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August 12, 2009 F/SEC2: TJ

MEMORANDUM TO: Roy Crabtree, Ph.D.
Regional Administrator, Southeast Regional Office

FROM: Bonnie Ponwith, Ph.D. Theo R. Brainerd
Science Director, Southeast Fisheries Science Center

SUBJECT: Data Analyses for Amendment 17A and 17B to the South Atlantic Snapper Grouper Fishery Management Plan

Enclosed are the Southeast Fisheries Science Center data analyses for actions being considered in Amendments 17A and 17B of the South Atlantic Fishery Management Council.

For Amendment 17A, the following red snapper analyses were conducted and contained in the attached files, "**Red Snapper Projections Revised VI**" and "**Red Snapper Projections VII**":

(1) Suite of projections with "high" recruitment in 2005-2006;
(2) Projection that rebuilds in 35 years;
(3) Suite of projections using F30%;
(4) Yield at F45%.

For Amendment 17B, the following analyses were conducted and contained in the attached files, "**Average Weight of tilefish (*Lopholatilus chamaeleonticeps*) in recreational landings**" and "**P* Tables for Gag, *Mycteroperca microlepis*, off the Southeastern United States**":

(5) Identify conversion factor for landings of tilefish;
(6) Gag grouper P* tables.

You may contact Erik Williams at (252) 728-8603 or Erik.Williams@noaa.gov if you have any questions or clarifications.

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Average weight of tilefish (*Lopholatilus chamaeleonticeps*) in recreational landings

Sustainable Fisheries Branch, SEFSC-Beaufort
31 July 2009

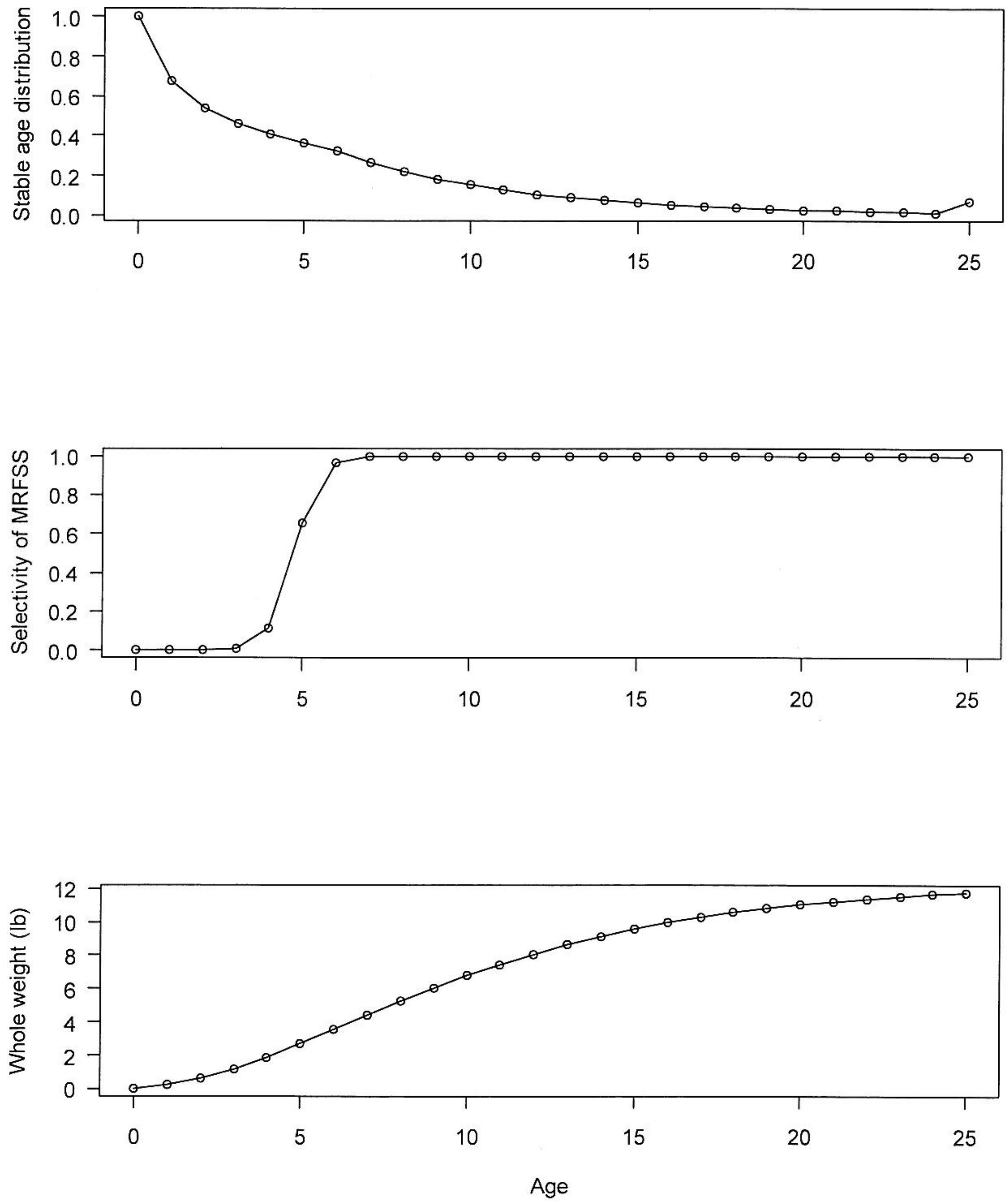
In a memorandum dated 10 July 2009, from Dr. Crabtree to Dr. Ponwith, SERO requested that the SEFSC provide a conversion factor for tilefish to convert recreational landings in weight to landings in numbers. This document provides that conversion factor and describes the methods used to compute it.

The conversion factor was computed using results from the SEDAR-4 benchmark assessment of tilefish. That assessment applied a mixed Monte Carlo and bootstrap procedure, which included many model runs. The run used here was the primary run (labeled "initial run" in the assessment report). From the initial run, we applied the stable age distribution (N_a), selectivity at age of MRFSS (s_a), and average whole weight at age (w_a) (Figure 1). The stable age distribution was computed using the total mortality at age averaged over the last five years of the assessment (1998–2002), and it treated the oldest age as a plus-group. The mean weight (μ_L) of fish landed by MRFSS was then calculated as,

$$\mu_L = \frac{\sum_a (N_a s_a w_a)}{\sum_a (N_a s_a)}$$

This resulted in an average weight of 6.21 lb whole weight per fish. Thus, to convert landings in pounds of whole weight to landings in numbers, one should divide landings (pounds whole weight) by 6.21.

Figure 1. Tilefish stable age distribution (top), selectivity of MRFSS (middle), and mean weight at age (bottom).



P* Tables for
Gag, *Mycteroperca microlepis*, off the Southeastern United States

Last modified: August 14, 2009

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1. Introduction

To help guide management decisions, this preliminary report offers a method to compute annual catch limits (ACLs) of gag off the southeastern United States. Because ACLs are a new requirement under the reauthorized Magnuson–Stevens Fishery Conservation and Management Act (MSFCMA), a body of practice does not yet exist on implementation. We describe a probability-based approach to compute ACLs that maintains a low probability of overfishing, which is the intent of the new requirement, and accommodates uncertainty in both stock dynamics and assessment results. The method is based on the REPAST approach to setting target reference points (Prager et al. 2003), but considerably revised to (1) establish reference points in catch, not fishing mortality rate, and (2) add a stock-projection component, which is needed to set catch for more than one year following a stock assessment.

As of the date of this report, ACLs are not clearly defined. In fact, they have yet to be specified as either a target or a limit. In this report, they are treated as a target. However, the methods could still apply if ACLs were specified as a limit simply by changing terminology.

This preliminary report is not intended to propose actual ACLs of any stock, although the method is illustrated with an application to gag grouper. The purpose of this preliminary report is to provide the SSC a chance to review the method and application. If the method is found acceptable, suggested improvements could be incorporated into a subsequent report, which would be made available for review at a future SSC meeting. The subsequent report would propose actual ACLs for management of gag.

2. Methods

Given the uncertainties in fishery management and science, it is arguably impossible to fish without at least some risk of overfishing. Rather than attempt to achieve zero probability of overfishing, we describe a method whose goal is to keep the probability of overfishing in any year below a preset value (e.g., 0.1), thus satisfying the new requirement of the MSFCMA. The method is general, but can incorporate details of almost any stock previously subjected to assessment, in this case, gag off the southeastern US.

2.1 A probability-based approach to setting catch limits (PASCL)

Our proposed method is a probability-based approach to setting catch limits (PASCL). It acts as a control rule, incorporating uncertainties in assessment results and in future stock dynamics. Given these uncertainties, PASCL sets annual levels of catch consistent with the risk of overfishing considered acceptable by managers.

Uncertainty in assessment results is standard output of most stock assessments, for example, through Bayesian or bootstrap approaches. For use in PASCL, the key assessment result is uncertainty in the limit reference point (LRP) of fishing mortality rate (F). Characterizing such uncertainty is quite flexible in PASCL; it can be described by any appropriate probability density function, whether parametric (e.g., normal, lognormal) or nonparametric (e.g., empirical, kernel density estimate). Where a distribution is unavailable, PASCL could utilize a single point estimate; however, we do not recommend this approach as it ignores uncertainty in assessment results.

Uncertainty in stock dynamics is described by a stochastic projection model. The projection not only allows setting ACLs for more than a single year, but also accounts for the inevitable lag between final year of assessment data and first year of ACL implementation. The projection model can include any source of uncertainty deemed appropriate, no different from other projection models used currently for fishery management. Sources often considered are recruitment dynamics and initial number at age.

In PASCL, as in REPAST (Prager et al. 2003), the level of risk acceptable to managers is quantified and transparent. Here we define *risk* as the probability (P^*) that F in any given year exceeds its LRP. A small value of P^* would imply risk-averse management, and a large value would imply risk-prone management. Either way, P^* should be less than 0.5, as $P^*=0.5$ would, in effect, treat the limit as a target, with overfishing expected in half of all years.

If the LRP is fixed (i.e., a point estimate), P^* in year t depends only on the probability density function (ϕ_{F_t}) of F_t:

$$P^* = \Pr(F_t > F_{LRP}) = \int_{F_{LRP}}^{\infty} \phi_{F_t}(F)dF = 1 - \Phi_{F_t}(F_{LRP}) \qquad (1)$$

where $\Phi_{F_t}(F_{LRP})$ is the cumulative density function of F_t evaluated at the limit F_{LRP}. If the LRP is uncertain, described by its own probability density function ($\phi_{F_{LRP}}$), P^* is computed from the following:

$$P^* = \Pr(F_t > F_{LRP}) = \int_{0}^{\infty} \left[1 - \Phi_{F_t}(F)\right] \phi_{F_{LRP}}(F)dF \qquad (2)$$

In essence, Equation 2 is the weighted sum of probabilities computed through Equation 1, for all possible values of F_{LRP}. Because P^* is defined as an annual probability, the risk of overfishing in at least one year grows as the time horizon is extended (Figure 1).

The goal of PASCL is to set the ACL such that the realized P^* equals the desired P^*. This can be achieved through projection (Figure 2):

1) For each of N replicates of the stock, compute F_t that yields a fixed catch C. This will produce N values of F_t, which can be used to define its probability density (ϕ_{F_t}).
2) Given ϕ_{F_t} and the probability density of F_{LRP} ($\phi_{F_{LRP}}$), compute the realized P^* according to Equation 2.
3) Adjust C until the realized P^* equals the desired P^*, which could be accomplished with an optimization routine. This C is the ACL.
4) Project each replicate one year forward with its F_t that provides the ACL.
5) Repeat for T years.

The needed duration (T) of the projection will vary from stock to stock, but should extend at least until ACLs based on the next scheduled assessment could be implemented.

2.2 Application to gag

Gag was most recently assessed in 2006 using data through 2004 (SEDAR 2006). The assessment had two base models that differed regarding their assumptions about catchability in fishery-dependent indices of abundance. One model assumed that catchability has remained constant over the past several decades; the other assumed that catchability has increased with improved technology and gear. In this application, we used the model with constant catchability to remain consistent with the recommendation of the SEDAR review panel. Although that panel acknowledged a likely increase in catchability over time, the rate of increase remains an open question, and thus the panel recommended adopting the status quo of constant catchability.

Implementation of PASCL requires probability densities of the limit reference point and of the fishing rates that achieve ACLs. The LRP of F was based on F_{MSY}, the fishing rate at maximum sustainable yield (*MSY*). In this application, as in the assessment, the probability density of F_{MSY} ($\phi_{F_{MSY}}$) was estimated from values that were generated by empirical bootstrap of the Beverton–Holt spawner-recruit curve (Figure 3). The probability density of F_t (ϕ_{F_t}) was estimated from values that were generated by a stochastic projection model with $n=2000$ replicates. Both densities ($\phi_{F_{MSY}}$, ϕ_{F_t}) were quantified nonparametrically using kernel density estimation with a Gaussian kernel and bandwidth equal to that kernel's standard deviation (Venables and Ripley 2002).

The projection model was identical to the age-structured assessment model, and parameter values were those used or estimated in the assessment (SEDAR 2006). The projection included two sources of uncertainty in stock dynamics. One was uncertainty in recruitment, which was assumed to follow the lognormal distribution of error estimated in the assessment. The other was uncertainty in initial number at age. The assessment provided only point estimates of number at age in 2005, the first year of projection; to add uncertainty, we assumed the initial number at each age followed a lognormal distribution with standard deviation equal to that of recruitment and mean equal to the point estimate. This approach accounts for uncertainty in the initial conditions, while maintaining any strong year classes estimated in the last year of the assessment.

The projection started in 2005, yet ACLs would not likely be implemented until 2008. To project the stock through this initialization period (2005–2007), we applied a fixed F set at the geometric mean of values estimated by the assessment for 2002–2004. The duration of projection was set to 10 years, which included three years of initialization followed by seven years of ACLs.

PASCL requires as input the quantified risk of overfishing. This allows managers to acknowledge such risk explicitly and to decide on a level considered acceptable. To help guide that decision, we present ACLs computed from six values of P^*: 0.10–0.35, in increments of 0.05.

3. Results

For any level of catch, the $n=2000$ projection replicates produced $n=2000$ values of F_t, because stock structure (number at age) varied stochastically among the replicates. The ACLs were set by adjusting catch until the values of F_t provided the desired P^* (example in Figure 4).

By definition, P^* quantifies the acceptable risk of overfishing. In general, a higher P^* led to larger ACLs (Tables 1–6). It also led to more dead discards and smaller spawning stock biomass (SSB). Ultimately, the choice of P^* is a management decision.

References

Prager, M. H., C. E. Porch, K. W. Shertzer, and J. F. Caddy. 2003. Targets and limits for management of fisheries: a simple probability-based approach. N. Am. J. Fish. Manag. 23:349–361.

SEDAR. 2006. SEDAR 10 Stock Assessment Report 1: South Atlantic Gag Grouper. South Atlantic Fishery Management Council. Charleston, SC.

Venables, W. N. and B. D. Ripley. 2002. *Modern Applied Statistics with S.* New York: Springer.

Table 1. Projection with annual probability of overfishing *P*=0.10*.

Yr	SSB (1000 lb)	Recruits (1000s)	F(/yr)	Landings (1000 lb)	Dead Discards (1000s)	Dead Discards (1000 lb)
2005	8033	455	0.31	1574	23	114
2006	7356	457	0.31	1542	21	88
2007	6472	459	0.31	1387	25	98
2008	5928	446	0.15	628	14	56
2009	6475	453	0.15	651	15	64
2010	7092	450	0.15	686	15	65
2011	7680	452	0.14	737	14	64
2012	8234	448	0.14	797	14	64
2013	8759	457	0.14	852	14	63
2014	9208	465	0.14	898	14	63

Table 2. Projection with annual probability of overfishing *P*=0.15*.

Yr	SSB (1000 lb)	Recruits (1000s)	F(/yr)	Landings (1000 lb)	Dead Discards (1000s)	Dead Discards (1000 lb)
2005	8033	455	0.31	1574	23	114
2006	7356	457	0.31	1542	21	88
2007	6472	459	0.31	1387	25	98
2008	5928	446	0.16	676	15	61
2009	6420	453	0.16	693	16	68
2010	6984	450	0.16	725	16	70
2011	7531	452	0.15	775	15	69
2012	8033	448	0.15	835	15	68
2013	8511	456	0.15	888	15	68
2014	8923	464	0.15	932	15	68

Table 3. Projection with annual probability of overfishing *P*=0.20*.

Yr	SSB (1000 lb)	Recruits (1000s)	F(/yr)	Landings (1000 lb)	Dead Discards (1000s)	Dead Discards (1000 lb)
2005	8033	455	0.31	1574	23	114
2006	7356	457	0.31	1542	21	88
2007	6472	459	0.31	1387	25	98
2008	5928	446	0.17	715	16	64
2009	6375	453	0.17	727	17	72
2010	6898	449	0.17	755	17	74
2011	7410	452	0.16	804	16	73
2012	7873	447	0.16	863	16	72
2013	8319	456	0.16	916	16	72
2014	8696	464	0.16	957	16	71

Table 4. Projection with annual probability of overfishing *P*=0.25*.

Yr	SSB (1000 lb)	Recruits (1000s)	F(/yr)	Landings (1000 lb)	Dead Discards (1000s)	Dead Discards (1000 lb)
2005	8033	455	0.31	1574	23	114
2006	7356	457	0.31	1542	21	88
2007	6472	459	0.31	1387	25	98
2008	5928	446	0.18	749	17	68
2009	6336	453	0.18	755	17	76
2010	6828	449	0.18	782	17	77
2011	7306	452	0.17	830	17	76
2012	7739	447	0.17	889	17	76
2013	8147	455	0.17	940	17	75
2014	8493	463	0.17	980	17	75

Table 5. Projection with annual probability of overfishing $P^*=0.30$.

Yr	SSB (1000 lb)	Recruits (1000s)	F(/yr)	Landings (1000 lb)	Dead Discards (1000s)	Dead Discards (1000 lb)
2005	8033	455	0.31	1574	23	114
2006	7356	457	0.31	1542	21	88
2007	6472	459	0.31	1387	25	98
2008	5928	446	0.19	778	17	70
2009	6302	453	0.19	781	18	79
2010	6762	449	0.18	805	18	80
2011	7213	451	0.18	854	18	79
2012	7615	447	0.18	914	18	79
2013	7996	455	0.18	963	18	79
2014	8308	463	0.18	1002	18	78

Table 6. Projection with annual probability of overfishing $P^*=0.35$.

Yr	SSB (1000 lb)	Recruits (1000s)	F(/yr)	Landings (1000 lb)	Dead Discards (1000s)	Dead Discards (1000 lb)
2005	8033	455	0.31	1574	23	114
2006	7356	457	0.31	1542	21	88
2007	6472	459	0.31	1387	25	98
2008	5928	446	0.20	805	18	73
2009	6272	453	0.19	804	19	82
2010	6704	449	0.19	827	19	83
2011	7127	451	0.19	876	19	82
2012	7501	446	0.19	937	19	82
2013	7856	455	0.19	985	18	82
2014	8140	462	0.19	1022	18	81

Figure 1. Risk of overfishing extended across years, calculated as the probability of overfishing in at least one year as a function of the annual risk $P*$, assuming independence among years.

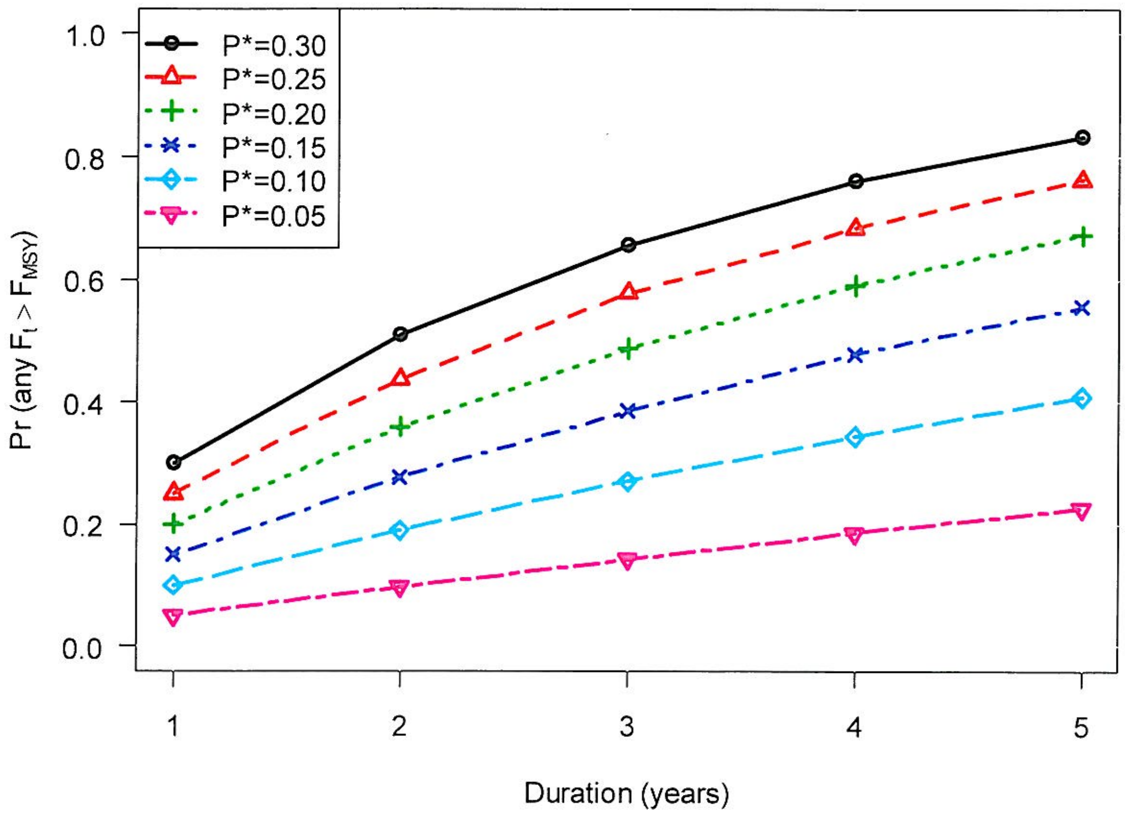


Figure 2. Flowchart of method to compute ACLs.

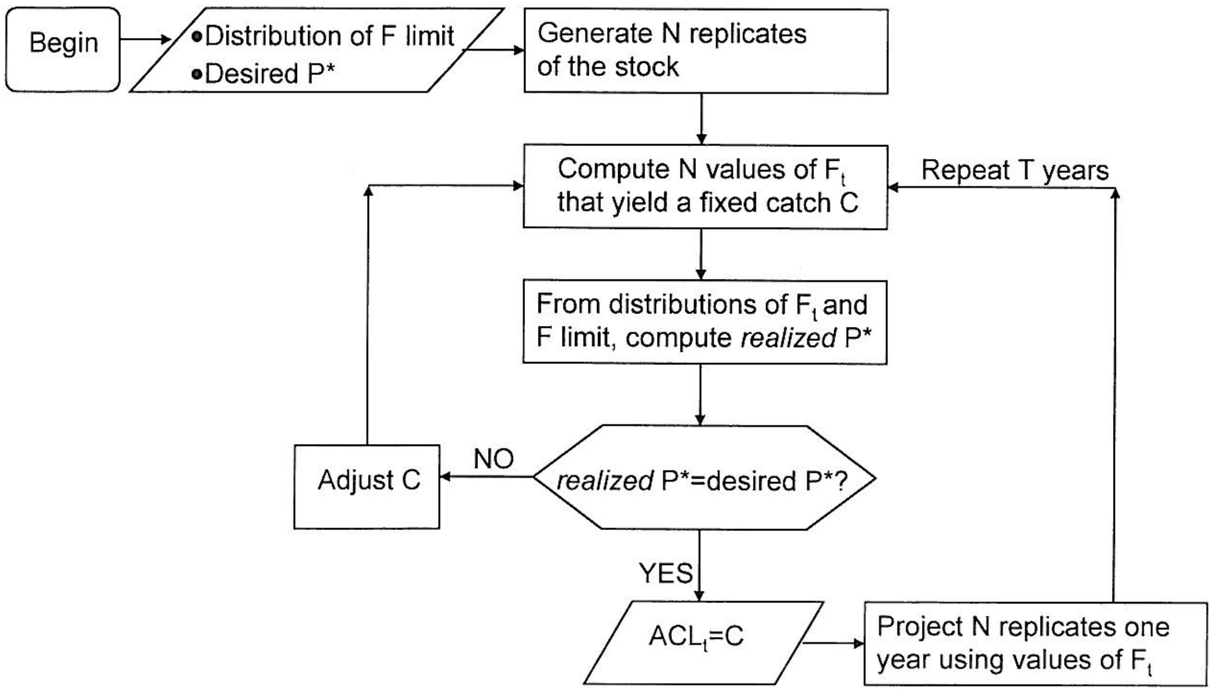


Figure 3. Probability density of F_{MSY}, estimated from the SEDAR 10 assessment and used as input for PASCL.

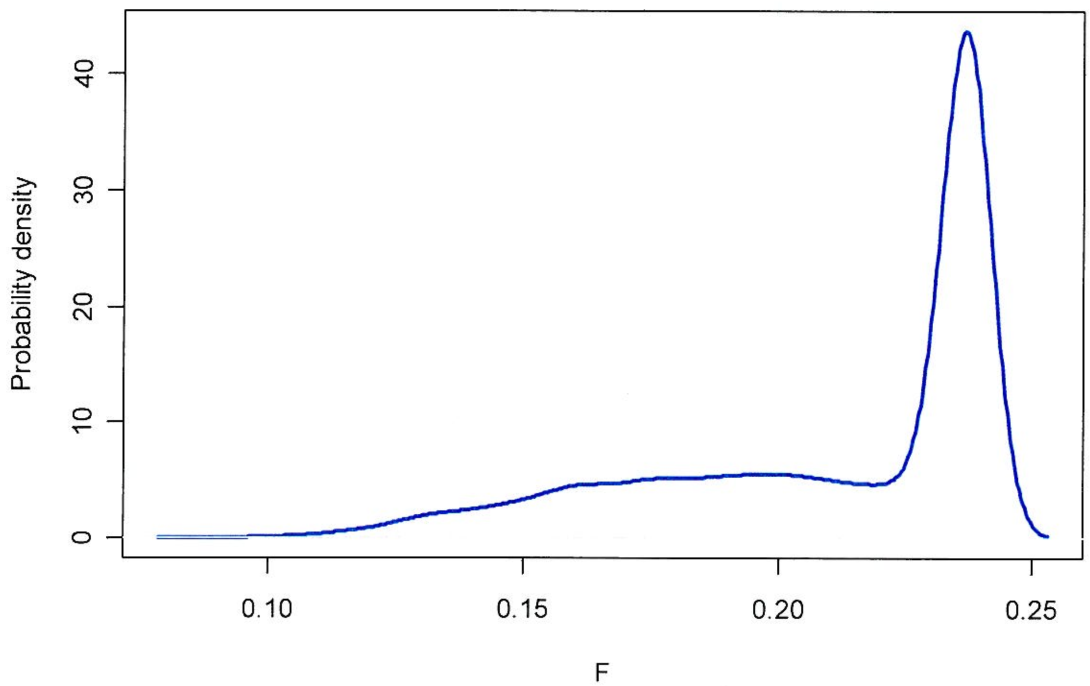
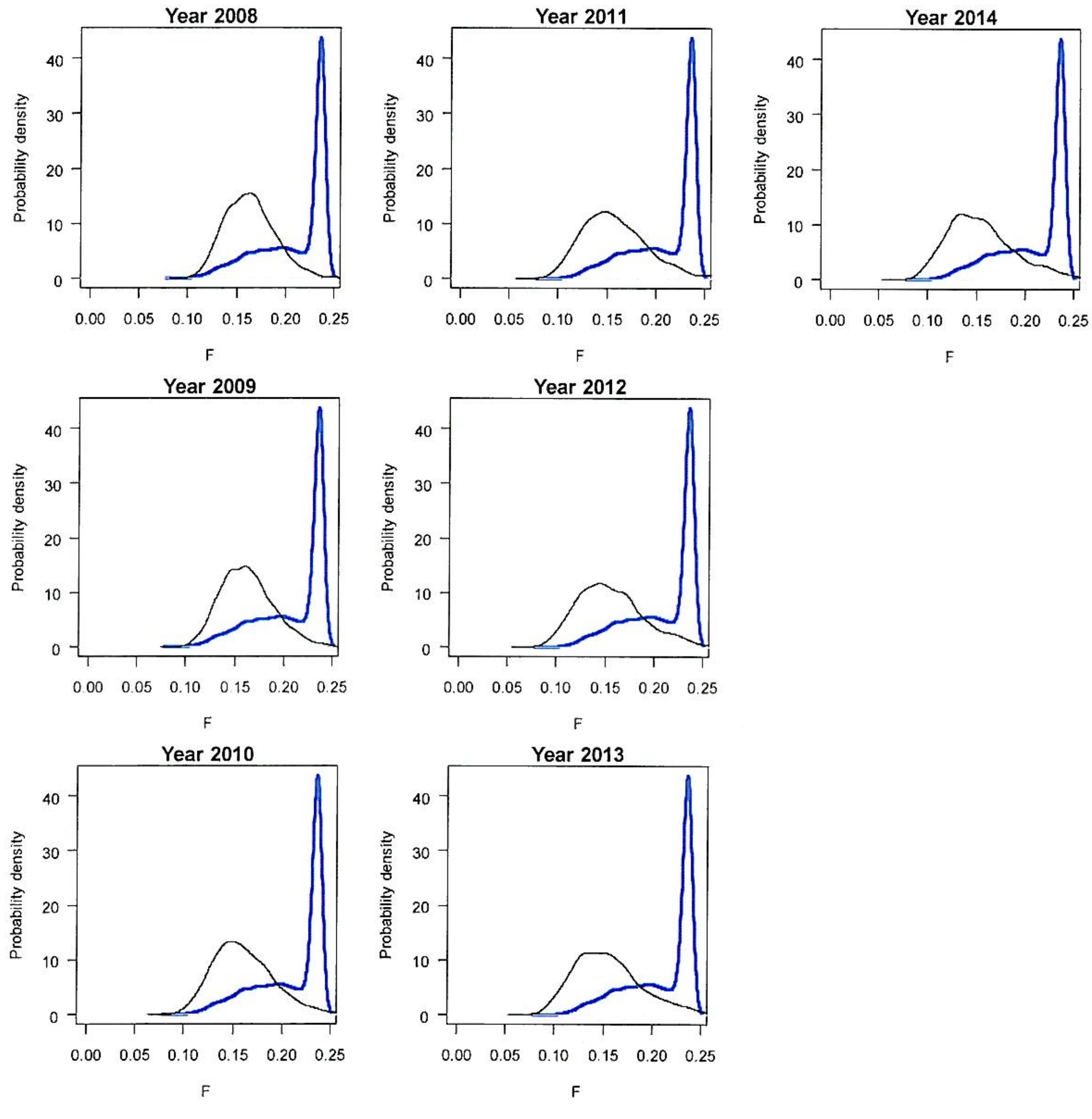


Figure 4. Example distributions: Probability density of F_{MSY} (thick, blue line) and of F_t (thin, black line) that achieve $P^*=0.15$. For lower P^* (less risk), the probability densities of F_t would shift to the left; for higher P^* (more risk), to the right.



Red Snapper Projections VI—Revised

Issued: 29 May 2009

Revised: 23 July 2009

Revision notes: This report was issued originally on 19 May 2009, in response to informal requests. In a memorandum dated 10 July 2009, from Dr. Crabtree to Dr. Ponwith, the projections were formally requested. This revision has the same analyses as the original, but includes tables of output.

1 Description of projections

The 2008 recreational landings of red snapper in the U.S. South Atlantic were much higher than have been observed in recent years, and the 2008 commercial landings were on the high end of their recent range. Preliminary reports of 2009 landings also indicate higher than typical values. The majority of fish being landed are near the legal limit of 20 inches. This suggests that the high landings are being driven by a particularly strong year-class entering the fishery. This document examines effects of such a strong year-class on recovery projections.

The estimated selectivity curve of the general recreational fishery indicates that fish are nearly fully selected by age 3. Average growth of red snapper suggests that age-3 fish would be near the legal size limit (Fig. 5.1). This suggests that the pulse of red snapper entering the fishery in 2008 were age-3, or equivalently, were recruited to the population in 2006 as age-1 fish. To examine effects of such a pulse on projections, the 2006 year-class was inflated to one of three levels, corresponding to 50%, 100%, and 150% of the maximum recruitment event observed in the assessment over the years 1974–2006. This maximum recruitment event occurred in 1984 and was about 753,000 age-1 fish. The assessment-estimated value for 2006 was approximately 280,000 age-1 fish, and thus the three values used in these projections—$\sim 376,000$, $\sim 753,000$, and $\sim 1,129,000$—are labelled as high, very high, and extremely high, respectively. Results are compared graphically to those of earlier projections that used the assessment-estimated value.

For each of the three levels of 2006 recruitment, two levels of fishing rate were considered: $F = F_{\text{current}}$ and $F = 0.75F_{40\%}$. These new projections are labeled:

- Scenario P1: $F = F_{\text{current}}$, high 2006 recruitment (50% the observed maximum)
- Scenario P2: $F = F_{\text{current}}$, very high 2006 recruitment (100% the observed maximum)
- Scenario P3: $F = F_{\text{current}}$, extremely high 2006 recruitment (150% the observed maximum)
- Scenario P4: $F = 0.75F_{40\%}$, high 2006 recruitment
- Scenario P5: $F = 0.75F_{40\%}$, very high 2006 recruitment
- Scenario P6: $F = 0.75F_{40\%}$, extremely high 2006 recruitment

Projected fishing mortality rates in 2007–2009, prior to new management, assumed the regression levels used in the report titled, Red Snapper Projections V. These rates do not reflect any increase in fishing effort that may be associated with the very high landings reported by MRFSS in 2008. If effort has actually increased along with the high landings, these projections could be considered overly optimistic in terms of spawning biomass, recruitment, and landing in subsequent years.

2 Results

In scenarios with fishing at the current level, an unusually strong year class in 2006 was projected to boost spawning biomass, recruits, and landings, relative to estimates from the base projections (Tables 4.1–4.3, Figure 5.2). Over time, expected values were projected to converge back to the current low levels, as the strong year class disappeared from the population. In scenarios with fishing at $0.75F_{40\%}$, an unusually strong year class in 2006 was projected to have little effect on the trajectory of stock recovery (Tables 4.4–4.6, Figure 5.3). In both fishing scenarios, the 2006 recruitment class affected short-term transient dynamics, but not the long-term trends.

3 Comments on Projections

Projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- These projections reflect a belief that the 2006 year-class was strong. However, the recruitment values applied are based on guesswork. Thus, results of these projections should be interpretted in a qualitative light.
- Initial abundance at age of the projections, other than 2006 age-1 recruits, were based on estimates from the last year of the assessment. If those estimates are inaccurate, rebuilding will likely be affected.
- The 2008 recreational landings reported by MRFSS indicate very high levels of landings, which could be due to a very strong 2006 year-class, as explored in these projections. The high landings could also be due, at least in part, to increased fishing effort, which is not accounted for here. If effort has actually increased along with the high landings, these projections could be considered overly optimistic in terms of spawning biomass, recruitment, and landing in subsequent years.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect rebuilding.
- The projections assumed no change in the selectivity applied to discards. As recovery generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If changes in environmental or ecological conditions affect recruitment or life-history characteristics, rebuilding may be affected.
- The projections used a spawner-recruit relationship with steepness of $h = 0.95$, the value estimated in the assessment but with considerable uncertainty. Such a high value implies that the stock, at its currently low abundance, spawns nearly as many recruits as it would at high abundance. That is, productivity is nearly independent of spawning biomass. If productivity depends on spawning biomass, stock recovery would take longer than projected.

4 Tables

Table 4.1. Red snapper: Projection results under scenario P1—fishing mortality rate F = F_{current}*, with high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching* $SSB_{F_{40\%}}$*, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	215	286	472	472	105	182	115
2008	1.22	0	222	331	595	1066	129	212	137
2009	0.974	0	177	337	443	1509	98	161	112
2010	0.974	0	198	297	454	1963	102	176	113
2011	0.974	0	202	317	468	2431	103	170	111
2012	0.974	0	204	320	475	2906	104	169	112
2013	0.974	0	207	322	479	3386	105	173	114
2014	0.974	0	209	324	485	3871	106	175	115
2015	0.974	0	211	326	490	4361	107	176	116
2016	0.974	0	213	328	494	4855	108	177	116
2017	0.974	0	215	329	498	5353	109	178	117
2018	0.974	0	216	331	502	5855	109	179	117
2019	0.974	0	217	332	504	6359	110	179	118
2020	0.974	0	218	333	507	6866	110	180	118
2021	0.974	0	219	334	509	7376	111	180	119
2022	0.974	0	220	334	511	7887	111	181	119
2023	0.974	0	220	335	513	8400	111	181	119
2024	0.974	0	221	336	514	8914	112	182	119
2025	0.974	0	222	336	516	9429	112	182	120
2026	0.974	0	222	337	517	9946	112	182	120
2027	0.974	0	222	337	518	10,464	112	183	120
2028	0.974	0	223	337	518	10,982	112	183	120
2029	0.974	0	223	337	519	11,501	112	183	120
2030	0.974	0	223	338	520	12,021	113	183	120

Table 4.2. Red snapper: Projection results under scenario P2—fishing mortality rate $F = F_{\text{current}}$, with very high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (mt)*, R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	262	286	541	541	144	292	177
2008	1.22	0	290	367	759	1300	174	297	165
2009	0.974	0	225	385	579	1878	124	176	125
2010	0.974	0	242	339	563	2442	122	199	129
2011	0.974	0	240	352	560	3001	120	193	125
2012	0.974	0	237	351	555	3557	119	189	125
2013	0.974	0	235	349	549	4105	118	190	125
2014	0.974	0	234	347	545	4651	117	189	124
2015	0.974	0	232	346	542	5193	117	189	124
2016	0.974	0	231	345	540	5733	116	188	123
2017	0.974	0	230	344	537	6270	116	187	123
2018	0.974	0	230	344	536	6806	115	187	123
2019	0.974	0	229	343	534	7340	115	186	122
2020	0.974	0	228	342	533	7872	115	186	122
2021	0.974	0	228	342	531	8403	115	186	122
2022	0.974	0	228	342	530	8934	114	186	122
2023	0.974	0	227	341	529	9463	114	185	122
2024	0.974	0	227	341	529	9992	114	185	122
2025	0.974	0	227	341	528	10,519	114	185	121
2026	0.974	0	226	341	527	11,047	114	185	121
2027	0.974	0	226	340	527	11,574	114	185	121
2028	0.974	0	226	340	526	12,100	114	185	121
2029	0.974	0	226	340	526	12,626	114	185	121
2030	0.974	0	226	340	526	13,152	114	184	121

*Table 4.3. Red snapper: Projection results under scenario P3—fishing mortality rate $F = F_{\text{current}}$, with extremely high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	309	286	610	610	183	402	240
2008	1.22	0	358	396	923	1533	218	382	193
2009	0.974	0	271	421	714	2247	149	188	135
2010	0.974	0	283	372	668	2915	139	217	141
2011	0.974	0	274	380	644	3559	134	211	136
2012	0.974	0	265	374	625	4185	131	205	134
2013	0.974	0	259	369	608	4792	128	204	133
2014	0.974	0	254	364	595	5387	126	201	131
2015	0.974	0	249	361	584	5972	124	198	129
2016	0.974	0	246	358	575	6547	122	196	128
2017	0.974	0	243	355	568	7115	121	194	127
2018	0.974	0	240	353	561	7676	120	193	126
2019	0.974	0	238	351	556	8232	119	192	126
2020	0.974	0	236	349	551	8784	118	191	125
2021	0.974	0	235	348	548	9331	118	190	124
2022	0.974	0	233	347	544	9875	117	189	124
2023	0.974	0	232	346	541	10,417	116	188	123
2024	0.974	0	231	345	539	10,956	116	188	123
2025	0.974	0	230	344	537	11,492	116	187	123
2026	0.974	0	229	343	535	12,027	115	187	122
2027	0.974	0	229	343	533	12,561	115	186	122
2028	0.974	0	228	342	532	13,093	115	186	122
2029	0.974	0	228	342	531	13,623	115	186	122
2030	0.974	0	227	341	530	14,153	114	186	122

*Table 4.4. Red snapper: Projection results under scenario P4—fishing mortality rate F = 75%$F_{40\%}$, with high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish*).* For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	215	286	472	472	105	182	115
2008	1.22	0	222	331	595	1066	129	212	137
2009	0.974	0	177	337	443	1509	98	161	112
2010	0.078	0	198	297	47	1556	11	18	11
2011	0.078	0	437	317	83	1639	17	23	13
2012	0.078	0	663	455	131	1770	23	26	15
2013	0.078	0	944	519	190	1959	31	32	19
2014	0.078	0	1289	565	261	2220	40	39	22
2015	0.078	0	1693	599	347	2567	50	44	24
2016	0.078	0	2143	623	444	3012	60	47	26
2017	0.078	0	2625	640	548	3560	69	49	27
2018	0.078	0	3125	652	656	4216	78	51	27
2019	0.078	0	3629	661	766	4982	86	52	28
2020	0.078	0	4127	668	874	5856	94	53	28
2021	0.078	0.01	4610	674	978	6834	101	53	29
2022	0.078	0.01	5073	678	1078	7912	107	54	29
2023	0.078	0.03	5510	681	1172	9084	113	54	29
2024	0.078	0.06	5920	683	1260	10,344	118	55	29
2025	0.078	0.09	6300	685	1342	11,685	122	55	29
2026	0.078	0.14	6651	687	1417	13,103	126	55	29
2027	0.078	0.19	6972	688	1486	14,589	130	55	29
2028	0.078	0.25	7266	690	1549	16,138	133	55	29
2029	0.078	0.33	7533	690	1606	17,744	136	55	29
2030	0.078	0.39	7774	691	1658	19,403	139	55	30

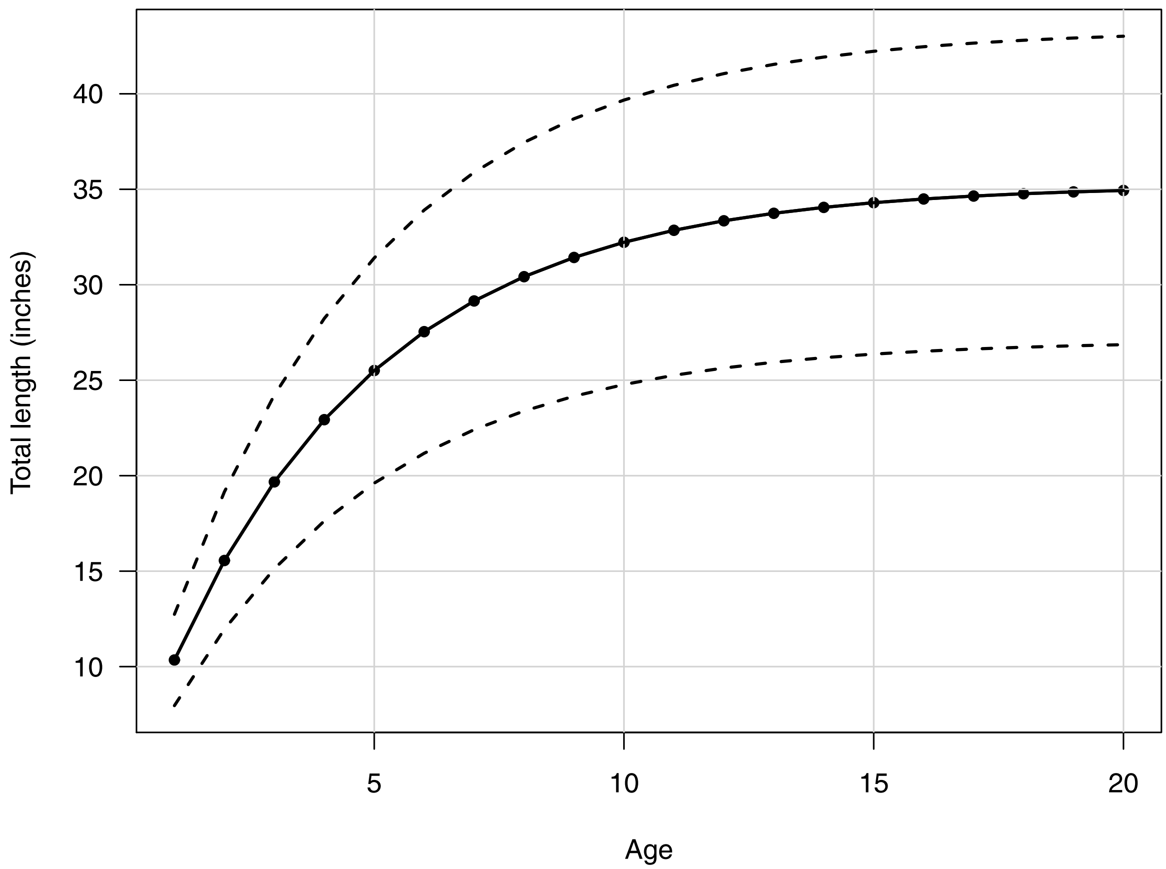
Table 4.5. Red snapper: Projection results under scenario P5—fishing mortality rate $F = 75\%F_{40\%}$, with very high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (mt)*, R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\mathrm{SSB}_{F_{40\%}} = 8102.5$ mt, $\mathrm{R}_{F_{40\%}} = 692,864$ fish, $\mathrm{Y}_{F_{40\%}} = 2,303,676$ lb, and $\mathrm{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	262	286	541	541	144	292	177
2008	1.22	0	290	367	759	1300	174	297	165
2009	0.974	0	225	385	579	1878	124	176	125
2010	0.078	0	242	339	59	1937	13	20	12
2011	0.078	0	520	352	99	2036	19	26	14
2012	0.078	0	776	483	154	2190	27	29	17
2013	0.078	0	1086	541	219	2410	35	34	20
2014	0.078	0	1458	581	297	2706	44	41	23
2015	0.078	0	1884	610	388	3094	54	45	25
2016	0.078	0	2349	631	489	3583	64	48	26
2017	0.078	0	2840	646	595	4178	73	50	27
2018	0.078	0	3343	657	704	4882	82	51	28
2019	0.078	0	3845	665	812	5694	90	52	28
2020	0.078	0	4338	671	919	6613	97	53	28
2021	0.078	0.01	4813	675	1022	7635	104	54	29
2022	0.078	0.02	5265	679	1119	8754	110	54	29
2023	0.078	0.04	5690	682	1211	9965	115	54	29
2024	0.078	0.07	6087	684	1296	11,261	120	55	29
2025	0.078	0.11	6455	686	1375	12,636	124	55	29
2026	0.078	0.16	6793	688	1448	14,084	128	55	29
2027	0.078	0.21	7102	689	1514	15,598	131	55	29
2028	0.078	0.28	7384	690	1575	17,172	135	55	29
2029	0.078	0.36	7640	691	1629	18,802	137	55	29
2030	0.078	0.42	7871	692	1679	20,481	140	55	30

*Table 4.6. Red snapper: Projection results under scenario P6—fishing mortality rate $F = 75\%F_{40\%}$, with extremely high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\mathrm{SSB}_{F_{40\%}} = 8102.5$ mt, $\mathrm{R}_{F_{40\%}} = 692,864$ fish, $\mathrm{Y}_{F_{40\%}} = 2,303,676$ lb, and $\mathrm{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	309	286	610	610	183	402	240
2008	1.22	0	358	396	923	1533	218	382	193
2009	0.974	0	271	421	714	2247	149	188	135
2010	0.078	0	283	372	70	2316	14	22	14
2011	0.078	0	596	380	114	2430	22	29	16
2012	0.078	0	875	504	175	2605	30	31	18
2013	0.078	0	1209	556	245	2850	38	36	21
2014	0.078	0	1601	592	328	3178	48	43	24
2015	0.078	0	2042	618	422	3600	57	46	25
2016	0.078	0	2518	637	525	4125	67	49	26
2017	0.078	0	3014	650	633	4758	76	50	27
2018	0.078	0	3518	660	742	5500	85	52	28
2019	0.078	0	4018	667	850	6349	92	53	28
2020	0.078	0	4505	673	955	7305	99	53	29
2021	0.078	0.01	4973	677	1056	8361	106	54	29
2022	0.078	0.02	5416	680	1152	9513	112	54	29
2023	0.078	0.05	5831	683	1241	10,754	117	54	29
2024	0.078	0.08	6218	685	1324	12,078	121	55	29
2025	0.078	0.13	6575	687	1401	13,479	125	55	29
2026	0.078	0.18	6903	688	1471	14,950	129	55	29
2027	0.078	0.24	7203	689	1536	16,486	133	55	29
2028	0.078	0.31	7476	690	1594	18,080	136	55	29
2029	0.078	0.38	7723	691	1647	19,727	138	55	30
2030	0.078	0.44	7946	692	1695	21,423	141	55	30

Figure 5.1. Average length at age (solid line) with plus/minus two standard deviations (dashed lines).



5 Figures

Figure 5.2. Projection results under scenarios with fishing mortality rate fixed at $F = F_{\text{current}}$. For reference, the proxy reference point used to define stock recovery is $\text{SSB}_{\text{MSY}} = 8102.5$ *mt, which corresponds to a yield of about 2.3 million lb.*

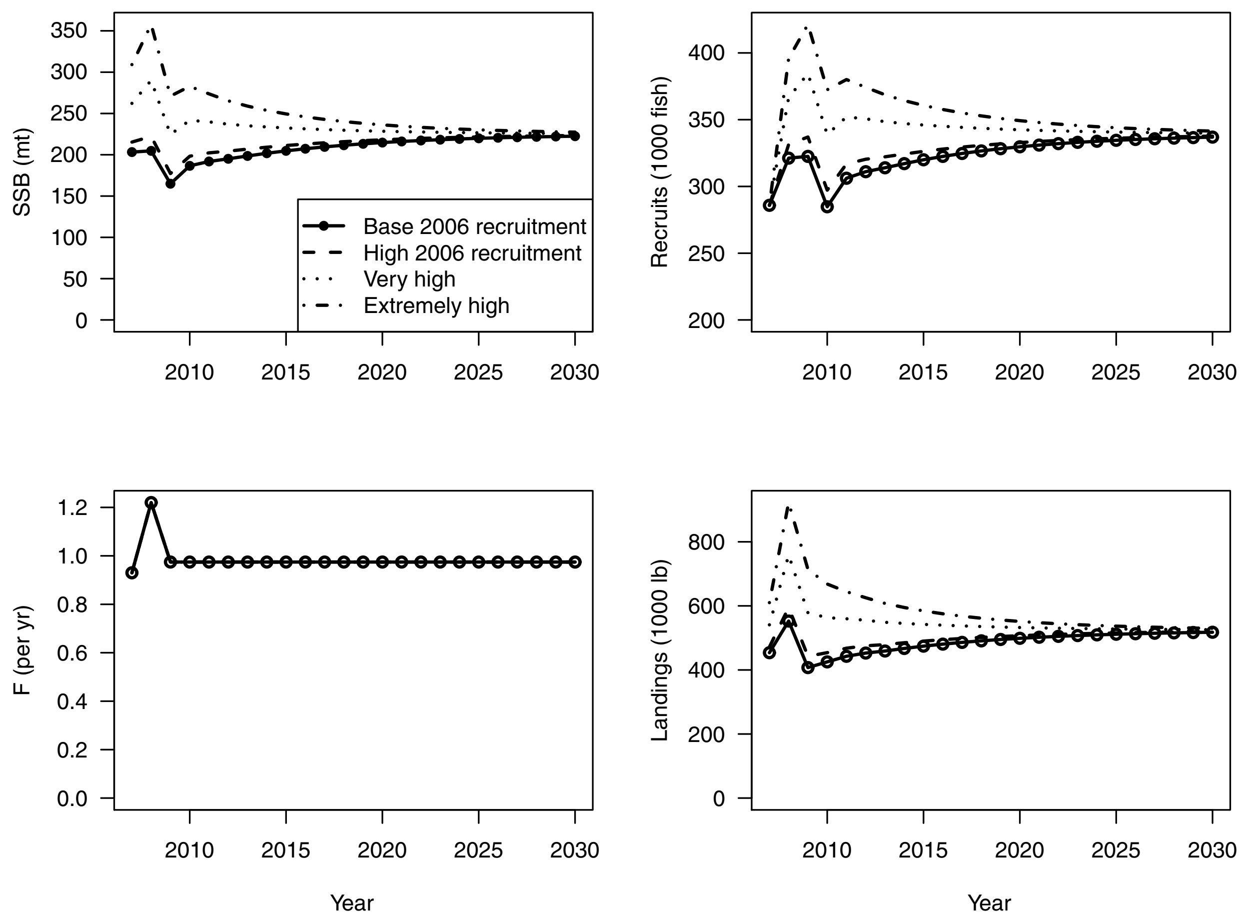
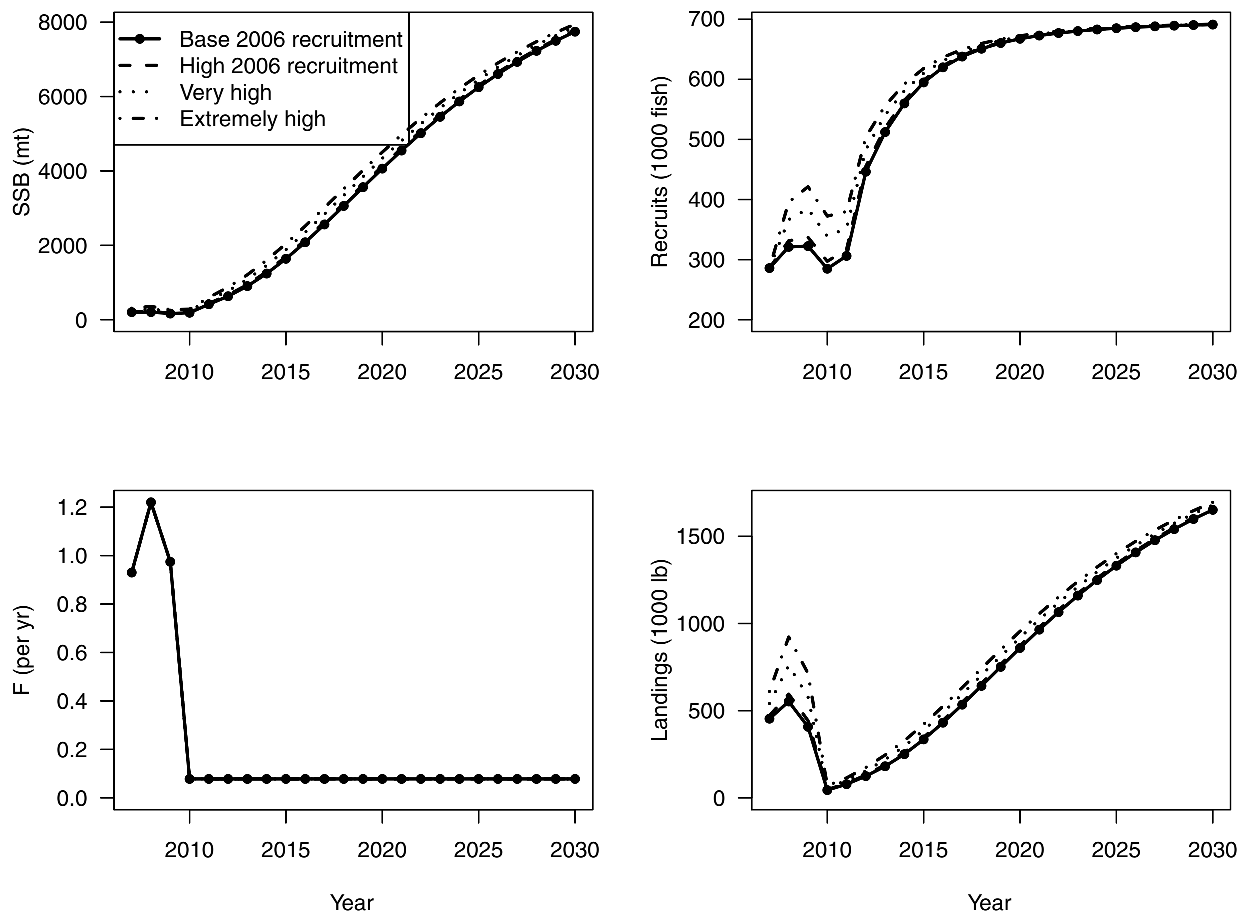


Figure 5.3. Projection results under scenarios with fishing mortality rate fixed at $F = 0.75F_{40\%}$. For reference, the proxy reference point used to define stock recovery is $\mathrm{SSB}_{\mathrm{MSY}} = 8102.5$ mt, which corresponds to a yield of about 2.3 million lb.



Red Snapper Projections VII

31 July 2009

1 Introduction

Projections of red snapper in the U.S. South Atlantic were completed as part of SEDAR-15 and were described in the SEDAR-15 assessment report. Following the SEDAR-15 Review Workshop, those projections were revised according to an SAFMC memorandum (dated August 12, 2008) from Bob Mahood to Dr. Bonnie Ponwith; the revised projections were described in the SEDAR-15 "Addenda and updates." Additional projections were computed for consideration of the SAFMC SSC at their December, 2008 meeting, as described in a report titled "Red snapper: Estimation of biomass benchmarks and projections." During that meeting, the SSC requested more projections, which were computed and described in a follow-up report to the SSC titled, "Red Snapper Projections: the SSC Alternative (1 December 2008)."

A SERO memorandum (dated February 13, 2009), from Dr. Roy Crabtree to Dr. Bonnie Ponwith, requested additional red snapper projections. Those projections were described in the report titled, "Red Snapper Projections V". Following that report, the Council requested an additional projection, which was described in "Red Snapper Projections V – Addendum". In preparation for the June 2009 Council meeting, further projections were run to explore the potential effects of strong recruitment in 2006. Those projections were described in "Red Snapper Projections VI."

A SERO memorandum (dated July 10, 2009), from Dr. Roy Crabtree to Dr. Bonnie Ponwith, requested more red snapper projections. This report, along with the report titled, "Red Snapper Projections VI—Revised," documents these projections. A synopsis of the request follows:

1. New constant fishing mortality projections similar to those provided on March 9, 2009, which incorporates high recruitment that appears to have occurred in 2005 or 2006
2. An additional constant fishing mortality projection that would rebuild the stock in 35 years, which is the maximum allowable rebuilding time
3. A suite of projections using $F_{30\%}$
4. Provide the value of the yield at $F_{45\%}$

Item one regarding high recent recruitment is described in a companion report, titled "Red Snapper Projections VI—Revised." Items two through four are covered in this report.

To accomplish the fourth item, biomass benchmarks associated with $F_{45\%}$ were computed through long-term, deterministic projections with bias correction, as was done with $F_{30\%}$ and $F_{40\%}$. Similar long-term projections were run to compute the yield associated with 65%, 75%, and 85% of $F_{45\%}$. Benchmarks are shown in Table 5.1.

2 Projection scenarios

To accomplish the second and third items, several projection scenarios with constant F were considered:

- Scenario A: $F = F_{\text{rebuild}}$, defined as the maximum F that allows rebuilding by the start of 2045
- Scenario B: $F = 65\%F_{30\%}$
- Scenario C: $F = 75\%F_{30\%}$
- Scenario D: $F = 85\%F_{30\%}$
- Scenario E: $F = F_{30\%}$

Methods are described more fully in "Red Snapper Projections V."

3 Projection Results

Results of projections with $F = F_{\text{rebuild}}$ are tabulated in Table 5.2 and are presented graphically in Fig. 6.1. The maximum F that allowed rebuilding was $F_{\text{rebuild}} = 0.1$.

Results of the projections associated with $F_{30\%}$ are tabulated in Table 5.3–5.6, and are presented graphically in Figs. 6.2–6.5.

4 Comments on Projections

Projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- Initial abundance at age of the projections were based on estimates from the last year of the assessment. If those estimates are inaccurate, rebuilding will likely be affected.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect rebuilding.
- The projections assumed no change in the selectivity applied to discards. As recovery generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If changes in environmental or ecological conditions affect recruitment or life-history characteristics, rebuilding may be affected.
- The projections used a spawner-recruit relationship with steepness of $h = 0.95$, the value estimated in the assessment but with considerable uncertainty. Such a high value implies that the stock, at its currently low abundance, spawns nearly as many recruits as it would at high abundance. That is, productivity is nearly independent of spawning biomass. If productivity depends on spawning biomass, stock recovery would take longer than projected.

5 Tables

Table 5.1. Estimated status indicators, benchmarks, and related quantities, conditional on estimated current selectivities averaged across fisheries. Values are MSY*-based proxies associated with* $F_{40\%}$*, the recommended proxy for* F_{MSY}*, and also* $F_{35\%}$ *and* $F_{30\%}$*. Biomass-based and number-based quantities were computed as equilibrium values from projections with fishing rate* $F_{30\%}$*,* $F_{40\%}$*, or* $F_{45\%}$ *(or X% of those rates), as indicated. Estimates of yield (*Y*) do not include discard mortalities (*D*). The* MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$*, with constant* $M = 0.078$*.*

Quantity	Units	$F_{45\%}$ Proxy	$F_{40\%}$ Proxy	$F_{30\%}$ Proxy
F_{MSY}	y^{-1}	0.088	0.104	0.148
$\mathrm{SSB}_{\mathrm{MSY}}$	mt	9120.6	8102.5	6025.1
$\mathrm{D}_{\mathrm{MSY}}$	1000 fish	33	39	54
Recruits at F_{MSY}	1000 fish	695	693	686
Y at 65% F_{MSY}	1000 lb	1833	1984	2257
Y at 75% F_{MSY}	1000 lb	1963	2104	2338
Y at 85% F_{MSY}	1000 lb	2070	2199	2391
Y at F_{MSY}	1000 lb	2196	2304	2431
MSST	mt	8409.2	7470.5	5555.1
$F_{2006}/F_{\mathrm{MSY}}$	–	9.06	7.67	5.39
$\mathrm{SSB}_{2006}/\mathrm{SSB}_{\mathrm{MSY}}$	–	0.02	0.02	0.03
$\mathrm{SSB}_{2006}/\mathrm{MSST}$	–	0.02	0.03	0.04

*Table 5.2. Red snapper: Projection results under scenario A—fishing mortality rate $F = F_{\text{rebuild}}$. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	203	286	454	454	95	153	99
2008	1.22	0	205	321	553	1007	117	190	129
2009	0.974	0	165	322	407	1414	91	157	109
2010	0.1	0	187	285	56	1470	13	22	13
2011	0.1	0	406	306	98	1568	20	28	16
2012	0.1	0	612	443	155	1723	28	31	18
2013	0.1	0	868	508	223	1946	37	39	23
2014	0.1	0	1182	555	305	2251	48	48	27
2015	0.1	0	1548	590	405	2656	59	54	30
2016	0.1	0	1955	615	518	3174	71	58	32
2017	0.1	0	2389	634	638	3812	82	61	33
2018	0.1	0	2837	647	762	4574	93	63	34
2019	0.1	0	3285	657	886	5460	103	65	35
2020	0.1	0	3726	664	1009	6469	112	66	36
2021	0.1	0	4150	669	1127	7595	119	67	36
2022	0.1	0.01	4553	674	1238	8833	127	68	36
2023	0.1	0.01	4931	677	1342	10,176	133	68	37
2024	0.1	0.02	5281	680	1439	11,615	139	68	37
2025	0.1	0.04	5603	682	1528	13,142	144	69	37
2026	0.1	0.06	5898	684	1609	14,751	148	69	37
2027	0.1	0.08	6165	685	1682	16,434	152	69	37
2028	0.1	0.1	6407	686	1749	18,183	155	69	37
2029	0.1	0.13	6625	687	1809	19,991	159	69	37
2030	0.1	0.16	6819	688	1862	21,854	161	70	37
2031	0.1	0.2	6994	689	1910	23,764	164	70	37
2032	0.1	0.23	7149	690	1953	25,717	166	70	37
2033	0.1	0.26	7287	690	1991	27,708	168	70	37
2034	0.1	0.29	7410	691	2025	29,733	169	70	37
2035	0.1	0.32	7519	691	2055	31,788	171	70	37
2036	0.1	0.35	7615	691	2081	33,869	172	70	37
2037	0.1	0.37	7700	692	2105	35,974	173	70	37
2038	0.1	0.4	7776	692	2125	38,099	174	70	37
2039	0.1	0.42	7842	692	2144	40,243	175	70	37
2040	0.1	0.44	7901	692	2160	42,403	176	70	37
2041	0.1	0.47	7953	692	2174	44,577	177	70	38
2042	0.1	0.48	7999	692	2187	46,764	177	70	38
2043	0.1	0.5	8040	693	2198	48,962	178	70	38
2044	0.1	0.51	8075	693	2208	51,170	178	70	38
2045	0.1	0.52	8107	693	2216	53,386	179	70	38
2046	0.1	0.52	8135	693	2224	55,610	179	70	38
2047	0.1	0.53	8159	693	2231	57,841	179	70	38
2048	0.1	0.52	8181	693	2237	60,078	180	70	38
2049	0.1	0.53	8200	693	2242	62,320	180	70	38
2050	0.1	0.53	8217	693	2247	64,566	180	70	38

*Table 5.3. Red snapper: Projection results under scenario B—fishing mortality rate $F = 65\% F_{30\%}$. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{30\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{30\%} = 0.148$, $SSB_{F_{30\%}} = 6025.1$ mt, $R_{F_{30\%}} = 685,824$ fish, $Y_{F_{30\%}} = 2,430,792$ lb, and $D_{F_{30\%}} = 99,092$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	203	286	454	454	95	153	99
2008	1.22	0	205	321	553	1007	117	190	129
2009	0.974	0	165	322	407	1414	91	157	109
2010	0.096	0	187	285	54	1468	12	21	13
2011	0.096	0	408	306	95	1563	19	27	15
2012	0.096	0	615	444	150	1713	27	30	18
2013	0.096	0	874	509	216	1928	36	37	22
2014	0.096	0	1192	556	296	2224	46	47	26
2015	0.096	0	1563	591	394	2618	58	52	29
2016	0.096	0	1977	616	504	3122	69	56	31
2017	0.096	0	2418	634	621	3743	80	59	32
2018	0.096	0	2874	648	743	4486	90	61	33
2019	0.096	0.01	3332	657	865	5351	100	63	34
2020	0.096	0.03	3782	665	985	6336	109	64	34
2021	0.096	0.06	4216	670	1101	7438	116	65	35
2022	0.096	0.11	4629	674	1211	8649	123	65	35
2023	0.096	0.18	5017	678	1314	9963	130	66	35
2024	0.096	0.27	5377	680	1410	11,373	135	66	35
2025	0.096	0.37	5709	683	1498	12,870	140	66	36
2026	0.096	0.47	6013	684	1578	14,449	145	67	36
2027	0.096	0.58	6290	686	1652	16,101	148	67	36
2028	0.096	0.65	6541	687	1718	17,819	152	67	36
2029	0.096	0.72	6766	688	1778	19,596	155	67	36
2030	0.096	0.78	6969	689	1831	21,428	158	67	36
2031	0.096	0.84	7150	690	1879	23,307	160	67	36
2032	0.096	0.87	7313	690	1922	25,229	162	67	36
2033	0.096	0.9	7457	691	1961	27,190	164	67	36
2034	0.096	0.92	7586	691	1995	29,184	166	67	36
2035	0.096	0.93	7700	691	2025	31,209	167	67	36
2036	0.096	0.95	7801	692	2052	33,260	169	68	36
2037	0.096	0.96	7891	692	2075	35,336	170	68	36
2038	0.096	0.97	7971	692	2096	37,432	171	68	36
2039	0.096	0.97	8041	693	2115	39,547	172	68	36
2040	0.096	0.97	8103	693	2131	41,678	172	68	36
2041	0.096	0.98	8159	693	2146	43,824	173	68	36
2042	0.096	0.98	8207	693	2159	45,983	174	68	36
2043	0.096	0.98	8251	693	2170	48,154	174	68	36
2044	0.096	0.98	8289	693	2180	50,334	175	68	36
2045	0.096	0.99	8322	693	2189	52,524	175	68	36
2046	0.096	0.99	8352	693	2197	54,721	176	68	36
2047	0.096	0.99	8378	693	2204	56,925	176	68	36
2048	0.096	0.99	8402	694	2210	59,135	176	68	36
2049	0.096	0.99	8422	694	2216	61,351	176	68	36
2050	0.096	0.99	8440	694	2221	63,572	177	68	36

*Table 5.4. Red snapper: Projection results under scenario C—fishing mortality rate $F = 75\% F_{30\%}$. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{30\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{30\%} = 0.148$, $SSB_{F_{30\%}} = 6025.1$ mt, $R_{F_{30\%}} = 685,824$ fish, $Y_{F_{30\%}} = 2,430,792$ lb, and $D_{F_{30\%}} = 99,092$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	203	286	454	454	95	153	99
2008	1.22	0	205	321	553	1007	117	190	129
2009	0.974	0	165	322	407	1414	91	157	109
2010	0.111	0	187	285	62	1476	14	24	15
2011	0.111	0	402	306	108	1584	22	31	17
2012	0.111	0	603	441	169	1753	30	34	20
2013	0.111	0	851	506	242	1995	40	43	26
2014	0.111	0	1154	553	330	2325	52	53	30
2015	0.111	0	1506	588	437	2763	64	59	33
2016	0.111	0	1895	613	556	3319	77	64	35
2017	0.111	0	2308	631	683	4002	89	67	37
2018	0.111	0	2732	645	814	4816	100	69	38
2019	0.111	0.01	3156	655	944	5760	110	71	39
2020	0.111	0.01	3570	662	1072	6832	120	72	39
2021	0.111	0.03	3967	668	1194	8026	128	73	40
2022	0.111	0.07	4341	672	1309	9335	135	74	40
2023	0.111	0.12	4691	675	1416	10,751	142	75	40
2024	0.111	0.18	5014	678	1515	12,266	148	75	40
2025	0.111	0.24	5310	680	1606	13,872	153	75	41
2026	0.111	0.32	5578	682	1688	15,560	158	76	41
2027	0.111	0.41	5821	684	1762	17,322	162	76	41
2028	0.111	0.48	6039	685	1829	19,151	165	76	41
2029	0.111	0.56	6235	686	1888	21,039	168	76	41
2030	0.111	0.62	6409	687	1942	22,980	171	76	41
2031	0.111	0.68	6564	687	1989	24,969	173	76	41
2032	0.111	0.73	6701	688	2031	27,000	175	77	41
2033	0.111	0.76	6823	689	2068	29,068	177	77	41
2034	0.111	0.79	6930	689	2101	31,169	179	77	41
2035	0.111	0.82	7025	689	2130	33,298	180	77	41
2036	0.111	0.84	7108	690	2155	35,453	182	77	41
2037	0.111	0.86	7182	690	2177	37,631	183	77	41
2038	0.111	0.88	7246	690	2197	39,828	184	77	41
2039	0.111	0.89	7303	690	2215	42,043	184	77	41
2040	0.111	0.89	7353	691	2230	44,272	185	77	41
2041	0.111	0.9	7397	691	2243	46,515	186	77	41
2042	0.111	0.9	7435	691	2255	48,770	186	77	41
2043	0.111	0.91	7469	691	2265	51,035	187	77	41
2044	0.111	0.92	7499	691	2274	53,310	187	77	41
2045	0.111	0.93	7525	691	2282	55,592	188	77	41
2046	0.111	0.92	7547	691	2289	57,881	188	77	41
2047	0.111	0.93	7567	691	2295	60,176	188	77	41
2048	0.111	0.93	7585	691	2300	62,476	189	77	41
2049	0.111	0.93	7600	691	2305	64,781	189	77	41
2050	0.111	0.94	7614	692	2309	67,090	189	77	41

Table 5.5. Red snapper: Projection results under scenario D—fishing mortality rate $F = 85\%F_{30\%}$. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{30\%}}$, SSB = mid-year spawning biomass (mt)*, R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{30\%} = 0.148$, $SSB_{F_{30\%}} = 6025.1$ mt, $R_{F_{30\%}} = 685,824$ fish, $Y_{F_{30\%}} = 2,430,792$ lb, and $D_{F_{30\%}} = 99,092$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	203	286	454	454	95	153	99
2008	1.22	0	205	321	553	1007	117	190	129
2009	0.974	0	165	322	407	1414	91	157	109
2010	0.126	0	187	285	70	1484	16	27	17
2011	0.126	0	397	306	121	1605	25	35	19
2012	0.126	0	591	439	187	1792	34	38	23
2013	0.126	0	828	503	267	2059	45	48	29
2014	0.126	0	1117	549	362	2421	57	59	34
2015	0.126	0	1451	584	477	2898	71	66	37
2016	0.126	0	1817	610	604	3501	84	71	39
2017	0.126	0	2204	628	738	4240	97	75	41
2018	0.126	0	2599	642	876	5115	109	77	42
2019	0.126	0	2991	652	1013	6128	120	79	43
2020	0.126	0.01	3371	659	1146	7274	130	81	44
2021	0.126	0.02	3734	665	1272	8546	138	82	44
2022	0.126	0.04	4075	670	1391	9937	146	83	45
2023	0.126	0.07	4390	673	1500	11,437	153	83	45
2024	0.126	0.11	4680	676	1601	13,038	159	84	45
2025	0.126	0.15	4943	678	1692	14,730	164	84	45
2026	0.126	0.2	5181	680	1775	16,505	169	85	46
2027	0.126	0.26	5395	681	1849	18,354	173	85	46
2028	0.126	0.32	5585	683	1915	20,268	176	85	46
2029	0.126	0.38	5755	684	1973	22,242	180	85	46
2030	0.126	0.43	5905	685	2025	24,267	182	85	46
2031	0.126	0.48	6037	685	2071	26,338	185	85	46
2032	0.126	0.53	6154	686	2112	28,450	187	86	46
2033	0.126	0.58	6257	686	2147	30,597	188	86	46
2034	0.126	0.61	6346	687	2178	32,775	190	86	46
2035	0.126	0.64	6425	687	2205	34,980	191	86	46
2036	0.126	0.67	6494	688	2229	37,210	193	86	46
2037	0.126	0.69	6554	688	2250	39,460	194	86	46
2038	0.126	0.71	6607	688	2268	41,728	194	86	46
2039	0.126	0.73	6653	688	2284	44,012	195	86	46
2040	0.126	0.74	6693	688	2298	46,310	196	86	46
2041	0.126	0.75	6728	689	2310	48,620	197	86	46
2042	0.126	0.76	6758	689	2321	50,941	197	86	46
2043	0.126	0.76	6785	689	2330	53,271	197	86	46
2044	0.126	0.77	6808	689	2338	55,608	198	86	46
2045	0.126	0.78	6828	689	2345	57,953	198	86	46
2046	0.126	0.78	6845	689	2351	60,304	198	86	46
2047	0.126	0.78	6861	689	2356	62,660	199	86	46
2048	0.126	0.79	6874	689	2361	65,021	199	86	46
2049	0.126	0.79	6885	689	2365	67,385	199	86	46
2050	0.126	0.79	6895	689	2368	69,753	199	86	46

*Table 5.6. Red snapper: Projection results under scenario E—fishing mortality rate $F = F_{30\%}$. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{30\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish). For reference, estimated proxy reference points are $F_{30\%} = 0.148$, $\text{SSB}_{F_{30\%}} = 6025.1$ mt, $\text{R}_{F_{30\%}} = 685,824$ fish, $\text{Y}_{F_{30\%}} = 2,430,792$ lb, and $\text{D}_{F_{30\%}} = 99,092$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	203	286	454	454	95	153	99
2008	1.22	0	205	321	553	1007	117	190	129
2009	0.974	0	165	322	407	1414	91	157	109
2010	0.148	0	187	285	82	1496	19	32	20
2011	0.148	0	390	306	139	1635	28	40	23
2012	0.148	0	573	436	214	1849	39	44	27
2013	0.148	0	796	498	301	2150	51	55	33
2014	0.148	0	1064	544	405	2555	64	68	39
2015	0.148	0	1372	579	529	3084	79	76	43
2016	0.148	0	1707	605	666	3749	94	81	45
2017	0.148	0	2058	623	809	4558	108	86	47
2018	0.148	0	2412	637	954	5513	121	89	49
2019	0.148	0	2761	647	1097	6610	132	91	50
2020	0.148	0	3097	655	1236	7846	143	93	51
2021	0.148	0.01	3415	661	1366	9212	152	94	51
2022	0.148	0.02	3710	666	1487	10,698	160	95	52
2023	0.148	0.03	3981	669	1598	12,296	167	96	52
2024	0.148	0.05	4227	672	1698	13,994	173	96	52
2025	0.148	0.07	4449	674	1789	15,783	179	97	53
2026	0.148	0.1	4648	676	1870	17,653	183	97	53
2027	0.148	0.12	4824	678	1942	19,595	187	98	53
2028	0.148	0.15	4980	679	2005	21,600	191	98	53
2029	0.148	0.18	5118	680	2061	23,662	194	98	53
2030	0.148	0.22	5238	681	2110	25,772	196	98	53
2031	0.148	0.25	5344	682	2153	27,925	198	98	53
2032	0.148	0.28	5436	682	2191	30,116	200	98	53
2033	0.148	0.3	5515	683	2223	32,339	202	99	53
2034	0.148	0.32	5585	683	2252	34,591	204	99	53
2035	0.148	0.35	5645	684	2276	36,867	205	99	53
2036	0.148	0.37	5697	684	2297	39,164	206	99	53
2037	0.148	0.38	5742	684	2316	41,480	207	99	54
2038	0.148	0.4	5781	684	2331	43,811	208	99	54
2039	0.148	0.41	5815	685	2345	46,157	208	99	54
2040	0.148	0.43	5844	685	2357	48,514	209	99	54
2041	0.148	0.45	5869	685	2367	50,881	209	99	54
2042	0.148	0.46	5890	685	2376	53,257	210	99	54
2043	0.148	0.46	5909	685	2384	55,640	210	99	54
2044	0.148	0.47	5925	685	2390	58,031	210	99	54
2045	0.148	0.48	5939	685	2396	60,426	211	99	54
2046	0.148	0.47	5951	685	2401	62,827	211	99	54
2047	0.148	0.47	5961	685	2405	65,232	211	99	54
2048	0.148	0.47	5970	686	2408	67,640	211	99	54
2049	0.148	0.47	5978	686	2412	70,052	212	99	54
2050	0.148	0.47	5984	686	2414	72,466	212	99	54

6 Figures

Figure 6.1. Projection results under scenario A—fishing mortality rate fixed at F_{rebuild}, the maximum F that allows rebuilding by the start of 2045. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Thick horizontal lines represent $F_{40\%}$ benchmarks.

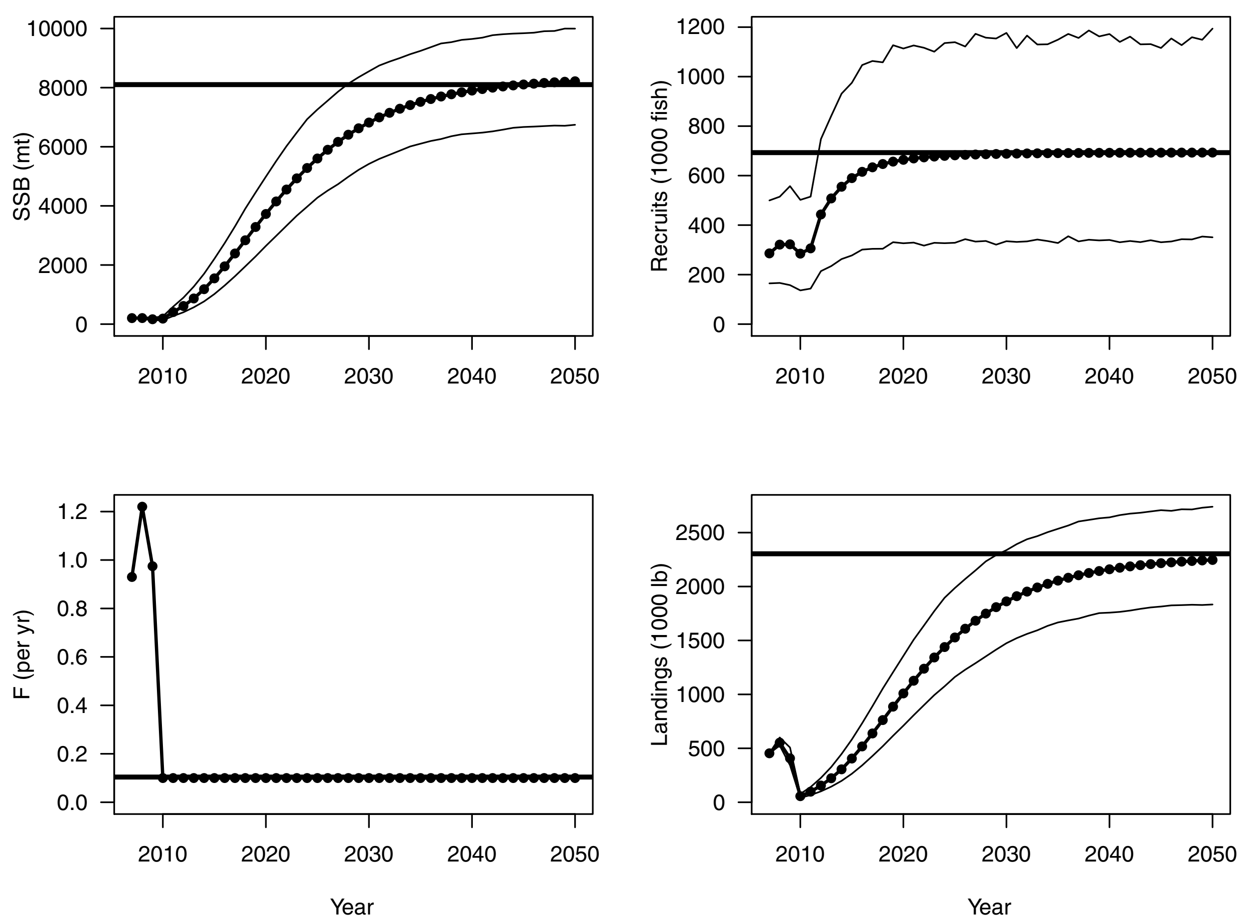


Figure 6.2. Projection results under scenario B—fishing mortality rate fixed at F = 65%$F_{30\%}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Thick horizontal lines represent $F_{30\%}$ benchmarks.

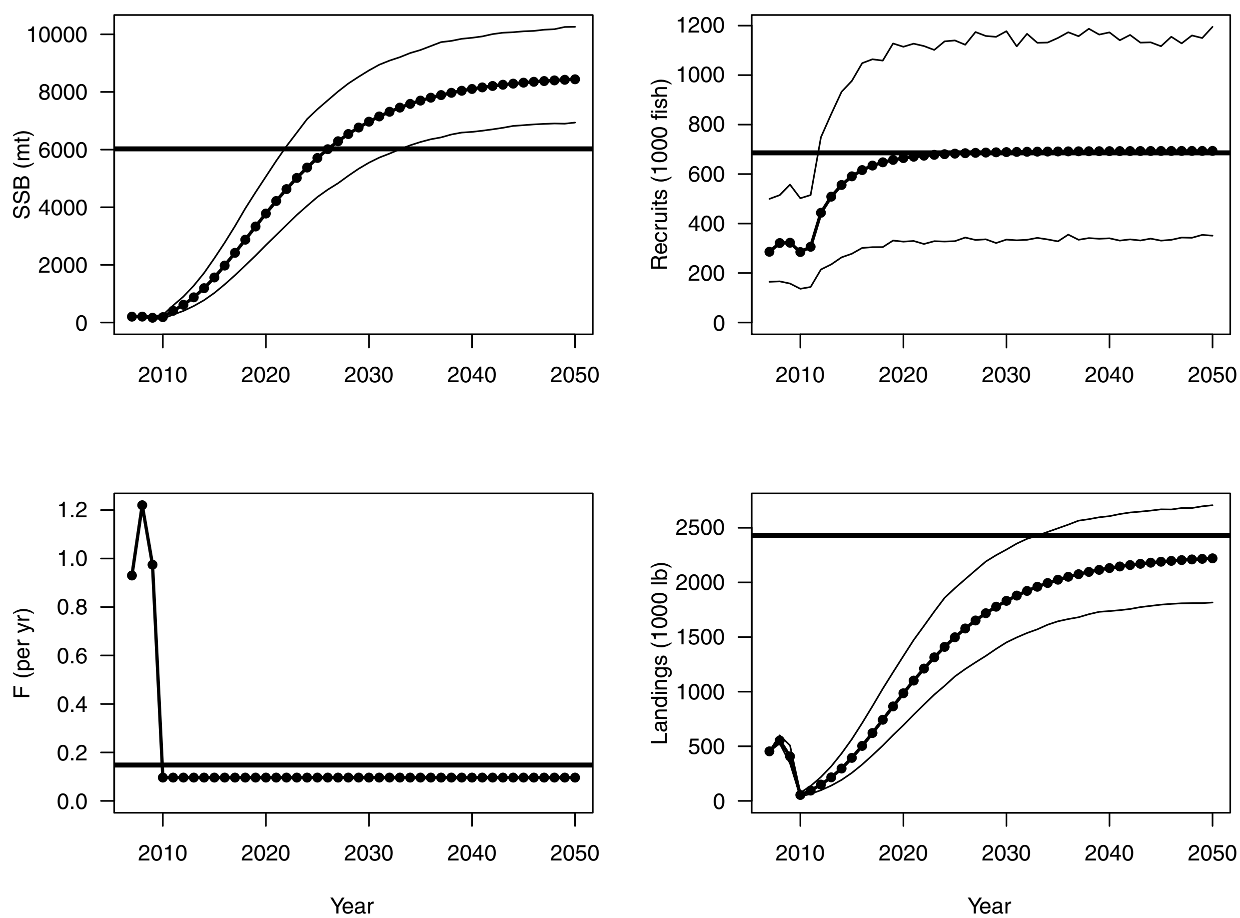


Figure 6.3. Projection results under scenario C—fishing mortality rate fixed at F = 75%$F_{30\%}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Thick horizontal lines represent $F_{30\%}$ benchmarks.

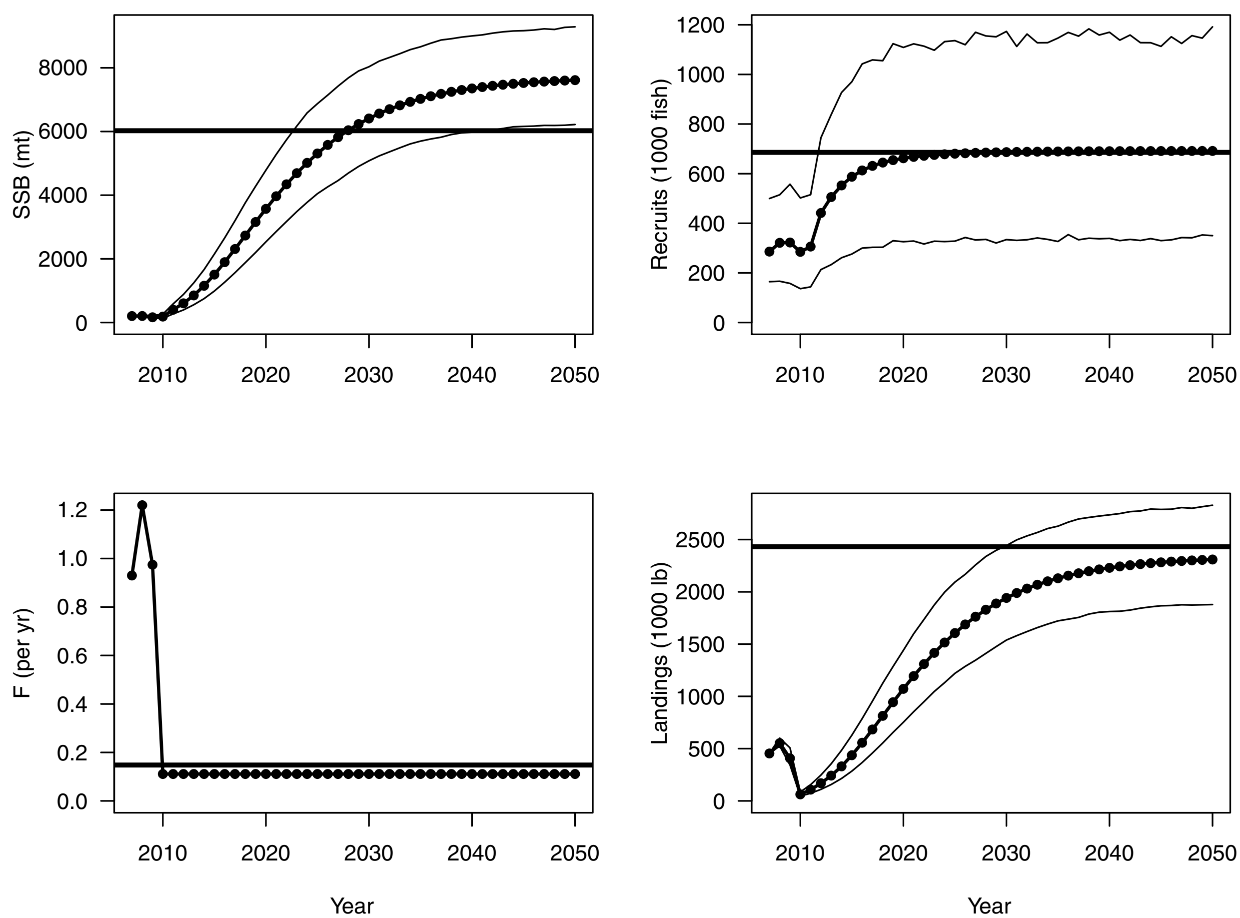


Figure 6.4. Projection results under scenario D—fishing mortality rate fixed at $F = 85\%F_{30\%}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Thick horizontal lines represent $F_{30\%}$ benchmarks.

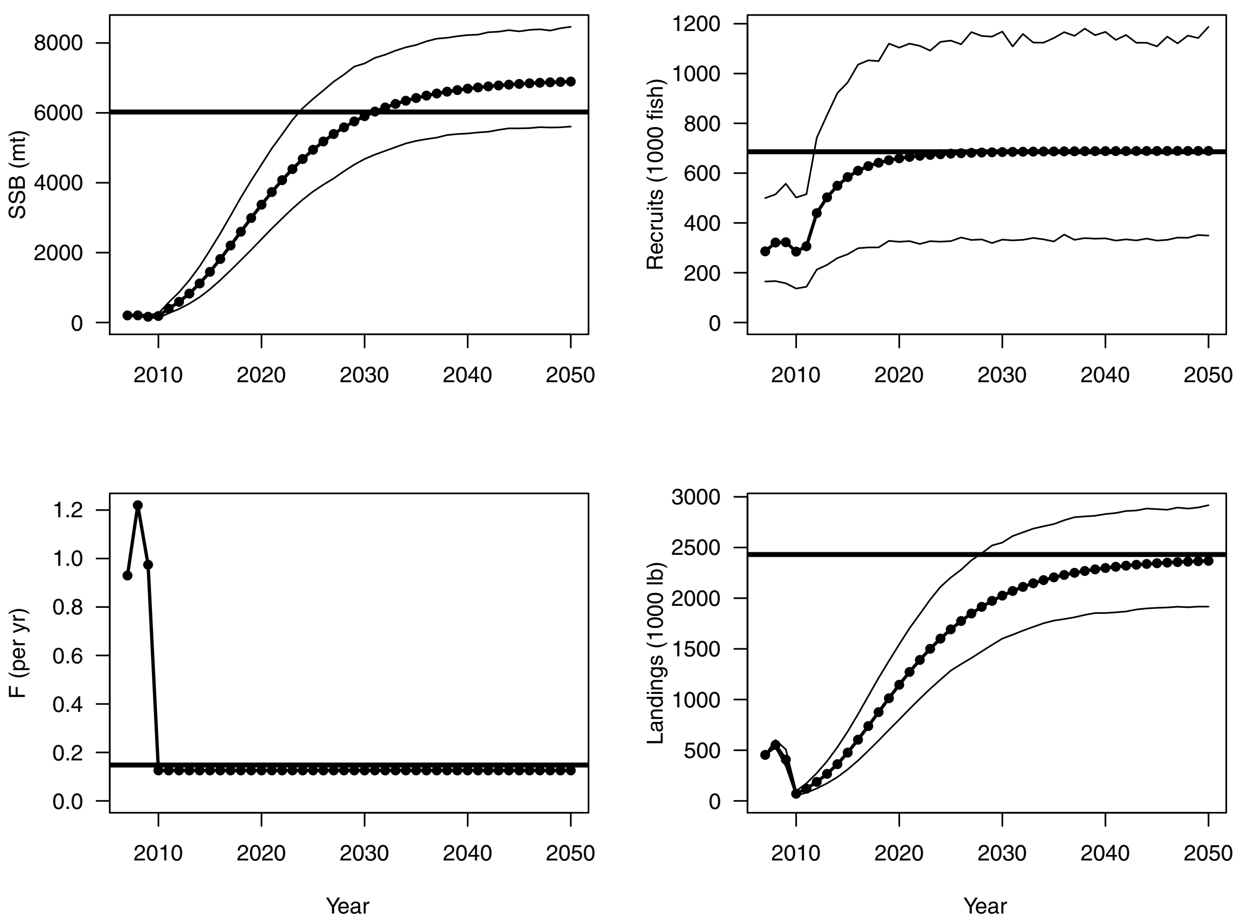
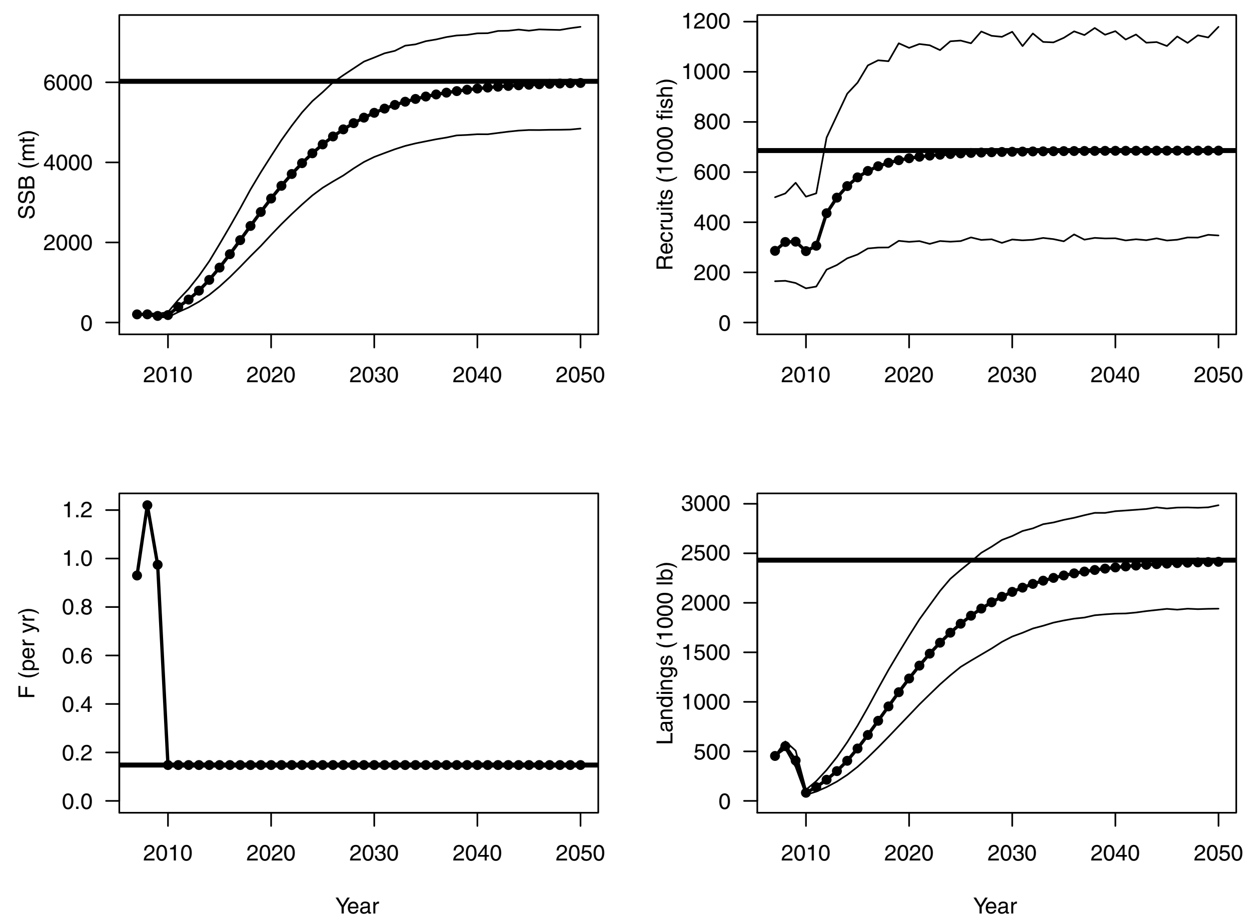


Figure 6.5. Projection results under scenario D—fishing mortality rate fixed at $F = F_{30\%}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 10^{th} and 90^{th} percentiles of 2000 replicate projections. Thick horizontal lines represent $F_{30\%}$ benchmarks.



Red Snapper Projections VII

Prepared by the NOAA/NMFS Southeast Fisheries Science Center
Issued: 6 November 2009

1 Description of projections

This report describes a suite of projections requested in a memorandum, dated 8 October 2009, from Dr. Crabtree to Dr. Ponwith. In addition to projections, the memorandum requested a table of status indicators and related quantities associated with very high 2006 recruitment, similar to Table 4.1 in the document titled Red Snapper Projections V (dated March 19, 2009). However, because such quantities are based on longterm equilibrium values, they would not be affected by any one year of high, or low, recruitment. Thus, values of that previous table would not change. The table is repeated here for ease of reference (Table 4.1).

The projections assume that recruitment in 2006 was equal to the maximum level predicted by the stock assessment during the years 1974–2006. This maximum occurred in 1984 and was about 753,000 age-1 fish.

Several levels of fishing mortality rate were projected:

- Scenario P1: $F = F_{\text{rebuild}}$, the maximum fishing rate that allows rebuilding by the start of 2045
- Scenario P2: $F = 0.65F_{40\%}$
- Scenario P3: $F = 0.75F_{40\%}$
- Scenario P4: $F = 0.85F_{40\%}$
- Scenario P5: $F = F_{40\%}$

Projected fishing mortality rates in 2007–2009, prior to new management, assumed the regression levels used in the report titled, Red Snapper Projections V. These rates do not reflect any increase in fishing effort that may be associated with the very high landings reported by MRFSS in 2008.

2 Results

Results of the five projection scenarios are tabulated in Tables 4.2–4.6, and are shown graphically in Figures 5.1–5.5. The longterm equilibrium yield associated with F_{rebuild} is 2,287,000 lb.

3 Comments on Projections

Projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- These projections reflect a belief that the 2006 year-class was strong. However, for now, the actual strength can only be guessed, and thus the scientific merit of these projections is questionable. The real value of these projections may be more qualitative than quantitative.
- The projections used a spawner-recruit relationship with steepness of $h = 0.95$, the value estimated in the assessment but with considerable uncertainty. On this topic, the SEDAR-15 Review Workshop Report stated, "One of the principal difficulties with the SCA model estimate of stock recruitment parameters is that the steepness estimate appears unrealistically high." Such a high value implies that the stock, at its currently low abundance, spawns nearly as many recruits as it would at high abundance. That is, productivity is nearly independent of spawning biomass. If productivity depends on spawning biomass, stock recovery would take longer than projected.
- The 2008 recreational landings reported by MRFSS indicate very high levels of landings, which could be due to a very strong 2006 year-class, as explored in these projections. The high landings could also be due, at least in part, to increased fishing effort, which is not accounted for here. If effort has actually increased along with the high landings, these projections could be considered overly optimistic in terms of spawning biomass, recruitment, and landing in subsequent years.
- The rebuilding time frame was computed without high 2006 recuitment. If it were recomputed using the high recruitment of these current projections, the rebuilding time frame may be shorter, which would lead to lower estimates of F_{rebuild}. Nonetheless, longterm stock projections, on which F_{rebuild} depends, are highly uncertain. (See last paragraph of this report.)
- Initial abundance at age of the projections, other than 2006 age-1 recruits, were based on estimates from the last year of the assessment. If those estimates are inaccurate, rebuilding will likely be affected.
- Fleets were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect rebuilding.
- The projections assumed no change in the selectivity applied to discards. As recovery generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If changes in environmental or ecological conditions affect recruitment or life-history characteristics, rebuilding may be affected.

On the topic of uncertainty in projections, the SEDAR-15 Review Workshop Report stated in January of 2008, "The panel discussed the value of projections made beyond 5–10 years. Clearly the uncertainty increases rapidly with time as the currently measured stock is replaced by model values into the future. Realistically, the projections beyond the range of the predominant age groups in the stock are highly uncertain. In this assessment, the best that can be concluded is that rebuilding times will be very long." The assessment team concurs with that statement, and would add that uncertainty is even greater now because of the increased duration between the terminal year of the assessment (2006) and any new implementation of management (Shertzer and Prager. 2007. Delay in fishery management: diminished yield, longer rebuilding, and increased probability of stock collapse. ICES Journal of Marine Science 64:149–159.).

4 Tables

Table 4.1. Estimated status indicators, benchmarks, and related quantities, conditional on estimated current selectivities averaged across fisheries. Values are MSY*-based proxies associated with $F_{40\%}$, the recommended proxy for F_{MSY}, and also $F_{30\%}$. Biomass-based and number-based quantities were computed as equilibrium values from projections with fishing rate $F_{30\%}$ or $F_{40\%}$ (or X% of those rates), as indicated. Estimates of yield (Y) do not include discard mortalities (D). The* MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$, *with constant* $M = 0.078$. *This table is repeated from the report titled Red Snapper Projections V of 19 March 2009.*

Quantity	Units	$F_{40\%}$ Proxy	$F_{30\%}$ Proxy
F_{MSY}	y^{-1}	0.104	0.148
$\mathrm{SSB}_{\mathrm{MSY}}$	mt	8102.5	6025.1
$\mathrm{D}_{\mathrm{MSY}}$	1000 fish	39	54
Recruits at F_{MSY}	1000 fish	693	686
Y at 65% F_{MSY}	1000 lb	1984	2257
Y at 75% F_{MSY}	1000 lb	2104	2338
Y at 85% F_{MSY}	1000 lb	2199	2391
Y at F_{MSY}	1000 lb	2304	2431
MSST	mt	7470.5	5555.1
$F_{2006}/F_{\mathrm{MSY}}$	–	7.67	5.39
$\mathrm{SSB}_{2006}/\mathrm{SSB}_{\mathrm{MSY}}$	–	0.02	0.03
$\mathrm{SSB}_{2006}/\mathrm{MSST}$	–	0.03	0.04

*Table 4.2. Red snapper: Projection results under scenario P1—fishing mortality rate $F = F_{\text{rebuild}}$, with very high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish*).* For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	262	286	541	541	144	292	177
2008	1.22	0	290	367	759	1300	174	297	165
2009	0.974	0	225	385	579	1878	124	176	125
2010	0.101	0	242	339	75	1954	16	26	16
2011	0.101	0	510	352	126	2079	25	34	19
2012	0.101	0	751	480	193	2272	34	36	21
2013	0.101	0	1041	537	272	2544	44	43	25
2014	0.101	0	1386	576	365	2909	55	52	29
2015	0.101	0	1775	605	472	3381	67	57	31
2016	0.101	0	2197	626	590	3972	78	61	33
2017	0.101	0	2638	642	714	4686	89	63	34
2018	0.101	0	3085	653	839	5525	99	65	35
2019	0.101	0	3528	661	963	6488	109	66	36
2020	0.101	0	3957	667	1084	7572	117	67	36
2021	0.101	0	4367	672	1198	8770	124	68	36
2022	0.101	0.01	4753	676	1306	10,076	131	68	37
2023	0.101	0.01	5112	679	1406	11,482	137	69	37
2024	0.101	0.03	5444	681	1499	12,981	142	69	37
2025	0.101	0.05	5747	683	1583	14,564	147	69	37
2026	0.101	0.07	6024	685	1660	16,224	151	70	37
2027	0.101	0.09	6274	686	1729	17,953	155	70	37
2028	0.101	0.11	6499	687	1792	19,745	158	70	38
2029	0.101	0.14	6702	688	1848	21,594	161	70	38
2030	0.101	0.18	6882	689	1899	23,492	164	70	38
2031	0.101	0.21	7044	689	1943	25,435	166	70	38
2032	0.101	0.24	7187	690	1983	27,419	168	70	38
2033	0.101	0.26	7315	690	2019	29,437	170	70	38
2034	0.101	0.29	7428	691	2050	31,487	171	70	38
2035	0.101	0.33	7528	691	2078	33,565	172	71	38
2036	0.101	0.35	7617	691	2102	35,668	174	71	38
2037	0.101	0.37	7695	692	2124	37,792	175	71	38
2038	0.101	0.39	7764	692	2143	39,935	176	71	38
2039	0.101	0.41	7826	692	2160	42,096	176	71	38
2040	0.101	0.44	7879	692	2175	44,271	177	71	38
2041	0.101	0.46	7927	692	2189	46,460	178	71	38
2042	0.101	0.47	7969	692	2200	48,660	178	71	38
2043	0.101	0.48	8006	693	2211	50,871	179	71	38
2044	0.101	0.5	8039	693	2220	53,090	179	71	38
2045	0.101	0.51	8068	693	2228	55,318	180	71	38
2046	0.101	0.51	8093	693	2235	57,553	180	71	38
2047	0.101	0.51	8115	693	2241	59,794	180	71	38
2048	0.101	0.51	8135	693	2246	62,040	181	71	38
2049	0.101	0.51	8152	693	2251	64,291	181	71	38
2050	0.101	0.52	8168	693	2255	66,547	181	71	38

*Table 4.3. Red snapper: Projection results under scenario P2—fishing mortality rate F = 65%$F_{40\%}$, with very high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish*).* For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\mathrm{SSB}_{F_{40\%}} = 8102.5$ mt, $\mathrm{R}_{F_{40\%}} = 692,864$ fish, $\mathrm{Y}_{F_{40\%}} = 2,303,676$ lb, and $\mathrm{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	262	286	541	541	144	292	177
2008	1.22	0	290	367	759	1300	174	297	165
2009	0.974	0	225	385	579	1878	124	176	125
2010	0.068	0	242	339	51	1929	11	17	11
2011	0.068	0	525	352	87	2016	17	23	13
2012	0.068	0	787	485	135	2152	24	25	14
2013	0.068	0	1107	543	194	2346	31	30	17
2014	0.068	0	1492	583	264	2609	39	36	20
2015	0.068	0	1935	612	346	2955	48	40	22
2016	0.068	0	2421	633	437	3392	57	42	23
2017	0.068	0	2937	648	534	3926	65	44	24
2018	0.068	0	3467	658	633	4559	73	45	24
2019	0.068	0	3999	666	733	5292	80	46	25
2020	0.068	0.01	4524	672	831	6123	87	46	25
2021	0.068	0.01	5032	677	927	7050	93	47	25
2022	0.068	0.04	5518	680	1017	8067	99	47	25
2023	0.068	0.08	5977	683	1103	9170	104	48	25
2024	0.068	0.12	6408	686	1183	10,353	108	48	25
2025	0.068	0.18	6809	687	1258	11,611	112	48	26
2026	0.068	0.25	7179	689	1327	12,938	116	48	26
2027	0.068	0.33	7521	690	1390	14,328	119	48	26
2028	0.068	0.41	7833	691	1448	15,776	122	48	26
2029	0.068	0.49	8118	692	1501	17,278	125	48	26
2030	0.068	0.57	8377	693	1549	18,827	127	49	26
2031	0.068	0.64	8612	694	1593	20,420	129	49	26
2032	0.068	0.7	8824	694	1633	22,053	131	49	26
2033	0.068	0.75	9016	695	1668	23,721	133	49	26
2034	0.068	0.78	9189	695	1700	25,422	134	49	26
2035	0.068	0.81	9345	695	1729	27,151	136	49	26
2036	0.068	0.84	9486	696	1756	28,907	137	49	26
2037	0.068	0.86	9612	696	1779	30,686	138	49	26
2038	0.068	0.89	9726	696	1800	32,486	139	49	26
2039	0.068	0.91	9828	696	1819	34,305	140	49	26
2040	0.068	0.91	9919	697	1836	36,141	141	49	26
2041	0.068	0.91	10,002	697	1851	37,992	141	49	26
2042	0.068	0.93	10,075	697	1865	39,857	142	49	26
2043	0.068	0.94	10,142	697	1877	41,735	143	49	26
2044	0.068	0.94	10,201	697	1888	43,623	143	49	26
2045	0.068	0.94	10,254	697	1898	45,521	144	49	26
2046	0.068	0.95	10,302	697	1907	47,429	144	49	26
2047	0.068	0.96	10,345	697	1915	49,344	145	49	26
2048	0.068	0.95	10,384	697	1922	51,266	145	49	26
2049	0.068	0.96	10,418	697	1929	53,195	145	49	26
2050	0.068	0.97	10,449	697	1934	55,129	145	49	26

*Table 4.4. Red snapper: Projection results under scenario P3—fishing mortality rate $F = 75\%F_{40\%}$, with very high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish*)*. For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	262	286	541	541	144	292	177
2008	1.22	0	290	367	759	1300	174	297	165
2009	0.974	0	225	385	579	1878	124	176	125
2010	0.078	0	242	339	59	1937	13	20	12
2011	0.078	0	520	352	99	2036	19	26	14
2012	0.078	0	776	483	154	2190	27	29	17
2013	0.078	0	1086	541	219	2410	35	34	20
2014	0.078	0	1458	581	297	2706	44	41	23
2015	0.078	0	1884	610	388	3094	54	45	25
2016	0.078	0	2349	631	489	3583	64	48	26
2017	0.078	0	2840	646	595	4178	73	50	27
2018	0.078	0	3343	657	704	4882	82	51	28
2019	0.078	0	3845	665	812	5694	90	52	28
2020	0.078	0	4338	671	919	6613	97	53	28
2021	0.078	0.01	4813	675	1022	7635	104	54	29
2022	0.078	0.02	5265	679	1119	8754	110	54	29
2023	0.078	0.05	5690	682	1211	9965	115	54	29
2024	0.078	0.08	6087	684	1296	11,261	120	55	29
2025	0.078	0.12	6455	686	1375	12,636	124	55	29
2026	0.078	0.17	6793	688	1448	14,084	128	55	29
2027	0.078	0.22	7102	689	1514	15,598	131	55	29
2028	0.078	0.29	7384	690	1575	17,172	135	55	29
2029	0.078	0.35	7640	691	1629	18,802	137	55	29
2030	0.078	0.41	7871	692	1679	20,481	140	55	30
2031	0.078	0.47	8080	692	1724	22,204	142	55	30
2032	0.078	0.54	8268	693	1764	23,969	144	56	30
2033	0.078	0.59	8437	693	1800	25,769	146	56	30
2034	0.078	0.63	8588	694	1833	27,602	147	56	30
2035	0.078	0.68	8724	694	1862	29,464	149	56	30
2036	0.078	0.71	8845	694	1888	31,351	150	56	30
2037	0.078	0.74	8954	695	1911	33,263	151	56	30
2038	0.078	0.76	9051	695	1932	35,195	152	56	30
2039	0.078	0.79	9138	695	1951	37,145	153	56	30
2040	0.078	0.8	9216	695	1967	39,113	154	56	30
2041	0.078	0.81	9285	695	1982	41,095	154	56	30
2042	0.078	0.82	9347	696	1995	43,090	155	56	30
2043	0.078	0.83	9402	696	2007	45,097	156	56	30
2044	0.078	0.84	9451	696	2018	47,115	156	56	30
2045	0.078	0.85	9495	696	2027	49,142	157	56	30
2046	0.078	0.86	9534	696	2036	51,178	157	56	30
2047	0.078	0.88	9569	696	2043	53,221	157	56	30
2048	0.078	0.87	9600	696	2050	55,270	158	56	30
2049	0.078	0.87	9628	696	2056	57,326	158	56	30
2050	0.078	0.87	9652	696	2061	59,387	158	56	30

*Table 4.5. Red snapper: Projection results under scenario P4—fishing mortality rate F = 85%$F_{40\%}$, with very high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish*)*. For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	262	286	541	541	144	292	177
2008	1.22	0	290	367	759	1300	174	297	165
2009	0.974	0	225	385	579	1878	124	176	125
2010	0.088	0	242	339	66	1945	14	23	14
2011	0.088	0	516	352	111	2056	22	30	16
2012	0.088	0	764	482	172	2228	30	32	19
2013	0.088	0	1066	539	244	2472	39	38	23
2014	0.088	0	1425	579	328	2800	49	46	26
2015	0.088	0	1834	608	428	3228	60	51	28
2016	0.088	0	2279	629	537	3764	71	54	29
2017	0.088	0	2747	644	651	4416	81	56	30
2018	0.088	0	3223	655	768	5184	90	58	31
2019	0.088	0	3698	663	885	6069	99	59	32
2020	0.088	0	4161	669	998	7067	106	60	32
2021	0.088	0.01	4605	674	1107	8174	114	60	32
2022	0.088	0.01	5026	678	1210	9384	120	61	32
2023	0.088	0.03	5420	680	1306	10,690	126	61	33
2024	0.088	0.05	5786	683	1395	12,085	131	61	33
2025	0.088	0.08	6123	685	1477	13,562	135	62	33
2026	0.088	0.11	6431	686	1552	15,115	139	62	33
2027	0.088	0.15	6712	688	1621	16,735	143	62	33
2028	0.088	0.19	6967	689	1683	18,418	146	62	33
2029	0.088	0.25	7197	690	1738	20,156	149	62	33
2030	0.088	0.29	7403	690	1789	21,945	151	62	33
2031	0.088	0.35	7589	691	1834	23,779	153	62	33
2032	0.088	0.38	7755	691	1874	25,654	155	62	33
2033	0.088	0.43	7904	692	1910	27,564	157	62	33
2034	0.088	0.48	8037	692	1943	29,507	159	62	33
2035	0.088	0.52	8155	693	1971	31,478	160	62	33
2036	0.088	0.55	8260	693	1997	33,475	161	63	33
2037	0.088	0.58	8354	693	2020	35,495	163	63	33
2038	0.088	0.6	8437	693	2040	37,535	164	63	33
2039	0.088	0.63	8511	694	2058	39,593	164	63	33
2040	0.088	0.65	8577	694	2074	41,667	165	63	33
2041	0.088	0.67	8635	694	2088	43,755	166	63	33
2042	0.088	0.68	8687	694	2101	45,856	166	63	33
2043	0.088	0.69	8733	694	2112	47,967	167	63	33
2044	0.088	0.7	8774	694	2122	50,089	167	63	33
2045	0.088	0.71	8810	694	2131	52,220	168	63	33
2046	0.088	0.72	8842	695	2138	54,358	168	63	33
2047	0.088	0.73	8871	695	2145	56,504	169	63	33
2048	0.088	0.73	8896	695	2151	58,655	169	63	33
2049	0.088	0.74	8918	695	2157	60,812	169	63	33
2050	0.088	0.74	8938	695	2162	62,974	169	63	33

*Table 4.6. Red snapper: Projection results under scenario P5—fishing mortality rate $F = F_{40\%}$, with very high 2006 recruitment. F = fishing mortality rate (per year), Pr(recover) = proportion of replicates reaching $SSB_{F_{40\%}}$, SSB = mid-year spawning biomass (*mt*), R = recruits (1000 fish), L = landings (1000* lb *whole weight or fish), Sum L = cumulative landings (1000* lb*), and D = discard mortalities (1000* lb or fish*).* For reference, estimated proxy reference points are $F_{40\%} = 0.104$, $\text{SSB}_{F_{40\%}} = 8102.5$ mt, $\text{R}_{F_{40\%}} = 692,864$ fish, $\text{Y}_{F_{40\%}} = 2,303,676$ lb, and $\text{D}_{F_{40\%}} = 72,717$ lb.

Year	F	Pr(recover)	SSB(mt)	R(1000)	L(1000 lb)	Sum L(1000 lb)	L(1000)	D(1000 lb)	D(1000)
2007	0.93	0	262	286	541	541	144	292	177
2008	1.22	0	290	367	759	1300	174	297	165
2009	0.974	0	225	385	579	1878	124	176	125
2010	0.104	0	242	339	78	1956	17	27	16
2011	0.104	0	509	352	129	2085	25	35	19
2012	0.104	0	748	480	198	2283	35	37	22
2013	0.104	0	1036	536	278	2561	45	44	26
2014	0.104	0	1376	576	373	2934	56	53	30
2015	0.104	0	1762	605	483	3417	68	59	32
2016	0.104	0	2178	626	603	4019	80	62	34
2017	0.104	0	2613	641	728	4747	91	65	35
2018	0.104	0	3053	652	855	5602	101	67	36
2019	0.104	0	3488	660	981	6583	111	68	37
2020	0.104	0	3910	667	1102	7685	119	69	37
2021	0.104	0	4312	671	1218	8903	127	70	37
2022	0.104	0.01	4690	675	1327	10,230	134	70	38
2023	0.104	0.01	5042	678	1428	11,658	140	71	38
2024	0.104	0.02	5366	681	1521	13,178	145	71	38
2025	0.104	0.04	5662	683	1606	14,784	150	71	38
2026	0.104	0.06	5931	684	1683	16,467	154	72	38
2027	0.104	0.08	6175	685	1752	18,219	158	72	38
2028	0.104	0.1	6394	686	1815	20,034	161	72	39
2029	0.104	0.12	6590	687	1871	21,905	164	72	39
2030	0.104	0.15	6765	688	1921	23,826	166	72	39
2031	0.104	0.18	6921	689	1966	25,792	169	72	39
2032	0.104	0.21	7060	689	2006	27,798	171	72	39
2033	0.104	0.23	7183	690	2041	29,839	172	72	39
2034	0.104	0.26	7292	690	2072	31,911	174	72	39
2035	0.104	0.28	7388	691	2099	34,010	175	72	39
2036	0.104	0.31	7473	691	2124	36,134	176	72	39
2037	0.104	0.33	7549	691	2145	38,279	177	72	39
2038	0.104	0.34	7615	691	2164	40,444	178	73	39
2039	0.104	0.36	7673	692	2181	42,625	179	73	39
2040	0.104	0.38	7725	692	2196	44,820	180	73	39
2041	0.104	0.41	7770	692	2209	47,029	180	73	39
2042	0.104	0.42	7810	692	2220	49,249	181	73	39
2043	0.104	0.43	7845	692	2230	51,479	181	73	39
2044	0.104	0.44	7876	692	2239	53,718	182	73	39
2045	0.104	0.45	7904	692	2247	55,965	182	73	39
2046	0.104	0.46	7928	692	2254	58,218	183	73	39
2047	0.104	0.46	7949	692	2260	60,478	183	73	39
2048	0.104	0.46	7967	692	2265	62,743	183	73	39
2049	0.104	0.45	7984	693	2270	65,013	183	73	39
2050	0.104	0.45	7998	693	2274	67,287	184	73	39

5 Figures

Figure 5.1. Projection results under scenarios with fishing mortality rate fixed at $F = F_{\text{rebuild}}$. For reference, the proxy reference point used to define stock recovery is $\text{SSB}_{\text{MSY}} = 8102.5$ mt, which corresponds to a yield of about 2.3 million lb.

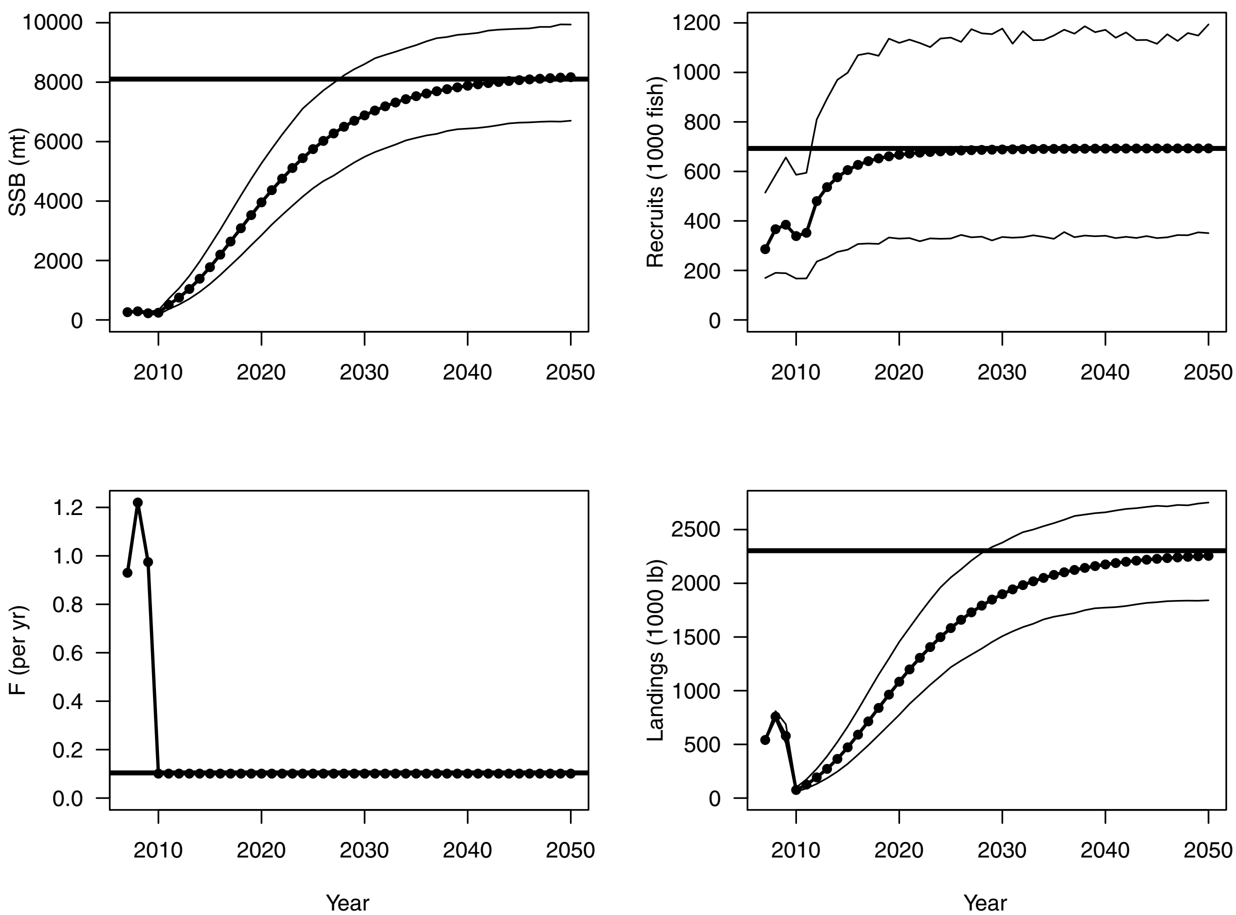


Figure 5.2. Projection results under scenarios with fishing mortality rate fixed at $F = 0.65F_{40\%}$. For reference, the proxy reference point used to define stock recovery is $\mathrm{SSB}_{\mathrm{MSY}} = 8102.5$ mt, which corresponds to a yield of about 2.3 million lb.

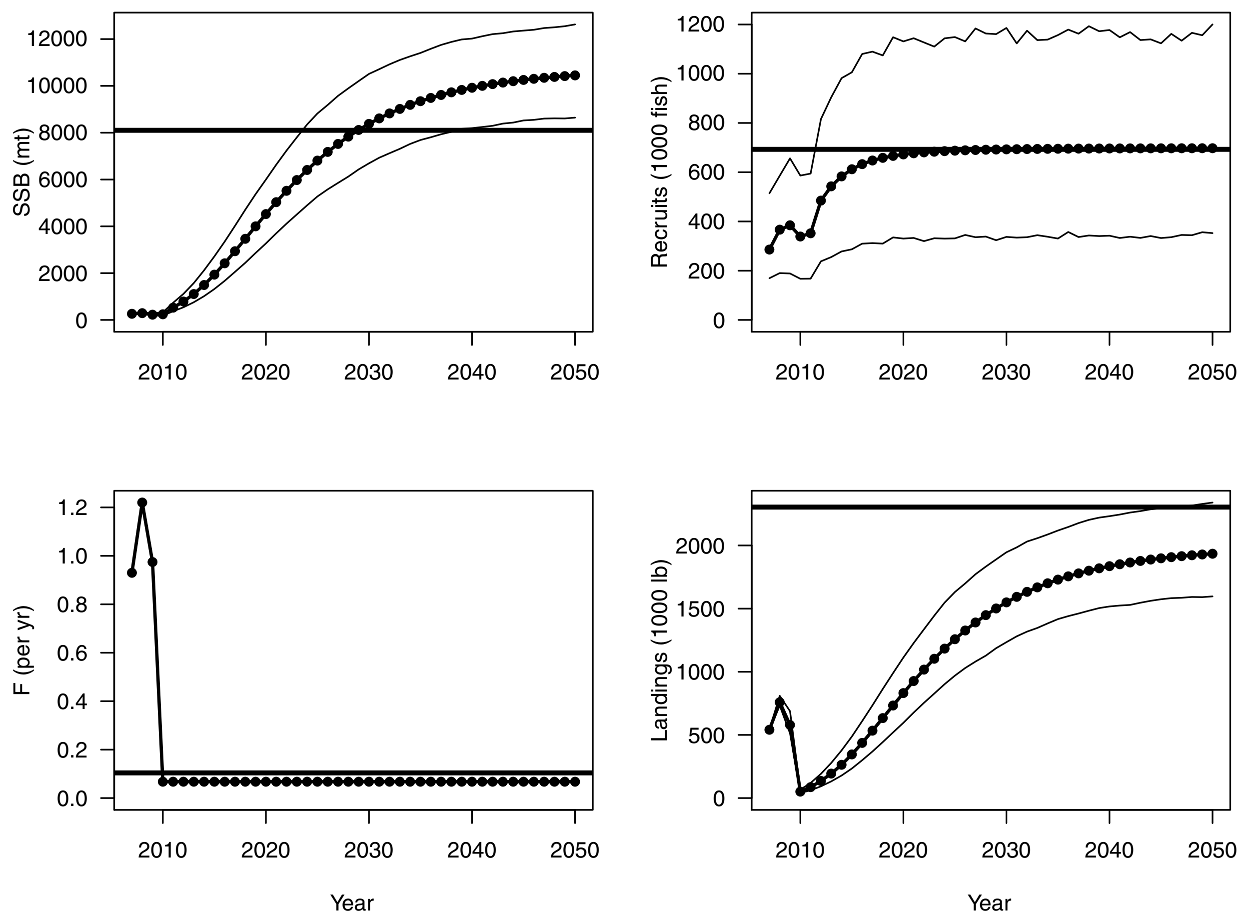


Figure 5.3. Projection results under scenarios with fishing mortality rate fixed at $F = 0.75F_{40\%}$*. For reference, the proxy reference point used to define stock recovery is* $\mathrm{SSB}_{\mathrm{MSY}} = 8102.5$ *mt, which corresponds to a yield of about 2.3 million lb.*

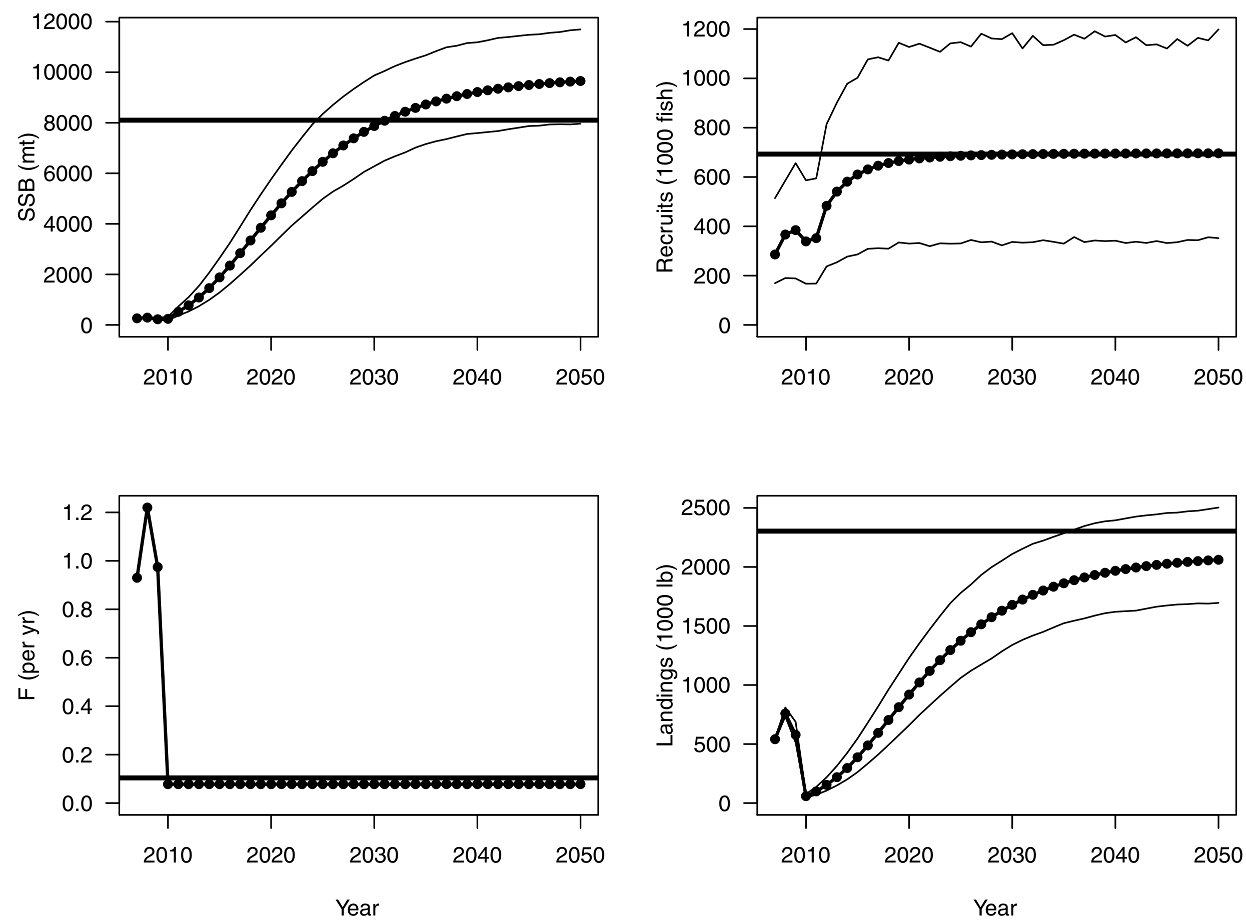


Figure 5.4. Projection results under scenarios with fishing mortality rate fixed at $F = 0.85F_{40\%}$. *For reference, the proxy reference point used to define stock recovery is* $\mathrm{SSB_{MSY}} = 8102.5$ *mt, which corresponds to a yield of about 2.3 million lb.*

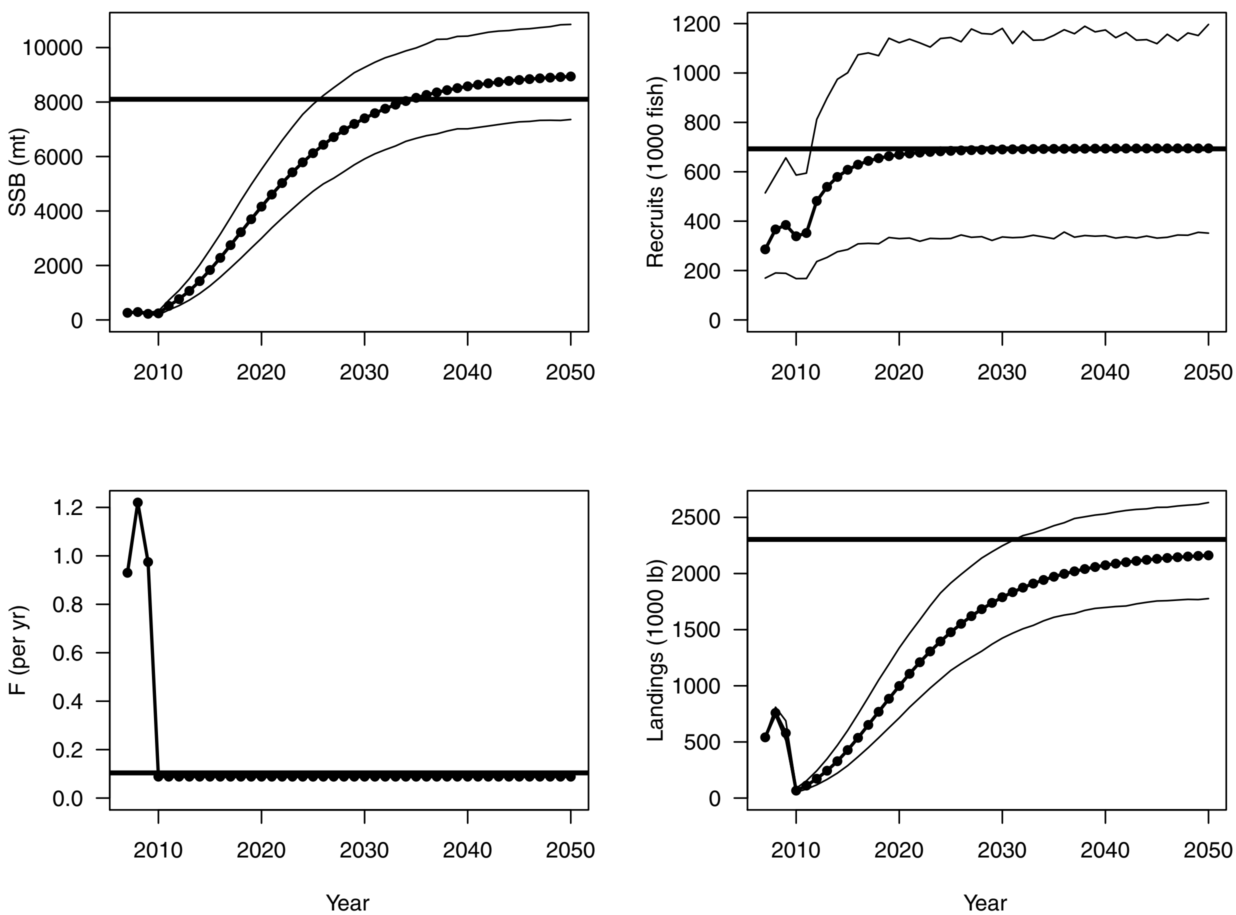
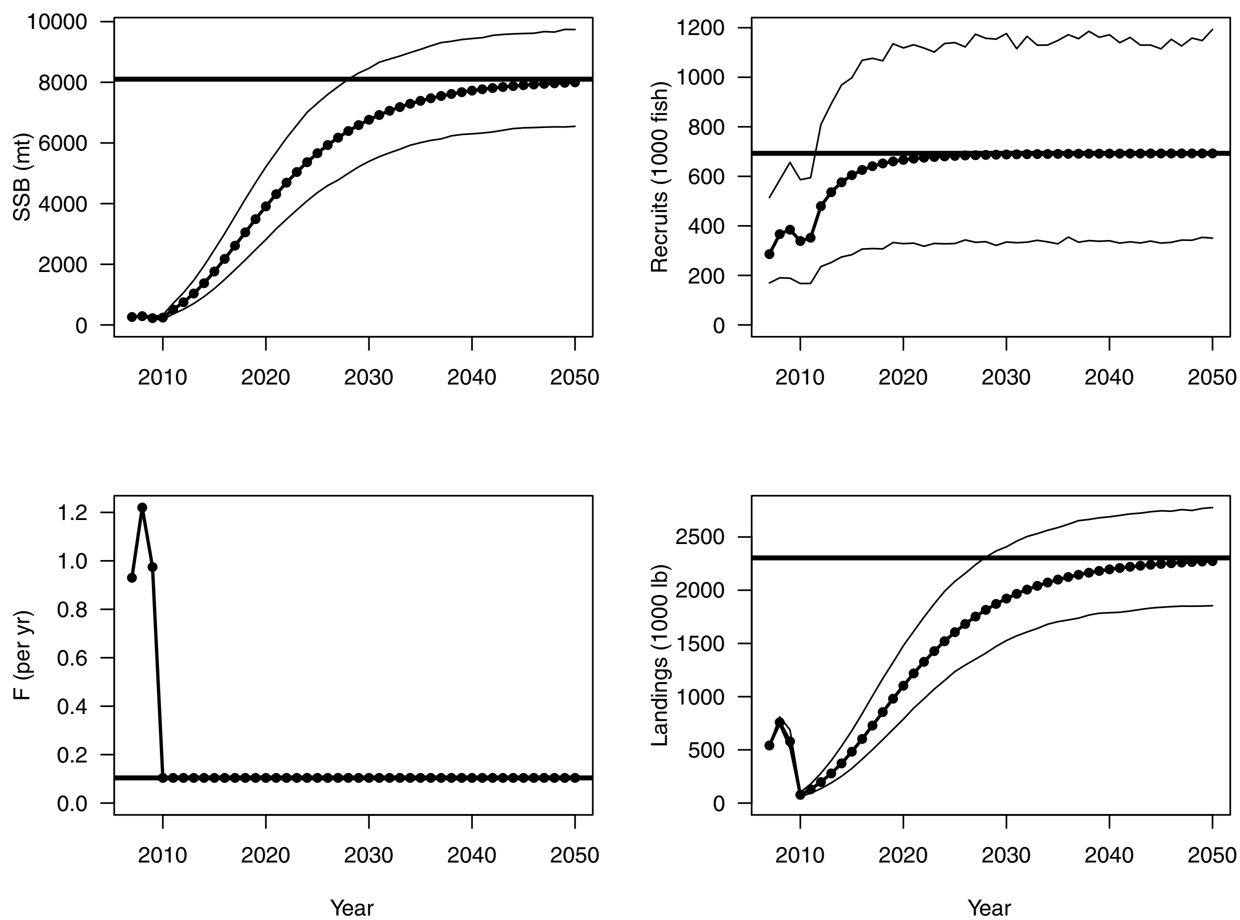
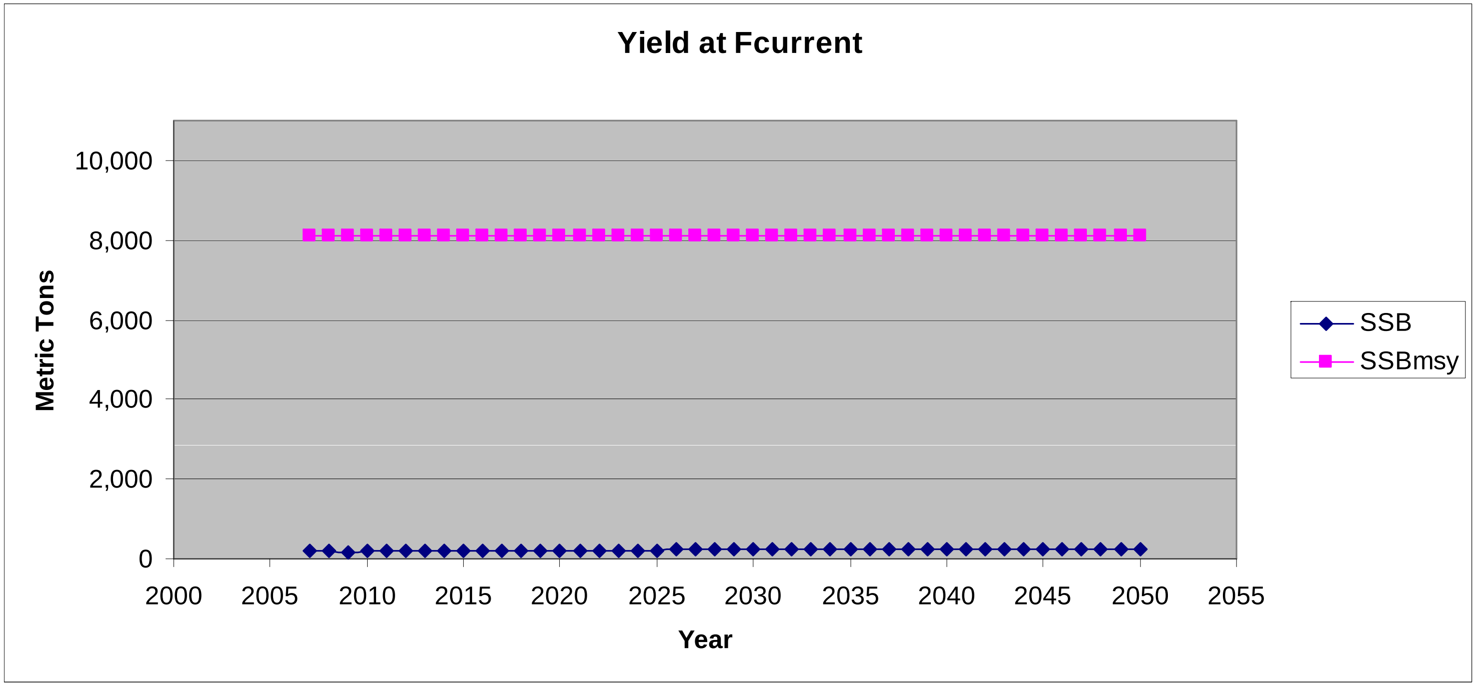
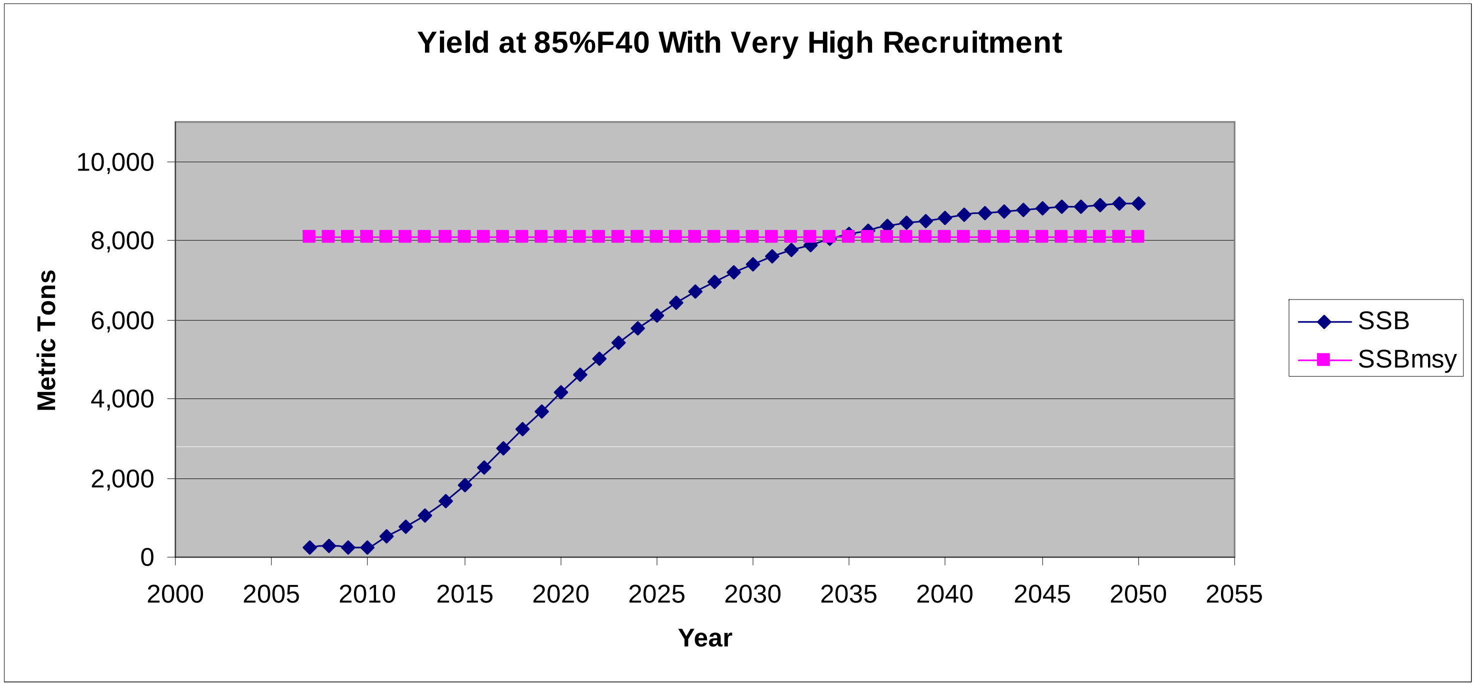


Figure 5.5. Projection results under scenarios with fishing mortality rate fixed at F = $F_{40\%}$. For reference, the proxy reference point used to define stock recovery is $SSB_{MSY} = 8102.5$ *mt, which corresponds to a yield of about 2.3 million lb.*

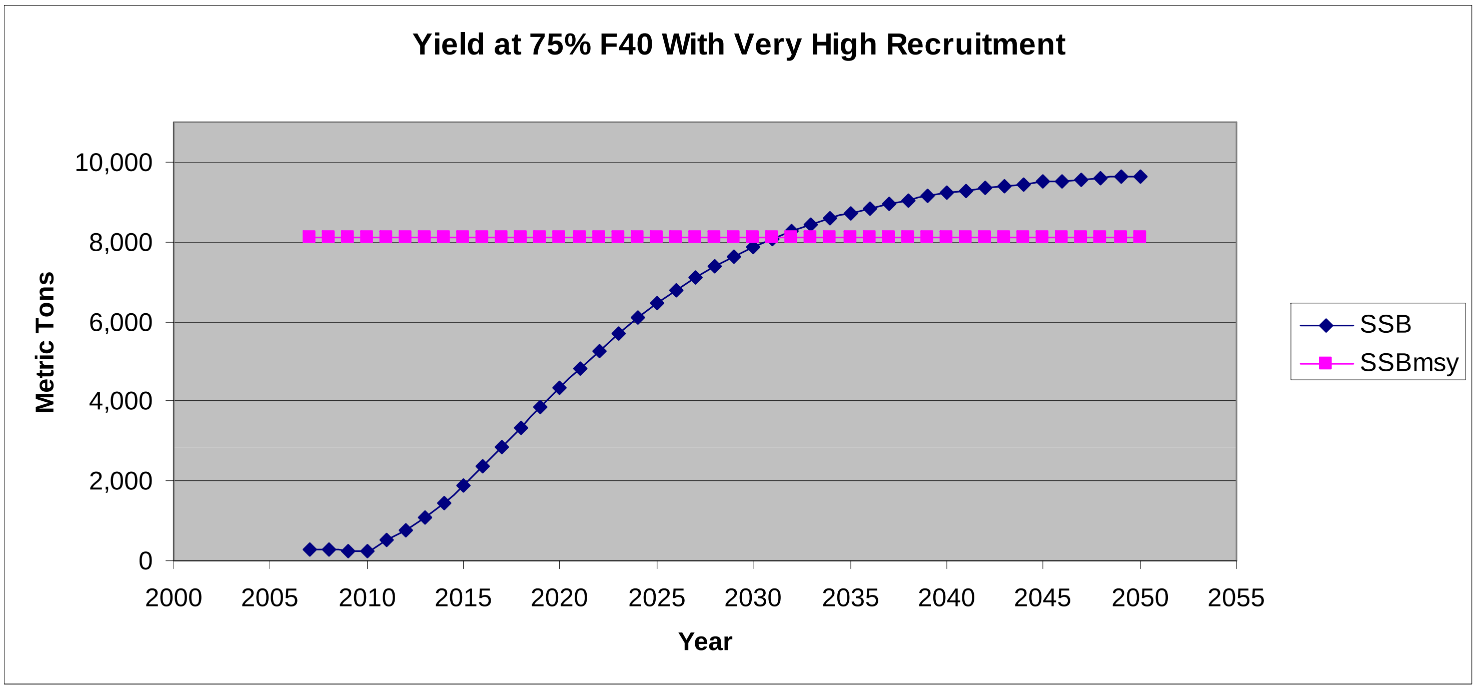


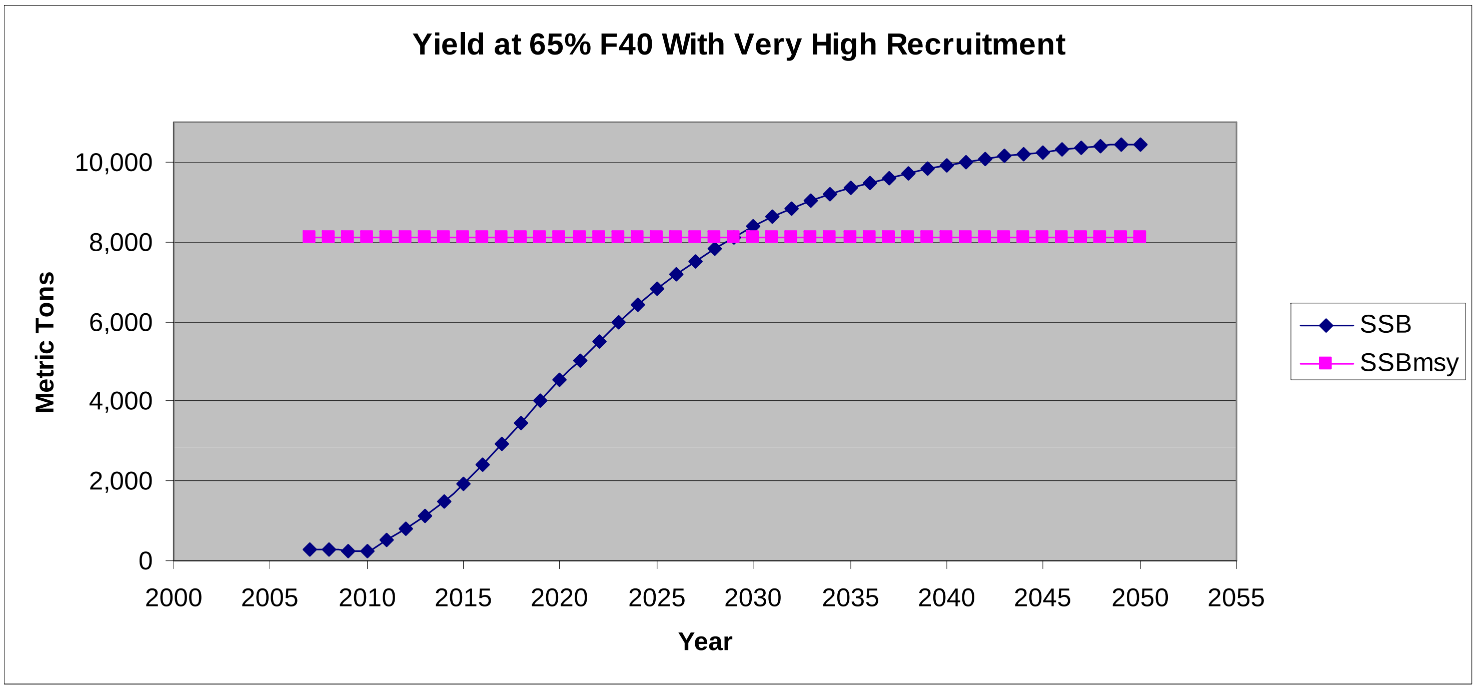


Yield at Fcurrent
Metric Tons
10,000
8,000
6,000
4,000
2,000
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
Year
SSB
SSBmsy

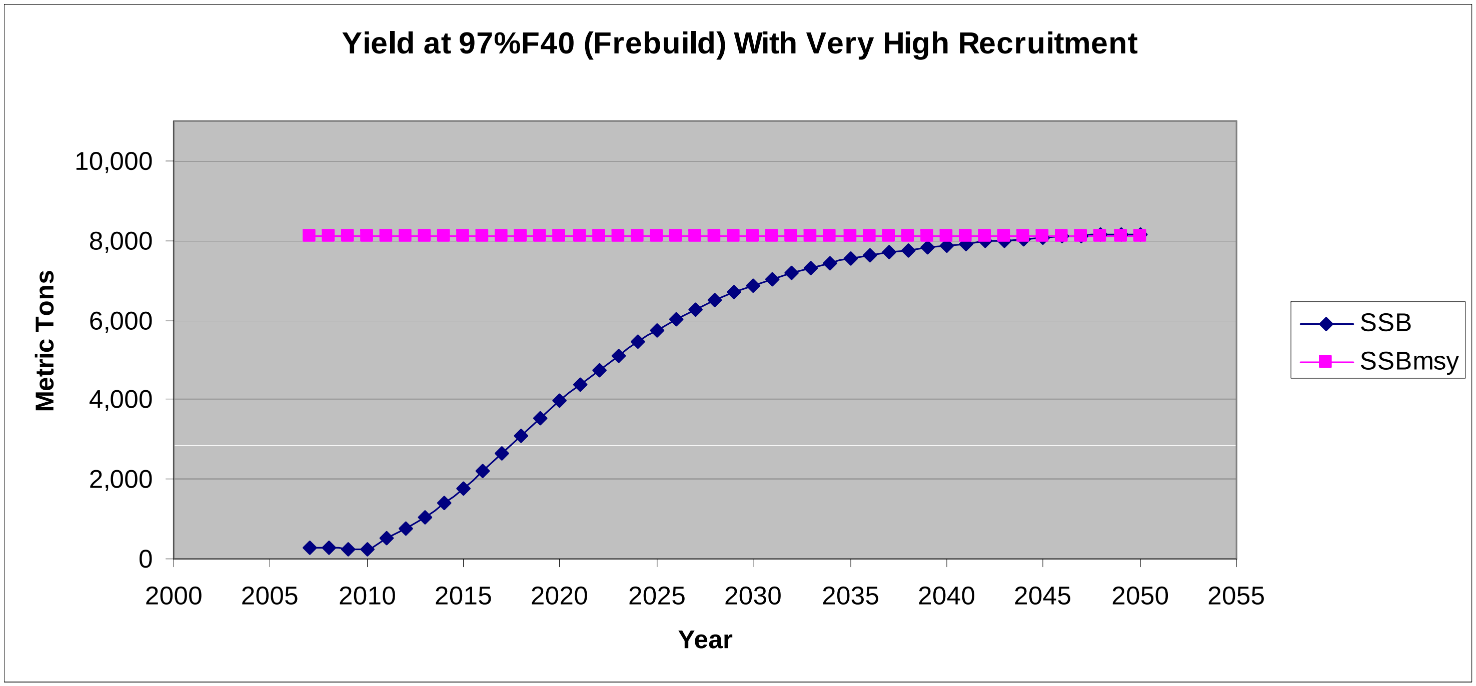


Yield at 85%F40 With Very High Recruitment
Metric Tons
10,000
8,000
6,000
4,000
2,000
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
Year
SSB
SSBmsy


Yield at 75% F40 With Very High Recruitment
Metric Tons
10,000
8,000
6,000
4,000
2,000
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
Year
SSB
SSBmsy



Yield at 65% F40 With Very High Recruitment
Metric Tons
10,000
8,000
6,000
4,000
2,000
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
Year
SSB
SSBmsy


Yield at 97%F40 (Frebuild) With Very High Recruitment
Metric Tons
10,000
8,000
6,000
4,000
2,000
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
Year
SSB
SSBmsy

Reduction in total removals (landings plus dead discards) needed end overfishing. Non-shaded areas determined by comparing actual landings from 2005-2007 with allowable removals in 2010. Shaded areas are estimated by interpolation.

Fmsy proxy	F40% proxy				F30% proxy			
Recruitment	Base Estimated	High	Very High	Extremely High	Base Estimated	High	Very High	Extremely High
Alternative 2 (FMSY)	86%	86%	83%	81%	81%	80%	78%	76%
Alternative 3 (85% FMSY)	89%	88%	85%	83%	84%	83%	81%	79%
Alternative 4 (75% FMSY)	90%	89%	87%	85%	86%	85%	83%	81%
Alternative 5 (65% FMSY)	91%	90%	89%	86%	88%	87%	85%	83%
Alternative 6 (Frebuild)	87%	86%	83%	82%	82%	81%	79%	77%

Total removals (landings in thousands of pounds plus dead discards) needed end overfishing. Shaded areas are estimated by interpolation.

Fmsy proxy	F40% proxy				F30% proxy			
Recruitment	Base Estimated	High	Very High	Extremely High	Base Estimated	High	Very High	Extremely High
Alternative 2 (FMSY)	82	87	105	124	114	121	148	172
Alternative 3 (85% FMSY)	69	74	89	104	97	103	126	146
Alternative 4 (75% FMSY)	61	65	79	92	86	92	111	130
Alternative 5 (65% FMSY)	54	58	68	81	75	80	97	113
Alternative 6 (Frebuild)	78	83	101	118	108	116	140	164

UNITED STATES DEPARTMENT OF COMMERCE
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National Marine Fisheries Service
Southeast Fisheries Science Center
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(305) 361-4200 Fax: (305) 361-4499

August 13, 2009 F/SEC2: TJ

MEMORANDUM TO: Roy E. Crabtree, Ph.D.
Regional Administrator, Southeast Regional Office

FROM: Bonnie Ponwith, Ph.D. Theo R. Brainerd
Science Director, Southeast Fisheries Science Center

SUBJECT: SEFSC Revised Report on Red Snapper in the U.S. Atlantic: Sensitivity Analyses Using Dome-Shaped Selectivity for Recreational Sectors

As per request by the South Atlantic Fishery Management Council (SAFMC) and the NMFS Southeast Regional Office (SERO), the Southeast Fisheries Science Center (SEFSC) completed a sensitivity analyses on Dr. Frank Hester's query. These analyses were contained in the earlier SEFSC memo to SERO dated August 5, 2009.

The SEFSC submits the following revised report containing the results of the sensitivity analyses to the Southeast Regional Office for transmission to the SAFMC:

- ***Red Snapper in the U.S. Atlantic: Sensitivity analyses using dome-shaped selectivity for recreational sectors (12 August 2009).***

Please contact Erik Williams (erik.williams@noaa.gov) if you have any questions.

Encl.

CC: F/SEC - Theo Brainerd
F/SEC - Peter Thompson
F/SEC - Tom Jamir
F/SEC - Sophia Howard
F/SER - Heather Blough
F/SER - Jack McGovern

Red snapper in the U.S. Atlantic: Sensitivity analyses using dome-shaped selectivity for recreational sectors

Prepared by Southeast Fisheries Science Center
12 August 2009

1 Executive summary

Although the SEDAR-15 red snapper stock assessment for the U.S. South Atlantic has been through exhaustive review, concern remains within the fishing community. Dr. Frank Hester, a consultant hired by the fishing industry, conducted his own review of the stock assessment and issued his report on May 8, 2009. Most of Dr. Hester's concerns have already been addressed by the South Atlantic Fishery Management Council or by previous work conducted through the SEDAR process. For example, Dr. Hester questioned the use of historical Fish and Wildlife Service (FWS) recreational catch data. Those data were already considered by SEDAR to be a source of uncertainty, and sensitivity analyses had previously addressed the issue: Assessment results are qualitatively insensitive to those historical FWS recreational catch data. The primary subject of this report is the effect of a dome-shaped selectivity curve for the recreational sector, as hypothesized by Dr. Hester. Here, three additional sensitivity runs were conducted using various combinations of estimated dome-shaped selectivity curves and a curve proposed by Dr. Hester in his report. Dr. Hester's selectivity curve assumes no fish over age 10 are caught in the fishery, an assertion that is demonstrated here to be incorrect (samples of recreational catches do include fish over 10 years old, including a 50 and 53 year old fish). More realistic dome-shaped selectivity curves yield results very similar to the base stock assessment model run. Nonetheless, the nature of the fisheries and analyses in this report do not support the use of a dome-shaped selectivity function for commercial handline or recreational sectors. Nearly forty different sensitivity analyses of the red snapper model have been conducted, and although results vary quantitatively, they are all in strong qualitative agreement pointing to a stock that is depleted and experiencing overfishing. This red snapper stock demonstrates hallmarks of stock depletion: truncated age structure and constricted spatial range.

2 Background

The SEDAR-15 stock assessment of red snapper in the U.S. Atlantic has been through exhaustive review, first by internationally esteemed independent experts within the SEDAR process, and then through multiple reviews conducted by scientists of the South Atlantic Fishery Management Council's own Scientific and Statistical Committee. Following those scientific reviews, the Southeastern Fisheries Association, Inc. hired a consultant, Dr. Frank Hester, to conduct a review on behalf of the fishing industry. In his report dated 8 May 2009, Dr. Hester raised several questions about the stock assessment. The Council has already addressed those questions in a previous document (attached here as an Appendix). One question left unanswered, however, was whether selectivity of recreational sectors might have been dome-shaped (i.e., excluded older fish) rather than flat-topped (i.e., included older fish, as in the SEDAR assessment). This report explores such an assumption for its effects on assessment results.

3 Sensitivity analyses

In his report, Dr. Hester guessed at a possible shape of recreational dome-shaped selectivity (reproduced in Fig. 6.1—top panel). Here, the hypothesis of dome-shaped selectivity was applied to the red snapper assessment in three different ways. In the first application, Dr. Hester's assumed shape was applied to both headboat and general recreational fishing throughout the entire assessment time frame (1945-2006). In the second application, his assumed shape was applied to both headboat and general recreational fishing in the early time period (1945-1983), and in later periods (1984-1991 and 1992-2006), dome-shaped selectivities were estimated (separately for each period). The third application was similar to the second, but differed by applying the estimated selectivity of the middle time period to the early time period, rather than applying Dr. Hester's assumed shape. The three different approaches are labeled S37, S38, S39 (36 sensitivity analyses have been conducted previously as part of the assessment and review workshops):

- S37: Hypothesized dome-shaped selectivity (Fig. 6.1—top panel) applied to headboat and general recreational sectors throughout the entire assessment time frame.
- S38: Hypothesized dome-shaped selectivity (Fig. 6.1—top panel) applied to headboat and general recreational sectors in the early time period, and estimated dome-shaped selectivities used in subsequent periods.
- S39: Estimated dome-shaped selectivities (Fig. 6.1-bottom panel) applied to headboat and general recreational sectors throughout the full assessment time frame.

Initial runs of these analyses fitted the age and length composition data poorly. Thus, the likelihood weighting on those components were increased by a factor of ten (relative to the weights used in the base assessment) to give these hypotheses a chance to achieve reasonable fits to data. Weights on other data components (e.g., landings, CPUE) remained the same.

For each sensitivity run, management benchmarks were based on the proxy of $F_{40\%}$. The equilibrium spawning biomass and yield corresponding to $F_{40\%}$ were computed through long-term projections.

4 Results

As expected, sensitivity runs with dome-shaped recreational selectivities estimated somewhat different time series of fishing rate and spawning biomass than those of the base assessment model (Fig. 6.2). In the early years, sensitivity runs had higher estimates of full fishing mortality rates, and different absolute levels of spawning biomass (although similar trends). However, since about 1980, estimates of full F have been similar among the four models (base, S37, S38, and S39), as have been estimates of spawning biomass.

Management benchmarks differed among the four models (Table 6.1). This result is expected, because benchmarks are conditional on selectivity. However, stock and fishery status in the terminal assessment year were qualitatively the same across these models and other sensitivity runs: the stock is experiencing overfishing and is depleted relative to the benchmark level (Fig. 6.3).

5 Discussion

5.1 Sensitivity runs using dome-shaped selectivity

Of the three sensitivity runs described in this report, S37 (which applies Dr. Hester's selectivity) is the most questionable, for at least three reasons. First, S37 does not account for changes in size limits. Second, one cannot reliably guess the shape of selectivity simply by visual inspection of data (as Dr. Hester attempted), for reasons detailed in the subsequent section §5.2. Third, Dr. Hester's assumed selectivity does not include fish older than age 10 (Fig. 6.1—top panel), which is demonstrably wrong (Fig. 6.4). Runs S38 and S39 do not suffer from those same problems, and their results were quite similar to those of the base run.

Although S38 and S39 are clearly preferable to S37, all three should be viewed with strong skepticism. By objective criteria (discussed in subsequent sections), the assumption of dome-shaped selectivity for red snapper in the Atlantic does not appear to be realistic. Evidence suggests flat-topped selectivity, and therefore sensitivity runs using dome-shaped selectivity (S37, S38, S39) do not deserve equal footing as other sensitivity runs (although results were qualitatively the same).

5.2 Selectivity (general)

The commonly used term "selectivity" in stock assessment modeling refers to an age-specific (or length-specific) schedule composed of spatial/temporal availability and fishing gear selectivity. The concepts of availability and selectivity should not be confused with vulnerability and catchability, which relate primarily to a unit of effort. Because selectivity includes both gear characteristics and population availability components, it unfortunately cannot be surmised simply by visual inspection of catch-at-age or average-weight data. In many fisheries around the world, the tendency is to target the largest and oldest individuals, simply because they tend to be more valuable. Red snapper is one of the U.S. South Atlantic's more valuable snapper-grouper species.

When modeling selectivity, stock assessments tend to use functional curves to describe selectivity-at-age. One reason for doing this is to use fewer parameters in the model, thus increasing the statistical degrees of freedom. Often a model can achieve the same fit to the data with fewer parameters being estimated, a property referred to as parsimony.

Stock assessment models used in the U.S. South Atlantic have primarily used one of two functional forms for selectivity-at-age, the logistic and double-logistic equations. The two-parameter logistic function results in a flat-topped selectivity curve and assumes that the oldest and largest fish are fully available to the fishery. The four parameter double-logistic function can assume either a flat-topped or dome-shaped selection curve. A dome-shaped curve implies that the oldest and largest fish are not fully available to the fishery. Dome-shaped selectivity can result from factors such as 1) the oldest fish move to areas that are not fished, 2) fish outgrow the gear being used for capture, or 3) regulations inhibit the ability to capture the oldest fish.

The primary data that stock assessment models draw upon for the estimation of selectivity are the age and length composition data from the fishery. The slope of the decline of the oldest or largest fish in the age and length composition data is a function of both mortality and age-specific selectivity. Separating mortality and selectivity can be difficult, especially when dome-shaped selectivity is suspected in a given fishery. Fortunately, for most fisheries, there is at least one sector that tends to target the oldest largest fish (flat-topped selectivity). The establishment of at least one sector as having flat-topped selectivity tends to anchor the other sectors, enabling the estimation of dome-shaped selectivity functions. If a fishery is suspected of being composed entirely of dome-shaped selectivity functions, the estimation can be difficult and often gets confounded with mortality estimates.

5.3 Selectivity (red snapper)

It has been demonstrated for some snapper-grouper species in the U.S. South Atlantic that older larger individuals tend to occur in deeper water, although the patterns differ across species. For example, in the case of red grouper, the pattern suggests that shallower waters contain both big and small fish, and that as depth increases the smaller fish disappear. In this case the largest fish are available across both shallow and deep depths. For many species, relationships between size and depth are weak or nonexistent. Unfortunately, the U.S. South Atlantic has very little depth or detailed spatial data to definitively describe depth-size relationships for our snapper-grouper species. To complicate the issue, seasonal shifts in species distributions can occur as well. Anecdotal reports from fishermen off the coast of northeast Florida have suggested that the largest red snapper tend to move inshore during June–September to depths as shallow as 60–90 feet. Such a pattern of seasonal shift would support using a flat-topped selectivity curve.

Commercial fishermen often have economic incentive to catch large fish, and thus if possible, will rationally do so. Indeed, evidence suggests that the commercial sector does fish in depths and areas where the oldest and largest red snapper exist. For example, vessels with bandit rigs, a type of hook-and-line gear, fish in depths that are likely beyond where red snapper occur (e.g., when fishing for snowy grouper and tilefish). This strongly suggests that the full depth range is covered by commercial vessels. Furthermore, in areas off northeast Florida where red snapper are most abundant, the shelf edge is relatively close to shore, suggesting that travel distance is not likely an impediment to fishing in the deeper waters for large red snapper. It is difficult to imagine a plausible scenario in which selectivity for the commercial handline fishery is anything but flat-topped. (However, for the commercial diving sector, the SEDAR-15 red snapper stock assessment did assume a dome-shaped selectivity function; the clear reason being that divers are depth limited.)

In the recreational fishery the sectors include private/shore fishermen, charter boats, and headboats. These recreational sectors can fish quite differently in some cases. The charter and headboats tend to fish snapper-grouper species in similar areas, using similar gear. A common pattern for charter boats in the Carolinas is to troll in the Gulf Stream for pelagic species and then bottomfish for snapper-grouper species. In those cases, the vessels are fishing deep enough depths where the largest red snapper are likely to occur. Headboats may be constrained in the distance they can travel offshore because they are typically slower and may only fish half-day trips. Unfortunately, the ability to know fishing locations is lacking in the U.S. South Atlantic. The implementation of Vessel Monitoring Systems (VMS), as applied in other regions of the United States, would help resolve such data needs.

Although precise data on fishing locations are unavailable, it is possible to explore the hypothesis of dome-shaped selectivity by comparing age composition data from different sectors. In the case of red snapper, recreational age composition data can be compared to those of the commercial handline fishery, which is believed to have flat-topped selectivity (for reasons described above). For evidence of dome-shaped selectivity in the recreational sector, one should expect the descending limbs of recreational age compositions to decline more quickly than those of the commercial sector. For red snapper in the U.S. South Atlantic, no such evidence exists (Figs. 6.4, 6.5), which supports using flat-topped selectivity for the recreational sector.

5.4 Early recreational landings

The base assessment model used recreational landings from the U.S. Fish and Wildlife Service (FWS) Salt-Water Angling Reports. As explained in the Council's response (Appendix of this report) to Dr. Hester's questions, those survey landings were used because 1) the surveys collected legitimate data, 2) they were preferable to any available alternatives (e.g., linear interpolation), and 3) they improved the model by helping to explain the already reduced population when age/size sampling began. Furthermore, angling effort in those surveys was corroborated by other data. Nonetheless, the FWS surveys were considered to be a source of uncertainty, and consequently several sensitivity analyses were run to address this issue (Runs S0, S7, S8, S32 and S33 in Table 6.1). Although use of FWS landings provided better fidelity to other data sources (age/length compositions), the qualitative results of current stock status were insensitive to the early recreational landings.

5.5 Stock status

In addition to applying multiple models, nearly forty different sensitivity analyses of the base model have been conducted on the red snapper assessment (as part of the assessment workshop, as part of the review workshop, and now in response to Dr. Hester's report). Although results vary quantitatively among the multiple assessment models and nearly forty sensitivity analyses, results are all in strong qualitative agreement. The base model and each sensitivity run show that overfishing is occurring and the red snapper stock is depleted to levels much lower than the spawning biomass benchmark (Table 6.1, Fig. 6.3).

The overfished status is consistent with two strong lines of evidence. First, red snapper can live more than 50 years, yet fish older than 10 years are rarely caught by fishermen. Such a severely truncated age structure typically signals that the exploitation rate does not allow many fish to reach older ages. Although some large fish are caught, they are not necessarily old fish, because of the variability of size at age. Second, red snapper were once abundant along the southeast U.S. coast, but now are primarily caught off northeast Florida, apparently the center of this stock's range. Relative to earlier decades, few red snapper are now caught, for example, off North Carolina's coast. The constriction of a fish population's range typically signals reduced abundance.

6 Tables and Figures

Table 6.1. Results from sensitivity runs of the red snapper catch-age assessment model. Runs S0–S31 were previously reported in the original Assessment Workshop Report (Table 3.13; S0 was then called base). Runs S32–S36 were previously reported in the Review Workshop Report (Table 2). Runs S37–S39 are new, described in this report. Note that S37–S39, as well as the base model, use $F_{40\%}$ proxies for MSY-based reference points.

Run	Description	F_{MSY}	SSB_{MSY} (mt)	MSY (1000 lb)	F_{2006}/F_{MSY}	SSB_{2006}/SSB_{MSY}	steep	R0(1000)
Base	—	0.104	8103	2304	7.67	0.02	0.95	638
S0	Recr L transposed	0.112	5184	2319	7.51	0.04	0.95	605
S1	Low M	0.097	6112	1977	10.36	0.03	0.95	377
S2	High M	0.112	5089	2362	7.25	0.04	0.95	673
S3	q slope 0.0	0.111	5304	2226	5.72	0.05	0.95	603
S4	q slope 0.04	0.107	5174	2355	9.20	0.03	0.95	606
S5	Rec dev 1972	0.106	5203	2299	7.82	0.04	0.95	608
S6	Rec dev 1976	0.106	5209	2302	7.79	0.04	0.95	602
S7	Low early recr L	0.143	1729	559	11.09	0.11	0.95	152
S8	Bias early recr L	0.104	9024	3927	7.72	0.02	0.94	1034
S9	Comm D mort 0.7	0.105	5180	2316	7.72	0.04	0.95	603
S10	Comm D mort 0.8	0.106	5186	2302	7.70	0.04	0.95	604
S11	Comm D mort 1.0	0.106	5238	2289	7.79	0.04	0.95	606
S12	Recr D mort 0.2	0.115	4978	2424	6.01	0.04	0.95	601
S13	Recr D mort 0.6	0.113	5417	2176	8.51	0.04	0.95	607
S14	D sel age 1 0.25	0.113	5201	2295	7.94	0.04	0.95	605
S15	D sel age 1 0.75	0.128	5157	2381	6.65	0.04	0.95	605
S16	steep=0.8	0.131	7648	2056	9.59	0.03	0.80	562
S17	steep=0.6	0.118	10554	1624	7.09	0.05	0.60	441
S18	Retro 2005	0.107	4812	2107	7.74	0.04	0.95	559
S19	Retro 2004	0.106	4936	2150	7.80	0.04	0.95	569
S20	Retro 2003	0.106	5020	2194	7.78	0.04	0.95	581
S21	Retro 2002	0.106	5109	2241	7.76	0.04	0.95	592
S22	Retro 2001	0.105	5367	2333	7.82	0.04	0.95	619
S23	B1/K=0.95	0.105	5463	2401	7.79	0.04	0.95	633
S24	B1/K=0.90	0.109	5588	2492	7.64	0.03	0.95	649
S25	B1/K=0.85	0.105	5706	2528	7.75	0.03	0.95	664
S26	B1/K=0.80	0.105	5851	2600	7.74	0.03	0.95	682
S27	B1/K=0.70	0.104	5211	2326	7.34	0.05	0.95	606
S28	B1/K=0.65	0.106	5197	2325	8.05	0.05	0.95	605
S29	B1/K=0.60	0.132	5070	2415	8.23	0.04	0.95	604
S30	B1/K=0.55	0.104	5239	2325	9.21	0.05	0.95	600
S31	B1/K=0.50	0.176	4870	2571	12.84	0.04	0.94	601
S32	0.5 Early recr L	0.112	3189	1314	8.3	0.06	0.95	356
S33	1.5 Early recr L	0.104	7419	3283	7.73	0.03	0.94	858
S34	Finit=0.05	0.106	5431	2416	7.71	0.06	0.95	635
S35	Finit=0.1	0.105	6069	2696	7.74	0.03	0.95	706
S36	Finit=0.15	0.104	6600	2912	7.83	0.03	0.95	764
S37	Dome recr sel 1	0.263	13110	1336	2.04	0.09	0.95	528
S38	Dome recr sel 2	0.156	12882	3129	6.16	0.02	0.92	595
S39	Dome recr sel 3	0.184	9846	2274	5.93	0.02	0.93	778

Figure 6.1. Dome-shaped selectivity for recreational sectors as considered in sensitivity runs of this report (see text for details). Top panel) Selectivity hypothesized by Dr. Hester (reproduced from Dr. Hester's report dated 8 May 2009) and applied in sensitivity runs S37 and S38 (full assessment period in S37; early time period only in S38). Bottom panel) Dome-shaped selectivities estimated in sensitivity run S39.

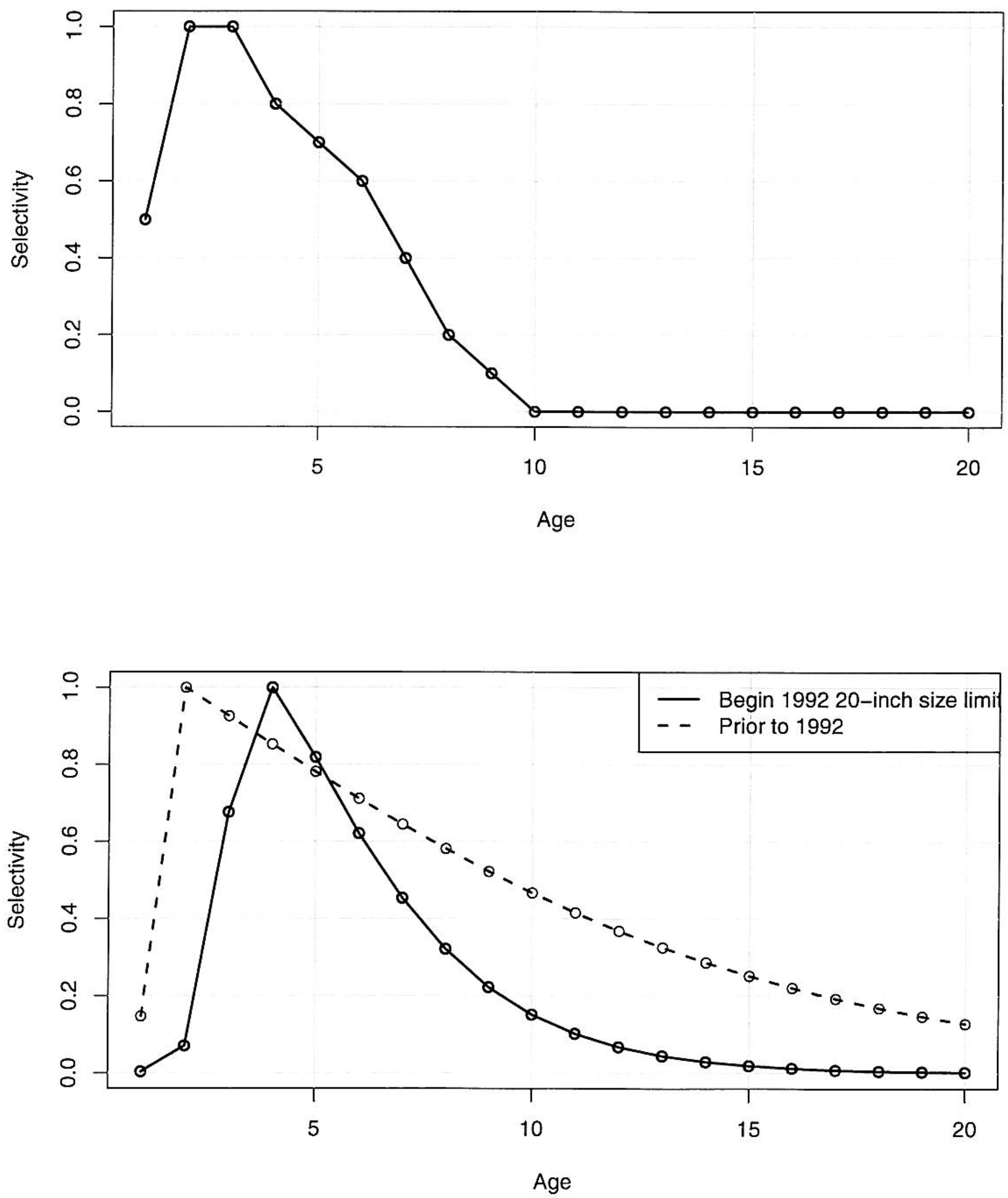
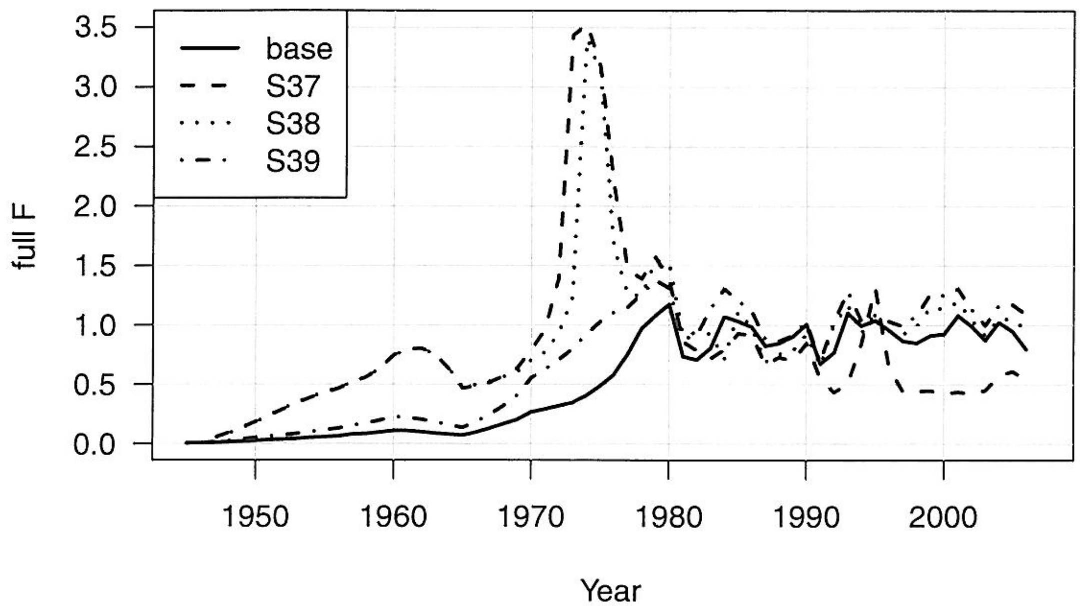


Figure 6.2. Comparison of full F (top) and spawning biomass (bottom) from the base assessment model (base) and three sensitivity runs (S37, S38, S39) with dome-shaped selectivity for recreational sectors (see text for details).



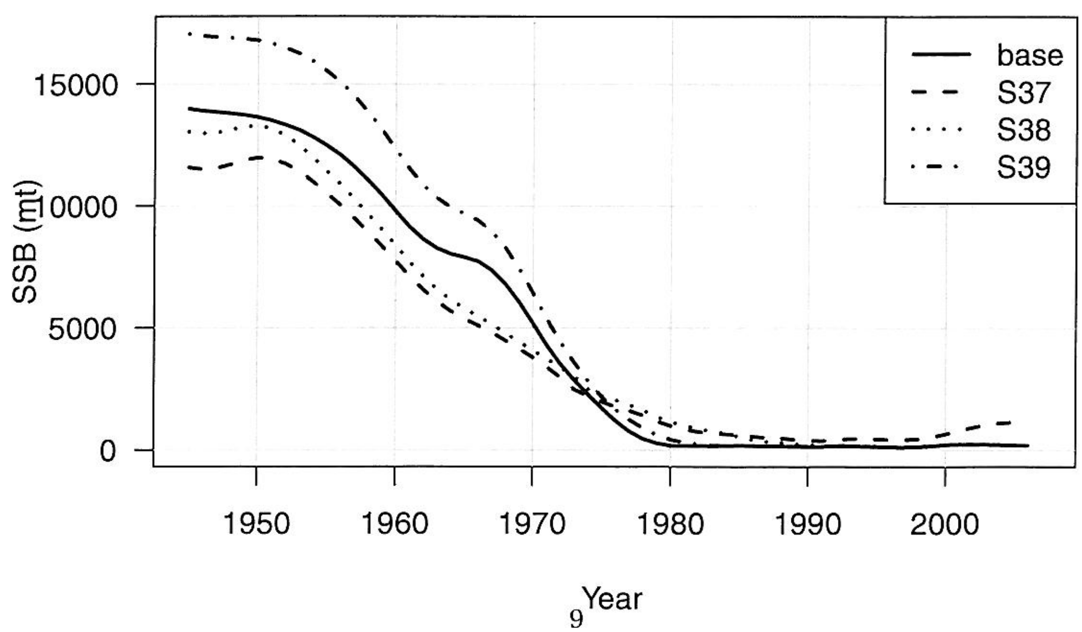


Figure 6.3. Stock and fishery status of base run (solid circle) and 40 sensitivity runs (open circles). Values have been jittered (small noise added) to improve distinction of overlapping circles. Note that sensitivity runs S37-S39, as well as the base model, use $F_{40\%}$ proxies for MSY*-based reference points.*

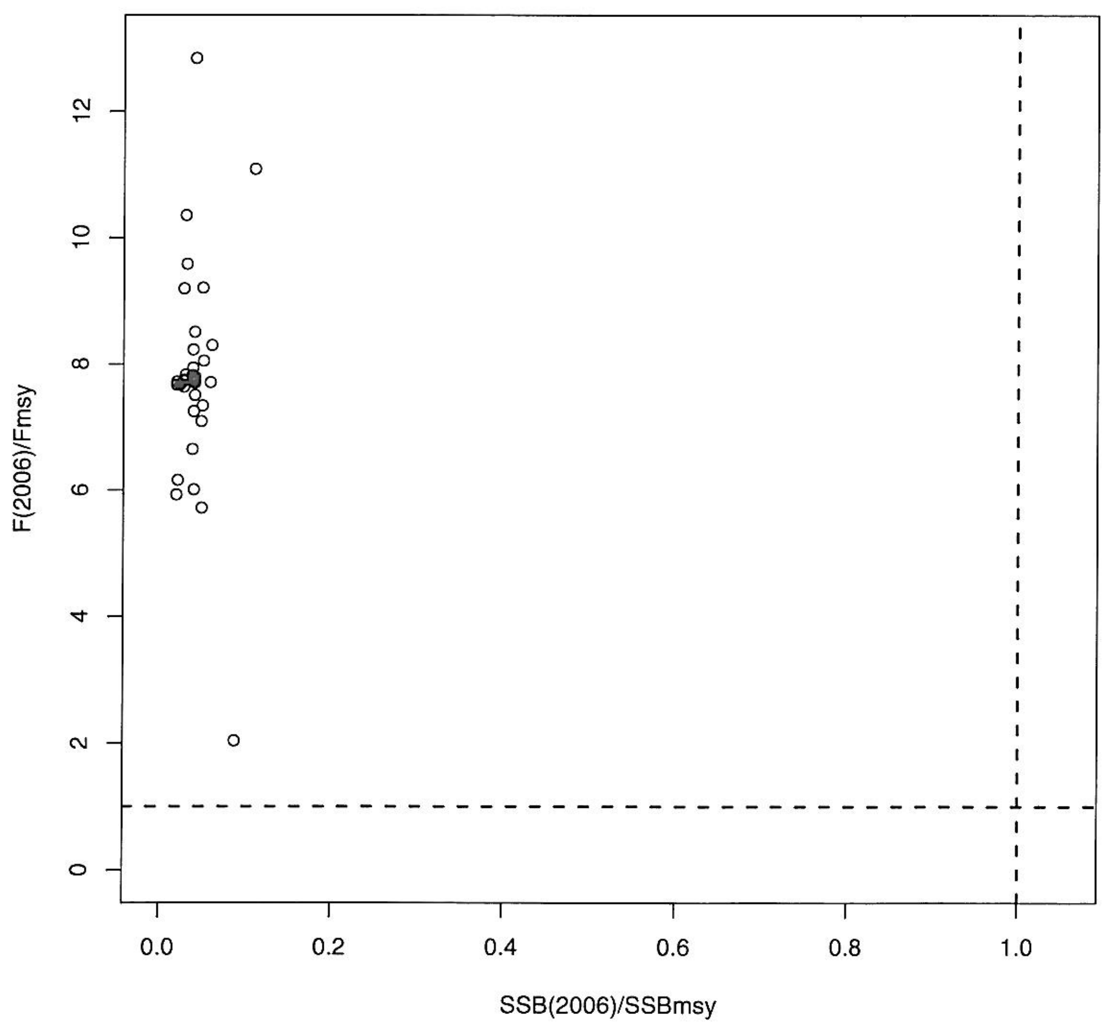


Figure 6.4. Comparison of catch-at-age data from recreational and commercial sectors. Y-axis is on log scale. Age 20 was pooled.

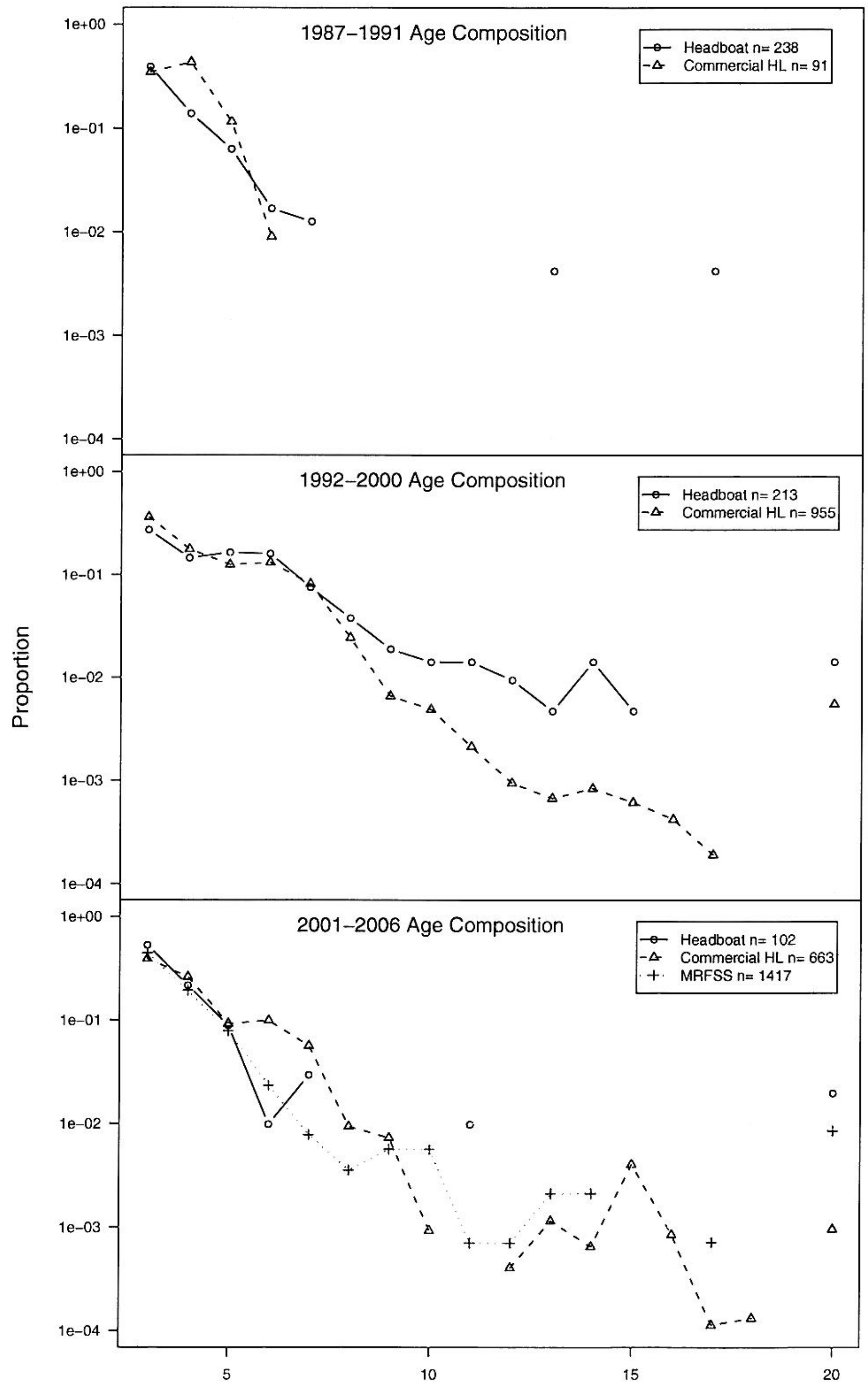
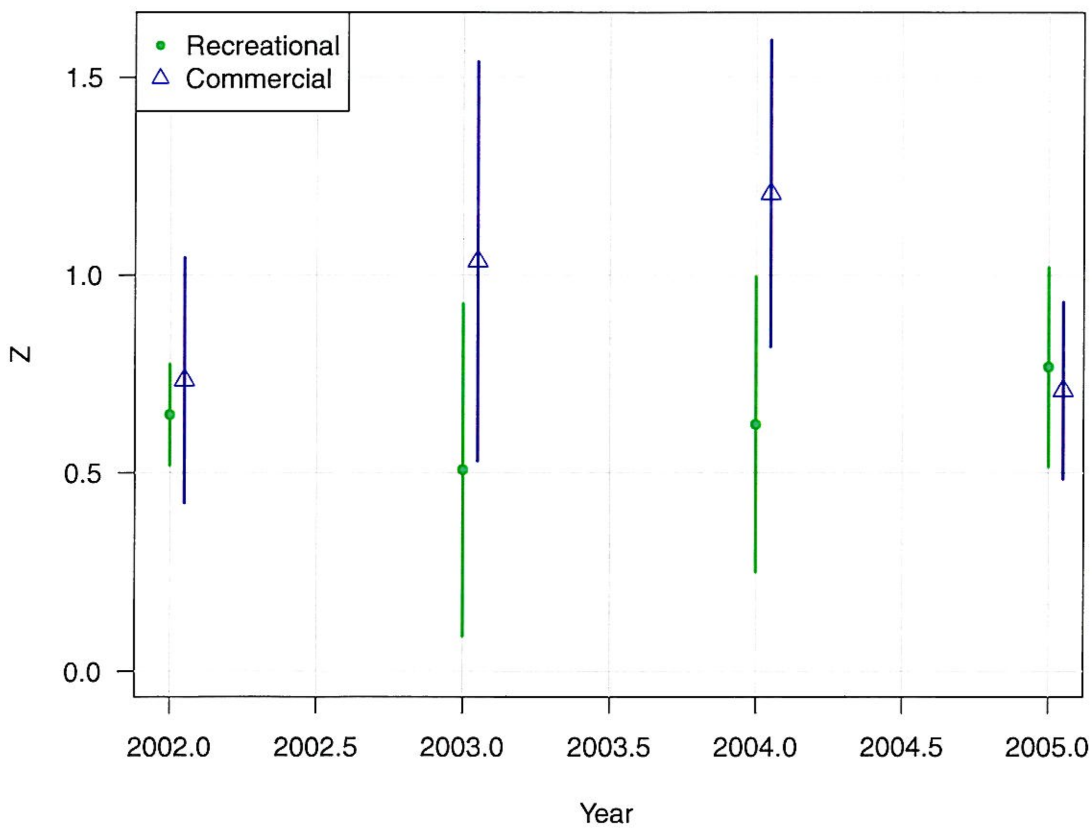


Figure 6.5. Estimates of total mortality (Z) from catch curve analysis using recreational or commercial catch-at-age data. Lines represent 95% confidence intervals. A higher estimate of Z indicates that the right-hand limb of age composition data descends more quickly, which could occur because mortality is higher or because of dome-shaped selectivity. Thus, assuming that selectivity of the commercial sector is flat-topped, one can compare estimates of Z for evidence of dome-shaped selectivity in the recreational sector. A much higher value of Z could indicate dome-shaped selectivity. This analysis reveals no evidence for dome-shaped selectivity of the recreational sector.



7 Appendix

SAFMC Staff Review of Comments Submitted by Dr. Frank Hester Regarding the Red Snapper Assessment

Upon review of the comments on the red snapper assessment submitted by Dr. Hester, there may be a need to further evaluate the selectivity assumption, its impact on the disparity between historical mean catch weight estimates and observations, and any potential impacts on recent SSB estimates. The underlying question is with selectivity, and whether a dome or flat top pattern is more appropriate for the recreational fishery. Potential evidence that the flat top assumption may bias some results is provided through Dr. Hester's comparison of the model produced mean catch weight (from total estimated catch in numbers and in weight) and the mean catch weight from the FWS reports in 1965 and 1970.

1. Dr. Hester criticizes the DW for information not provided. The observations are correct, but criticisms are somewhat unfounded as the DW report fully acknowledges these and several other data concerns.

- The DW provided the life history information that was available. Fecundity is seldom available for SG stocks, and this criticism would only be warranted if he cited some information that was overlooked. He does not.
- Very few species have available 'observations based estimates of natural mortality'. In fact, I cannot think of a single wild stock where such information is available.
- The DW provided one approach to estimating pre 1981 recreational catches – a linear interpolation that has little justification and is soundly disputed by the observations that area available in the FWS reports.
- No issues requiring additional analyses are raised in this section.

2. Comparison of VPA and forward projecting catch-age

- That VPA is more 'familiar' than catch-age is the opinion of the author. My opinion is that SEDAR participants are much more familiar with the model framework used for red snapper as it has been in use since the first SEDAR.
- It is true that both models suffer from poor data. Extensive comparisons of the various model classes in use today prove that all models suffer from poor and missing data, and that some models are better than others at dealing with particular data holes. SEDAR assessments seldom use VPA because VPA models require a complete catch-age input and apply an assumption that the catch is measured without error. Most stocks managed by the SAFMC have only a short time series of age observations adequate for constructing catch at age, and it is widely accepted that key catch sectors have considerable error in their catch estimates. In fact, determining the level of uncertainty in historic catch records is usually a topic of extensive discussion. The model used for red snapper is state of the art and has been extensively reviewed by independent peer review panels.
- Both models suffer from terminal year uncertainty and provide more accurate estimates farther back in time. This is a simple fact of all age structured assessments that essentially rely on tracking a cohort as it progress through its life.
- No issues requiring additional analyses are raised in this section.

3. It is stated that use of the FWS reports causes a major problem

- I disagree with this statement. As Dr Hester states in quotations from the AW report, initial model runs without the FWS observations suggested that pre-1981 catches were significantly higher than those estimated by the simple linear interpolation provided by the DW group. The fact is that age and length composition information suggest that the population was already reduced by the time sampling began, and observations of catch post-1981 were inadequate to drive the population down to accommodate the age composition observed when actual age composition observations became available. The model was looking for a way to remove fish, and since recreational catches are specified to have greater uncertainty than commercial catches, in terms of minimizing error the appropriate way for the model to do this was to increase early recreational catches. When reviewed further at the AW, the panel recognized that the FWS reports corroborated the path the model was determined to take, and therefore including those observations and developing an alternative historical catch series improved overall model performance, in terms of fit and residual patterns.
- The FWS observations are legitimate observations and deserved further consideration at the AW. They are based on survey results and recall, and their precision may be difficult to ascertain, but they are believed to provide better information than the linear interpolation put forth by the DW. Historical catch records are important to inferring long-term productivity, and this debate underscores the need to refine methods for estimating pre-1981 recreational landings and other historical removals

4. Conversion of catch in weight to catch in numbers. This section indicates that perhaps Dr. Hester believes that the problem with the assessment is more in how the FWS observations are incorporated than in the fact that they were incorporated at all.

- I am not familiar enough with the internal workings of the model to know all the steps it takes to go from an overall annual weight to the annual estimates of abundance and then catches at age, but I am fairly certain it involves more than just the selectivity curve. We could request further clarification, but I don't think this is critical to the potentially relevant point that emerges later.
- It is stated "The fact that these are averages implies that half the landings are less than 3 pounds" . This is not always true. It is true, however, that the preferred statistic to describe the center value of a distribution is the median, and if the median were 3 pounds then half of the observations would be less than 3 pounds. However, the same cannot be said of the average. Consider a simple example with 3 observations: 25, 50, and 225. The average is 100 and the value of the median observation is 50, so in this example one-third of the values are less than the median and two-thirds have values less than the average. All of this is really beside, and unfortunately detracts from, the fundamental observation that is identified later— that there is a discrepancy between the mean weight from the FWS reports, which provide the bulk of the landings in the early years, and the mean weight from the overall, model-estimated catch at age.
- I don't see adequate information provided to support the statement that the catch at age should heavily favor fish less than three years old. I'm also confused by the switch from an argument based on pounds to an argument based on age. If the population was indeed lightly exploited in the earliest years, and retained reasonable numbers of older fish, it

should not be surprising that the sum total of catches across the oldest 17+ ages would be more than the total across the youngest 3 ages. Even more so when less than full selectivity is applied to age 1, a model feature that is not disputed.

5. Selectivity Issues
   - The model does incorporate a flat selectivity curve for the recreational fisheries. I am not clear whether this was a specification or whether the shape of the selectivity curve was something the model was free to determine. It is not apparent in the assessment report whether an alternative selectivity was forced in a sensitivity analysis and I can't recall that being explored at the AW.
   - Concerns over the use of the flat selectivity curve were raised by Roy Crabtree some time ago. The Gulf red snapper assessment used a dome curve, and while this alone is not ample reason to apply a dome shaped selectivity pattern to Atlantic red snapper, it does provide some justification to consider a sensitivity incorporating a similar pattern.
   - Some anecdotal reports suggest that species like red snapper which inhabit bottom substrates and can grow to very large size may have domed selectivity patterns by size because the largest fish are more difficult to land. There is some confounding though when selectivity is considered by age, especially for a stock such as this where the life history observations reveal that length is not informative of age. In other words, while the biggest fish may be harder to land, the biggest fish are not always and necessarily the oldest fish. Again, though, since this perception exists the domed selectivity pattern should be explored if it has not already.
   - The selectivity issue may somewhat alter the model estimates of overall annual catch mean weight.

6. Conclusions
   - Concerns are raised with the early catch records and the selectivity. To me, the issues go hand in hand as the selectivity assumption will influence the estimated catch age distribution and hence the back calculated average weight of the catch.
   - Given Dr. Hester's submission and prior concerns raised regarding selectivity, I would like to know more about how the selectivity curve was modeled. I would also like to see a sensitivity analysis fixing a dome shaped selectivity curve in the recreational fisheries, at least in the early years when there are substantial numbers of older fish in the estimated population.
   - I believe the issue of selectivity should be explored. I will be surprised if specifying a dome shaped selectivity curve will substantially change stock status estimates, but the issue requires attention so that the process can move ahead.
   - It is within reason to hypothesize that a domed shaped selectivity would increase the estimated abundance of older fish, impact SSB, and ultimately influence the Stock-Recruit relationship and steepness.
   - It is also within reason to hypothesize that switching to a dome shaped selectivity pattern will increase the overall F. The model needs to account for a certain number of dead fish, and if you specify that a certain segment of the population is 'off limits' or receives a smaller portion of the overall F, the model will likely be forced to increase the overall removal rate. Considering beyond the scientific ramifications, given this outcome, actions applied to the portion of the population that is exploited might need to be more severe.

- Hypothesizing even further along these lines, increased abundance of older fish would increase SSB and potentially decrease the extent to which the stock is overfished, but keep in mind that all estimates suggest the stock is severely overfished and current SSB is on the order of 3% of the desired level.

7. Discussion Items

- Dr. Hester's concluding discussion largely reflects the opinions stated by the Review Panel, namely that while the stock appears to be at a point of equilibrium, the relation of this point of equilibrium to desirable conditions and long term maximization of yields is uncertain.
- While current F may be sustainable over a short time, there is considerable evidence to suggest that yield is well below MSY. Also, evidence suggests the fishery is highly susceptible to fluctuations in correlation with year class strength which is risky and a classic sign of excessive exploitation.
- There is well noted uncertainty in the biological reference for exploitation, but it should be acknowledged that estimates of current F are well above any of the proposed values for MFMT.
- I am skeptical that new data sources will be found at this point, largely because none have surfaced over the last year as controversies regarding this assessment arose and because Dr. Hester, who clearly devoted considerable time and effort to reviewing the assessment, fails to point out any even potential sources of information to shed light on the uncertainties in the assessment.
- I am skeptical that increased sampling of the current population in the short term will resolve the problems with estimating long-term productivity. Improving estimates of productivity can only be achieved through reducing exploitation so the age structure can expand and ensuring adequate monitoring as the population recovers.
- Increased sampling may shed some light on the current age composition, and should at least provide greater confidence in the age composition estimates. Such endeavors should not be short lived however, as the assessment considerably suffers from a lack of both age and length sampling. Commercial age samples range from 7 to 332 annually, and only 1820 are available over nearly 20 years. That is less than 100 per year on average, which is pretty poor for a fish with a life span over 50 years.
- I agree the Council needs to take action, and all the available evidence indicates that fishing mortality must be reduced substantially.
- I strongly and completely disagree with the characterization that all assessment scientists presuppose a stock is depleted. This is one of several unfortunate opinion statements that detract from the potentially legitimate concerns raised regarding the selectivity pattern, and the questions raised regarding the differences in observed and estimated overall mean weight.

Age Structure of U.S. South Atlantic Red Snapper, *Lutjanus campechanus*, Landed In June, July and August 2009

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NMFS TIP Agents
NMFS Headboat Survey
NC DMF
SCDNR
GA DNR
FL FWC

10 September 2009

The data for this report were gathered in response to a request from the South Atlantic Fishery Management Council (SAFMC) to determine the age structure of red snapper captured in commercial and recreational fisheries operating from North Carolina through the east coast of Florida during the summer months of 2009. This report is a compilation of age data provided by staff from the NMFS SEFSC in Beaufort, NC, FL FWC, GA DNR. The researchers responsible for ageing red snapper had participated in an age workshop to ensure consistency in age readings.

The center of the red snapper abundance is located off the coast of northeast Florida. Peak spawning occurs during the summer, July through September (SEDAR15). Fishers from northeast Florida have commented that more large red snapper are available to the fishery during the summer months. They would like to know the current age structure of this population.

Effort to collect red snapper landed by the commercial and recreational fisheries in June, July and August of 2009 was intensified in the northeast Florida area – Jacksonville to Cape Canaveral. Directed effort was also applied to the For-Hire sector of the recreational fishery off the coast of Georgia during this time. All agencies and programs involved in sampling maintained their respective agency's random sampling protocol. Therefore, other than a bias in effort to collect red snapper age samples, there should have been no bias in size selection of the fish to be sampled (Table 1).

A table of sample size and number of trips sampled by area and fishery (Table 1) and a table of percent of fish at each age (Table 2) are presented, as well as frequency plots of fish size (Figure 1) and ages (Figure 2), and a figure illustrating length-at-age (Figure 3) of red snapper from the different areas. All lengths are reported as total length in inches; the ages of the fish are reported as calendar age in years. All fish were sampled from vertical hook and line gear with the exception of 21 samples from commercial dive operations. In northeast Florida, 6% (n=73) of the fish were older than ten years (Table 2). The oldest fish was 37 years and was 37 inches total length. In the Georgia samples, 5% (n=9) were older than age 10 (Table 2). The oldest fish in the sample was 22 years and was 36 inches total length. The modal age for northeast Florida and Georgia was 4 years representing 57% and 58% of the samples, respectively (Figures 2a and 2b).

The data presented in this report are not directly comparable to the age composition data used in the SEDAR15 model. The age data used in the assessment model are weighted by the landings for each fishery, gear and state. In addition, age compositions are expected to fluctuate from year to year, reflecting variations in year-class strength. Nonetheless, these samples appear to support results of the SEDAR15 stock assessment in at least two respects. First, the distribution of ages contains far more, younger fish than would be expected from a healthy population of red snapper. Second, the assessment model predicted strong age-1 year classes in 1998, 1999, and 2000. Those fish should now be ages 10 through 12, and indeed, they appear to be reflected in the 2009 age compositions.

Table 1. Number of age samples and trips sampled ( ) of red snapper landed in the U.S. South Atlantic in June, July and August 2009.

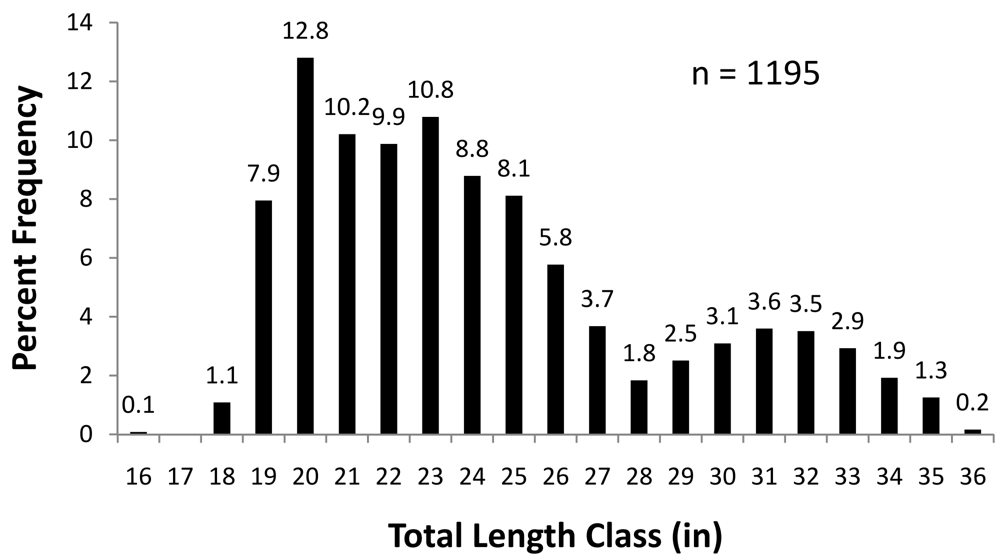
	Northeast Florida				Florida Keys	North Carolina		South Carolina		Georgia
Month	**Commercial**	**Headboat**	**Charter Boat**	**Private Boat**	**Charter Boat**	**Commercial**	**Headboat**	**Commercial**	**Headboat**	
June	336 (21)	2 (2)				14 (8)	2 (1)	26 (12)	1 (1)	86 (11)
July	439 (23)	110 (31)	120 (22)	12 (3)	12 (2)	11 (5)	1 (1)	7 (3)	4 (2)	55 (10)
August	100 (4)	35 (14)	41 (10)			12 (2)				36 (5)
Total	875 (48)	147 (47)	161 (32)	12 (3)	12 (2)	37 (15)	3 (2)	33 (15)	5 (3)	177 (26)

Table 2. Age frequency of red snapper sampled from commercial and recreational fisheries operating off northeast Florida and Georgia during June, July, and August 2009.

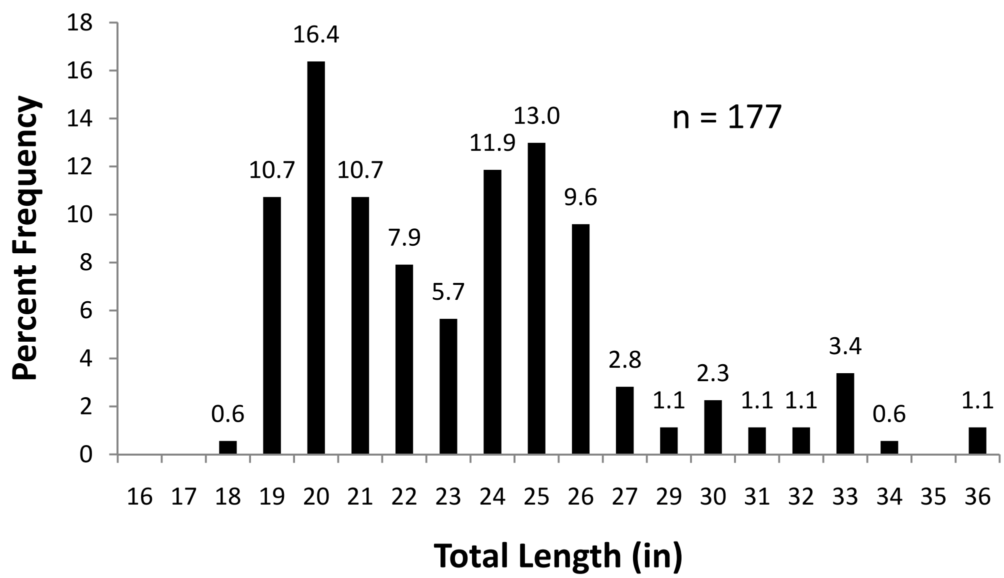
	Northeast Florida (n= 1195)		Georgia (n= 177)	
Age	Percent	Cumulative Percent	Percent	Cumulative Percent
1				
2	0.2	0.2	0.6	0.6
3	22.3	22.4	27.7	28.3
4	56.5	78.9	58.2	86.4
5	0.8	79.7	2.3	88.7
6	1.2	80.8	2.3	91.0
7	5.2	86.0		
8	2.4	88.5	1.7	92.7
9	3.2	91.6	0.6	93.2
10	2.3	93.9	1.7	94.9
11	2.1	96.0	2.3	97.2
12	1.3	97.3	0.6	97.7
13	0.3	97.7		
14	0.5	98.2		
15				
16	0.3	98.5		
17	0.7	99.2		
18	0.2	99.3		
19			1.7	99.4
20	0.1	99.4		
21	0.1	99.5		
22			0.6	100.0
23				
24	0.1	99.6		
25				
26				
27				
28				
29				
30				
31				
32	0.2	99.8		
33				
34				
35	0.1	99.8		
36	0.1	99.9		
37	0.1	100.0		

Figure 1. Total length (in) frequency of commercially and recreationally caught red snapper sampled for age structures in June, July and August 2009 from (a) northeast Florida, (b) Georgia, and (c) North Carolina, South Carolina and Florida Keys.

a. Northeast Florida



b. Georgia



c. North Carolina, South Carolina and Florida Keys

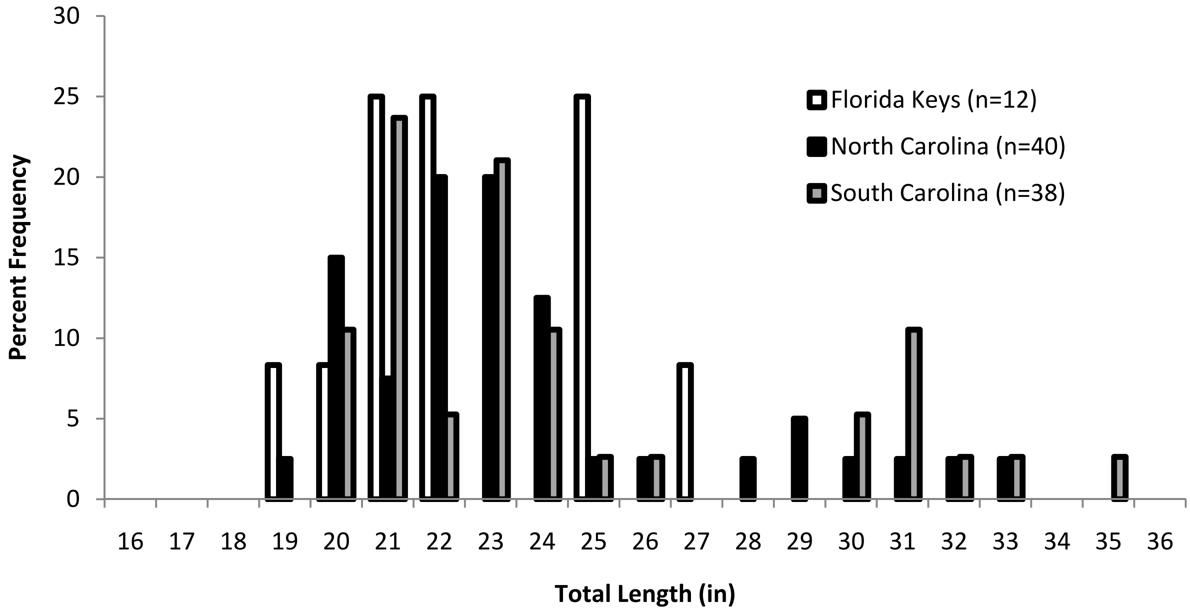
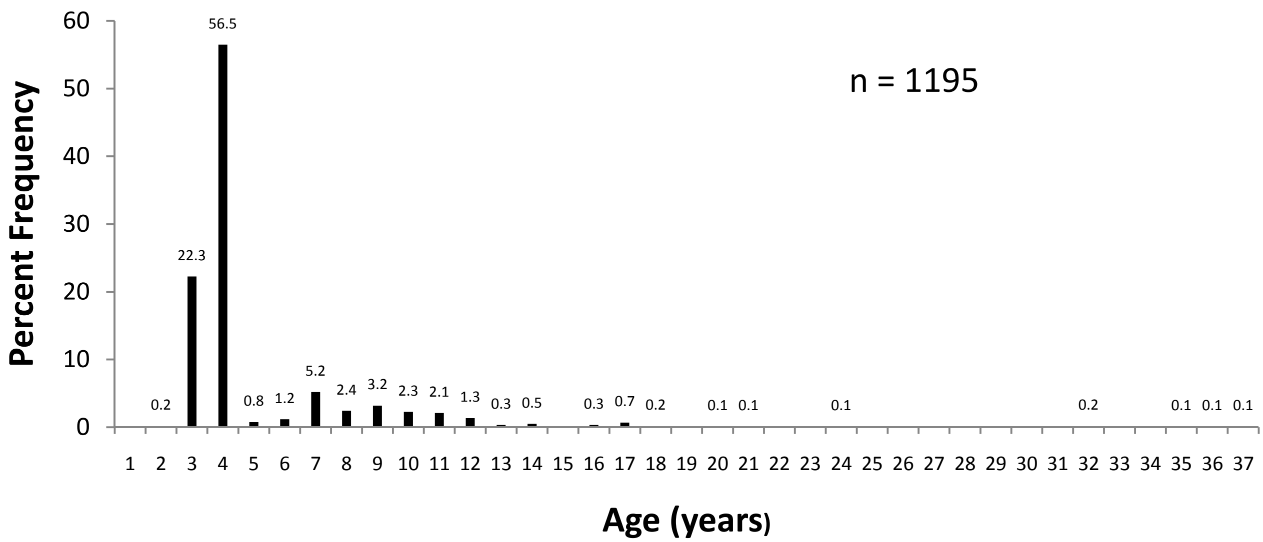
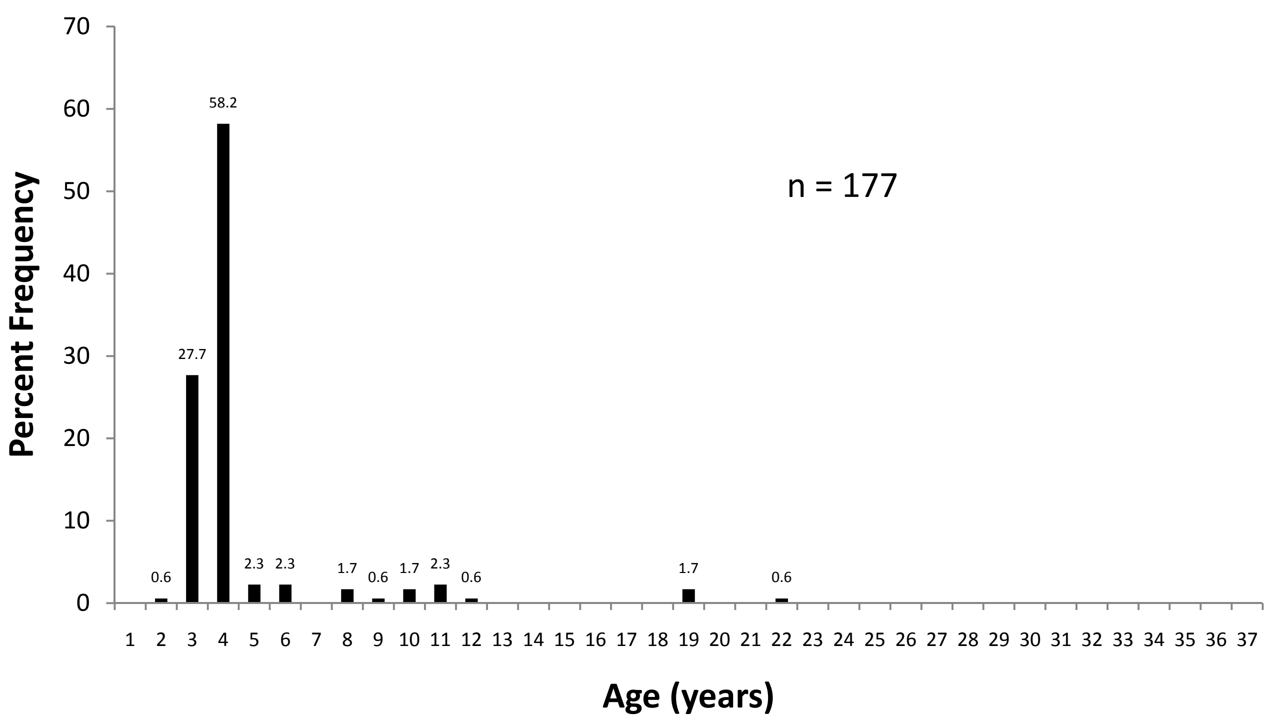


Figure 2. Age (years) frequency of commercially and recreationally caught red snapper sampled in June, July and August 2009 from (a) northeast Florida, (b) Georgia, and (c) North Carolina, South Carolina and Florida Keys.

a. northeast Florida



b. Georgia



c. North Carolina, South Carolina and Florida Keys

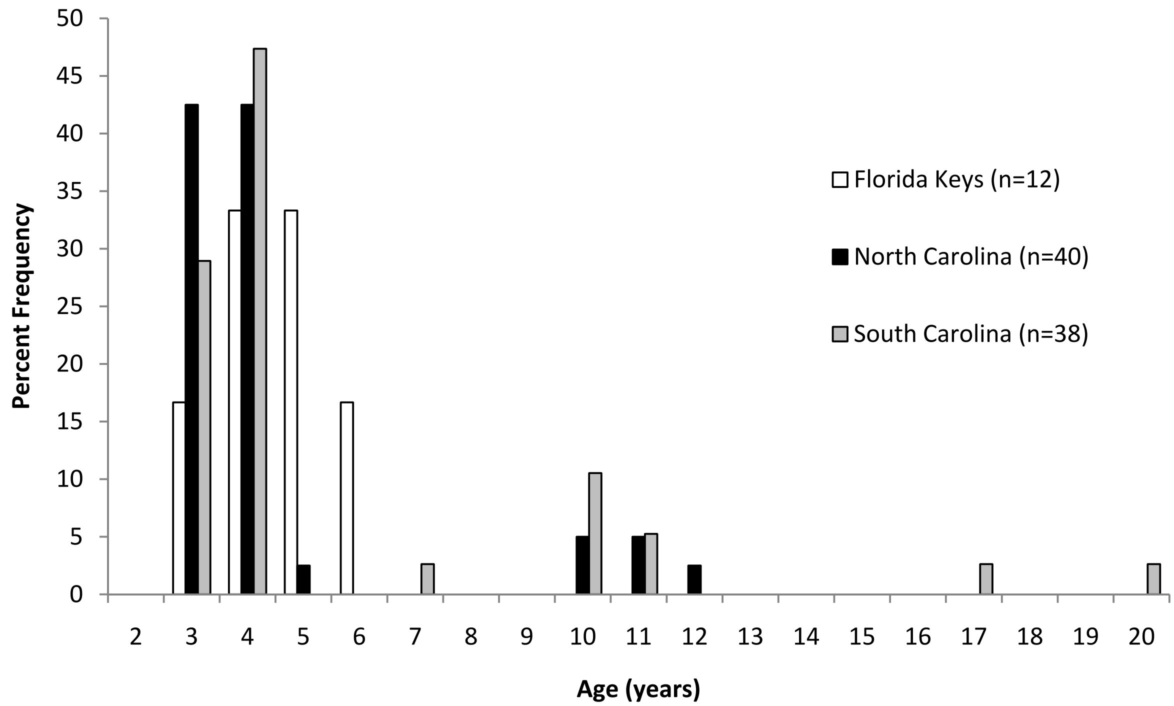
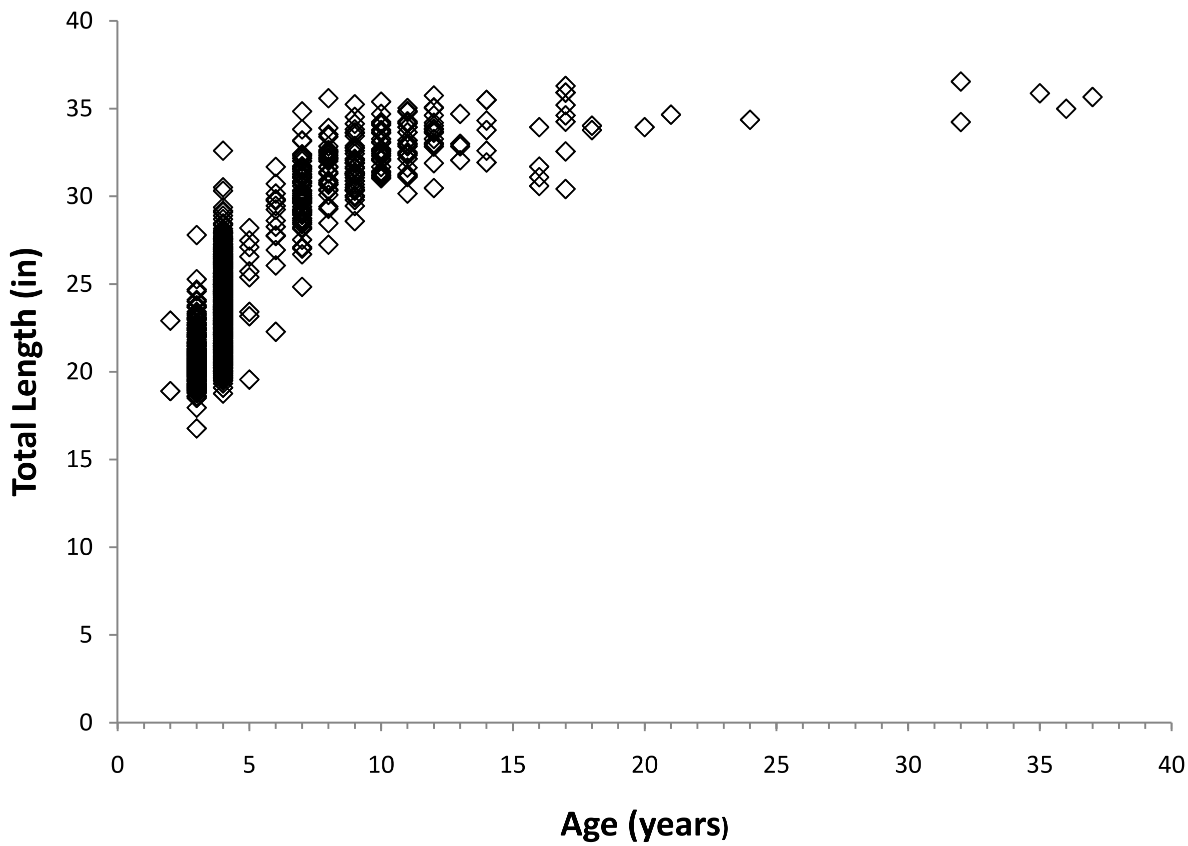
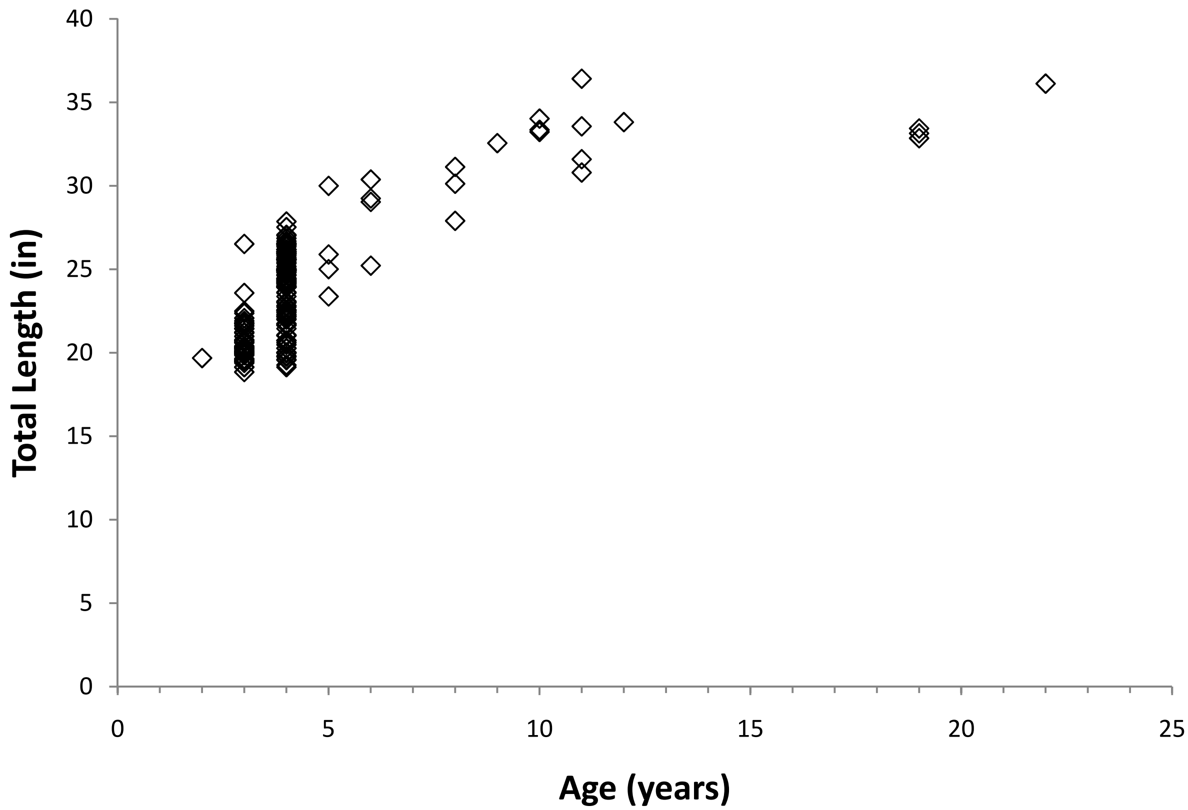


Figure 3. Total length-at-age of commercially and recreationally caught red snapper sampled in June, July and August 2009 from (a) northeast Florida, (b) Georgia, and (c) North Carolina, South Carolina and Florida Keys.

a. northeast Florida



b. Georgia



c. North Carolina, South Carolina and Florida Keys