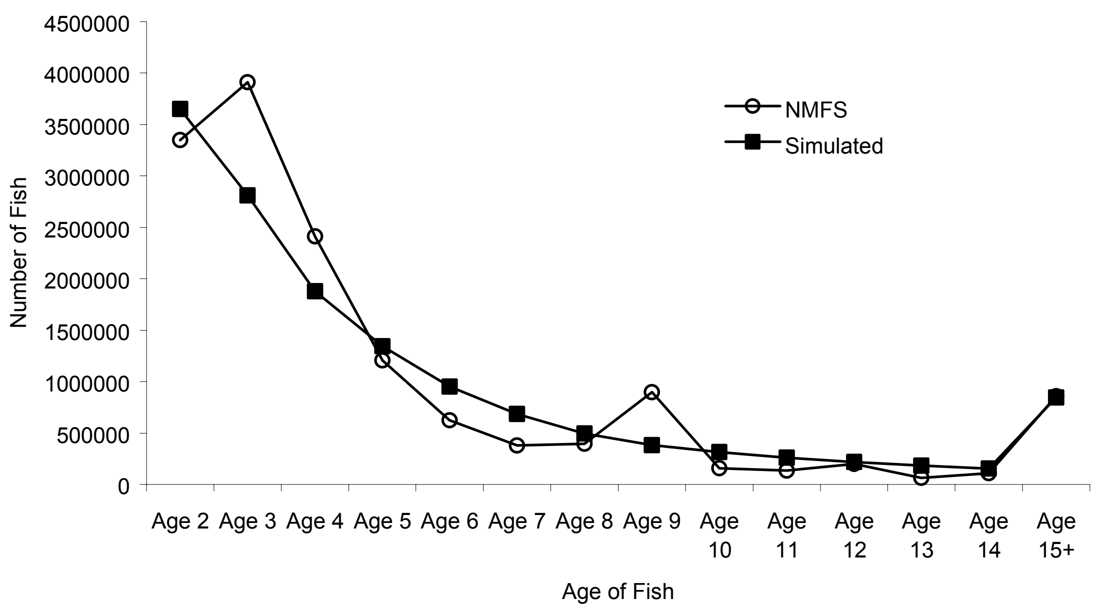

Figure C.21. Simulated compared to NMFS (Schirripa and Legault, Table 28 between pages 83 and 84) population abundance at the start of the year for ages 2 an higher in 1998