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Final Report

Bioeconomic Analysis of the Red Snapper Rebuilding Plan and Transferable Rights Policies in the Gulf of Mexico.

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Chapter 1: Simulation Results of Typical Policies[1]

I. Introduction

The General Bioeconomic Fishery Simulation Model (GBFSM) is a multiple species, multiple length-based model using cohort analysis and instantaneous mortality. A description of the model can be found in Griffin (2003). Several modifications were made to GBFSM for this project. The main change was to allow fishing effort to be re-directed to other fisheries, thereby allowing a given vessel class to continue to fish for other fish. For example, when the TAC is filled, commercial vessels could no longer land red snapper but they could redirect their fishing effort toward other species, such a vermilion snapper or other reef fish. The other major change was not to GBFSM itself, but rather we created user-friendly Excel model to manage the large amount of data and to run GBFSM. We also developed Excel output models that allow quick analysis of the simulation results. We call this the bioeconomic simulation system or BESS (GBFSM).

The dimensioning and calibration of GBFSM (presented in Appendix A) yielded results that differ in a number of ways from the SEDAR 7 assessments. To calibrate four different species (shrimp, red snapper, vermilion snapper, and other reef fish) in a single model, we select January 1 as the beginning of a year in GBFSM. Further, we simulate all fish at actual age instead of year classes as does SEDAR 7 assessments, which may contribute to some of the differences between our results and those of previous research. We also use a density dependent model whereas the SEDAR 7 assessment did not. Gazey et al. (2008) have shown that red snapper are density dependent. More importantly, unlike SEDAR 7, we incorporate the applicable fishing policies in the appropriate years in our calibrating process, to obtain more realistic estimations. That is, for each year we imposed the policies that were in effect for that year.

We consider four cases of natural mortalities for juvenile red snapper in our calibration process, as shown in the Table 1.1. Case 1 is used in SEDAR 7 and yields a Shrimper Fishing Index of 1. Gazey, Gallaway, and Fournier (2008) have suggested that M_0 is much higher for red snapper and they estimated a value of $M_0 = 2.03$ and $M_1 = 1.25$. Wells, Cowan, Patterson, and Walters (2008) have estimated that M_0 could range from 2.6 to 11.0 depending on the habitat characteristics[2] and if it a trawled or non-trawled fishing area. As the natural mortality of red snappers increases for age 0 and age 1 groups, from Case 1 to Case 4, the Shrimper Fishing Index decreases from 1 to 0.05926. This relationship suggests that the impact of shrimpers on red snapper fishing industry diminishes while the natural mortality of juvenile red snappers rises. Gazey, Gallaway, and Fournier report in their estimation that age-0 mortality exceeds 2.03 and

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[1] This chapter has greatly benefited by comments from Jim Waters. Any remaining errors are the responsibility of the authors

[2] Wells, Cowan, Patterson, and Walters (2008) state that, "Shell-rubble and reef habitats may be important for red snapper by providing protection from predators; however, the sand and mud habitat appears to be the most important for enhancing production and early life survival of age 0 fish based upon faster daily growth rates and higher production potential."

age-1 mortality exceeds 1.25 at a probability of 95%. Consequently, we select Case 2 for the calibrating our model.

It should be noted that, although our analysis uses a bioeconomic model, it does not represent the official biological research finding of the NMFS about the status of the red snapper stock in the Gulf of Mexico (Gulf). Therefore, we present our biological findings as suggestive rather than definitive. However, it is strongly recommended that future stock assessments by SEDAR should consider the recent contributions of Gazey et al. (2008) and Wells et al. (2008).

For vermilion snapper the natural mortality used in SEDAR9 and Porch and Cass-Calay (2001) for all ages was 0.25 yr^{-1}. It seems only logical that age 1 fish would have a higher natural mortality than age 2+ fish and age 0 would be higher than age 1 fish. Underestimating natural mortality for age 0 and age 1 fish will result in an overestimate of shrimp bycatch relative to the total number of age 0 and age 1 fish recruited into the fishery. Therefore, given no other guidance from the literature, we use a natural mortality for age 0 of 1.0 yr^{-1}, age 1 of 0.5 yr^{-1} and age 2 and above of 0.25 yr^{-1}. For a more detailed discussion of GBFSM and its calibration see Appendix A.

II. Calibration of GBFSM

In this analysis, we treat each species east and west of the Mississippi River as separate stocks. The commercial effort (Trips) and landings data are logbook data, provided by Jim Waters, NMFS Beaufort, NC, for the period of 1993 to 2005. The recreational data are from MRFSS, head boat and Texas Parks and Wildlife Department, and they are provided by Patty Phares, NMFS Miami, FL, for the period of 1993 to 2002. Commercial cost data for reef fish vessels was provided by Larry Perruso at the NMFS Miami Lab. The shrimp landings data (1965-2006) comes from the NMFS Galveston Lab and were provided by Frank Patella. We used our approach (Griffin) to expand effort (days fished) to all landings files.[3]

We define the period of 1985 to 2002 as our "historical" era, and use the generated data for this period to set up BESS (GBFSM). The maximum age of red snappers was set at 35 years; therefore we also adopt a "prehistoric" period (1935-1984) to get the old fishes in the model. Our data base is sufficient to generate a quasi prehistoric data set of the 1935-1984 period, and will be "used as a burn in to scale the model results", which is a procedure similar to that adopted by SEDAR9 Section III, Assessment Workshop Report. This prehistoric period allows us to "get the appropriate number of old fish in the model at the appropriate length and weight."[4] After calibrating the prehistoric period (1935-1984), we calibrate the model to predict the historic period (1985-2002), which facilitates realistic policy analysis beyond 2002.

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[3] Days fished for 2006 could not be expanded to all trips due to the very poor quality of the sampling data.

[4] Our model is a cohort model instead of an age structured model. We prefer the cohort model because actual sample data are collected in the length of fish instead of the age of fish. Therefore we calibrate the model to the length of the fish and not the age of the fish. However, we keep track of the age of the fish, and can report results by both length and age. In addition, we use actual age, instead of year-class age that is adopted in SEDAR assessments.

We start the simulation in 1935 and introduce age 0 red snapper at a constant rate for two years. Then, in 1937, we activate the stock recruitment relationship. Every year, we apply the appropriate management regulations, as they are enforced in the real world fishing industry. We used this same method for vermilion snapper and other reef fish. Details of the shrimp, red snapper, vermilion snapper, and other reef fish can be seen in Appendix A.

After calibrating the biological model of GBFSM, we run the model through 1992 and store the biological information into files. This allows us to begin the model in 1993 by reading in the biological information that was stored and the end of 1992, cutting down computer simulation time by a significant amount. We then run the model from 1993 to 2005 to calibrate the cost and revenue data. After being satisfied that the model is working properly, we store the biological information at the end of the simulation, 2005. Our policy analysis will begin in 2006 and we will use the actual yearly policies for 2006, 2007 and 2008. Differences in policies proposed will be for the period 2009 through 2032. Prices and unit cost are in 2005 dollars.

III. Simulation policies

The base policy is given in Table 1.2. The policies analyzed are given in Table 1.3. All policies analyzed are changes for recreational red snapper fishery. Only the change in the TAC affects the commercial red snapper fishery. We look at how the changes in recreational red snapper policies affect the red snapper stock and consumer surplus (CS) and producer surplus (PS) to vermilion and other reef fish. Although we treat red snapper as two separate stocks (east and west Gulf), the TAC for red snapper is for the entire Gulf. Also, we assume that reef vessels (commercial and recreational) that fish in the east Gulf will land their fish in the east Gulf and reef vessels that fish in the west Gulf will land their fish in the west Gulf. That is, how a reef vessel behaves in the east Gulf due to a change in the regulations will not affect reef fish vessel in the west Gulf and vice versa except to the extent that the total TAC is filled.

IV. Results

A. Shrimp

First we examine the shrimp fishery. Shrimp prices and unit costs are held constant for the simulation period except for fuel prices. The fuel price index increases to 1.59 in 2009 and then we reduce it to 1.2 for the remainder of the simulation period. The GBFSM allows shrimp vessel to enter and exit the fishing fleet based on economic profit (total revenue less total costs including opportunity cost). We allow small vessels to enter and exit the fishing fleet but we restrict the large vessels from re-entering the fishing fleet due to the moratorium on federal permit to shrimp in federal waters.

Because of low shrimp prices due to imported shrimp and high fuel prices the total effort in the Gulf has declined by 63.2% over the simulation period (Table 1.4). The larger proportion of the decline is by small vessels. The large vessels declined by 44% and most of this decline occurred in the first two years (Figure 1.1). The reason the large vessels do not continue to decline is because as the small vessels leave the industry, more shrimp migrate to the offshore area, thus increasing the amount of shrimp available to the larger vessels. Landings by large vessels in 2008 decline to 85% of the 2006 value and then increase to 99% of the 2006 value. So,

even though the large vessel's effort decline by 44%, their landings only decline by 1% over the simulation period. The recent amendment 27/14 for reef fish and shrimp established that in order to rebuild red snapper stocks that shrimp bycatch mortality would need to be reduced by 74% and a reduction of 60% by 2032. The average effort for large vessels for the 2001-2003 period was 149,923 days fished. The days fished by large vessels in 2011 to 2032 are 54,743, which is a reduction of 63.5%. Given the new publications revealing that natural mortality rates for juvenile red snapper are much higher than used in the SEDAR 7 stock assessment, shrimp fishermen's significance is tremendously reduced, especially in the east Gulf.

B. Base Simulation

The base simulation requirements are given in Table 1.2. In 2007 the IFQs are in effect for the commercial sector and their directed effort is more evenly distributed across the year for harvesting red snapper. In the Gulf, the hand line with 2000 pound endorsement (HL2000) is the major source of landing for commercial red snapper (Figure 1.2). In the east Gulf, regular commercial hand line (HL) fishermen land as many red snapper as the HL2000 vessels. In the west Gulf landings are dominated by the HL2000 vessels. Landings by long line commercial (LL) are basically irrelevant.

In Figure 1.2 the recreational private[5] (PB) vessels land most of the red snapper, followed by the charter (CB) for-hire vessels then the head boat (HB) for-hire vessels. The major portion of the commercial harvest is west of the Mississippi river and the major portion of the recreational harvest is east of the Mississippi river. Figure 1.3 shows a historical picture of the percent of commercial and recreational red snapper caught in the east and west Gulf. Around 1977 through 1996 the commercial fishery shifted to the west Gulf. Then, when the recreational red snapper fishery began to be closed for part of the year in 1997, the recreational landings begin to shift from the west to the east Gulf. This occurred because the recreational sector in the western part of the Gulf was made up in large part by people who move south for the winter and college students who go to the Texas beaches during spring break. The closures in the early part of the year affected these fishermen disproportionally. We see that the commercial red snapper fishery began to shift back to the east Gulf after 1997, although approximately 80% still remains in the west Gulf. In the base model the red snapper recreational season is from June 1 to September 30 which will keep most of the recreational catch in the east Gulf for the simulation period. The current recreational closure policies give an advantage to the east Gulf recreational fishermen which will cause most of the recreational fishing to remain in the east Gulf.

Figure 1.4 shows the condition of the stock of red snapper in the east and west Gulf. In the time period we consider (1965-2032) the effective number of spawners in the east Gulf reaches a low of 0.92 million in 2008 and reaches 1.15 million fish by 2032. The effective number of spawners in the west Gulf is at a low point of 1.05 million in 2003 and reaches 2.3 million fish by 2032 and appears to be continuing to increase. In both the east and west Gulf the effective number of spawners associated with MSY (current-shrimp) reported by SEDAR 7 (Figure 7) is approximately 0.7 million in the east Gulf and 0.9 million in the west Gulf. Our model is a density dependent model whereas the SEDAR 7 model is not. Even though our models are not directly comparable, according to their criteria both the effective number of

[5] Includes private and rental offshore.

spawners in the east and west Gulf are greater than the effective number of spawners associated with their MSY (current-shrimp).

The current to virgin stock ratio (S/S_0) is at a low of 0.53 in the east Gulf in 2007 and a low of 0.36 in the west Gulf. SEDAR 7 suggests that they are at a low of 0.05 in the east Gulf and 0.02 in the west Gulf. It should be remembered that we used a density dependent model and our natural mortality for age 0 and age 1 red snapper is higher than used in SEDAR 7 assessment. Age 2 recruits in the east Gulf hit a maximum of approximately 4.4 million fish by 2012 and remained fairly constant through 2032. In the west Gulf, Age 2 recruits hit a maximum of approximately 7.4 million fish by 2008 and remained fairly constant through 2032. It should be noted, however, that in the early eighties in the east Gulf the Age 2 recruits took a sharp decrease to almost 1 million age 2 recruits due to a spike in recreational fishing.

C. Policy Analysis

1. Base Case

The present value (PV) of PS and CS under the base-case scenario is given in Table 1.5. We do not include a PV of CS for shrimp since there are no current estimates of price flexibilities for shrimp and, in any case is likely to be quite small since imports have such a significant impact on domestic shrimp prices. We also do not include PV of CS measures for vermilion snapper and other reef fish. The simulation period is from 2006 to 2032. Since policies are held constant for 2006 to 2008, Table 1.5 is cumulative PV for the base case by fisheries for the period from 2009 to 2032. The PV is calculated using a 7% discount rate.

The commercial shrimp fishery has the greatest PV of PS among the all commercial fisheries. The recreational for-hire PV of PS is about half of shrimp PV of PS (Table 1.6). The PV of CS for other reef fish anglers and vermilion snapper anglers is 3.8 time greater the red snapper anglers (Table 1.5). The PV of PS for other reef fish for-hire vessels and vermilion snapper for-hire vessels is approximately 3.5 times that of red snapper for-hire vessels.

The east Gulf has the highest PV of total surplus (TS) since most of the recreational fishing occurs in the east Gulf (Table 1.7). The recreational reef fish PV of PS+CS for the period 2009 to 2032 is $9.9 billion dollars (Table 1.7). Shrimp is the second most valuable at over $1.65 billion followed by commercial reef fish PV of PS+CS at $0.27 billion. In the west Gulf the PV of PS for shrimp exceeds that of recreational PV of PS and CS combined. The PV for all fisheries is slightly more than $11.8 billion.

2. Bag Limits

The base case has a bag limit of 2 fish since that was in effect in 2008. Table 1.8 shows the difference in the cumulative distribution for different bag limits to the base case; holding the other policies constant[6] for the east, west and total Gulf. We subtract the base case from the proposed options. It is apparent that the greatest difference is between the base case and a 1-fish bag limit per angler for red snapper. The reason there is such a large loss of PV of CS for red snapper anglers is that they do not fill the TAC by the end of December (Table 1.9). This is true for both the east and west Gulf. The maximum they land is 1.62 millions pounds. The effective number of spawners and the S/S_0 increase more with a 1-fish bag limit than the other three bag limits (Figure 1.5) which is reasonable since anglers are almost a million pounds shy of filling the TAC, leaving more adult fish in the stock. However, the number of age 2 recruits increases slightly as the bag limit declines (Figure 1.5). Since the TAC is not filled with the 1-fish bag limit, this has a negative effect on the PV of PS for the red snapper for-hire fishery. While the 1-fish bag limit has negative effect on recreational red snapper PV of PS and CS, it has a positive effect on recreational PV of PS and CS for vermilion and other reef fish.

The 3-fish bag limit has a negative effect on PV of CS of red snapper anglers in the east Gulf but a positive effect in the west Gulf. The recreational TAC is filled for the Gulf (Table 1.9). Table 1.10 reveals that, for the 3-fish bag limit, recreational landings decline relative to the 2-fish bag limit, but in the west Gulf the recreational landings for red snapper anglers increase relative to a 2-fish bag limit. This is reasonable since the larger stock of fish is in the west Gulf and the greatest number of red snapper anglers is in the east Gulf. The same situation occurs for the 4-fish bag limit. In total, the decline in PV of CS of red snapper anglers in the east is greater than the increase in the west Gulf so that for the total the PV of CS declines. The change in the recreational PV of CS in the east and west Gulf is mostly offset by the change in the other direction in angler's PV of CS for other reef fish.

Another point to consider when evaluating the decline in PV of CS by red snapper anglers in the east is that intuitively one would think that recreational anglers would prefer a higher bag limit and that their PV of CS should increase with higher bag limits. The problem however, has to do with the length of season. In this analysis we allow the simulation model to close the recreational red snapper fishery instead of setting a specific closure date. With a higher bag limit the season closes earlier in the year than it does with a lower bag limit (Table 1.9). So, while on a given day an angler may prefer a higher bag limit (if this is his only option), overall he may actually prefer a lower bag limit if the season is extended. Hence, PV of CS can be greater for lower bag limits.[7] Therefore the red snapper angler may prefer a 2-fish bag limit with a longer season than the 3-fish or 4-fish bag limit with the shorter fishing season.

The interaction between PV of CS for red snapper anglers, vermilion anglers, and other reef fish anglers is determined by the recreational demand equation at the end of each simulation time step (month). The recreational demand equation is described in detail in Chapter 3. The coefficients used in the simulation are taken from Model 4 in Table 3.3, with all variable evaluated at their means except for the following. Costs per trip are held constant at the average

[6] Recreation TAC = 2.45 million fish; minimum size limit = 16"; opening date = June 1.

[7] This argument does not hold if they are unable to fill the TAC within the year as with the 1-fish bag limit.

levels by vessel class. The most important variation between simulations is the variation that arises in the catch per unit of effort (CPUE) by month and vessel class. In this simulation model we did not determine the directed effort by recreational vessels and species before calibrating the model. In the simulation model we have total effort by all recreational vessels. During the simulation we allocate directed effort by vessel and species based on CPUE as follows:

$$DE_{s,v,m} = RE \cdot CPUE_{s,v,m} \Big/ \left(\sum_{v} \sum_{s} CPUE_{s,v,m} \right)$$

where DE_{svm} is the directed recreational effort to species s by vessel v in month m, RE is the total recreational effort, $CPUE_{svm}$ is the catch per unit effort by vessels, species and month. If the red snapper fishery is open, then the total recreational effort must be allocated across red snapper, vermilion snapper, and other reef fish. This will cause a positive value for PV of CS for red snapper and will reduce the PV of CS for vermilion snapper and other reef fish. If the red snapper fishery is closed, then directed effort will only be between vermilion snapper and other reef fish, though all three recreational vessels will continue to catch red snapper but at a reduced catchability coefficient and all red snapper will be discarded.

The PV of PS for the for-hire recreational vessels is based on the number of angler trips for that species. Since the anglers trips are allocated based on CPUE as explained above, a 1-fish bag limit will cause the CPUE to decline for red snapper and more recreational trips will be assigned to vermilion snapper and other reef fish. This causes PV of PS for the red snapper for-hire recreational vessels to fall in both the east and west Gulf (Table 1.8). Table 1.11 compares the PV of PS for for-hire vessels with PV of CS recreational anglers. In the east Gulf the change in PV of PS for for-hire vessels is positive whereas PV of CS for recreation anglers is negative. The change in PV of TS is negative in the east Gulf. Thus, in the east Gulf changing from a 2-fish bag limit to any of the three alternatives will cause PV of TS to decline. In the east or the west Gulf changing to a 1-fish bag limit is costly especially for the east Gulf. In the west Gulf increasing bag limit to 3 or a 4-fish has minor positive benefits (Table 1.11). Adding recreational PV of PS and CS gives the same basic results (Table 1.12).

3. Minimum Size Limits for Recreational Vessels

The base case has a recreational minimum size limit equal to 16 inches since that requirement was in effect in 2008. Commercial red snapper minimum size limit is held constant at 13 inches. Table 1.13 displays the difference in the cumulative PV of PS and CS for different minimum size limits compared to the base case (holding other policies constant except the closing date). We subtract the base case from the proposed options.

The most noticeable effect of changing the minimum size is that basically we get the opposite results in PV of CS in the east and west Gulf for red snapper recreational anglers. In the east Gulf, lowering the minimum size limit has a negative effect on the PV of CS of red snapper recreational anglers, which is offset by the increase in PV of CS of the recreational anglers of vermilion snapper and other reef fish anglers. In the west Gulf, there are positive results for recreational red snapper anglers for lowering the minimum size limit and negative results for other reef fish anglers. The TAC is filled for all minimum size limits and the lower the size limit the quicker the TAC is filled (Table 1.14)

As discussed above the east Gulf has the smaller red snapper stock than the west Gulf and a larger percent of the recreational angler's landings. Figure 1.6 shows that the number of age 2 fish recruited to the fishery is very sensitive to the minimum size fish that can be landed in the east Gulf. In the east Gulf when the size limit is 13 inches the number of age 2 fish recruited to the red snapper fishery is 3.83 million. At a minimum size limit of 14 inches 4.24 million are recruited to the fishery. If the minimum size limit is 15 or 16 inches, then 4.42 to 4.43 million age-2 fish are recruited to the fishery. So by having at least a 15 inch minimum size limit, approximately 600,000 more age 2 fish are recruited to the fishery than with a minimum size limit of 13 inches. This has a significant impact on the effective number of spawners and the S/S_0. With a 13 inch minimum size limit the effective number of spawners and the S/S_0 decline slightly. In the west Gulf, the minimum size limit has basically no impact on the age 2 recruits, the effective number of spawners, and the S/S_0.

The decrease in PV of CS of red snapper anglers in the east Gulf is more than offset by the vermilion snapper and other reef fish angler's increase in PV of CS (Table 1.13). The red snapper for-hire vessels experience a negative change in PV of PS only for a red snapper minimum size limit of 13 inches in both the east and west Gulf. Red snapper commercial fishermen experience a slight negative impact in PV of PS for all reductions in the minimum size limit. These last results occur because at a lower minimum size limit more fish are required to fill the recreational TAC based on pounds, leaving fewer fish to be harvested by the commercial red snapper fishermen.

Table 1.15 shows the PV of PS, CS and TS by fishery. The most significant results revealed by this analysis is the change to PV of CS by other reef anglers in the east Gulf more than offsets the negative effect to the PV of CS for the red snapper recreational anglers. This implies that evaluating policies for a single species may lead to an incorrect policy because of the effect on other fisheries. So, reducing to a 13 inch minimum size limit in the east Gulf could have a PV of CS for recreational red snapper fishermen of -$155.8 million, but the change in PV of TS would be a positive $11.6 million, mainly because of the increase in other reef angler's PV of CS of $157.6 million. However, when factoring in the effect on the stock of red snapper, a minimum size limit should be not less than 14 inches (Figure 1.6). The marginal increase in the effective number of spawners decreases as the minimum size limit declines. In the west Gulf there is basically no difference in the effective number of spawners as the minimum size limits changes. Based on these results, we believe that different size limits for the east and west Gulf would be worth considering.

4. Total Allowable Catch (TAC)

The base case has the total TAC at 5 million pounds of which 51% goes to the commercial sector and 49% to the recreational in 2008. The minimum size limit is held constant at 16 inches, the bag limit at 2-fish, and the recreational season open on June 1. As with the minimum size limit, the impacts on the PV of CS for the red snapper recreational anglers in the west Gulf are the opposite sign of the impacts on the east Gulf (Table 1.17). What is surprising is that under these base-case settings is that the red snapper anglers do not fill the TAC if it is greater the 5.0 million pounds with 49% allocated to recreational anglers. So with a TAC greater than 5.0 million pounds, the recreational anglers get catch to red snapper to the end of December.

Not being able to land more than approximately 2.5 million pounds is good news for increasing the adult stock. Looking at Figure 1.7, we find that there is basically no effect on the number of age 2 fish recruited to the fishery in the east or west Gulf. This is because the minimum size limit is 16 inches for the recreational anglers. We see that effective number of spawners and the S/S_0 decrease as the TAC increases. This is because the commercial red snapper harvester's do land their TAC (Table 1.19). However, at each alternative TAC level considered, the effective number of spawners and the S/S_0 increase over the 24-year period and they are still increasing in 2032.

Table 1.21 shows that increasing the TAC increases the PV of TS in the east and in the west Gulf. The only decrease is for the for-hire recreation vessels in the east Gulf. This decrease is due to the decrease in PV of PS for other reef fish for-hire vessels (Table 1.17). However, the PV of PS for all the for-hire vessels in the east and west Gulf is positive (Table 1.21).

Increasing the TAC appears to be beneficial to PV of TS and the stock of red snapper in both the east and west Gulf continue to increase through 2032. This assumes that a 16 inch size limit, a 2 fish bag limit and the recreational season begins June 1, especially in the east Gulf.

5. Efficiency Frontier

Thus far we have restricted the simulation by allowing only one policy to changes at a time while holding all the others policies at their base level. In this section we consider all policies combinations to vary simultaneously. The policy combinations range will be:

Bag limit: 1 to 4 fish

Minimum size limit: 13 to 16 inches

TAC: 5 to 12 million pounds with 51% to commercial and 49% to recreational

Opening month for the recreational fishery: April 1 and June 1.

Running all combinations involves 256 simulations. Figures 1.8 and 1.9 show the plot of these 256 simulations for the east and west Gulf, respectively. The horizontal axis is the S/S_0 by the end of the policy simulation (2032) and the vertical axis is the change in the PV of surplus (in million dollars) from the base case[8]. Plotted on each graph is the change in the PV of TS for all reef fish and for just red snapper fishery. The main results is that if only the PV of TS for red snapper is considered then in the east Gulf the change in discounted PV of TS could exceed $1.5 billion or could be lower than -$500 million. When taking into account the effect of change in

[8] Only changes are made in the red snapper policies: TAC=2.45, bag limit=2, size limit=16 inches, and the opening month is June 1

PV of TS on all reef fish fisheries then the change in the PV of TS is much narrower, no higher than $500 million or lower than -$20 million. The same is true in the west Gulf. When just considering the changes in PV of TS for red snapper the variation in PV of TS range by about $490 million, while aggregating across all reef fisheries the range is only about $150 million.

Another interesting difference between the two figures is the horizontal spread of the data points. In the east Gulf (Figure 1.8) many of the data points fall below $S/S_0 = 0.5$ where as in the west Gulf all data point are well above $S/S_0 = 0.5$. This makes sense since most of the recreational fishing is in east Gulf while the greatest stock of red snapper is in the west Gulf. More concern must be given to the effect on S/S_0 in the east Gulf when changing red snapper recreational policy than in the west Gulf. A "one size fits all" policy is not necessarily the correct approach when changing red snapper recreational policy for the Gulf.

From the data presented in Figures 1.8 and 1.9 we develop an efficiency frontier (EF) for the east and west Gulf and for the red snapper fishery and for the total reef fish fishery. We select the outer most points from the origin and, using a quadratic equation, we calculate a regression for the four EFs. All four regressions yielded as R-squared values greater than 0.999. We then developed a rating for each policy combination based on economic performance which is the vertical distance from the EF. The results are presented in Figures 1.10. The top two graphs include only changes in PV of TS for red snapper and the graphs in the bottom include changes in PV of TS for all reef fish.

In the graphs in Figure 1.10 there are seven different ratings of economic performance based on their vertical distance from the EF. Notice that each vertical axis in the four graphs has different scale due the value of the fishery. In each graph the group of policies closest to the EF (the squares) are given a rating of 1; the policies next closest to the EF are given a rating of 2; etc. Policies are given a rating of 8 if they would cause the change in PV of TS to be less than the base case (the black dot on the graphs).

We view the policies rated 8th (below the black dot) as inferior since these policies would have a negative impact on PV of TS. Any policy above the black dot would be superior to the base policy in terms of PV of TS. Any policy above and to the right of the black dot would improve both the S/S_0 and change in PV of surplus. However, the problem is that policies that are above and to the right of the black dot for red snapper in the east Gulf may not be the same policies that are above and to the right of the black dot for red snapper in the west Gulf as Table 1.22 illustrates. Likewise, policies that are above and to the right of the black dot for red snapper in the east Gulf may not are above and to the right of the black dot for total reef fish in the east Gulf.

There are only 15 policy combinations that are above and to the right of the black dot for at least one of the four graphs are shown in Table 1.22. A blank in any of the four "S/S_0" columns means that policy is not above and to the right of the black dot for that given region and fishery combination although it is for at least one other region and fishery combinations. For example, the column labeled "West RS" under "S/S_0" has only two policies (number 1 and 2) that are above and to the right of the black dot. The column labeled "East RS" under "S/S_0" has 13 of the 15 policies that are above and to the right of the black dot. Only policy numbers 1 and 2 are above and to the right of the black dot for all four regions and fishery combinations shown in the four graphs in Figure 1.10. That is, only 2 of the 15 policies show an improvement in both the "Change in surplus" and in "S/S_0" for the four region and fishery combinations.

Notice also that there are several negative values for the "Change in Surplus" in table 1.22. This means that while a policy may show an improvement in both the "S/S_0" and "Change

in Surplus" for a given region and fishery combination, it would be considered an inferior policy in terms of "Change in Surplus" for a different region and fishery combination. For example, policies 13 through 15 would be an improvement in the west Gulf for the total reef fish "Change in Surplus", but would be considered an inferior policy for the other three region and fisheries combinations because there "Change in Surplus" is negative.

Now there are numerous policies above and to the left of the black dot for which there can be a trade off between S/S_0 and PV of TS. The problem is how to determine which policies are better since the red snapper fishery in the Gulf is being managed as a single unit. We will use an ad hoc ranking method based on the rating method described above to evaluate the superior policies (those with PV of TS greater then zero). We will use the following equation to calculate the "Total" ratings for polices as:

Total = East RSS + West RSS + East TS + West TS

where East RSS is the rating when only considering the change in PV of TS for the east Gulf red snapper; West RSS is the rating when only considering the change in PV of TS for the west Gulf red snapper; West TS is the rating when only considering the change in PV of TS for the west Gulf total reef fish; and East TS is the rating when only considering the change in PV of TS for the west Gulf total reef fish. We will also calculate the "Sum S/S_0" as:

Sum S/S_0 = East S/S_0 + West S/S_0.

Ranking the policies is determined by sorting the "Total" value for the policies in ascending order and then the "Sum S/S_0" in descending order. The results for the top 30 ranked policies are given in Table 1.23[9] and for all policies in Appendix B.

Policies numbers 1 through 5 all have a Total rank of 4 which means they were ranked 1 by East RSS, West RSS, East TS, and West TS; that is, they are all on or near the EF. We show these first five ranked policies in Figure 1.11. Policy number 1 would be very good in increasing the stocks in the east and west Gulf, but have little effect on PV of TS for the east and west Gulf red snapper fishery. As we move from policy number 1 to policy number 5 we see a decline in S/S_0 for both the east and west Gulf and an increase in the change in PV of TS.

Figure 1.12 shows the impact on the effective number spawners, S/S_0, and age 2 recruits of the top five ranked policies for the east and west Gulf. In the west Gulf we see that the stock continues to improve for all policies. In the east Gulf, however, the 4th and 5th ranked policies cause all three biological measures to decline in a manner that would probably be unacceptable. In essence, there was too much of a tradeoff between economic efficiency and S/S_0 in the east Gulf. For the 4th and 5th ranked policies the east S/S_0 was decreased from 0.64 (the base) to 0.41 and 0.30, respectively which is a decline of 27% and 54%. These values for S/S0 are the values in 2032. The value of S/S_0 in the east Gulf in 2008 is 0.53 and if the base policies are maintained through 2032 the value would be 0.64. So let's arbitrarily impose an additional criterion that the S/S_0 for the east red snapper cannot fall below 0.5. As an example, we see in Table 1.23 there are a number of policies that meet this criterion. We choose the 14th ranked policy because it is well within this new criterion but sufficiently below the 2032 base S/S_0 of 0.64. We chose the 20th ranked policy just meet this new criterion.

[9] The policy ranking numbering in Table 1.23 is unrelated to the policy numbering in Table 1.22.

In Figure 1.13 we substitute the 4th and 5th ranked policies with the 14th and 20th ranked policies (Table 1.23). There is a strong increase in the effective numbers of spawners in the east Gulf for policy ranked 14th and policy ranked 20th basically maintains the status quo. Therefore, when there is a single Gulf wide policy for recreational red snapper anglers, the ranking must have an additional limitation that in the east Gulf the S/S_0 cannot fall a given value, say 0.50, since it would cause the S/S_0 to decline. Any policy combination that causes a decline in the S/S_0 to decline should have a rating of 8. That is, in the equation

Total = East RSS + West RSS + East TS + West TS

the East RSS would be set to 8 if S/S_0 was less than 0.50.

When a single set of recreational red snapper policies is used Gulf wide, the stock in the east Gulf will be the limiting factor because it is the smaller of the red snapper stocks and it has about 80% of the red snapper anglers fishing in the Gulf. Serious consideration should be given to using separate managing policies for the red snapper recreational anglers in the east and west Gulf. For example, if the east Gulf was managed under the 14th ranked set of policies, with a TAC of 8 million lbs and a bag limit of 1, the gain in changed PV of TS in that region would be $114 M and the S/S_0 would be greater then 0.50. While if the west Gulf was managed under 5th ranked set of policies with a TAC of 11 million lbs and a bag limit of 3 then the gain in changed PV of TS for the west Gulf would be $128 M (Table 1.23).

Above we have shown that in an effort to increase economic value of the red snapper fishery while at the same time maintaining or improving a healthy fish stock, we find system is more complex and has multiple objectives that do not all perform exactly the same so that a policy that improves in one objective may also be less than satisfactory in another objective. It is clear that more work is needed. For example, it's not certain that fishery managers would accept a tradeoff in which biological status that would be lower than the base case. It is obvious that our ranking system in Table 1.23 should include additional constraint such as, in the east Gulf, S/So should not decline below the 2008 level of 0.53. Thus, the top ranking policies would not include any policy combinations in which the S/So would be less then 0.53.

V. Conclusions

In this chapter we have analyzed three major policy tools used by fisheries managers for the red snapper fishery. We have looked at the impact of alternative red snapper management policies on the PV of PS and CS not only for the red snapper fishery but also for the vermilion snapper and other reef fish fisheries. The policies considered have included the bag limit, minimum size limit, and the TAC. We have also looked at the stock effects to red snapper for each of the policies.

The PV of TS of the shrimp and reef fish fisheries in PV (7% discount rate) for the period 2009 to 2032 is $11.8 billion dollars. The recreational anglers contribute $9.1 billion followed by the shrimp fishery at $1.6 billion, the recreational for-hire fishery at $0.83 billion and the commercial reef at $0.27 billion.

An increase in red snapper bag limits from the current two-fish limit was found to have a negative influence on the red snapper recreational angler PV of CS in the east Gulf but a positive effect on vermilion and other reef fish recreational angler PV of CS. In the west Gulf it had a positive effect on both red and vermilion snapper recreational angler PV of CS, but a negative effect on other reef fish recreational anglers. A change to a 1-fish bag limit could not fill the

TAC by the end of December, and therefore was costly to both the east and west Gulf red snapper recreational anglers. This policy led to a decline in the PV of TS by as much as $40.0 million for the period 2009 to 2032. An increase in the bag limit basically had no effect on the stock of red snapper in the east and west Gulf with the exception of a 1-fish bag limit which increased the stock in the Gulf because anglers, beginning the open season June 1, were unable to harvest enough fish to fill the TAC.

A decrease in red snapper minimum size limit from the current 16 inches was found to have a negative influence on the red snapper recreational angler PV of CS in the east Gulf but a positive effect on other reef fish recreational angler PV of CS, which more than offset the decrease in red snapper PV of CS. Therefore the effect on PV of TS was always positive for decreases in the minimum size limit. The minimum size limit did have an effect on the red snapper stock of fish in the east Gulf but none in the west Gulf. In the east Gulf the 13 inch minimum size limit allowed the recreational fishermen to harvest more age 1 fish and reduce the number of red snapper that were recruited to the age 2 fish. This caused the number of effective spawners to remain fairly constant in the east Gulf from 2009 to 2032. A minimum size limit equal to or greater than 14 inches causes the effective numbers of spawners to increase in the east Gulf.

An increase in TAC always increased the PV of TS because in the east Gulf the increase an the red snapper recreational angler PV of CS was greater then the loss in the other reef recreational angler PV of CSs. The effective number of spawners increased in the east and west Gulf for all levels of TAC; although they increased at a slower rate at higher TACs and the recreational red snapper anglers could not fill the higher TACs by the end of December.

All previous stock assessments have concluded that red snapper in the Gulf are overfished and undergoing overfishing. Their results were the same when the two stocks (east and west stock) were managed independently or managed as a single unit. They did note that the east stock could recover in the time period allowed under certain conditions (SEDAR 7 SARI Section 1). However, recent published studies have shown that red snapper are density dependent and that age 0 and age 1 fish have a much higher natural mortality rate than was used in previous stock assessments. By using a density dependent model and a higher natural mortality for age 0 and age 1 fish, it appears to us that red snapper stock are neither overfished nor undergoing overfishing. It should be remembered however that in setting up the biological model we calibrated the simulation as two separate stocks with no movement back and forth between to two stocks. Also, because the natural mortality for age 0 and age 1 fish are much higher than originally assumed, shrimp trawls have less effect on red snapper reaching age 2+ than previously thought and therefore have a much less impact on the adult red snapper stock than previous modeling suggests.

EFs were estimated for the east and west Gulf. The EF suggest that there is always trade-offs between the change in surplus and S/S_0. It was shown that improvements could be made in the total surplus and still increase the stock of red snapper in both the east and west Gulf. It was also shown that the stock of red snapper in the east Gulf was the constraining factor when using a single policy for the whole Gulf.

Finally, over 70% of the commercial red snapper landings are from the west Gulf. Approximately 83% of the recreational harvest in the Gulf come from east of the Mississippi river. So the major portion of the commercial harvest is west of the Mississippi river and the major portion of the recreational harvest is east of the Mississippi river. The stock of red snapper on the east Gulf is only approximately 60% as large as the stock of red snapper in the west Gulf.

A single total TAC for the red snapper in the Gulf which always has a 51%-49% split between commercial and recreational fishermen can more readily cause more overfishing in the east than in the west Gulf. Future research and stock assessments need to look at separate management policies for the east and west Gulf red snapper fishery.

VI. References

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Table 1.1: Natural Mortality by Age for Red Snapper

	Age				
Case	0	1	2+	Shrimper's Fishing Index	Remark
1	0.98	0.59	0.1	1.00000	SEDAR 7, 2005
2	2.03	1.25	0.1	0.36074	Gazey, Gallaway, and Fournier
3	4	1.25	0.1	0.08519	Intermediate case
4	7.665	1.25	0.1	0.05926	Wells, Cowan, Patterson, and Walters

Table 1.2. Base policies

				Minimum Size Limit (inches)				Total Allowable Catch (TAC; mil. Lbs.)			
	Shrimp	Price		Red Snapper		Vermilion Snapper		Red Snapper		Vermilion Snapper	
year	Entry/exit	Shrimp	Fuel index	Comm	Rec	Comm	Rec	Comm	Rec	Comm	Rec
2006	Yes	constant	1	15	16	10	10	4.65	4.47	none	none
2007	Yes	constant	1.12	13	16	10	10	3.32	3.19	none	none
2008	Yes	constant	1.20	13	16	10	10	3.32	3.19	none	none
2009	Yes	constant	1.59	13	16	10	10	2.55	2.45	none	none
2010	Yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2011	Yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2012	Yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2013	Yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2014	Yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2015	Yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2016	Yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2017	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2018	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2019	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2020	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2021	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2022	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2023	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2024	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2025	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2026	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2027	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2028	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2029	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2030	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2031	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none
2032	yes	constant	1.12	13	16	10	10	2.55	2.45	none	none

Table 1.2. continued

	BagLimit				Direct Fishery Open (mo/day)				Tradeable Rights		
	Red Snapper		Vermilion Snapper		Red Snapper		Vermilion Snapper		Red Snapper		IFQ
year	Comm	Rec	Comm	Rec	Comm	Rec	Comm	Rec	Comm	Rec	Comm
2006	2,000	4	None	20	none	4/21-10/31	none	none	none	none	none
2007	none	2	None	20	none	4/21-10/31	none	none	none	none	yes
2008	none	2	None	20	none	6/1-8/5	none	none	none	none	yes
2009	none	2	None	20	none	6/1-9/30	none	none	none	none	yes
2010	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2011	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2012	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2013	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2014	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2015	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2016	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2017	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2018	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2019	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2020	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2021	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2022	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2023	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2024	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2025	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2026	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2027	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2028	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2029	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2030	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2031	none	2	none	20	none	6/1-9/30	none	none	none	none	yes
2032	none	2	none	20	none	6/1-9/30	none	none	none	none	Yes

Table 1.3: Policies analyzed for recreational red snapper

Run	Recreational Minimum Size Limit* (TL inches)	TAC (million pounds; 51% commercial and 49% recreational)	Recreational Bag Limit (number fish)
Base	16	5	2
1	13	5	2
2	14	5	2
3	15	5	2
4	16	6	2
5	16	7	2
6	16	8	2
7	16	9	2
8	16	10	2
9	16	5	1
10	16	5	3
11	16	5	4

*Commercial minimum size limit is held constant at 13 inches for all policies.

Table 1.4: Percent decline in effort (days fished) and landings from 2006 in the Gulf of Mexico shrimp fishery

Effort:			
Vessel	East	West	Gulf
Small	99.1	99.9	99.8
Large	30.6	43.6	40.7
Both	47.9	66.6	63.2
Landings:			
Vessel	East	West	Gulf
Small	98.9	99.9	99.7
Large	6.4	1.2	2.2
Both	24.9	33.8	32.3

Table 1.5: Comparison of Cumulative Present Value of Surplus ($1,000,000) Base Case* By Area, Vessel Class and Fisheries

Region	Shrimp Comm. (PS)	Red Snapper Comm. (PS)	Vermilion Snapper Comm. (PS)	Other Reef Fish Comm. (PS)	Red Snapper Comm. (CS)	Red Snapper For-Hire (PS)	Vermilion Snapper For-Hire (PS)	Other Reef Fish For-Hire (PS)	Red Snapper Angler (CS)	Vermilion Snapper Angler (CS)	Other Reef Fish Angler (CS)
East	246.6	22.5	18.2	148.8	1.2	151.9	70.7	389.9	1,742.8	257.3	5,975.1
West	1,403.3	18.8	27.2	29.7	1.7	33.9	12.1	176.2	153.9	34.8	906.7
Total	1,649.9	41.2	45.4	178.5	2.9	185.8	82.8	566.1	1,896.8	292.1	6,881.8

Table 1.6: Comparison of Cumulative Present Value of Surplus ($1,000,000) Base Case by Area and Fisheries

Region	Shrimp Comm. (PS)	Comm. Reef Vessels (PS)	Comm. Reef (CS)	Rec. For-Hire Vessels (PS)	Rec. Reef Fish (CS)	Total Surplus
East	246.6	189.4	1.2	612.5	7,975.2	9,025.0
West	1,403.3	75.7	1.7	222.1	1,095.5	2,798.2
Total	1,649.9	265.1	2.9	834.6	9,070.7	11,823.2

Table 1.7: Comparison of Cumulative Present Value of Surplus ($1,000,000) Base Case by Area and Fisheries

Region	Shrimp Comm. (PS)	Comm. Reef (PS+CS)	Rec. (PS+CS)	Total Surplus
East	246.6	190.7	8,587.7	9,025.0
West	1,403.3	77.4	1,317.6	2,798.2
Total	1,649.9	268.0	9,905.3	11,823.2

Table 1.8: Difference in Cumulative Present Value ($1,000,000) Bag Limits (Base = 2) By Area, Vessel Class and Fisheries

Region	Bag Limit	Shrimp Comm. (PS)	Red Snapper Comm. (PS)	Vermilion Snapper Comm. (PS)	Other Reef Fish Comm. (PS)	Red Snapper Comm. (CS)	Red Snapper For-Hire (PS)	Vermilion Snapper For-Hire (PS)	Other Reef Fish For-Hire (PS)	Red Snapper Angler (CS)	Vermilion Snapper Angler (CS)	Other Reef Angler (CS)
East	1	0.0	2.6	0.0	0.0	0.1	-43.1	6.9	42.5	-394.7	19.9	287.8
East	3	0.0	-0.6	0.0	0.0	0.0	6.4	-1.5	3.6	-190.3	2.0	165.3
East	4	0.0	-0.7	0.0	0.0	0.0	3.7	-0.7	12.3	-344.1	9.3	288.4
West	1	0.0	-2.3	0.0	0.0	-0.1	-12.1	0.4	23.3	-52.0	0.2	38.1
West	3	0.0	0.5	0.0	0.0	0.0	7.0	0.3	-13.7	23.2	2.2	-18.3
West	4	0.0	0.6	0.0	0.0	0.0	11.4	0.2	-20.5	36.8	2.1	-27.3
Gulf	1	0.0	0.3	0.0	0.0	0.0	-55.2	7.3	65.8	-446.7	20.1	325.9
Gulf	3	0.0	-0.1	0.0	0.0	0.0	13.4	-1.1	-10.1	-167.1	4.2	146.9
Gulf	4	0.0	-0.1	0.0	0.0	0.0	15.1	-0.5	-8.2	-307.3	11.4	261.2

Table 1.9: Recreational Landings by Bag Limit and Month the TAC is Filled

	Landings (mil lbs)				Month TAC filled			
Year	1 Bag	2 Bag	3 Bag	4 Bag	1 Bag	2 Bag	3 Bag	4 Bag
2009	1.31	2.32	2.45	2.45	Not Filled	Not Filled	10	10
2010	1.42	2.45	2.51	2.45	Not Filled	12	10	9
2011	1.50	2.45	2.51	2.54	Not Filled	12	10	9
2012	1.54	2.49	2.54	2.49	Not Filled	12	10	9
2013	1.57	2.46	2.50	2.58	Not Filled	12	10	9
2014	1.59	2.45	2.56	2.47	Not Filled	11	10	9
2015	1.60	2.46	2.47	2.58	Not Filled	11	10	9
2016	1.60	2.46	2.53	2.45	Not Filled	11	10	9
2017	1.61	2.46	2.45	2.52	Not Filled	11	10	9
2018	1.61	2.46	2.47	2.45	Not Filled	11	10	9
2019	1.61	2.46	2.45	2.51	Not Filled	11	10	9
2020	1.61	2.47	2.46	2.45	Not Filled	11	10	9
2021	1.61	2.46	2.45	2.51	Not Filled	11	10	9
2022	1.61	2.47	2.45	2.45	Not Filled	11	10	9
2023	1.61	2.45	2.45	2.50	Not Filled	11	10	9
2024	1.61	2.46	2.45	2.45	Not Filled	11	10	9
2025	1.61	2.45	2.45	2.50	Not Filled	11	10	9
2026	1.62	2.46	2.45	2.45	Not Filled	11	10	9
2027	1.62	2.45	2.45	2.50	Not Filled	11	10	9
2028	1.62	2.46	2.45	2.45	Not Filled	11	10	9
2029	1.62	2.45	2.45	2.50	Not Filled	11	10	9
2030	1.62	2.46	2.45	2.45	Not Filled	11	10	9
2031	1.62	2.45	2.45	2.50	Not Filled	11	9	9
2032	1.62	2.46	2.45	2.45	Not Filled	11	9	9

Table 1.10: Landings (mil lbs) by Bag Limit and Area Fished

	Commercial Landings (mil lbs)				**Recreational Landings (mil lbs)**			
Region	1 Bag	2 Bag	3 Bag	4 Bag	1 Bag	2 Bag	3 Bag	4 Bag
East	0.81	0.79	0.79	0.79	1.38	2.03	1.84	1.84
West	1.75	1.83	1.85	1.83	0.24	0.43	0.61	0.61
Total	2.55	2.62	2.64	2.62	1.62	2.46	2.45	2.45

Table 1.11: Difference in Cumulative Present Value ($1,000,000)
Bag Limits (Base = 2) By Area and Fisheries

Region	Bag Limit	Shrimp Comm. (PS)	Comm. Reef Vessels (PS)	Comm. Reef (CS)	For-Hire Vessels (PS)	Rec. Reef Fish (CS)	Total Surplus
East	1	0.0	2.6	0.1	6.3	-87.0	-78.0
East	3	0.0	-0.6	0.0	8.6	-23.0	-15.1
East	4	0.0	-0.7	0.0	15.3	-46.4	-31.8
West	1	0.0	-2.3	-0.1	11.6	-13.7	-4.5
West	3	0.0	0.5	0.0	-6.4	7.1	1.2
West	4	0.0	0.6	0.0	-8.9	11.6	3.3
Gulf	Gulf	0.0	0.3	0.0	17.9	-100.7	-82.5
Gulf	Gulf	0.0	-0.1	0.0	2.1	-15.9	-13.9
Gulf	Gulf	0.0	-0.6	0.0	8.6	-23.0	-15.1

Table 1.12: Difference in Cumulative Present Value ($1,000,000)
Bag Limits (Base = 2) By Fisheries

Region	Bag Limit	Shrimp Comm. (PS)	Comm. Reef (PS+CS)	Rec. Reef (PS+CS)	Total Surplus (TS)
East	1	0.0	2.7	-80.7	-78.0
East	3	0.0	-0.6	-14.5	-15.1
East	4	0.0	-0.8	-31.1	-31.8
West	1	0.0	-2.4	-2.1	-4.5
West	3	0.0	0.5	0.6	1.2
West	4	0.0	0.6	2.6	3.3
Gulf	1	0.0	0.3	-82.8	-82.5
Gulf	3	0.0	-0.1	-13.8	-13.9
Gulf	4	0.0	-0.6	-14.5	-15.1

Table 1.13: Difference in Cumulative Present Value ($1,000,000)
Minimum Size Limits (Base = 16) For Recreational Anglers By Vessel Class and Fisheries

Region	Minimum Size Limit	Shrimp Comm. (PS)	Red Snapper Comm. (PS)	Vermilion Snapper Comm. (PS)	Other Reef Fish Comm. (PS)	Red Snapper Comm. (CS)	Red Snapper For-Hire (PS)	Vermilion Snapper For-Hire (PS)	Other Reef Fish For-Hire (PS)	Red Snapper Angler (CS)	Vermilion Snapper Angler (CS)	Other Reef Angler (CS)
East	13 Inch	0.0	-6.0	0.0	0.0	-0.2	-18.4	1.7	31.4	-155.8	1.3	157.6
East	14 Inch	0.0	-3.0	0.0	0.0	-0.1	1.6	-1.0	4.9	-66.3	-1.9	81.9
East	15 Inch	0.0	-0.8	0.0	0.0	0.0	0.9	-0.5	3.2	-38.7	-1.2	42.4
West	13 Inch	0.0	5.7	0.0	0.0	0.2	6.6	0.5	-14.4	31.7	2.5	-19.0
West	14 Inch	0.0	2.8	0.0	0.0	0.1	6.2	0.5	-13.9	21.0	2.5	-13.5
West	15 Inch	0.0	0.8	0.0	0.0	0.0	2.4	0.2	-5.6	6.3	1.7	-4.9
Gulf	13 Inch	0.0	-0.4	0.0	0.0	0.0	-11.8	2.3	17.0	-124.2	3.8	138.7
Gulf	14 Inch	0.0	-0.2	0.0	0.0	0.0	7.8	-0.5	-9.1	-45.3	0.6	68.4
Gulf	15 Inch	0.0	-0.1	0.0	0.0	0.0	3.4	-0.2	-2.3	-32.3	0.5	37.5

Table 1.14: Recreational Landings by Minimum Size Limit and Month the TAC Filled

	Landings (mil lbs)				Month TAC filled			
Year	13 Inch	14 inch	15 inch	16 inch	13 inch	14 inch	15 inch	16 inch
2009	2.45	2.45	2.45	2.33	9	10	11	Not filled
2010	2.53	2.58	2.45	2.45	9	10	11	12
2011	2.45	2.45	2.52	2.46	9	10	11	12
2012	2.48	2.54	2.45	2.48	9	10	11	12
2013	2.45	2.45	2.51	2.45	9	10	11	12
2014	2.49	2.53	2.45	2.45	9	10	11	11
2015	2.45	2.45	2.47	2.47	9	10	11	11
2016	2.49	2.53	2.45	2.45	9	10	10	11
2017	2.45	2.45	2.46	2.47	9	10	10	11
2018	2.49	2.53	2.45	2.45	9	10	10	11
2019	2.45	2.45	2.45	2.46	9	10	10	11
2020	2.49	2.52	2.45	2.45	9	10	10	11
2021	2.45	2.45	2.45	2.47	9	10	10	11
2022	2.49	2.52	2.45	2.45	9	10	10	11
2023	2.45	2.45	2.45	2.46	9	10	10	11
2024	2.49	2.53	2.45	2.45	9	10	10	11
2025	2.45	2.45	2.45	2.46	9	10	10	11
2026	2.49	2.52	2.45	2.45	9	10	10	11
2027	2.45	2.45	2.45	2.46	9	10	10	11
2028	2.49	2.52	2.45	2.45	9	10	10	11
2029	2.45	2.45	2.45	2.46	9	10	10	11
2030	2.49	2.53	2.45	2.45	9	10	10	11
2031	2.45	2.45	2.46	2.47	9	10	10	11
2032	2.49	2.52	2.45	2.45	9	10	10	11

Table 1.15: Difference in Cumulative Present Value ($1,000,000) Minimum Size Limits (Base = 16”) For Recreational Anglers By Fisheries

Region	Minimum Size Limit	Shrimp Comm. (PS)	Comm. Reef Vessels (PS)	Comm. Reef (CS)	For-Hire Vessels (PS)	Rec. Reef Fish (CS)	Total Surplus (TS)
East	13 Inch	0.0	-6.0	-0.2	14.7	3.2	11.6
East	14 Inch	0.0	-3.0	-0.1	5.4	13.7	16.0
East	15 Inch	0.0	-0.8	0.0	3.7	2.6	5.4
West	13 Inch	0.0	5.7	0.2	-7.2	15.2	13.8
West	14 Inch	0.0	2.8	0.1	-7.2	10.0	5.7
West	15 Inch	0.0	0.8	0.0	-2.9	3.1	1.0
Gulf	13 Inch	0.0	-0.4	0.0	7.4	18.3	25.4
Gulf	14 Inch	0.0	-0.2	0.0	-1.8	23.8	21.7
Gulf	15 Inch	0.0	-0.1	0.0	0.8	5.7	6.4

Table 1.16: Difference in Cumulative Present Value ($1,000,000) Minimum Size Limits (Base = 16”) For Recreational Anglers By Fisheries

Region	Region & Size Limit	Shrimp Comm. (PS)	Comm. Reef (PS+CS)	Rec. Reef (PS+CS)	Total Surplus (TS)
East	13 inch	0.0	-6.2	17.8	11.6
East	14 inch	0.0	-3.1	19.2	16.0
East	15 inch	0.0	-0.8	6.3	5.4
West	13 inch	0.0	5.9	7.9	13.8
West	14 inch	0.0	2.9	2.8	5.7
West	15 inch	0.0	0.8	0.2	1.0
Gulf	13 inch	0.0	-0.4	25.8	25.4
Gulf	14 inch	0.0	-0.2	21.9	21.7
Gulf	15 inch	0.0	-0.1	6.5	6.4

Table 1.17: Difference in Cumulative Present Value ($1,000,000) TAC (Base = 5) For Recreational Anglers By Vessel Class and Fisheries

Region	TAC (M lb)	Shrimp Comm. (PS)	Red Snapper Comm. (PS)	Vermilion Snapper Comm. (PS)	Other Reef Fish Comm. (PS)	Red Snapper Comm. (CS)	Red Snapper For-Hire (PS)	Vermilion Snapper For-Hire (PS)	Other Reef Fish For-Hire (PS)	Red Snapper Angler (CS)	Vermilion Snapper Angler (CS)	Other Reef Angler (CS)
East	6	0.0	-0.3	0.0	0.0	0.0	7.1	-0.7	-10.9	135.2	-2.5	-109.5
East	7	0.0	-0.3	0.0	0.0	0.0	7.1	-0.7	-11.0	135.4	-2.5	-109.6
East	8	0.0	-0.4	0.0	0.0	0.0	7.1	-0.7	-11.0	135.6	-2.5	-109.8
East	9	0.0	-0.5	0.0	0.0	0.0	7.1	-0.7	-11.0	136.0	-2.6	-110.1
East	10	0.0	-0.7	0.0	0.0	0.0	7.2	-0.7	-11.0	136.4	-2.6	-110.4
West	6	0.0	16.3	0.0	0.0	0.6	-0.1	-0.2	0.8	0.9	-1.2	0.4
West	7	0.0	32.4	0.0	0.0	1.2	-0.6	-0.2	1.7	-1.5	-1.2	2.1
West	8	0.0	48.4	0.0	0.0	1.7	-1.1	-0.2	2.7	-3.9	-1.1	3.8
West	9	0.0	63.9	0.0	0.0	2.3	-1.6	-0.1	3.7	-6.3	-1.1	5.6
West	10	0.0	79.1	0.0	0.0	2.8	-2.2	-0.1	4.6	-8.7	-1.0	7.3
Gulf	6	0.0	16.0	0.0	0.0	0.6	7.0	-0.9	-10.2	136.1	-3.8	-109.0
Gulf	7	0.0	32.1	0.0	0.0	1.1	6.5	-0.9	-9.2	133.9	-3.7	-107.5
Gulf	8	0.0	48.0	0.0	0.0	1.7	6.0	-0.8	-8.3	131.8	-3.7	-105.9
Gulf	9	0.0	63.3	0.0	0.0	2.3	5.5	-0.8	-7.3	129.8	-3.6	-104.5
Gulf	10	0.0	78.4	0.0	0.0	2.8	5.0	-0.8	-6.4	127.7	-3.6	-103.1

Table 1.18: Recreational Landings by TAC and Month the TAC Filled

	Landings (mil lbs)						Month TAC filled					
Year	5 TAC	6 TAC	7 TAC	8 TAC	9 TAC	10 TAC	5 TAC	6 TAC	7 TAC	8 TAC	9 TAC	10 TAC
2009	2.32	2.31	2.3	2.3	2.29	2.28	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2010	2.45	2.43	2.42	2.4	2.38	2.36	12	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2011	2.45	2.51	2.49	2.46	2.44	2.41	12	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2012	2.49	2.56	2.53	2.5	2.48	2.45	12	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2013	2.46	2.59	2.56	2.53	2.5	2.47	12	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2014	2.45	2.61	2.58	2.55	2.52	2.49	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2015	2.46	2.62	2.59	2.56	2.53	2.49	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2016	2.46	2.63	2.6	2.57	2.54	2.5	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2017	2.46	2.63	2.6	2.57	2.54	2.5	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2018	2.46	2.63	2.6	2.57	2.54	2.51	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2019	2.46	2.64	2.61	2.58	2.55	2.51	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2020	2.47	2.64	2.61	2.58	2.55	2.51	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2021	2.46	2.64	2.61	2.58	2.55	2.51	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2022	2.47	2.64	2.61	2.58	2.55	2.51	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2023	2.45	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2024	2.46	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2025	2.45	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2026	2.46	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2027	2.45	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2028	2.46	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2029	2.45	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2030	2.46	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2031	2.45	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled
2032	2.46	2.64	2.61	2.58	2.55	2.52	11	Not Filled	Not Filled	Not Filled	Not Filled	Not Filled

Table 1.19 Landings by TAC for the Recreational and Commercial Fisheries in 2032

	Commercial Landings (mil lbs)						Recreational Landings (mil lbs)					
Region/TAC	5	6	7	8	9	10	5	6	7	8	9	10
East	0.79	0.94	1.09	1.25	1.40	1.55	2.03	2.21	2.19	2.16	2.14	2.12
West	1.83	2.20	2.55	2.89	3.23	3.56	0.43	0.43	0.42	0.42	0.41	0.40
Gulf	2.62	3.14	3.65	4.14	4.63	5.11	2.46	2.64	2.61	2.58	2.55	2.52

Table 1.20: Difference in Cumulative Present Value ($1,000,000) TAC (Base = 5) For Recreational Anglers By Fisheries

Region	TAC (M lb.)	Shrimp Comm. (PS)	Comm. Reef Vessels (PS)	Comm. Reef (CS)	For-Hire Vessels (PS)	Rec. Reef Fish (CS)	Total Surplus (TS)
East	6	0.0	-0.3	0.0	-4.5	23.2	18.4
East	7	0.0	-0.3	0.0	-4.5	23.3	18.4
East	8	0.0	-0.4	0.0	-4.5	23.3	18.4
East	9	0.0	-0.5	0.0	-4.5	23.4	18.3
East	10	0.0	-0.7	0.0	-4.6	23.5	18.2
West	6	0.0	16.3	0.6	0.5	0.1	17.4
West	7	0.0	32.4	1.2	0.9	-0.5	34.0
West	8	0.0	48.4	1.7	1.4	-1.1	50.4
West	9	0.0	63.9	2.3	1.9	-1.7	66.3
West	10	0.0	79.1	2.8	2.3	-2.4	81.9
Gulf	6	0.0	16.0	0.6	-4.1	23.3	35.8
Gulf	7	0.0	32.1	1.1	-3.6	22.7	52.4
Gulf	8	0.0	48.0	1.7	-3.2	22.2	68.8
Gulf	9	0.0	63.3	2.3	-2.7	21.6	84.6
Gulf	10	0.0	78.4	2.8	-2.2	21.1	100.1

Table 1.21: Difference in Cumulative Present Value ($1,000,000) TAC (Base = 5) For Recreational Anglers By Fisheries

Region	TAC (M lb.)	Shrimp Comm. (PS)	Comm. Reef (PS+CS)	Rec. Reef (PS+CS)	Total Surplus (TS)
East	6	0.0	-0.3	18.7	18.4
East	7	0.0	-0.3	18.7	18.4
East	8	0.0	-0.4	18.8	18.4
East	9	0.0	-0.6	18.8	18.3
East	10	0.0	-0.7	18.9	18.2
West	6	0.0	16.9	0.5	17.4
West	7	0.0	33.6	0.4	34.0
West	8	0.0	50.2	0.3	50.4
West	9	0.0	66.2	0.1	66.3
West	10	0.0	81.9	0.0	81.9
Gulf	6	0.0	16.6	19.2	35.8
Gulf	7	0.0	33.2	19.1	52.4
Gulf	8	0.0	49.7	19.0	68.8
Gulf	9	0.0	65.6	19.0	84.6
Gulf	10	0.0	81.2	18.9	100.1

Table 1.22: Policies that Improve Both the Surplus and the S/So relative to the Base Policy by region and fishery. A blank in any or the S/S_0 means that policy is not above and to the right for that region and fisheries combination.

	Policies				Change in Surplus				S/So >= Base S/So			
Policy Number	Month Open	TAC	Bag Limit	Min. Size Limit	East RS	West RS	East TS	West TS	East RS	West RS	East TS	West TS
1	4	5	1	14	256	20	36	7	0.00771	0.01198	0.00771	0.01198
2	4	5	1	15	268	4	22	6	0.03663	0.01450	0.03663	0.01450
3	4	5	1	16	129	-7	-6	4	0.05825			0.01546
4	4	6	1	15	261	14	25	17	0.02757		0.02757	
5	4	6	1	16	121	3	-2	16	0.04881			
6	4	7	1	15	254	24	28	29	0.01856		0.01856	
7	4	7	1	16	114	13	2	28	0.03950		0.03950	
8	4	8	1	15	247	34	32	40	0.00959		0.00959	
9	4	8	1	16	106	23	5	39	0.03026		0.03026	
10	4	9	1	15	240	44	35	52	0.00061		0.00061	
11	4	9	1	16	98	33	9	50	0.02105		0.02105	
12	4	10	1	16	90	42	12	61	0.01185		0.01185	
13	6	5	1	13	-29	-21	8	4				0.00552
14	6	5	1	14	-140	-40	-19	0				0.01045
15	6	6	1	16	-420	-59	-73	8				0.00082

Table 1.23: Ranking Total = East RSS + West RSS + East TS + West TS) and Sum S/S_0 (descending)

	Policies				Rating							S/So			Change in Surplus			
Rank	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
1	4	5	1	15	1	1	1	1	2	2	4	0.69	0.78	1.47	268	4	22	6
2	4	6	1	14	1	1	1	1	2	2	4	0.64	0.76	1.40	450	35	68	20
3	4	6	1	13	1	1	1	1	2	2	4	0.60	0.76	1.36	608	58	107	25
4	4	9	2	13	1	1	1	1	2	2	4	0.41	0.68	1.09	1,322	210	268	82
5	4	11	3	13	1	1	1	1	2	2	4	0.30	0.61	0.91	1,610	320	350	128
6	4	6	1	15	1	2	1	1	3	2	5	0.68	0.76	1.45	261	14	25	17
7	4	5	1	14	2	1	1	1	3	2	5	0.66	0.78	1.44	256	20	36	7
8	4	7	1	14	1	2	1	1	3	2	5	0.63	0.75	1.38	444	46	71	32
9	4	7	1	13	2	1	1	1	3	2	5	0.59	0.74	1.34	605	68	110	37
10	4	10	2	13	1	2	1	1	3	2	5	0.40	0.66	1.06	1,404	223	284	96
11	4	12	3	13	1	2	1	1	3	2	5	0.29	0.59	0.88	1,658	332	359	141
12	4	12	4	13	2	1	1	1	3	2	5	0.24	0.57	0.81	1,638	390	381	152
13	4	7	1	15	1	3	1	1	4	2	6	0.67	0.75	1.42	254	24	28	29
14	4	8	1	13	2	2	1	1	4	2	6	0.58	0.73	1.31	601	79	114	49
15	4	11	2	13	1	3	1	1	4	2	6	0.39	0.64	1.03	1,397	233	286	108
16	4	10	3	14	1	1	1	3	2	4	6	0.38	0.64	1.03	1,384	258	284	96
17	4	12	2	13	1	3	1	1	4	2	6	0.38	0.63	1.01	1,390	243	288	120
18	4	8	1	14	2	3	1	1	5	2	7	0.63	0.73	1.36	439	56	75	43
19	4	8	2	15	1	2	1	3	3	4	7	0.54	0.71	1.25	976	128	158	51
20	4	8	2	14	2	1	1	3	3	4	7	0.50	0.70	1.20	944	155	183	56
21	4	9	2	14	1	2	1	3	3	4	7	0.47	0.69	1.16	1,200	173	224	70
22	4	11	3	14	1	2	1	3	3	4	7	0.37	0.63	1.00	1,445	269	295	108
23	4	12	3	14	1	3	1	2	4	3	7	0.37	0.61	0.98	1,457	278	300	119
24	4	7	1	16	2	4	1	1	6	2	8	0.69	0.75	1.44	114	13	2	28
25	4	8	1	15	2	4	1	1	6	2	8	0.66	0.73	1.40	247	34	32	40
26	4	9	1	14	2	4	1	1	6	2	8	0.62	0.72	1.33	434	66	78	55
27	4	7	2	16	1	2	1	4	3	5	8	0.59	0.73	1.32	744	98	107	34
28	4	9	1	13	2	4	1	1	6	2	8	0.57	0.71	1.29	597	91	118	62
29	4	9	2	15	1	3	1	3	4	4	8	0.53	0.69	1.22	964	137	161	63
30	4	10	2	14	1	3	1	3	4	4	8	0.47	0.67	1.14	1,191	183	226	82

Figure 1.1: Shrimp effort and landings in the Gulf of Mexico by small and large trawlers.

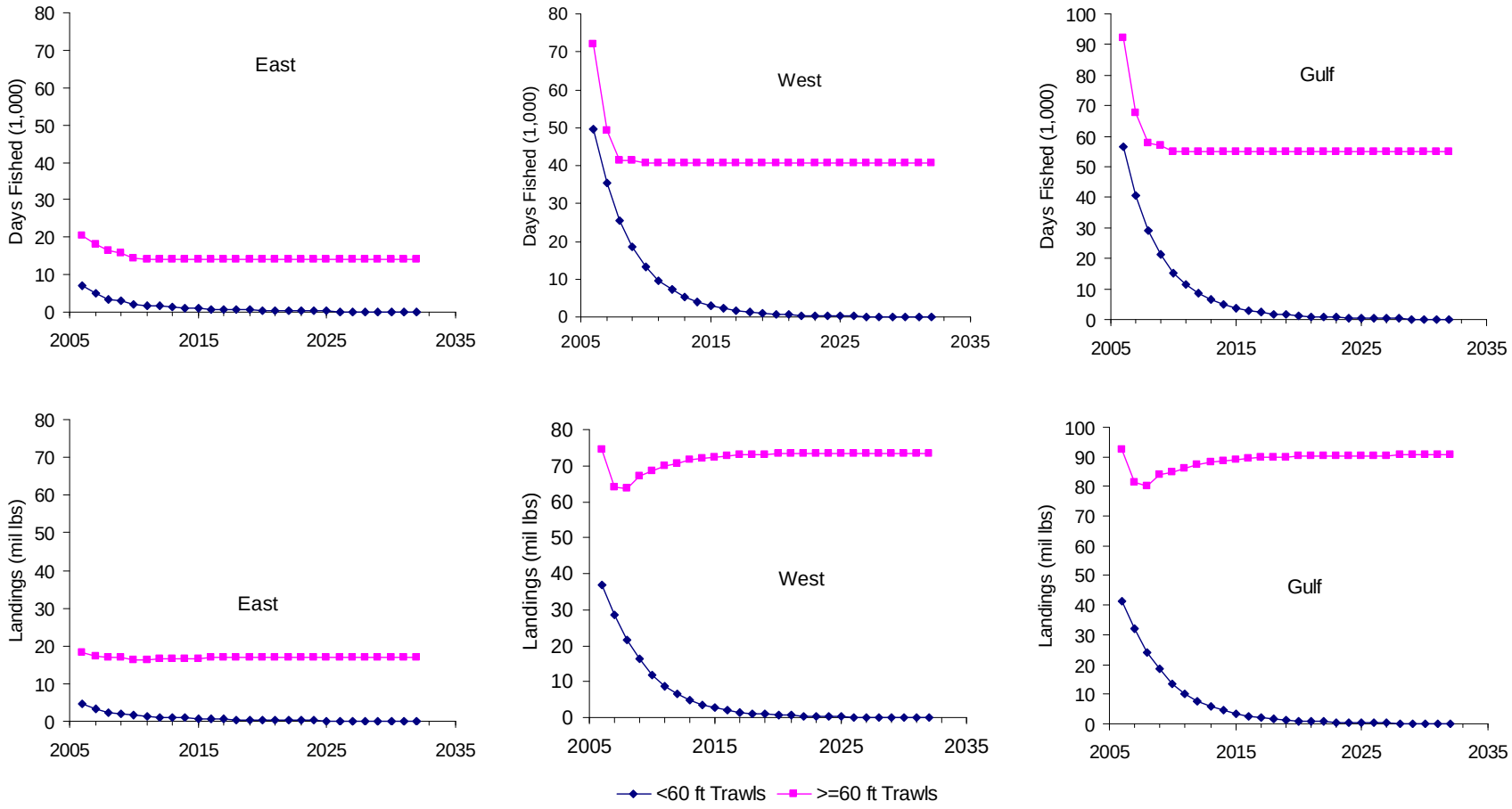


Figure 1.2: Landings for commercial and recreational red snapper for the east and west Gulf of Mexico in Base Case scenario

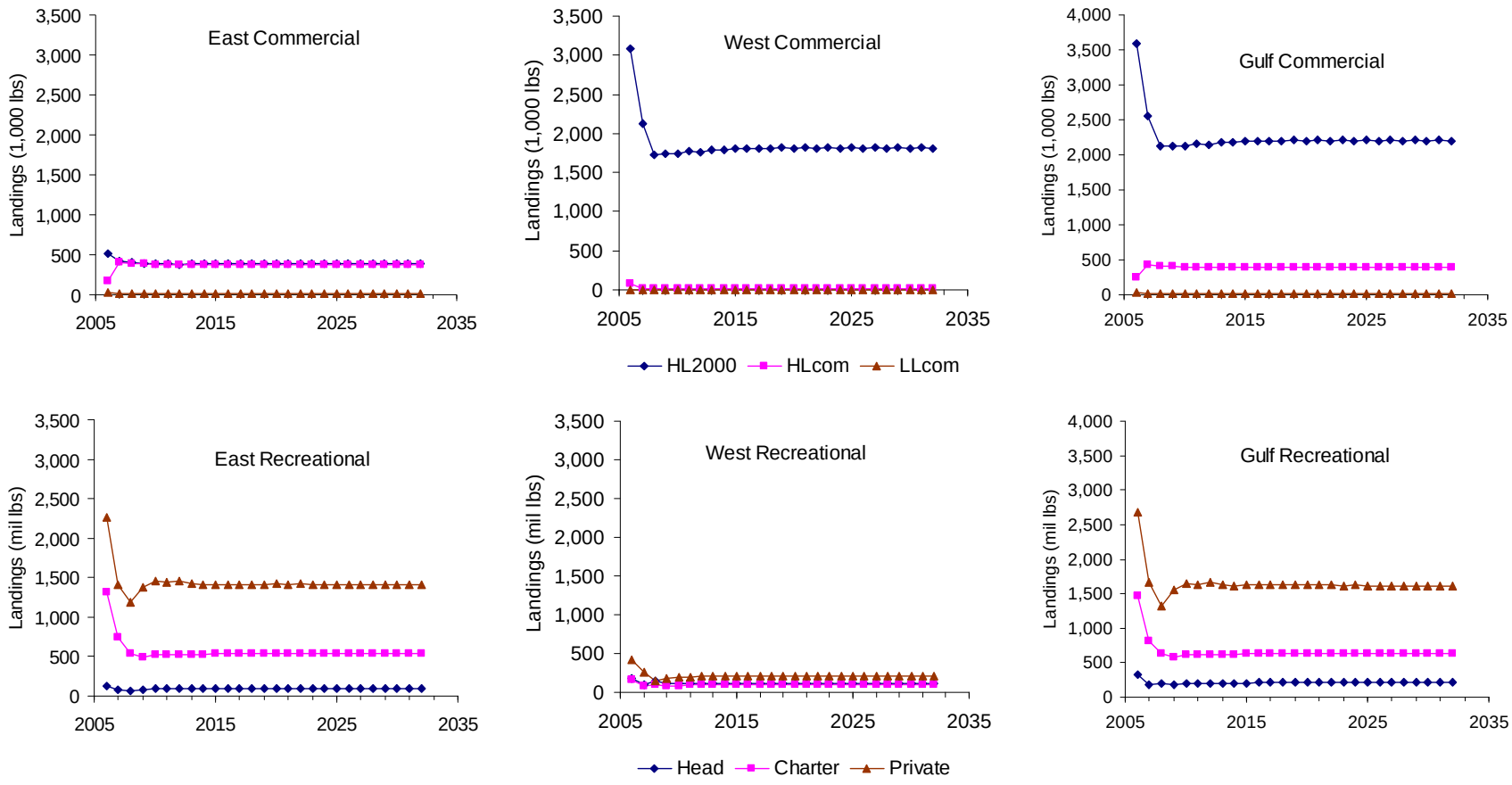
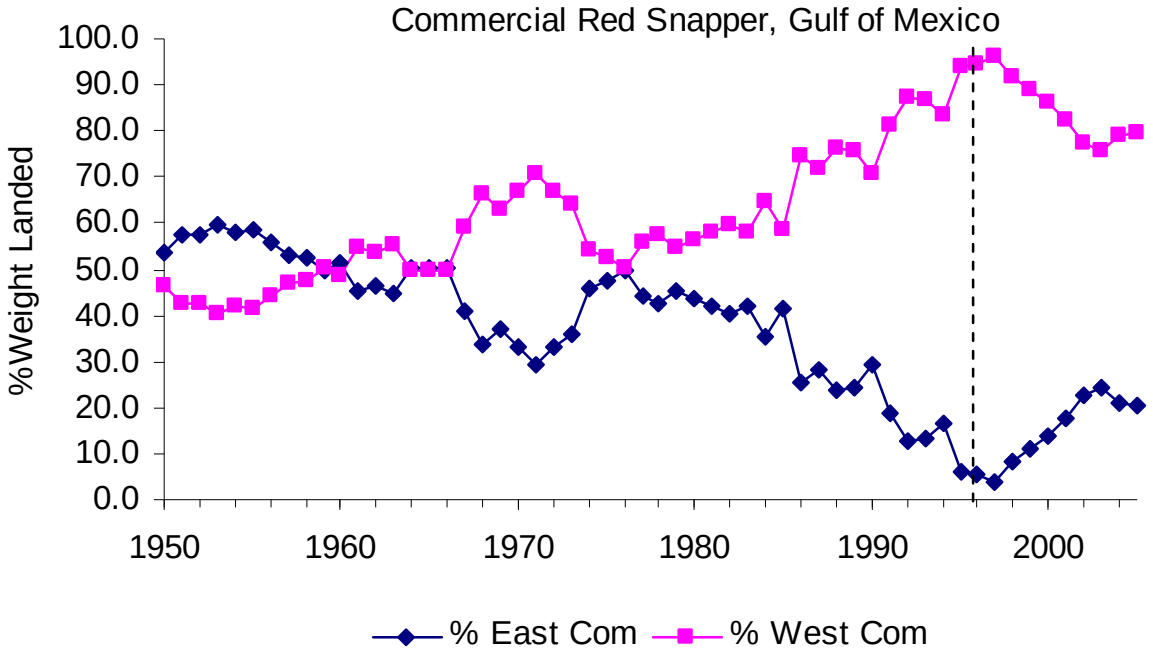


Figure 1.3: Percent of landings by weight for the commercial and recreational red snapper fisher in the east and west Gulf of Mexico.



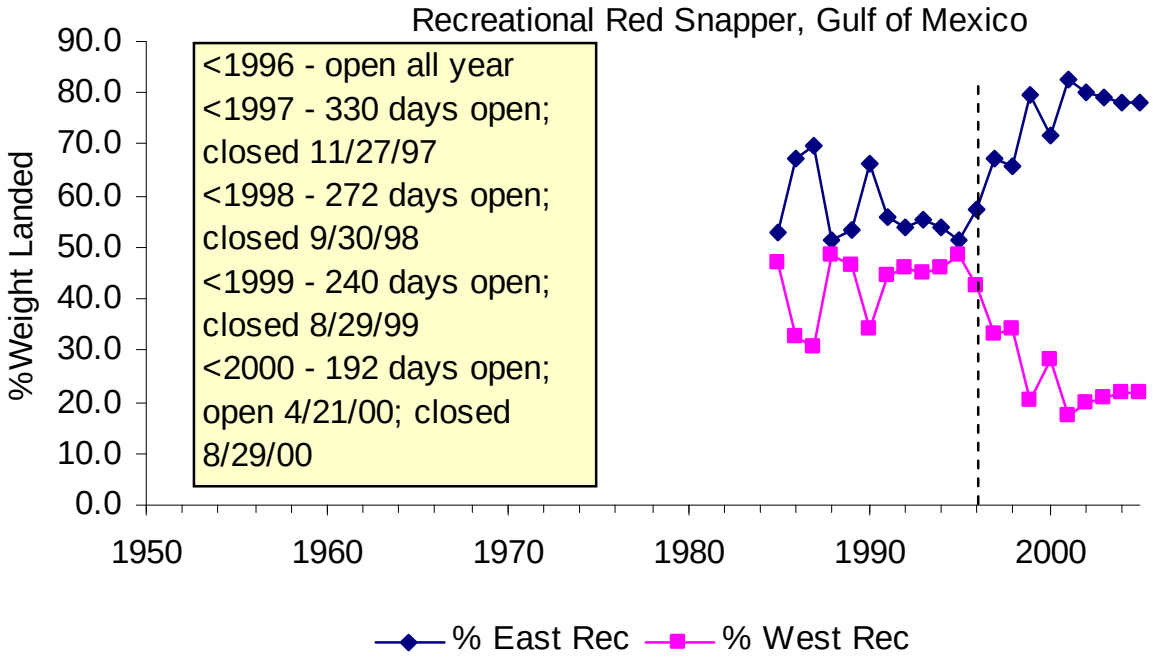
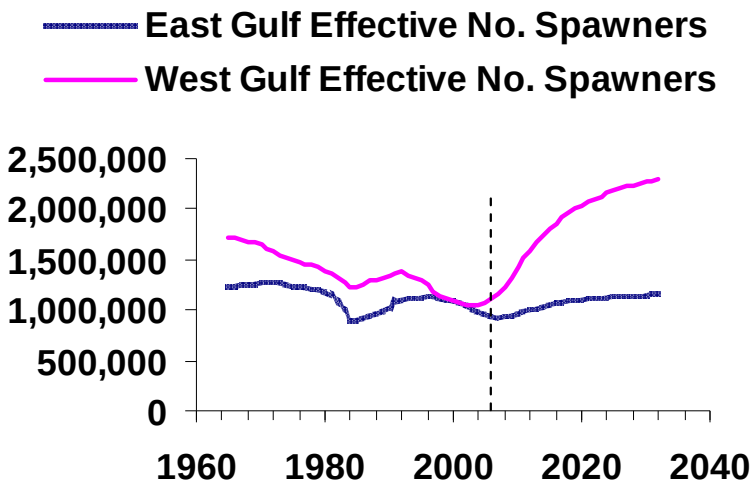
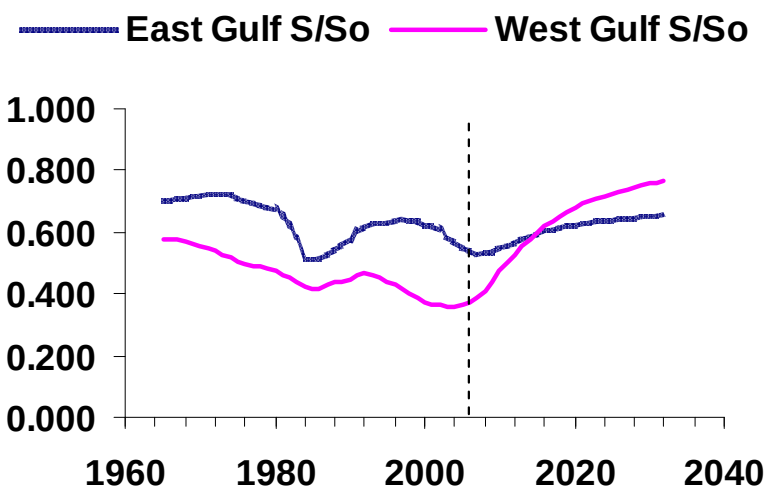


Figure 1.4: Effective number of spawners, ratio of current stock to virgin stock (S/S_0), and number of age 2 fish recruited into the red snapper fisher in the east and west Gulf of Mexico.





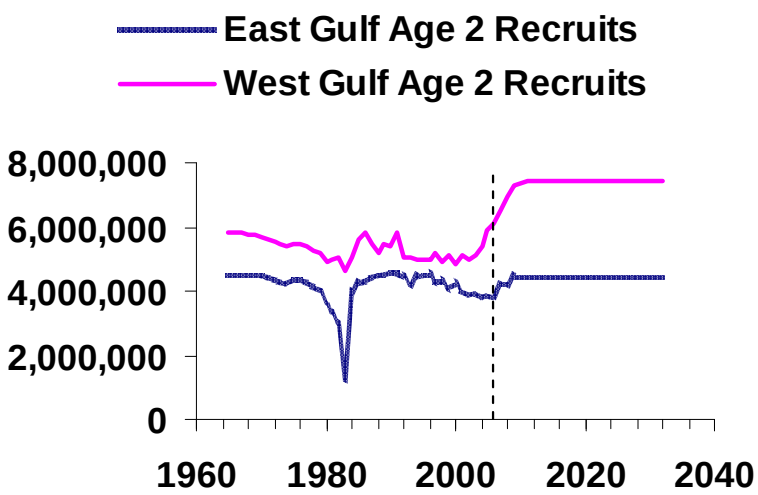


Figure 1.5: Red snapper effective Number spawners, S/S_0, and age 2 recruits as a result of changing the bag limit for the east and west Gulf of Mexico.

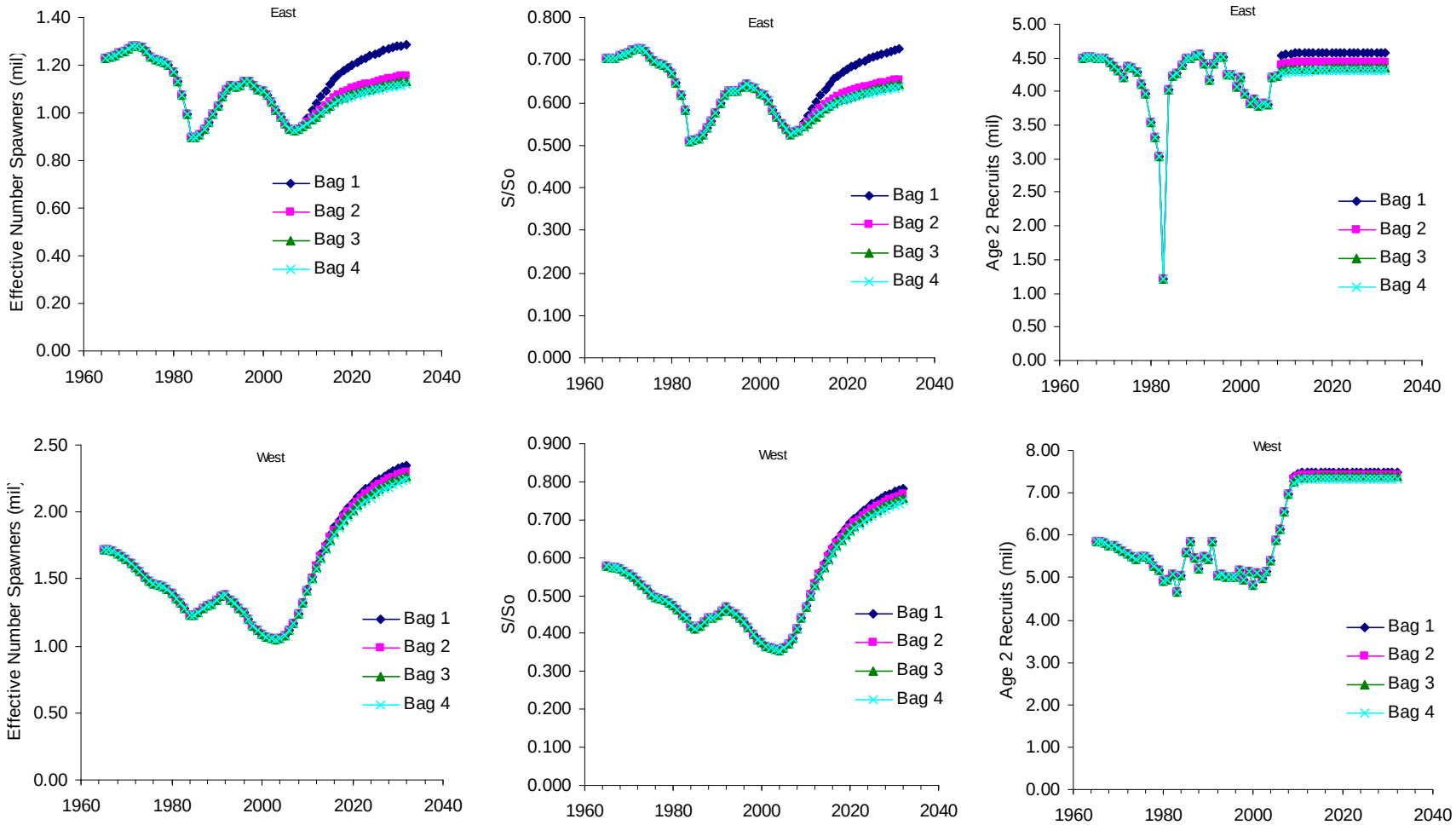


Figure 1.6: Red snapper effective Number spawners, S/S_0, and age 2 recruits as a result of changing the minimum size limit (inches) for the east and west Gulf of Mexico.

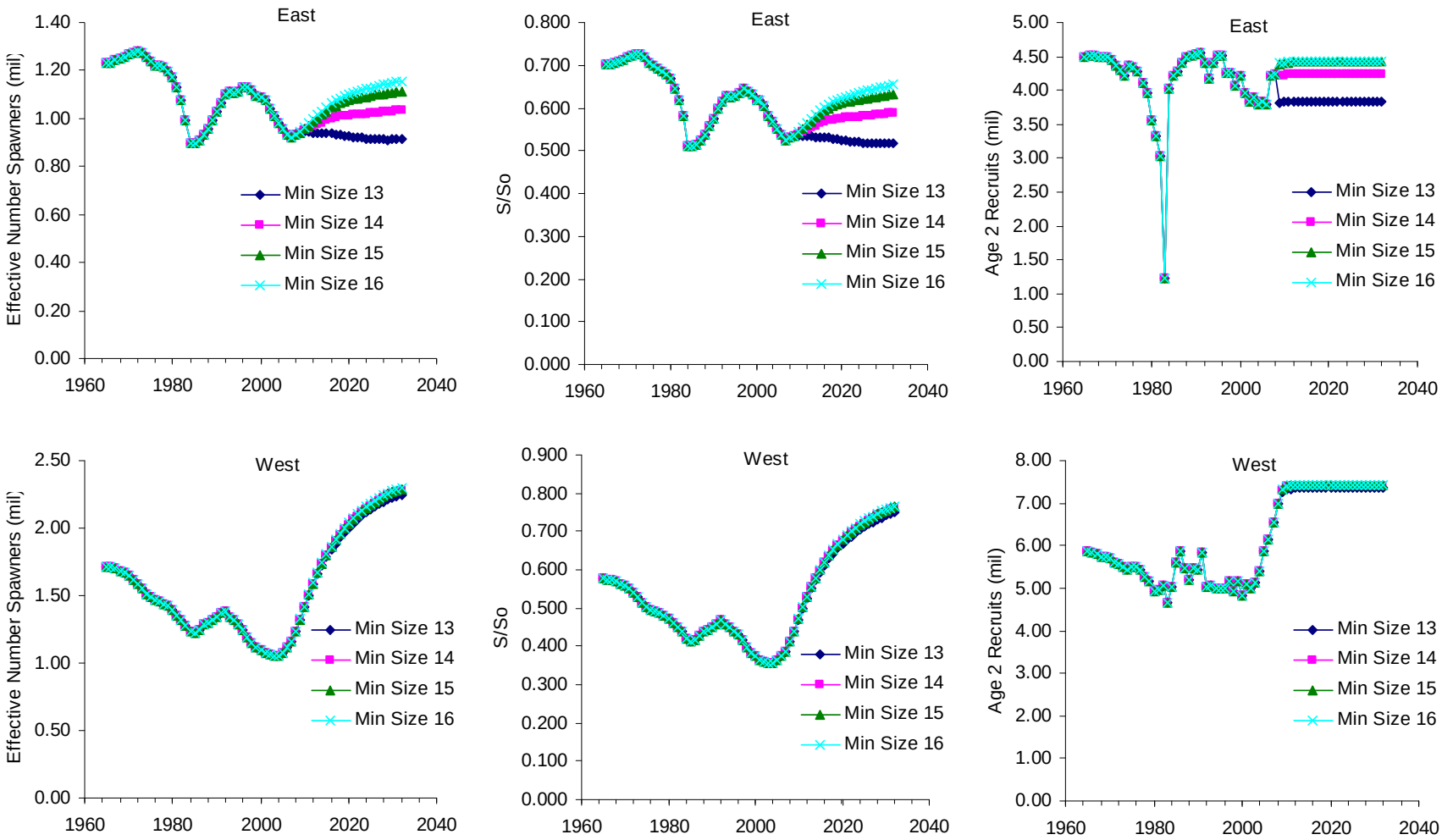


Figure 1.7: Red snapper effective Number spawners, S/S_0, and age 2 recruits as a result of changing the TAC for the east and west Gulf of Mexico.

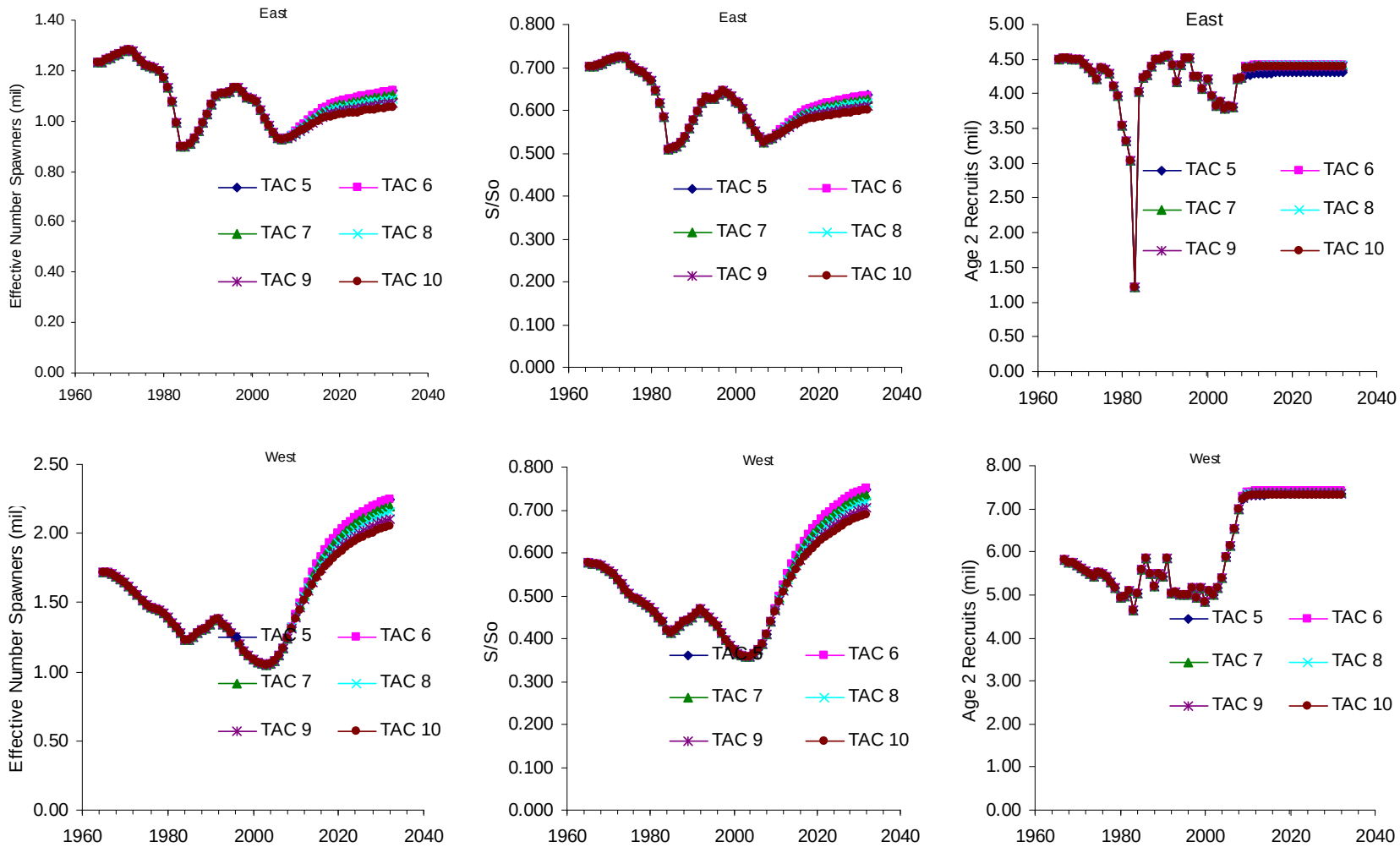


Figure 1.8: Comparison of the Change in the Present Value Total Surplus for all Reef Fish and the Total Surplus for just Red Snapper fishery in the East Gulf.

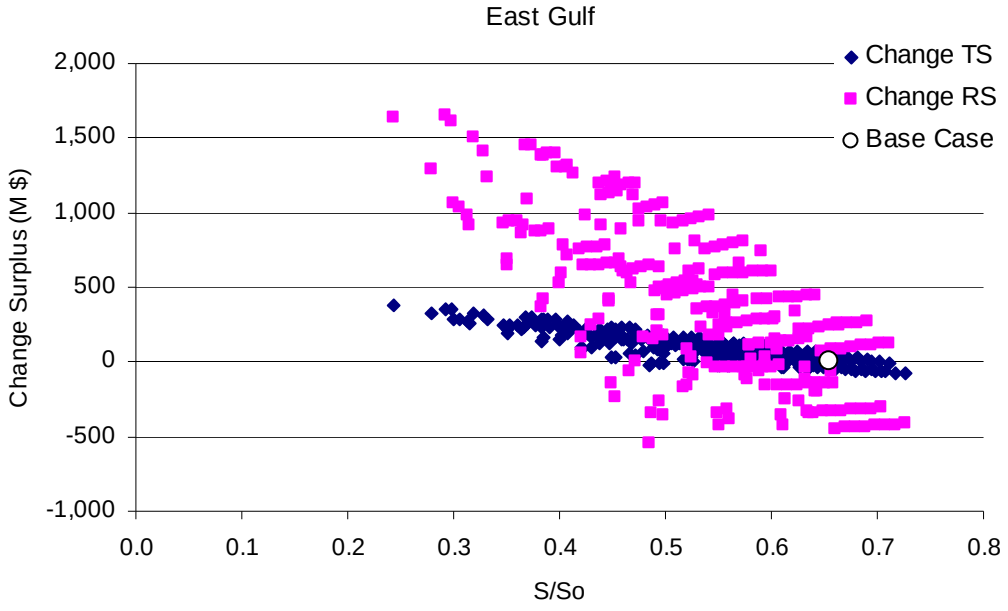


Figure 1.9: Comparison of the Change in the Present Value Total Surplus for all Reef Fish with the Total Surplus for just Red Snapper in the West Gulf

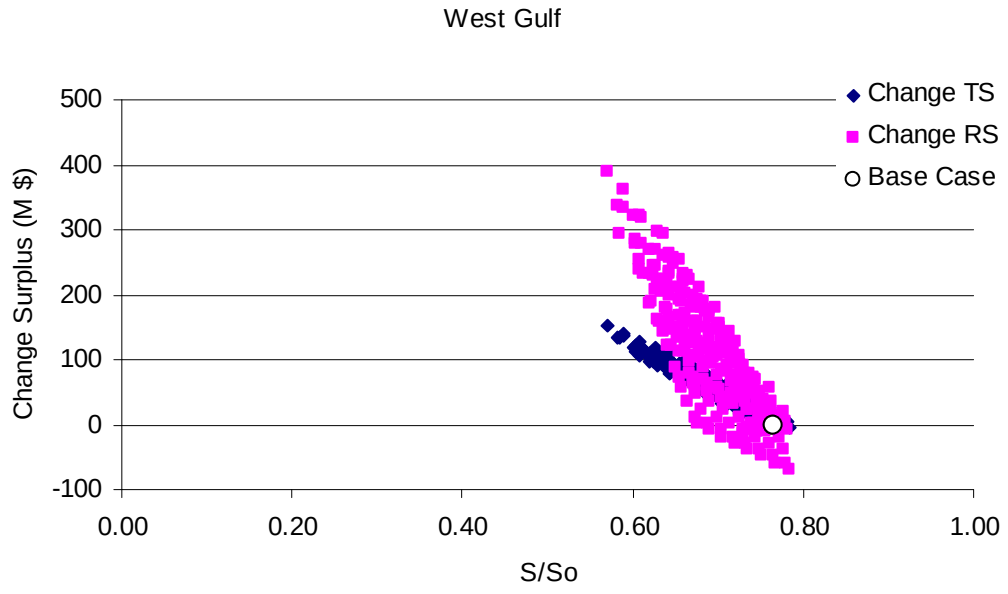


Figure 1.10: Change in Present Value of Surplus for 256 Policies Ranked by Their Vertical Distant from the Efficiency Frontier in the East Gulf of Mexico. The black dot is the base.

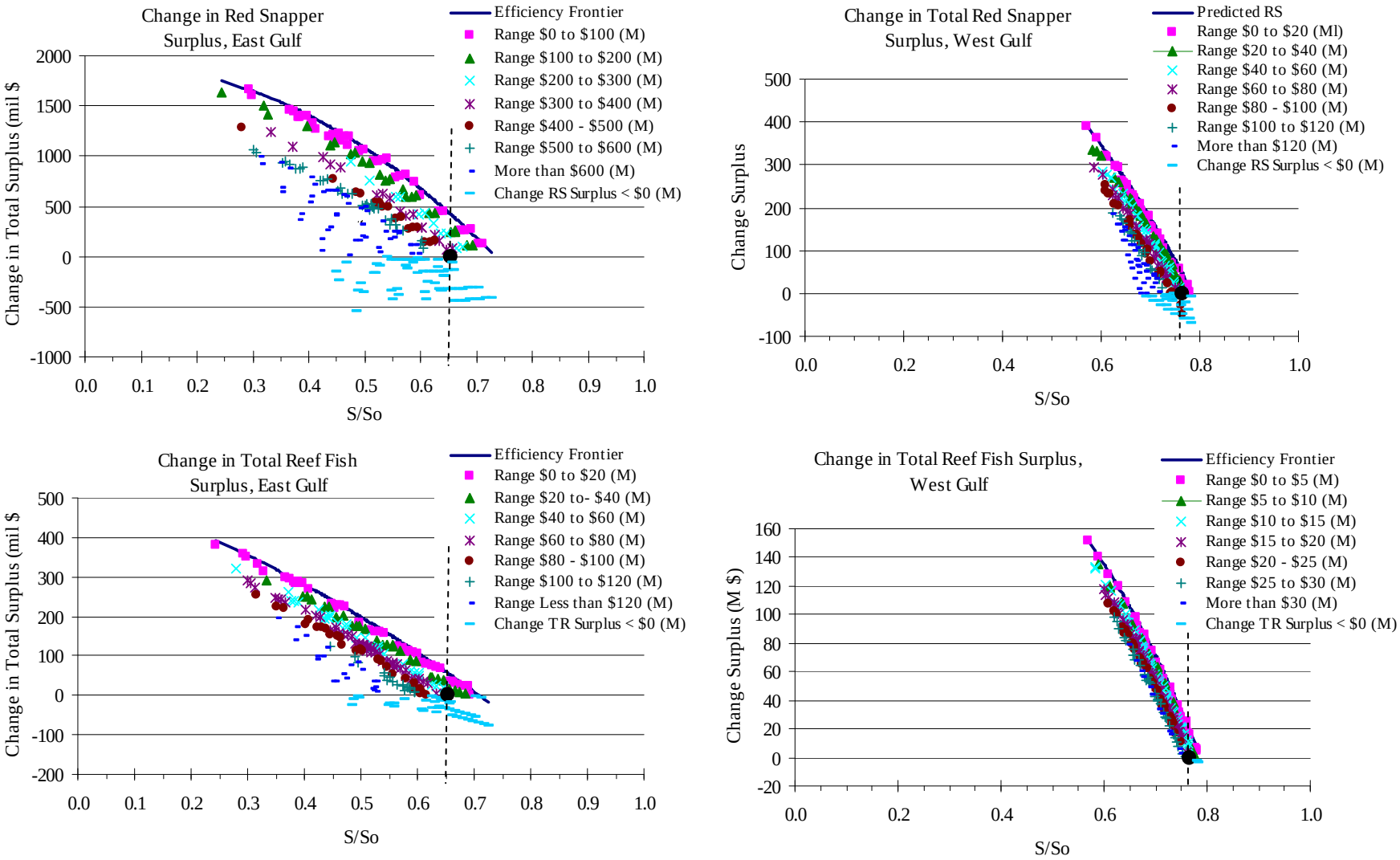


Figure 1.11: The top five ranked recreational red snapper policies.

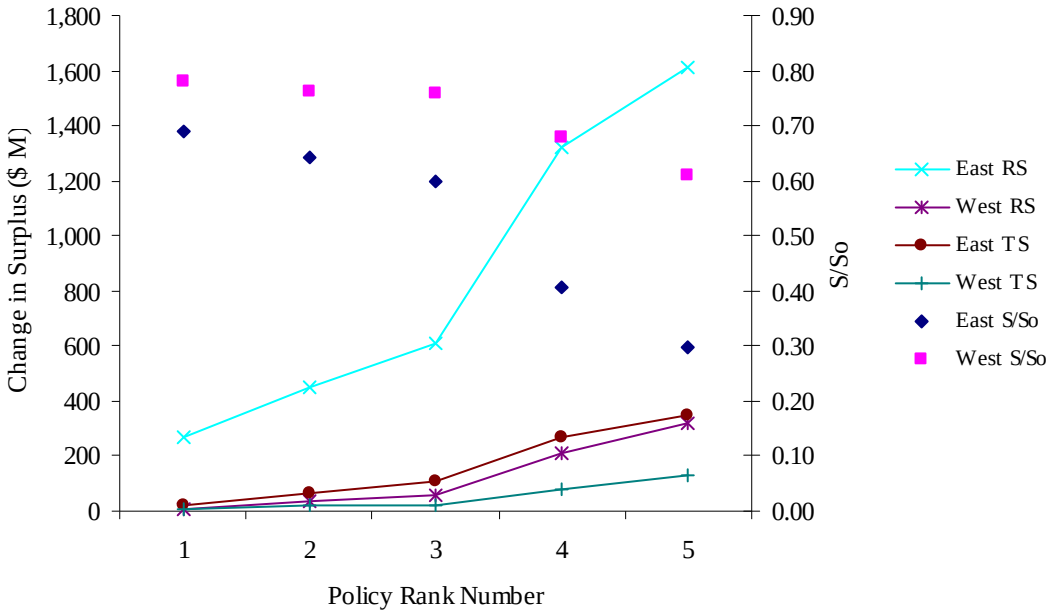


Figure 1.12: Red snapper effective Number spawners, S/S_0, and age 2 recruits by ranked policies for the east and west Gulf of Mexico.

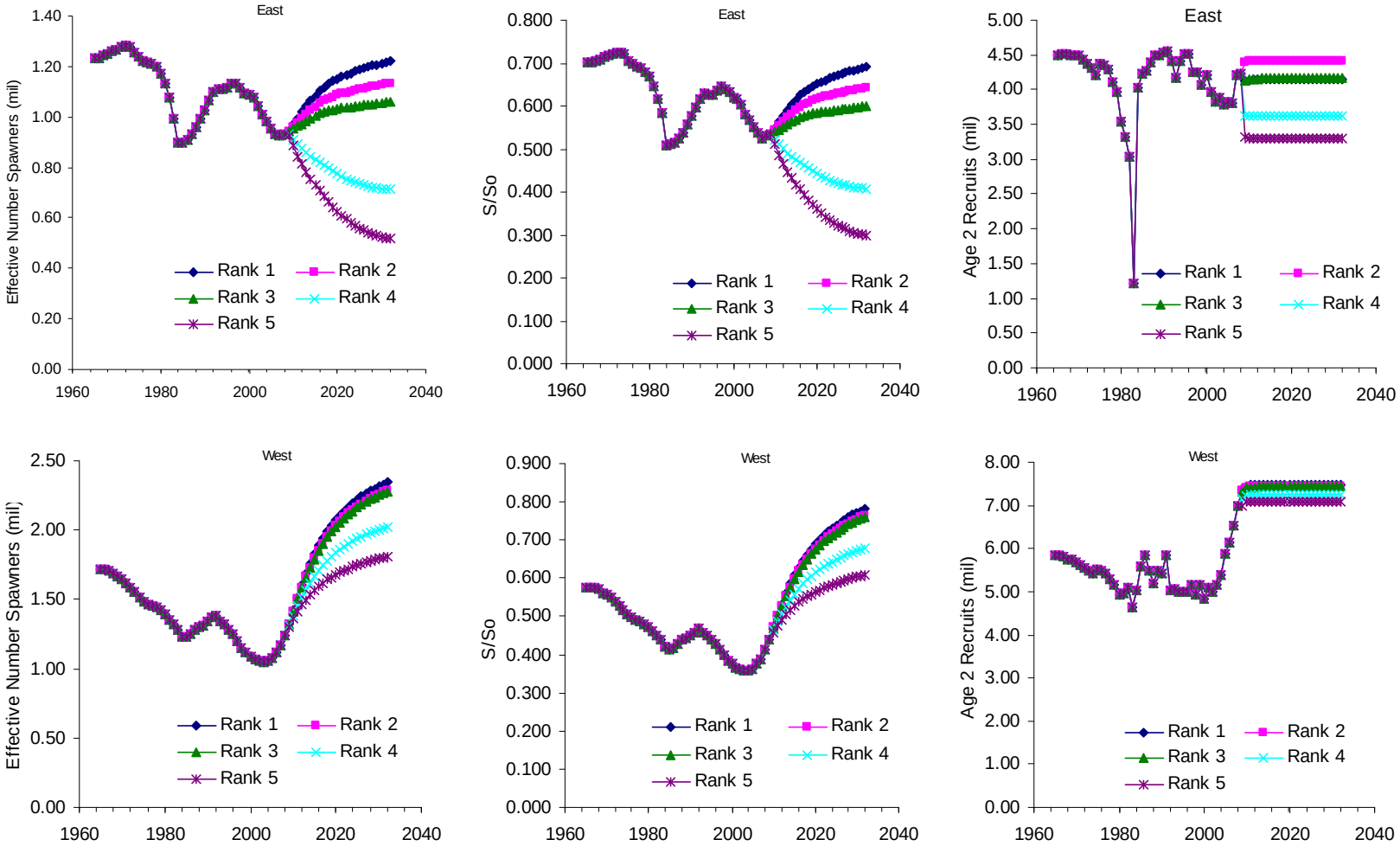
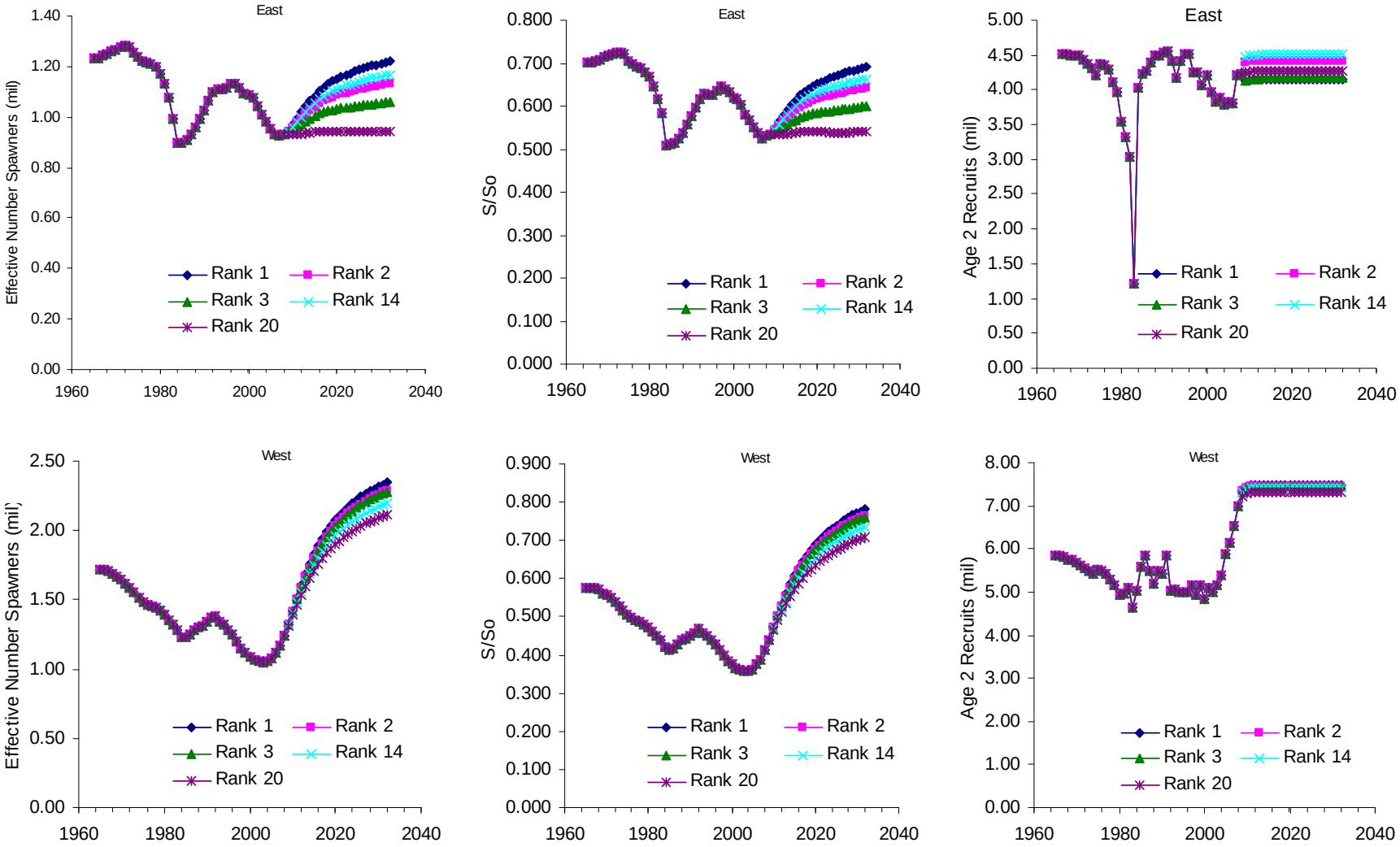


Figure 1.13: Red snapper effective Number spawners, S/S_0, and age 2 recruits as a result of changing the bag limit for the east and west Gulf of Mexico.



Chapter 2: Can Transferable Rights Work in Recreational Fisheries*

I. Introduction and motivation

Although innovations in the management of commercial fishing are being introduced around the world, recreational fisheries are still either unmanaged or managed using a set of policy tools with known inefficiencies. The use of these inefficient policies might be due to presumptions that efficient management of recreational fisheries would be too difficult or perhaps that recreational fisheries are not worthy of careful consideration because their impact is not consequential. We now know that the second of these assumptions is not valid; Coleman et al. (2004) document that recreational fisheries in the U.S. have a substantial impact on fish populations, representing 23% of total harvests of "populations of concern" and much higher levels in selected fisheries, including 64% in the Gulf of Mexico.

In recognition of the importance of recreational impacts on selected species, managers are beginning to address the recreational sector. In the red snapper fishery in the Gulf of Mexico (which will be our primary example throughout this paper) managers have imposed increasingly restrictive regulations by decreasing the bag limits; increasing the minimum size limits; and increasing the length of seasonal closures to limit recreational harvests (Table 2.1). Despite the increasing number of restrictions imposed on the Gulf's anglers, however, the total estimated recreational harvests still regularly exceeds the total allowable catch (TAC) allocated to the recreational sector. Hence, it seems that regulations are likely to become more restrictive and as this occurs, economic inefficiencies will become more pronounced.

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* This chapter was published in D.R. Leal and V. Majaraj (2009) *Evolving Approaches to Managing Marine Recreational Fisheries*. Lanham, MD: Lexignton Books, 2009. It also builds upon Chapter II in Kim (2007). It benefited by comments from David W Carter, Vishwanie Maharaj and participants at the PERC Political Economy Forum, Evolving Approaches to Managing Marine Recreational Fisheries. Any remaining errors are the responsibility of the authors.

Table 2.1 : Changes in recreational red snapper regulations

Year	Size Limit (Inches TL)	Daily Bag Limit (Number of Fish)	Season Length (days)	Recreational Allocation/Quota (MP)	Recreational Harvest (MP)
1991	13	7	365	1.96	1.94
1992	13	7	365	1.96	3.03
1993	13	7	365	2.94	5.29
1994	14	7	365	2.94	4.26
1995	15	5	365	2.94	3.25
1996	15	5	365	4.47	3.57
1997	15	5	330	4.47	5.41
1998	15	4	272	4.47	5.76
1999	15	4	240	4.47	5.51
2000	16	4	194	4.47	3.92
2001	16	4	194	4.47	4.52
2002	16	4	194	4.47	5.32
2003	16	4	194	4.47	4.58
2004	16	4	194	4.47	5.08
2005	16	4	194	4.47	4.59

Source: History of red snapper management in federal waters of the U.S. Gulf of Mexico -1984-2004: 2004 Red Snapper SEDAR, NOAA Fisheries, SEDAR7-DW-40 (Hood and Steele, 2004). Figures for 2004 and 2005 are from Vivian Matter (Personal Communication, 8/15/2006).

In this paper we will consider one possible approach to recreational fisheries management that could be more economically efficient -- a system of transferable rights (TRs). In the next section we provide an overview of some of the problems of the suite of traditional management tools, and then discuss in general terms the advantages of a TR approach to management. The introduction of a TR for recreational fisheries, although not completely new, has not been widely applied. We discuss the experience that we have found documented, and also draw some lessons from hunting programs and applications of TRs in addressing pollution. Although relatively simple in principle, the success of a TR approach to recreational fisheries would depend upon a number of institutional details, any one of which can be critical to the success of the program. In section IV of this paper we list and discuss nine critical questions that must be addressed in the design of such a program. We close in section VI with a proposal for a TR program for the red snapper recreational fishery in the Gulf of Mexico.

II. The management of recreational fisheries

A. The problems with traditional policies

For as long as economists have been studying environmental and natural resource issues, they have criticized the use of “command and control” type approaches to management. The

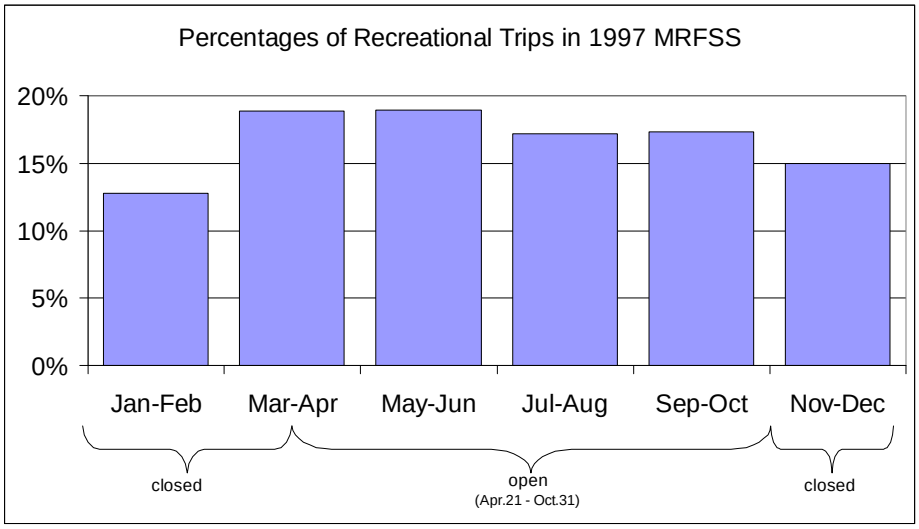
essential critique is that a policy that holds all participants to a single inflexible standard does not allow for heterogeneous parties to find ways to achieve the policy goals at lower cost or yielding greater benefits. Traditional approaches to management of recreational fisheries suffer from some of the same problems.

Three main policy instruments used to manage recreational fisheries are: seasonal closures, size limits and bag limits. There are two primary motivations for a seasonal closure. First, it is sometimes justified based on the biological cycle of the species. For example, harvesting during the spawning season might be prohibited. In this case, a closure might be economically efficient as the harvest of a single fish can have much greater impact on the future of the fishery.

Seasonal closures are also used to reduce total harvest and in this case their use is economically inefficient. The inefficiency arises because inevitably some anglers will prefer to move their effort from the open season to the closed season, yet doing so would not impact fishing mortality. As seen in Table 2.1, the length of the Gulf red snapper (GRS) fishery was reduced by over a third between 1997 and 2000 in an effort to reduce fishing effort. There is evidence that this move to closure has led to an inefficient temporal allocation of effort. Figure 2.1 presents the distribution of trips recorded in each of six two month "waves" that were recorded in the 1997 Marine Recreational Fishery Statistics Survey (MRFSS). Although the MRFSS data do not measure the relative portions of angler participation throughout the year, it is clear that fishermen did indeed participate year round.[1] The figure also shows the dates the red snapper fishery has been closed in recent years and we see that the current closure dates, between November 1 and April 20, correspond to times when many anglers used to fish.

[1] The data presented include all gulf fishing trips. The 1997 MRFSS data include 44 observations from anglers who targeted red snapper. Trips by these anglers are also distributed quite evenly throughout the year.

Figure 2.1. Open season in 2004 and distribution of recreational trips in 1997 (before closures)

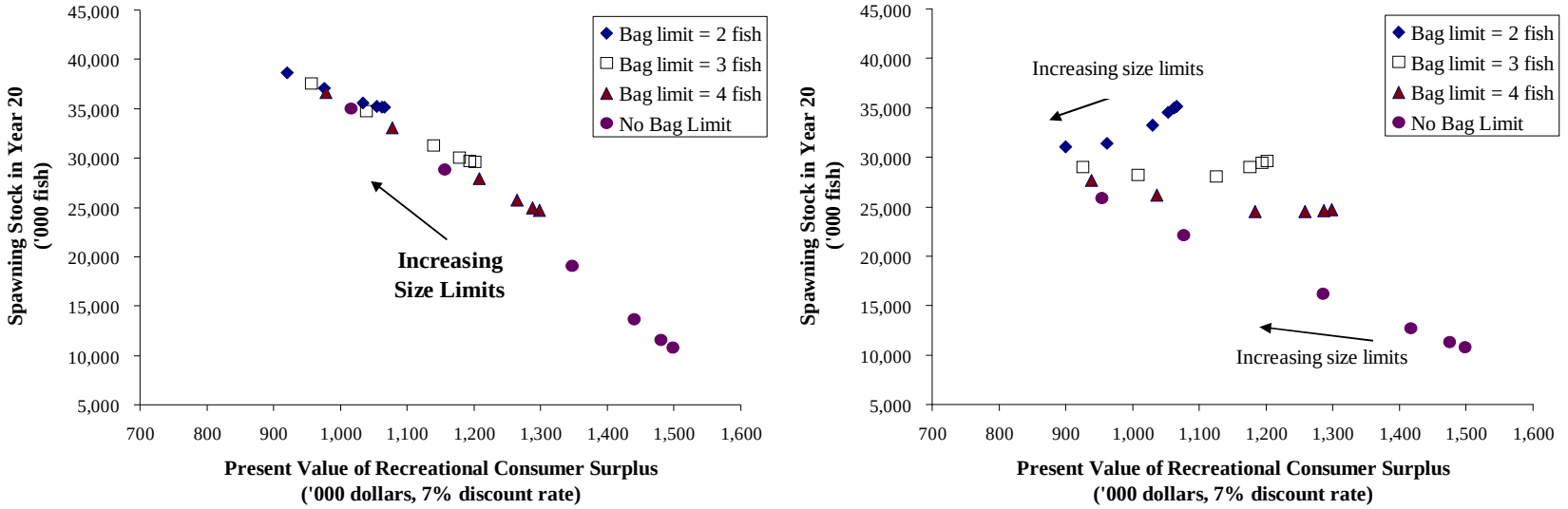


Source: 1997 Marine Recreational Fishery Statistics Survey (MRFSS)

The other two management tools used widely in recreational fisheries are size and bag limits. Virtually all managed fisheries have one or both of these regulations in place. The motivation behind the these tools is multifaceted. Bag limits not only control overall harvests, but also lead to a more equitable distribution of the catch between anglers and the restriction creates an obligatory guideline for what most would consider "good sportsmanship" in limiting one's catch on a given day. Placing a larger size limit on the size of fish that can be retained can help protect younger fish allowing for increased recruitment and, as with bag limits, the size limit can coincide with what is generally considered good sportsmanship. Size and bag limits can, therefore, be the right tools for the objectives being pursued.

On the other hand, bag limits and size limits are also used to reduce the overall harvest. In this case, these are not necessarily the right tools. Woodward and Griffin (2003) explore some of the limitations of these tools as means to reduce overall fishing mortality, focusing on the problems that arise when discard mortality rates are high.

Figure 2.2. Simulated consumer surplus and spawning stocks in year-20 under alternative policy options
(Mortality rates are for fish caught at three depths: 0-5 fathoms, 6-10 fathoms, and more than 10 fathoms.)



A: (discard mortality rates = 1%, 1%, and 1%)

B: (discard mortality rates: 33%, 46%, and 59%)

Source: Woodward and Griffin (2003).

Figure 2.2 presents the results from Woodward and Griffin's (2003) simulation analysis obtained from the General Bioeconomic Fisheries Simulation Model (GBFSM). GBFSM is a multi-species, multi-region simulation model in which both growth and catch rates are cohort-specific. This allows the model to identify the consequences of different combinations of bag and size-limit policies as presented in the figure. The figures show the impacts of different policies in terms of the present value of surplus on the horizontal axis and the stock in year 20 of the simulation. In Figure 2.2.A, release mortality rates are assumed to be quite low. In this case size and bag limits are essentially substitute policies – increasing the size limit has an effect similar to decreasing the bag limit – increasing future stocks at a cost to the immediate welfare of anglers in the fishery. In Figure 2.2.B the release mortality are high and increasing the size limit can actually be counterproductive because it leads anglers to discard more. Since a significant share of discarded fish die, increasing the size limit does not have a proportional impact on overall fishing mortality.[2]

The analysis in Figure 2.2 is based on the assumption that anglers respond simply to bag limits: they fish until their bag limit is reached and then stop fishing. With this assumptions it follows that bag limits do not cause anglers to discard fish. In reality, of course, bag limits can lead to discards of smaller fish as anglers hope to fill their bag with a larger fish. Hence, like size limits, when discard mortality is significant, bag limits too are likely to be inefficient policies. In the presence of release mortality, any policy that encourages discarding will be handicapped in its ability to achieve stock recovery goals.

B. The potential for a transferable rights regime

Economist's arguments against command-and-control policies are beginning to receive widespread endorsement from policy makers. Although economists have long noted that there are a variety of preferred policy alternatives, including taxes and subsidies, the use of transferable rights (TRs) has received the most attention in the U.S. and, more recently, throughout the world. From air pollution to commercial fisheries, TRs are increasingly being promoted as the first option to consider when new goals are proclaimed.

The basic principal in any TR program is that a limited number of rights to use a public resource (such as air quality or a fishery) is made available. These rights can be traded so that in the end the right is held by those who value it most. As with any market, a TRs market will function properly if the property rights are comprehensively assigned, exclusive, transferable, and secure (Hanley, Shogren, and White, 1997).

The first to propose the idea of using a system of transferable rights to address environmental problems were Crocker (1966) and Dales (1968). These authors recognized both the potential of TR markets and that implementing such a scheme would require deliberate actions by government to create the markets. Of particular importance in creating a successful

[2] Estimates of release mortality are difficult to obtain, but there is some evidence that release mortality rates can be quite high, especially in deep water marine fisheries (Harley et al., 2000 and Burns et al. 2002).

TR program is the definition of what Dales (1968) called the "asset-unit," defined as "the smallest physical amount of the asset to which it is practicable to apply property rights" (p. 797). Here we interpret the asset unit somewhat more broadly to include the full set of rights and responsibilities that are embodied in the TR.

In some situations, defining the asset unit is relatively straightforward. When applied in commercial fisheries in a standard individual transferable quota (ITQ) program, the asset unit is defined in terms of quantity of fish. In the national sulfur dioxide trading program, credits coincide with pounds of SO_2 emissions. The appropriate asset unit is not so straightforward in the case of recreational fisheries. As we consider in section IV below, there are a number of characteristics of the asset unit that must be addressed if a TR program is to be established and the answers to most of these questions are far from straightforward.

III. Experience with transferable rights management

A. Background on transferable rights – Lessons from environmental applications

A complete review of applications of TR programs is beyond the scope of this paper, however, it is useful to look at other applications of TR. First, we look at TR programs to control pollution, which gives insight into how an ideal program might be designed as well as how programs have also been designed under less than optimal circumstances.

The most prominent example of a TR program is the U.S. SO_2 trading program, set up under Title IV of the 1990 Clean Air Act. Since the second phase of the program began in 2000, over 2,000 electric generating plants are involved and a fluid market in the rights to emit SO_2 has resulted. A critical part of the success of the SO_2 program has been the availability of high quality monitoring through a continuous emission monitoring system that records emissions on an hourly basis. The monitoring program has made it possible to define the asset unit in the program in terms of measured SO_2 emissions. The large scale of the market and the high level of accuracy on actual emissions have made it possible to have a fluid TR market with very low transaction costs (Pérez Henríquez, 2004).

The experience with TR to control water quality has, in many ways, been a complete counter-example to the SO_2 program. Take, for example, the Lake Dillon program, which was created in 1984 to control phosphorous loading into Lake Dillon Reservoir in Colorado (Woodward, 2003). Two main sources of phosphorus were involved in the program: discharge from four publicly owned treatment works (POTW) and nonpoint discharge from septic systems throughout the region. A restriction prohibits POTWs from selling their surplus rights, so only nonpoint sources can generate credits for sale. Pollution reductions are created when an underground septic system is eliminated by connecting the home to one of the POTWs, which are able to eliminate a greater share of the phosphorus before it reaches the lake. Since it is impossible to measure the exact phosphorus load from each septic system and absence of records on historic loadings, credits cannot be given for actual phosphorus reductions. Instead, the asset unit in this program is based on *practices* – a credit is granted for each home connected to a POTW system. This simplistic assumption ignores the high degree of variability relating to the quality of the original septic system, the water flow in the household, geographic proximity to the lake and other factors. It is well known (e.g., Ribaudo et al., 1999) that quantifying credits based on practices rather than actual loadings leads to economic inefficiencies. Nonetheless,

because of the difficulty of monitoring nonpoint loadings, practice-based credit systems are used in all existing water-quality trading programs that involve nonpoint sources. Water quality trading programs have also been challenged by the fact that the size of their markets are often quite small because they are naturally constrained to a single watershed. In the Lake Dillon program the first real transaction did not take place until fifteen years after the program was introduced. Most other water quality trading programs have been similarly limited (Woodward et al., 2002).

Although perhaps far removed from fisheries, these two pollution examples provide interesting insights that can lead to success or (relative) failure in a TR program. The successful SO_2 program has a large market with an asset unit tied directly to the pollution load to be regulated. In contrast, water quality trading programs have small numbers of traders and asset units that are tied to practices rather than loads. As we consider the application of TR to recreational fisheries, we must remember that all TR programs do not work as smoothly as the SO_2 program.

B. Transferable rights in commercial fisheries

In fisheries, TR instruments are referred to as individual transferable quotas (ITQs) or individual fishing quotas (IFQ). Scott (1989) identifies three ways that ITQs can be an improvement over existing regulations. First, when a quota is used, administrators need not concern themselves with gear, net type and so on, but can instead focus on the issue of concern: the long-run management of the stock. Second, a quota system removes the incentive for a "race to the fish." Third, a quota system can be preferred in the management of mixed stocks.

Rossiter and Stead (2003) discuss problems associated with traditional TAC approach in which the fishery is closed once the TAC has been reached. Based on interviews of demersal fishermen in northeast Scotland, the economic welfare of fishermen in the region has declined despite the efforts to reduce total catch. Some of their unhappiness relates to the standard problem of a race to the fish that is created by the seasonal closure. However, the fishermen do not favor an ITQ program. Instead, they favor regulations based on days at sea, primarily because they believe that it would be easier to police. Rossiter and Stead and the fishermen they interviewed recognized that a day-based approach would introduce some inefficiencies, but the fishermen preferred such a method because of its transparency and the flexibility that is allowed under such an approach.

A number of nations use transferable quota systems in their commercial fisheries including Iceland, New Zealand, and Australia (FAO, 2001). Batstone and Sharp (1999) provide a thorough review of the New Zealand's ITQ programs, which began in 1986, and have expanded to include a number of species and regions. The initial allocations were designated in quantities of allowed catch based on historical harvests, but these were converted to a percentage of the TAC for each fishery in 1990. Batstone and Sharp find evidence that the programs have been quite successful in adding economic value. They point out that there are numerous practical challenges to implementing an ITQ: from recognizing historical rights of the Maori, to managing fisheries outside the ITQ system.

As a caveat to this general enthusiasm for ITQs, Clark et al. (forthcoming) have shown that if fishermen anticipate the introduction of an ITQ at some time in the future, all of the economic advantages of an ITQ program can be dissipated by excessive entry into the program in the pre-ITQ period. More generally, any time there is a perception that a TR program may be introduced, potential stakeholders will have incentives to alter their behavior in order to secure standing in the market that is to be created.

C. Experience with transferable rights in recreational fisheries

The National Research Council (1999) recommended that attention should be given to the implications of recreational participation in fisheries, and to consider the potential application of ITQs in recreational fisheries. The literature and experience with TR in recreational fisheries, however, appears to be quite limited. Sharp (1998) provided some initial ideas about how a recreational TR program might be structured and addressed some of the practical issues regarding allocation and monitoring. Sutinen et al. (2002) and Sutinen and Johnston (2003) provide more in depth discussion and discuss the existing examples of such programs.

The recreational TR program that deserves the most attention is the program that was proposed charter IFQ program for Alaska's halibut fishery, which Sutinen et al. (2002) describe as "the sole U.S. template for the design of joint commercial-recreational rights-based management" (p.9). Despite its careful design and extensive regulatory review, Criddle (2006) reports that this program was rescinded before it was introduced. Hence, our review of this program can offers insights into design elements merits and practical problems that led to its demise.

A 2001 report of the North Pacific Fishery Management Council (NPFMC, 2001a) summarizes major features of the approved charter IFQ program. The charter quotas were to be issued to charter owners, or to people who leased a vessel from an owner and who carried clients in 1998 or 1999 and 2000. The charter IFQ was to be set at 125% of the average 1995-99 charter harvests and was to be integrated into the existing commercial IFQ program and would be equal to about 13% of the combined commercial and charter quota in Southeast Alaska and about 14% of the combined commercial and charter quota in South-Central Alaska (NPFMC, 2001a).

Other noteworthy characteristics of the program's asset unit are:

- The unit of recreational IFQs was the number of fish, in keeping with current regulations.
- The 2-fish daily bag limit or the 2-day possession limit for charter anglers were retained.
- Charter quota shares were not be sold to the commercial sector but commercial shares were to be transferable to the charter sector, translating pounds to fish based on average weight.
- The program was not to affect non-charter recreational anglers.

As with any TR program, there were many practical issues that needed to be addressed and these are evident in the minutes of the NPFMC's committees (NPFMC 2001b and NPFMC 2003a). For example, in 2001, enforcement issues such as prior notice of landings, offload window, vessel clearance requirement, and shipment report were considered (NPFMC, 2001a).

Again, all of these essentially define characteristics of the asset unit – establishing the rights and responsibilities associated with a TR in the program and, through monitoring, establishing the program's integrity while at the same time influencing the transaction costs that would arise.

It is indicative of the challenges faced in all TR programs, that Criddle attributes the demise of the program to issues associated with the initial allocation. Despite the rule noted above that allocation would be based on effort from 1998-2000, the exclusion of new entrants was controversial and, in the end, led to the program's cancellation. This experience in Alaska should not be forgotten as efforts are made to use TRs in other recreational fisheries.

D. Transferable rights in hunting

Although there is a lack of examples of TRs program in recreational fishing, lessons about the management of a potential fishing TRs program can be drawn from the experience with TRs for recreational hunting. Johnston et al. (2006) survey many of the applications of TR (mostly tags) in hunting. Programs in California and Colorado allow transferability of the hunting right and in Texas there is essentially a free market for hunting rights. Here, we highlight the Kansas nonresident hunting market, which has many similarities to TR programs for recreational fishing.[3] This program, which began in 2000, has resulted in a competitive market in recreational hunting (Taylor and Marsh 2003).

The asset unit in the Kansas TR program is the right to kill one deer of a specific sex with a specific weapon. The right is valid only during the standard open season and only in the county of the landowner who originally obtained the right. Once sold, the rights may not be transferred again. Because the dates of the specific season are assigned, there is a limited duration on the permits, meaning that permits cannot be stored for future use. Hunters that purchase a TR in the Kansas program are required to comply with standard hunting regulations and hold a valid license to hunt in the state. Further, they must hold documentation of their purchase of the license during their hunt.

The allocation mechanism used in the Kansas program is worthy of specific attention. The rights are initially distributed through a lottery to residential landowners and tenants/managers who must apply for the lottery. Winners in the lottery must pay the state for that right, but then may resell the right to a nonresident hunter. Based on a 2002 Kansas Department of Wildlife and Parks' survey of hunters, Taylor and Marsh (2003) report that the mean price of non-residence deer hunting permits for all hunting modes was $760.13, which is high compared with the cost of a permit in the random draw lottery to the landowners of $205.50 during this period. However, the sales price was often bundled with other services including access to the land, guide services, etc. Using Taylor and Marsh's regression analysis evaluated at the mean of all variables other than guide services, we find that on average hunters who did not pay for guide services paid $656 for the permit, further reduced to $82 if they made use of land that did not require negotiating access with the landowner. Based on this analysis, it appears that

[3] We draw here on information from web pages of the Kansas Department of Wildlife and Parks (http://www.kdwp.state.ks.us/news/hunting/big_game/deer).

the hunting rights alone had an average value of about $573 and that in 2002, recipients of the rights were able to earn substantial rents. However, by 2006 the supply of permits for a number of regions in the state exceeded demand and there were surplus permits available from the state at the fixed price of $322. At least for those areas, it is unlikely that 2006 permits will sell for much above the government set price so that the state has begun to capture a significant share of the rents that can be generated through these permits.

Some design elements of the Kansas hunting rights program are worthy of note. First, the program is monitored by the state in that all transfers should be reported to the Kansas Department of Wildlife and Parks. This reporting can be done via the Internet, so transaction costs do not appear to be substantial. Although only 2% of the licenses were purchased via the Internet in the period studied by Taylor and Marsh, it is now possible to find many permits for sale on ebay, indicating that the market is becoming much more fluid.

Like fishing, hunting involves the exploitation of a public wildlife resource for personal recreation; observing the participation of every participant is difficult, though well-established license systems make information about hunters' participation accessible. Although policy makers are usually reluctant to create opportunities for profits from public resources, the Kansas program encourages such profit making. At the same time, however, the government set price has increased so that a larger share of the rents is now captured by the state. The Kansas program may have been more politically palatable because the transferable *non-resident* rights are initially allocated to landowners in the state. No similar market exists for the resident permits. Finally, we note that the relatively easy process of completing a transfer has resulted in a market that appears to function smoothly with relatively low transaction costs.

IV. Critical questions in the designing a TR program for a recreational fishery

In this section we will consider nine practical questions that must be answered before a TR program could be established for a recreational fishery. The answers to these questions are not independent, but each must be addressed. Two or more alternatives exist for each question and none have obvious answers. We close in the following section with a proposed program for a TR program for the GRS fishery that answers these questions.

A. How should transferable rights be measured?

In designing a TR program for recreational fisheries, the first question that must be answered is the unit of measurement of the rights. In the recreational fishery TRs program, it may be difficult to determine an asset-unit because of biological characteristics, i.e., fishing mortality when fish are released, and individuals' different fishing preferences. However, three alternatives seem to be apparent:

Alternative 1: Set the TR unit in number of fish caught (or retained).

Alternative 2: Set the TR unit in pounds of caught fish.

Alternative 3: Set the TR unit in fishing days.

Following on Dales, the question that must be asked of each of these options is, What is "practicable"? To answer this there are three issues that must be considered: control over the biological impact of the fishing activity, monitoring and enforcement, and transaction costs.[4]

Under alternative 1, a single TR would grant its holder a right to harvest one fish presumably of legal size. This approach has the most in common with the TR programs discussed above. For example, the Alaska halibut program is specified in number of fish and the Kansas hunting program is for a single deer. Sutinen et al. (2002) point out that the rights granted to the recreational fishery in the Alaskan Halibut program are denominated in fish to be as consistent as possible with existing regulations. Although a permit based on number of fish relates quite well to the biological impact that anglers impose on the fish stock, some uncertainty would remain because of variation in the size and age of the fish that might be caught.

The biggest obstacles to adopting a fish-based TR in marine recreational fisheries are the problems related to monitoring and enforcement. As with bag limits, a right denominated in fish creates a moral hazard problem since it creates an incentive to discard caught fish (that may not survive), so that the right is essentially used several times. These incentives are not a major problem in big-game hunting where discards are relatively rare and more easily caught. Johnston et al. (2006) explore the use of tags in numerous recreational fisheries and argue that these could be an effective way to enforce a TR program denominated in terms of a caught fish. In such programs anglers are required to terminate the right immediately after a fish is landed, usually by physically attaching the tag to the fish. Still, we are somewhat skeptical about the degree of compliance with such regulations in deep sea fishery where anglers regularly harvest multiple fish and multiple species on a single day.

A fish-based TR that takes the form of a tag would need to be purchased in advance of a trip and the right would probably need to take a physical form. This creates a transaction cost because time may be required to ship the right from the seller to the buyer. This may not be a limitation in big-game hunting, where participants plan their trip well in advance, but it may prove to be a more significant problem in a recreational fishery in which anglers frequently decide to participate with little prior planning. Further, because of uncertainty about how many fish an angler will land, anglers would either need to have a surplus number of rights before each trip and resell them afterwards, or buy too few rights and essentially face a small bag limit.

Under alternative 2, rights would be stated in terms of a number of pounds. This approach would specify the TR in the same units as the official TAC, facilitating transferability of rights between sectors and clarifying the fishing mortality associated with each TR used. This would also reduce the incentive to discard undersize fish since these would use up less of the angler's right. However, there are a number of problems with a pound-based right that would probably make it impractical. First, because most anglers will purchase relatively few permits and because of the uncertainty inherent in fishing, the limit on pounds might cause anglers to

[4] In separate analysis, we carry out a theoretical comparison of the welfare consequences of alternative right specifications. In that analysis we find that there is no clear winner across the three alternatives.

discard fish in order to come close to using their complete right. Second, as with a fish-based right, monitoring and enforcement would require that rights be purchased before a trip. Finally, unlike the one-fish one-right approach under alternative 1, there is no obvious way that an angler would terminate his or her right upon landing a fish. Transaction costs, therefore, are likely to be higher under this alternative.

Under alternative 3, rights would be stated in terms of a number of days for fishing. This approach is the least satisfactory in terms of its relationship between rights used and the physical impact on the fishery since fishing mortality depends on the angler's success. If the TRs are denominated in terms of days of access to the fishery, then bag limits would probably need to be used to control total catch per day. As with TR for nonpoint pollution, this alternative essentially represents a *practice-based* allocation, with its ensuant limitations. In this case an inefficiency arises because some anglers may not desire a complete bag limit while others may wish to exceed that limit; Pareto improving trades could be possible.

In spite of their known inefficiencies, practice-based TRs are used when monitoring of actual environmental impacts is costly and incentives exist for noncompliance. Hence, this asset unit may be appropriate here. As pointed out by the Scottish fishermen interviewed by Rossiter and Stead (2003), rights defined in terms of days of access could also have advantages in terms of monitoring and enforcement; the day-based right could be enforced in much the same way as requirements that anglers have a fishing license. Although anglers know that it is unlikely that their license will be checked during a day of fishing, they usually purchase the license before fishing because of the uncertainty as to whether they will be caught. The day-based right is also preferred because it affects the variable over which angler choices are most directly made – whether to go fishing or not. Finally, a user of a day-based right would be needed to terminate that right prior to leaving the dock. Hence, rights could be tracked electronically as entries in a database identifying those anglers with a right to fish on a given day. The entire market could be embodied in an electronic tracking system in which an angler could purchase, sell, and terminate a right through the Internet or a toll-free telephone number.

B. How should temporal and spatial elements of TRs be handled?

In specifying the units of the TR, their spatial and temporal characteristics must also be defined. Does a recreational TR grant its holder rights to use the fishery at any time and in any place, or in a limited region for a limited time period.

First, we consider the spatial dimension with specific attention to the GRS fishery: would permits be valid in all Gulf waters, or would the TAC be allocated across the states or even smaller regions? Based on the simplest conception of economic efficiency, economists would typically argue for no spatial limitation so that rights could go to those areas where the permits are most valuable. As seen in the Kansas TR hunting program, however, spatial limits are frequently imposed, presumably to ensure balanced harvesting throughout the state. There are two reasons that spatial limits might be imposed. First, there may be equity considerations and if, for example, the vast majority of the permits were purchased for use in a single region, this could adversely affect the remaining states -- political forces may push for a fixed geographical allocations. A second reason is biological: as pointed out by Sutinen and Johnston (2003) if rights became highly concentrated this could lead to localized stock depletion. We believe,

therefore, that the spatial scope of the TR should be determined primarily on biological considerations. Political considerations might also be considered, but this should be done with full awareness that efficiency costs will likely result.

With regard to the temporal dimension, there are two issues that must be resolved. First, how long a permit would be valid – e.g., would unused permits expire at the end of the year? There is strong evidence that such expirations would be counterproductive (Hahn and Hester, 1989) as they would encourage use at the end of the year when delay would actually be preferred by anglers. Further, if a fishery's stock is below MSY then delaying harvest of a fish can only increase stock over time. Hence, automatic expiration of permits would be counterproductive in terms of the biological health of the fishery and the economic welfare of anglers. There is, however, precedent for a time-limited right. To our knowledge, most hunting permit programs follow the model of the Kansas program in that the duration of use is specified, unused permits expire at the end of the specified date. Similarly, the recently approved IFQ program for the GRS commercial fishery program has a similar provision.

The second temporal issue is to control how long a permit would be valid for use. This is obvious if rights are specified in terms of a day of fishing. But if rights were specified in terms of fish or pounds, then it is less clear. We see advantages to specifying the right as an ex ante right – i.e., a right to catch fish, not a guarantee. Under this ex ante approach it might be possible for the rights to be tracked without the use of a physical tag, facilitating the electronic tracking and exchange of the TRs. On the other hand, in keeping with most hunting tag systems and commercial ITQs, quantity-based rights would be valid until the fish are actually captured or until the end of the season.

C. Should size and bag limits be retained?

As we noted above, size and bag limits can be very inefficient devices for the control of total harvests. Ideally, a TR program would replace these restrictions. However, there are legitimate reasons for maintaining these restrictions. If a TR is defined as a day of use, then the bag limit would probably need to be retained to avoid giving anglers an incentive to harvest very high levels of fish on a single day. If rights are defined in terms of pounds or fish, then bag limits could be eliminated. Nonetheless, in the Alaskan Halibut program, in which rights are defined in terms of fish landed, a bag limit is retained. Similarly, hunters who purchase a permit in the Kansas TR program face the same restrictions as other hunters in the state.

In light of the problems with size and bag limits discussed above, we believe that these management tools should be used sparingly as a means to reducing total catch. Regardless of the units in which the TR is established, we believe that size limits should be set only to address problems for which they are particularly well suited, such as protecting particular age classes or helping in the development of trophy-sized fish. In these capacities, they may play an important role in an efficient TR program.

D. How should monitoring and enforcement be carried out?

One of the central challenges of all TR programs is monitoring and enforcement. When commodities or services are purchased, the buyer and seller have a keen interest to ensure that

commitments are satisfied. When TRs are transacted, however, they are trading a right to use a public resource – the two parties usually have no incentive to assure that the other party truly upholds their obligations. A TR program, therefore, has value only to the extent the rights and obligations are enforced (King, 2005).

The traditional management tools of closures and gear restrictions are relatively easy to enforce. By contrast, particularly in a multiple-species deep-sea fishery such as the GRS, it would be difficult to ensure that all anglers fishing for red snapper have the necessary right. Sutinen and Johnston (2003) point out that the more disaggregated the rights are distributed, the more difficult monitoring becomes. As we have noted above, a day-based right may be easier to enforce, but has some limitations in terms of economic efficiency. Fish based permits, on the other hand, have significant advantages, but if they are not enforceable, the resulting program will lose its integrity.

Interestingly, it is possible that the TR program might generate funds to monitor the program in a fashion that varies proportionally with the incentive to cheat. If all or some of the TRs are sold by the government, revenue would result that could be used for monitoring. Furthermore the available funds would increase with the value of the TRs-- permits commanding a high price will generate more funds to monitor compliance, ensuring the integrity of the permits that were purchased.[5]

Adequate monitoring is necessary but not sufficient for TR market success. No matter how theoretically ideal an asset unit specification, if it cannot be enforced it will not adequately protect the resource or create value in the TRs. In any given recreational fishery, managers and participants are in the best position to determine which type of TR can be adequately policed.

E. How should transferable rights be allocated initially?

As exemplified by the collapse of the Alaskan charter IFQ, the question of initial allocation is one of the most problematic issues that must be addressed in developing any TR program. We consider four alternatives:

Alternative 1: Grandfathering based on historical use.

Alternative 2: Lottery

Alternative 3: Auction

Alternative 4: Federal sale (retail at fixed price)

A grandfathering program is the most common approach used in TR programs. In such a program TRs would be initially allocated based on historical catch records of all eligible applicants who owned or operated a vessel. Because grandfathering requires a foundation of

[5] Note, that some level of monitoring is necessary to avoid an equilibrium in which the price is low because everyone is cheating.

credible records, this approach would be difficult to implement in recreational fisheries with a substantial private component and could even be difficult in charter fisheries if operators have not been meticulous in their bookkeeping. The difficulty in establishing grandfathered rights is one of the reasons that Sutinen and Johnston (2003) argue that rights should be issued to regional angling management organizations as discussed below.

Like grandfathering, if the initial allocation of TRs is established through a lottery the rights would typically be given away at no cost. This approach is followed in many recreational systems in which the supply of available use rights is less than the demand. Applicants could apply separately, perhaps at a fee, for access rights, or all licensed anglers could automatically be qualified. In cases like the GRS fishery, in which there is a substantial presence of charter and "party" boats, a separate lottery to those vessels might needed to avoid too much dispersion of the rights. Scrogin and Berrens (2003) note that lotteries are prevalent in the United States including the Maine Moose hunting permits, the Kansas nonresident deer hunting permits, and a New Mexico lottery system for elk harvest rights. They emphasize that "since lotteries ration independently of income, they are commonly favored by the public due to equity concerns" (p. 137). As in the Kansas nonresident hunting permit program, a lottery does not have to give the right to winners at no cost, but can instead give winners the right to buy that right at a non-trivial cost.

Under alternative 3, the TRs permits would be initially distributed to the public through an auction. Auction participants could include not only individual users, but also retail shops, charter boat operators or groups of angler. Auctions are frequently used to transfer assets from public to private hands, as in timber rights and off-shore oil leases, and when the seller is unsure about the values that bidders are willing to pay. They also have the advantage of transparency, which is important in such transactions. Economic efficiency of the auction in the initial allocation of fisheries TRs might, however, depend on the detailed mechanism of the auction.

Morgan (1995) argued that the method of initially allocating fisheries quotas will eventually move to auctions because quota allocation by administrative decision is economically inefficient. Using auctions to allocate initial fisheries TRs might be better than using other alternatives because it identifies potential fishermen with the highest use value of the fisheries and maximizes revenues in an economically efficient way and facilitates the purchase of multiple permits by the for-hire sector.

The final allocation option would be to sell the licenses at a fixed price. For example, in the GRS fishery, rights might be held throughout the year by the GMFMC or National Marine Fisheries Service (NMFS) and sold directly to the public. A disadvantage is that the fixed price could create opportunities for rent-seeking behavior if the price chosen by the agency is too low.. In this case a secondary market would arise, creating opportunities for profiteering by those able to game the system and purchase their permits early. If a fixed-price approach is taken, governments may feel compelled to regulate transfers in a manner that diminishes the potential for the market to efficiently allocate the permits. A creative adaptation to this that could overcome many of the problems would be to have a government price that varies in response to supply and demand.

F. Who should receive rights?

Related to the question of how rights should be allocated, we also ask the question about who should receive the rights. At first glance, one might assume that the answer to this question is obvious – rights should be held by anglers. On closer inspection, however, this is only one of several options. The Alaskan Halibut program, for example, was to distribute rights to the charter fishermen (leaving private anglers outside the program). Sutinen and Johnston (2003) propose a novel alternative, arguing for the use of Angling Management Organizations (AMOs) that would manage and distribute the rights back to anglers.

Alternative 1: Individual anglers

Alternative 2: Angling Management Organizations

Alternative 3: For-hire recreational sector only

Alternative 4: Local or regional governmental authorities

In evaluating the four alternatives, two important issues that must be addressed are the information that is available and the transaction costs that might result. As noted by Sutinen and Johnston (2003), alternative 1 offers many advantages because of its connection to existing regulatory structure. However, they raise two main concerns about this approach: initial allocation issues and the question of enforcement. If rights are to be distributed using a grandfathering approach, this must be based on records of prior effort. Most recreational anglers would obviously lack such records. As noted above, monitoring and enforcement are challenges related to the definition of the asset unit. Nonetheless, if the TRs are distributed and held by private anglers, the problems of monitoring become much more complicated than, for example, if the rights were held by for-hire sector.

An alternative to distributing to individual anglers is to distribute to AMOs, an option favored by Sutinen and Johnston (2003). According to their proposal, AMOs would be owned by anglers who would act like shareholders of a company. The organization, rather than individual anglers would be granted the TRs, and the AMO could distribute rights back to anglers. This could be done directly, or they could engage in more creative management options, such as arranging lotteries of rights, tournaments, etc. As the holder of the rights, the AMOs would be responsible for monitoring harvests by anglers and it would be the AMOs rather than the anglers that would report actual harvests to the government. The authors believe that this could have economies of scale, reducing enforcement costs. Further, they argue that an AMO is also more likely to engage in activities that lead to improvements in the fishery, much like holders of ITQs sometimes participate in stock improvement activities (e.g., Repetto, 2001). Sutinen and Johnston argue that the monitoring cost borne by government might be lower since the AMOs could be audited as a whole, rather than monitoring each angler's activities. The AMO option has not been fully spelled out or attempted, but it has a number of attractive features. Sharp (1998) notes that although AMOs were proposed for New Zealand, they were not adopted in part because of its inconsistencies with legal authorities of management councils.

Alternative 3, in which the TRs would be held only by the for-hire recreational sector, is the system that was proposed for the Alaskan halibut fishery. This approach has advantages in

terms of monitoring and because information for grandfathered allocations would probably be available. However, this would leave the private anglers out of the program, it is only appropriate if the for-hire sector dominates the recreational fishery.

Finally, under alternative 4 the TR would be allocated to local or regional governmental authorities. These could function in much the same way as AMOs, with some of the same advantages. However, in many ways this is not that much different from the status quo and not likely to yield improvements unless the regional authorities adopt some form of TR program themselves. Moreover, for migratory species, lack of enforcement by one governmental authority would have consequences for the other regions.

G. Should trades of TRs be monitored?

With the exception of products like military weapons and dangerous chemicals, most goods are transacted in markets with no public monitoring of each trade. This is not true in many TR markets. TRs are essentially a government granted right to exploit a public resource so it is usually the case that the government must be informed of TR trades. If monitoring were required, it would mean that all trades would need to be reported to a government agency such as GMFMC or NMFS. There is precedent for such monitoring. For example, in case of the Kansas nonresident deer hunting permit program, all transfers are processed through the Kansas Department of Wildlife and Parks main office. If trades are reported it facilitates tracking of the rights and policing the system. A lack of monitoring is only an option only if the right takes a physical form such as a card or a tag and in that case care would need to be taken to avoid counterfeit tags, which could be costly. The main problem with such monitoring is that it introduces additional transaction costs. If trades are reported electronically then transaction costs can be kept low.

H. Will speculation be allowed?

We next consider the question about whether individuals or firms should be allowed to buy and sell TRs to make a profit. Speculation in rights to fish and hunt is not typical. Fishing licenses are typically sold at a fixed price determined by the government with the seller usually receiving regulated issuance fees. The Kansas program allows the TRs to be sold at a profit, but they may be transferred only once. We consider here whether there is an economic justification for such restrictions.

In general, efficiency requires that the price be allowed to vary depending on supply and demand. Unrestricted trading can be problematic if there are concerns that individuals or firms might corner the market. In the case of the GRS fishery, market power is likely to be a problem only if markets are isolated geographically, such as if anglers have only one bait shop at which they can purchase their rights in a given town. Market design to reduce transaction costs so that markets do not become isolated would substantially diminish these concerns.

There are two other reasons restrictions might be sought. In a market occasional spikes in prices are possible, and this could lead to public outcry and opposition to the TR system. There will probably be public opposition if there is the impression that individuals are making substantial profits from a public resource. However, there is precedent for resale and speculation

in the Kansas TRs program. Additionally, the perception of inequality of access should not be entirely ignored. Once again, there may be public opposition to a program if prices become so high that only the very wealthy are able to fish.

I. Will the transfer between sectors be allowed?

The basic economic notions of efficiency suggest that unfettered trading between the recreational and commercial sectors should be allowed. However the transfer of TRs between commercial sector and recreational sector can be controversial. While unconstrained transfer of the rights between sectors would increase short-run net benefits to market participants, it can have some negative consequences.

First, regional depletion could occur if the purchasing sector is geographically concentrated. Second, there is the potential for market concentration, particularly if rights are grandfathered and assigned in perpetuity as is done in most ITQ programs. The third reason for such a restriction would be concerns about secondary impacts on related economic participants. If the recreational sector purchased all the commercial rights, this could affect not only the fishermen, but the processing and marketing sectors as well. Similar impacts on the tourism industry would occur if the trades went the other direction. While in a full-employment economy such concerns have little economic merit, in situations of localized unemployment and/or situations with species-specific capital investments, such secondary impacts should not be ignored. Fourth, political pressure to protect the rights of one resource user group over those of another group may arise. Such pressures are likely to come with particular force from secondary market participants who have nothing to gain when rights are sold.

There is certainly a precedent for such restrictions. The Alaska Halibut program was to allow charter boat operators to purchase IFQ shares from the commercial fishery, but shares originally allocated to the charter sector could not be sold to the commercial sector (Sutinen et al., 2002). Similarly, the Kansas program allows transfers only of the non-resident permits; resident permits are not transferable.

For the most part, economists favor market solutions in which free trade between sectors is allowed, and with good reason (Aranson and Pearse, 2006). However, in developing a proposal for a TR program, economists should not ignore the real concerns that others will have about unfettered trade and the fact that allowing trade can actually be welfare decreasing in an economy that is not operating at or near a first-best equilibrium (Laffont, 1988).

V. A Proposal for a recreational TR program in the Gulf of Mexico Red Snapper fishery

We now briefly propose a system for TRs in the GRS fishery that we believe is implementable and would lead to substantial improvements in the management of that recreational fishery. We divide our proposal into three parts. The first addressing questions of the asset unit, the second related to questions of initial allocation, and then finally a variety of other questions.

A. Questions related to the asset unit

The first consideration in a red snapper TR (RSTR) program must be to define the right in a manner such that its impact on the resource correlates most directly with the right being traded. However, we return to Dales' point that the asset unit must be "practicable." A practicable TR is one that is easily enforced, and the design of which keeps transaction costs at a minimum. It is possible that a fish-based right could achieve these standards, and if so, it would be preferable to a day-based system.[6] But we have our concerns that noncompliance would become a problem and/or trading would be difficult and costly if the TR were specified in terms of fish caught. Hence, our proposal is as follows:

A. RSTRs would be day-based rights that must be terminated before beginning a fishing day. The rights would not take a physical form but would instead be a record on an electronically maintained registry. We believe that such a program would be easily monitored and understood, making the market more credible, while at the same time keeping transaction costs very low.

B. RSTRs would not expire and would be valid to fish anywhere in the Gulf of Mexico. In the event that excessive numbers of rights are carried over to future periods the agency may choose to reduce the number of RSTRs issued in future years.

C. Since we propose that rights be denominated as a day fished, bag limits would need to be retained, but they could be increased because they are no longer the principle tool used for control of total harvests. Size limits should be used to address biological concerns regarding recruitment, but they should not be used as a device to reduce harvests.

D. Since rights are electronic, monitoring of all trades would be critical. This could easily be done through an electronic system that could be accessed via the Internet or a toll-free telephone call.

B. Initial Allocation Issues

As evidenced by the recent demise of the Alaskan Charter IFQ, questions of initial allocation can be the most controversial and critical step in the development of a TR program. Though grandfathering is usually seen as the most politically palatable option, this requires adequate records. Although such records may be available from head-boat and charter-boat operators, it is highly unlikely that private anglers would have access to such information. It is possible that various allocation systems might be used, allocating rights differently to different

[6] In comments on an earlier draft of this paper, David Carter proposed an alternative asset unit in terms of daily bag limits. This approach deserves attention and, if it were required that anglers cancel that right before leaving the dock, this could retain many of the desirable characteristics of a day-based right while allowing more flexibility and a closer tie to the impact on the fishery.

sectors.[7] However, this might create perceptions of unfairness and could itself be controversial. The option that we advocate is to use auctions as a way to distribute the TRs. This will be controversial and politically unattractive, but the efficiency benefits are substantial and the resulting revenue could provide a source of funds for management, monitoring and enforcement, all of which would benefit the fishery in the long run.

E. The initial allocation would be carried out through multiple auctions during the year. A larger number of auctions might be necessary in the first years of the program, but after several years it may be possible to sell all rights in one or two auctions.

F. Rights could be bought by any individual, group, or for-hire operators.

C. Other questions that must be addressed in a GRS TR program

Finally, we turn to several other issues paying particular attention to market efficiency and transaction costs.

G. Given the electronic market that we propose above, monitoring and enforcement would be critical – the government would need to know which angler has the right to use which rights at any time. There should be a substantial fine for fishing without a valid TR.

H. We believe that no restrictions on speculation should be imposed so that the market will decide the clearing price of TRs.

I. Finally, we propose that initially limited transfer between commercial and recreational sectors would be allowed with commercial rights in pounds converted to recreational rights using a conversion factor based on the bag limit and average weight per fish. A limit on the number of cross-sector trades might be imposed for the first five years of the program to mitigate concerns about secondary impacts and market concentration.

VI. Conclusion and Some Caveats

Despite the rapid expansion in the use of transferable rights as a tool for environmental and resource allocation problems, there has been relatively little use of this tool in recreational fisheries. Although there are many practical problems that must be resolved, we believe that they can be overcome. Similar problems have been faced in resource allocation problems ranging from water pollution to hunting. Creative solutions will be needed, but the current situation of declining seasons, increasing size limits and decreasing bag limits is not tenable. A TR program offers hope as an alternative to this situation.

One critical question that we have not addressed here is the problem of bycatch and discard mortality. David Carter, in commenting on an earlier draft of this paper, showed that anglers not targeting red snapper frequently catch the fish. Such anglers are unlikely to purchase

[7] In comments at the PERC conference, Jim Sanchirico emphasized that each angler group might require separate consideration.

TRs in a system. The result will either be illegal harvests or discards, which will likely result in additional mortality. If targeting of the species is difficult, a single species TR will simply not work and we will need to look for alternative management tools.

With this caveat, we return to our initial question, Can a TR program work for the GRS recreational fishery? We believe it could. There are numerous practical decisions that need to be made, and we offer possible answers to some of these above. Our answers are proposed not as the final solution, but as a starting point from which managers, analysts and stakeholders can start and look for alternatives that might be preferred.

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Chapter 3: A Discrete Choice Model of Red Snapper Recreational Fishing Demand[1]

I. Introduction

The objective of this chapter is to empirically estimate recreation demand that incorporates TR permit demand. Because the model uses travel cost as an approximate variable of the price, it is often called Travel Cost model (TCM). We expect that when TR program is implemented the price (cost) of fishing will increase because anglers are required to buy TR permits additionally to go fishing. Our focus is on estimating an effect of price changes on the fishing trip demand.

Suppose the price of taking a fishing trip increases simply by paying a daily access fee. A daily fee will be directly compatible with day-based TRs discussed in the previous two chapters. The difference is that a fee is fixed by the government, but the price of day-based TRs can vary by market demand. In this chapter we examine a daily access fee policy as an approximate price instrument of TR program. We find that a fee can be very effective in reducing recreational fishing demand in the Gulf of Mexico. Income is an important determinant of an individual's choice to travel to go fishing and, if an individual chooses to fish, which fishing mode is chosen.

II. Background

A price instrument such as fees and TR programs might be a way to reduce recreational effort that would avoid the inefficiencies that arise because of season closures. In particular, relative to alternative ways to control congestion or over-use, fees have the advantage of leading to a more economically efficient outcome because they make it possible for those that value the resource most highly to use it. However, of most relevance here, fees are criticized on the grounds of equity since they tend to exclude the poorest user groups from use of resources (More and Stevens, 2000). Any implementation of fees (increase in price) in recreation management inevitably raises the issue of equity although fees are touted for the numerous advantages in terms of economic efficiency. Important questions to policy makers are: Is it unfair to low income people to charge substantial fishing fees? Do recreational fees disproportionately impact anglers who engage in the least expensive mode of fishing? Should we worry if secondary impacts on merchants and service providers are distributed inequitably?

Economic analysis of recreational behavior should provide results that capture distributional consequences so that these questions might be answered. Revealed preference models of recreation demand are often estimated using discrete choice approaches falling into the class of random utility models, and unfortunately, within these, the marginal utility of income is typically assumed to be constant [e.g., Caulkins et al.(1986) and Bockstael et al.(1987)]. In

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[1] The authors acknowledge the important contribution of W. Douglass Shaw to this chapter. This chapter is essentially equivalent to Chapter IV in Hwa (2007) and builds on Kim, Shaw Woodward (2007).

contrast, in our model below, the sensitivity to price varies across fishing modes (access by charter boat, private boat, from shore) and income, allowing estimation of the distributional impacts that a fee might have across user groups. The estimated recreational demand is mode-specific to analyze which mode users are more affected by price changes.

III. Literature Review

To begin, we first briefly consider the random utility model (RUM) and the role that income plays in such models. Second we review some literature on imposing fees in the recreational setting. The use of the RUM in recreation demand or travel cost models is now quite well documented in the literature. We cannot provide an extensive review of such literature here, and that has been done in numerous other papers (see for example, the introductory chapter in Hanley et al. (1997) and references therein). The RUM has a few distinct advantages over some other types of models (specifically the single-site count data approach) in that it handles substitution among sites rather well. However, in virtually all existing recreation demand models that have been estimated using the RUM-based approach, income effects are assumed to be absent. We are aware of very few estimated RUM models that appear in published or unpublished papers that allow for a non-constant marginal utility of income.[2] Doing so generally leads to some very difficult technical issues (for discussion see Herriges and Kling 1999; McFadden 1999; Shaw and Ozog 1999).

Distributional consequences of environmental or resource programs have been considered in a variety of settings, including tradable pollution permits, the share of water shortages, and in situations where "grandfathering" allocation schemes are allowed (see Ruström and Williams 2005). The distributional impacts of recreation fees, in the context of well-developed recreation demand models, have not been frequently addressed in the mainstream literature on travel cost modeling. One notable exception is the contingent valuation study by Adams et al. (1989): their study of hunting and fees illustrates that lower income groups have higher losses than higher income hunters when a flat "per-head' fee is imposed.

Several authors of leisure studies (Reiling et al., 1996; Bowker et. al, 1999; More and Stevens, 2000) have concluded that implementation of a fee or an increase in a fee would lower recreational participation by low-income people. More and Stevens (2000) found that a $5 daily fee to access public lands would affect almost half of the low-income people as compared to a smaller portion (33%) of high-income people. Reiling et al. (1996) estimated that recreational demand for public lands on the part of low-income groups is more elastic than that of middle or high income groups, which implies that low income people would be more responsive to a price increase. These studies support the notion that income inequity is problematic in recreational activities. In contrast to these studies, Kyle et al. (2002) find no significant correlation between

[2] Shonkwiler and Shaw (2003) consider the impact of a $5 increase in the fee at one of the Columbia River main-stem reservoirs within a finite mixture model that allows for income effects, but this is quite different than the usual RUM model. They find that recreational users in one regime experience almost twice the loss in consumer's surplus as those in another income regime.

household income and willingness to pay for fees, and Winter et al. (1999) found that income was less helpful in understanding public response to fees than a measure of social trust.

Our econometric model below draws on recent work by Morey et al. (2003a and 2003b) that incorporates income effects in a simple fashion. Morey and his colleagues assume that utility is "a piece-wise linear spline function" of expenditures. In this case, the change in the marginal utility of money is assumed to be a step function of money income. This piece-wise spline approach is used to deal with income effect below. The approach is well suited for our income data set, which is available categorically. We use this approach within the context of a repeated discrete choice random utility model.

IV. Model

To estimate recreational demand, one would ideally like to know the destination, the frequency, and what mode is chosen for each trip. Such data is rarely available, for the simple reasons that collecting it is complicated, there are limits to respondent recall, and such data are cost-prohibitive. Hence, it is often the case that data are gathered as in the Marine Recreational Fishery Statistics Survey (MRFSS) data used in this study, with rather complete information about a single intercept trip and less complete data for other trips that the individual may have taken. Although the data are not as complete as the analyst might desire, the partial data on the non-intercept trips do offer potentially valuable insights into angler preferences and their demand for fishing trips. Morey, Shaw, and Rowe (hereafter MRS-1991) developed a statistical and theoretical model that takes advantage of data of this type, and we follow very closely the discrete choice-random utility model they developed.

In the MSR model, the assumption was made that anglers engage in a pattern corresponding to a repeated decision, leading to a "repeated" discrete choice or random utility model of recreation demand. The repeated choice model framework is adopted by Morey et al. (1993), and Shaw and Ozog (1999), and a host of others. Issues and extensive discussion can be found in Morey (1999) and Parsons et al. (1999). Using this model in our context, an angler confronts two simultaneous decisions: whether to go recreational fishing at all, and if the angler does so, the mode that will be used, i.e. whether to fish from shore, from a private boat, from a rental boat, or from a charter boat. Kim, Shaw, and Woodward (2007) estimate a model with county specific destinations. Here our emphasis is on tradeoffs across modes, so we treat the Gulf of Mexico as a uniform destination, but the distance that an angler has to travel to reach the Gulf varies widely.

The econometric model essentially reduces to estimating two conditional probabilities. First, an angler i has a daily probability of not going fishing equal to π_i^{nf}. In the given fishing period, X, she takes Q_i trips, not including the trip where we observe the angler's destination. Over the X days in a period there are $\left[X!/\left(Q!\left(X-Q\right)!\right)\right]$ combinations of Q days so that the probability of observing Q_i trips becomes

(1) $$f_1(Q_i) = \left[\frac{X!}{Q_i!(X-Q_i)!}\right](\pi_i^{nf})^{(X-Q_i)}(1-\pi_i^{nf})^{Q_i}.$$

Second, we estimate the probability, π_{mi}^{f}, that an angler *i* chooses mode *m* for her intercept trip. Defining y_{mti} =1 if an angler *i* took mode *m* on the trip where we observe the angler's mode in period *t* and y_{mti} =0 otherwise, the marginal distribution of choosing mode *m* can be concisely written

(2) $$f_2(y_{mti}) = \prod_{s=1}^{M} (\pi_{si}^{f})^{y_{sti}} \ .$$

Finally, following MSR (1991), we combine these two conditional probabilities to form the likelihood function. Given a random sample of *N* independent participants and assuming that Q_i and y_{mti} are independently distributed, the probability of observing the participation and mode choices for the anglers in the sample is

(3) $$L = \prod_{i=1}^{N} f(Q_i, y_{mti}) = \prod_{i=1}^{N} f_1(Q_i) f_2(y_{mti}),$$

where $f(Q_i, y_{mti})$ is the joint distribution.

The use of the probability in equation (3) in the likelihood function would suffer from intercept bias since those that fish more often are more likely to be interviewed. Hence, in the likelihood function estimated, we introduce a correction for potential intercept bias, replacing the distribution of unobserved trips with a sampling distribution that assumes being in the sample is proportional to the total number of trips one takes.[3] With this assumption, the modified likelihood function becomes:

(4) $$L = \prod_{i=1}^{N} \left\{ \frac{Q_i + 1}{[(1-\pi_i^{nf})X + 1]} \right\} \left\{ \left(\frac{X!}{Q_i!(X-Q_i)!} \right) \left(\pi_i^{nf}\right)^{X-Q_i} \left(1-\pi_i^{nf}\right)^{Q_i} \right\} \left\{ \prod_{m=1}^{M} \left(\pi_{mi}^{f}\right)^{y_{mi}} \right\}.$$

In order to estimate the probabilities of making the mode and participation choices, a functional form for the indirect utility function must be specified. Applying the typical linear specification of a RUM model to the problem of mode choice, the utility of an angler in period *t* is a function of the angler's fishing budget in period *t*, B_{ti}, and whether or not a particular mode *m* has been chosen at a personal cost of P_{mi}. In addition to the price and budget, catch rate (CR_m) will affect utility when the angler takes a trip. That is, we write $U_{0ti} = \alpha_0 + \beta\left(B_{ti}\right)$ if the angler does not fish, and $U_{mti} = \alpha_m + \gamma \cdot CR_m + \beta\left(B_{ti} - P_{mi}\right) + \varepsilon_{mti}$ if the angler chooses mode *m*, where ε_{mti} is the error terms capturing unexplained variation in the utility when the angler chooses to

[3] See the intercept bias correction discussed in MSR (1991), their equation 14, and the relevant text where results are discussed.

fish. The coefficients α_0 and α_j can be functions of variables describing the angler, the mode, or the season.

An angler will not fish if the reservation utility, U_{0ti}, is greater than the utility enjoyed in all of the modes. Hence the probability that an angler does not fish, π_i^{nf}, is the probability that $U_{0ti}>U_{mti}$ for all other modes, so π_i^{nf} is a decreasing function of the difference $U_{mti}-U_{0ti}$. This difference can be simplified to

(5) $$U_{mti} - U_{0ti} = (\alpha_m - \alpha_0) + \gamma \cdot CR_m - \beta P_{mi} + \varepsilon_{mti} .$$

As in MSR (1991) it is assumed that the non-fishing utility is deterministic so that the error in this equation is captured in the single error term, ε_{mti}. There is a straight forward interpretation of equation (5). The difference between the α's in the parentheses can be thought of as the utility gain achieved by fishing using mode *m*. The $-\beta P_{mi}$ term reflects the cost in terms of decreased utility that the angler must pay in order to gain the benefits of the fishing trip. The usual assumption in the applied literature is that the marginal utility of income is constant so that β is the same for all possible uses of income or income levels. This specification implies, therefore, that if an angler's fishing costs increase by one dollar, his or her utility declines by a fixed amount that does not vary across incomes or for any other reason. We believe that it is intuitively plausible that βs may actually vary across both modes and incomes. For example, the angler's response to a one dollar increase in the cost of a charter fishing trip, with an average cost of over $250, may be quite different from his or her response to a one dollar increase in the cost of a $30 shore fishing trip. If the marginal effect of a price change varies across modes, then we would rewrite (5) as

(6) $$U_{mti} - U_{0ti} = (\alpha_m - \alpha_0) + \gamma \cdot CR_m - \beta_m P_{mi} + \varepsilon_{mti} ,$$

allowing for a separate coefficient β_m for each of the *m* categories. Regardless of whether (5) or (6) is used, only the coefficient on the price is identified; the coefficient on income can only be identified to the extent that it is assumed to be equal to the coefficients on the prices.

The specification suggested by (5) is a restricted form of (6), a theoretical restriction that can be tested empirically. In our empirical application, we allow the β parameters to vary across modes, after testing and rejecting this restriction. Rejection of this hypothesis does not necessarily mean that consumers are violating a fundamental principle of consumer behavior, but it does suggest that anglers' demand behavior is more complicated than is typically assumed.

In equation (6), it is assumed that the marginal utility of money varies depending on the type of mode being chosen. Alternatively or in addition, it might be that the β parameters vary across income groups. To allow for this type of variation, we adopt Morey et al.'s (2003a, 2003b) linear spline function approach in which the marginal utility of income varies for different income brackets. If this approach is adopted, then an angler's utility (temporarily suppressing the coefficient on and the catch rate variable) taking a trip in mode *m* would be written

$$
\begin{aligned}
U_{mti} &= \alpha_0 + \beta_0 \left(B_{ti} - P_{mi} \right) + \varepsilon_{mti} && \text{if } (B_{ti} - P_{mi}) \le M_0 \\
&= \alpha_0 + \beta_0 M_0 + \beta_1 \left(B_{ti} - M_0 - P_{mi} \right) + \varepsilon_{mti} && \text{if } M_0 < (B_{ti} - P_{mi}) \le M_1 \\
&= \alpha_0 + \beta_0 M_0 + \beta_1 \left(M_1 \right) + \beta_2 \left(B_{ti} - M_1 - P_{mi} \right) + \varepsilon_{mti} && \text{if } M_1 < (B_{ti} - P_{mi}),
\end{aligned} \tag{7}
$$

where M_0 and M_1 are threshold points where it is assumed that the marginal utility of income changes. If this approach is used, then the utility difference equation, (5), would be rewritten

$$U_{mti} - U_{0ti} = \left(\alpha_m - \alpha_0 \right) + \gamma \cdot CR_m - \beta_j P_{mi} + \varepsilon_{mti} \tag{8}$$

where j=0,1,2 for the three different income categories. Again, the specification in (5) is a testable restriction of (8).

Finally, equation (9) is the most flexible specification, in which the slope coefficients vary across both income and mode. In this case, (5) would be written

$$U_{mti} - U_{0ti} = \left(\alpha_m - \alpha_0 \right) + \gamma \cdot CR_m - \beta_{jm} P_{mi} + \varepsilon_{mti} \tag{9}$$

where the marginal utility of money, β_{jm}, is allowed to vary for each combination of mode and income.

Regardless of the utility specification chosen, as shown in Morey (1999) if we assume that in each period the angler's vector is randomly drawn from a Type I Extreme Value distribution then the joint CDF of this distribution is

$$F_\varepsilon(\varepsilon_{ti}) = \exp\left[\sum_{m=1}^{M} -\exp(-\varepsilon_{mti}) \right]. \tag{10}$$

Letting V_{0ti} and V_{mti} indicate the deterministic part of the angler's utility (i.e. without ε_{0ti} and ε_{mti}, respectively), we obtain the specifications that are actually used in estimation as in Morey et al. (1991). The probability of not fishing becomes

$$\pi_i^{nf} = \text{Prob } [U_{0ti} > U_{mti}, \forall m] = \exp\left\{ -\sum_{m=1}^{M} \exp\left[-(V_{0ti} - V_{mti}) \right] \right\}. \tag{11}$$

Once the decision to go fishing has been made, the probability of choosing mode m over the other modes can be written

$$\pi_{mi}^{f} = \text{Prob } [U_{mti} > U_{sti}, \forall s] = 1 \Big/ \sum_{s=1}^{M} \exp\left[-(V_{mti} - V_{sti}) \right] \tag{12}$$

After selecting the model to be estimated, (5), (6), (8), or (9), equations (11) and (12) are used in the likelihood function to find the parameters of each model.

V. Data, Estimation, and Empirical Results

A. Data

The data used here come from the 1997 Marine Recreational Fishery Statistics Survey (MRFSS). The history of the MRFSS data set is discussed in Hicks et al. (1999) and the data used here are from the 1997 study (discussed in detail in Whitehead and Haab, 1999), using the economic add-on to the standard intercept data. The approach to collecting the data is commonly used by the National Marine Fisheries Service and the data here are almost identical in nature to the data originally encountered by MSR (1991). In these data, there is complete information only about the intercept trip, and partial information about other trips that the angler takes in a two-month period. Anglers in 1997 MRFSS intercept survey were contacted at a variety of locations including docks, marinas, and other sites along the Gulf Coasts (except Texas coast). The follow-up economic survey was conducted over the telephone. The data are divided into six waves of two months each.

The questions in the survey include those about general characteristics of respondents, their number of fishing days within last two months, specific information of intercept trips, *i*.e., what mode of fishing they engaged in, when they went fishing, and what they targeted and caught. Here we focus on single-day trips at four states along the Gulf of Mexico coast. The sampling was stratified by mode (Table 3.1). Anglers that were interviewed fished an average of 7.11 days during the two month fishing period and they have an average of 18.1 years of fishing experience.

The most common mode of fishing for anglers in our sample was using a private boat (73%), which is not surprising since about 63% of anglers own a boat. The other modes are by charter boat (4.1%), with the remainder fishing from the shore (22.9%). Interviews were spread unevenly throughout the year with a greater proportion conduced in the Sep-Oct and May-Jun waves (19.8%) and the fewest in the coldest and hottest months, Jan-Feb and Jul-Aug (12.8% and 14.2%, respectively).

Anglers who inidcated that they were targeting red snapper were coded as Dredsn=1. The average for this variable, therefore, represents the percentage of respondents who targeted red snapper, just 1.1% of all observations. Our empirical focus is on red snapper, so it would have been preferable to only use observations from anglers targeting that species. This narrow focus was not possible however, because only 42 such observation were observed.

Table 3.1: Distributions and Variable Summary Statistics

		Frequency	Percentage
Mode Distribution			
Charter		153	4.1%
Private		2696	73.0%
Shore		845	22.9%
Fishing Period Distribution			
Jan-Feb	($Dwave_1$)	474	12.8%
Mar-Apr	($Dwave_2$)	579	15.7%
May-Jun	($Dwave_3$)	733	19.8%
Jul-Aug	($Dwave_4$)	525	14.2%
Sep-Oct	($Dwave_5$)	733	19.8%
Nov-Dec		650	17.6%
Income Distribution			
less than $35,000	(DM_0)	1768	47.9%
$35,001 to $75,000	(DM_1)	1559	42.2%
Greater than $75,001	(DM_2)	367	9.9%
Other Dummy			
Own a boat	(*Dboat*)	2314	62.6%
Target red snapper	(*Dredsn*)	42	1.1%
		Mean	Std. Dev
Trips		7.11	8.47
Experience	(*Exper*)	18.06	14.16

Note: Variable names in parentheses where appropriate.

The survey questionnaire identified income in 11 categories, which we aggregate into three broad categories: low (less than $35,000), middle ($35,001 to $75,000), and high (greater than $75,001). These income levels correspond roughly to the 50% and 80% thresholds for U.S. households reported in the U.S. Census Bureau's Current Population Survey.[4] Because 34% of respondents in the sample do not reveal their income, the log linear ordinary least squares regression model suggested and estimated by Haab et al. (2000) is used to impute missing income values. After using imputed income, those in the low income category constitute 47.9% of the total sample. The middle income category contains 42.2% of the respondents, and the rest of the sample (9.9%) falls into the high income category.

Travel costs to the three modes for 38 destinations near the angler's home (the intercept destinations) are constructed using distances calculated using the Zipfip program. In addition, the opportunity cost of an angler's time in travel to and from the site is factored in using assumed

[4] In 1997, 50% of the U.S. households had an income less than $40,699, 80% less than $78,638 (http://www.census.gov/hhes/income/histinc/ie4.html).

travel speeds and reported wage rates as the opportunity cost of time per hour, if these are available in the anglers' responses. For anglers not reporting wage rates but reporting annual income we used average hourly income instead, and for those reporting neither wage nor income, we used a hedonic regression to predict their wage rate per hour (see Appendix C). Retirees are assumed to have an opportunity cost of time equal to the minimum wage rate. Because we construct only a mode choice model, the travel costs and opportunity costs of time to get to the intercept destinations do not vary across modes but vary widely by anglers. Other expenses and boat fees varying by mode are computed simply as the sample average. It is noteworthy that the average cost of fishing from a charter vessel is considerably more than all other modes, and sometimes an order of magnitude more costly than the cost of shore fishing. The averages of the predicted prices for charter, private, and shore fishing are shown in Table 3.2.

Table 3.2: Average Predicted Prices across Modes of Fishing

Means	Charter	Private	Shore
Travel Cost and Opportunity Cost of Time	22.8	22.8	22.8
Other Expenditure	17.5	29.6	7.2
Boat Fee	222.5	-	-
Total Price	262.8	52.4	30.0

The mode-site catch rates are the average of reported catch rates for each site and mode. When, for a given mode-site combination, only a few anglers report catch, the average reported catch could be problematic. As our sample is rather large, this was not a major problem, but when less than 20 observations were available, observations from adjacent site(s) were included until at least 20 observations were obtained. In this way, a catch rate was available for each of the all sites and for each of the three modes. The averages of catch rates for charter, private, and shore fishing are 3.53, 2.71, and 1.71, respectively.

B. Estimation

The parameters of the model are estimated by maximizing the log likelihood function:

$$\begin{aligned} \ln L &= \ln(Q_i+1) - \ln[(1-\pi_i^{nf})X+1] - \ln[Q_i!(X-Q_i)!] + \ln(X!) \\ &\quad - \ln[Q_i!(X-Q_i)!] + (X-Q_i)\ln(\pi_i^{nf}) + Q_i \ln(1-\pi_i^{nf}) + \sum_{m=1}^{M} y_{mi} \ln(\pi_{mi}^{f}) \end{aligned} \tag{4.13}$$

We assume that the decision whether to fish or not is a function of the season as captured by an intercept term and the season as picked up by dummy variables for the five waves: $Dwave_1$ =1 if the respondent is surveyed in Jan-Feb,…, $Dwave_5$=1 if the respondent is intercepted in Sep-Oct. The probability of not fishing or staying at home is also a function of a dummy variable of targeting red snapper, *Dredsn*, boat ownership, *Dboat*=1 if yes, and the angler's experience in years, *Exper*. In addition to an intercept term for each mode, α_{0m}, mode choice is also assumed to be a function of $CatchRate_m$. Income levels are identified in the dummy variables DM_0=1 if household income is less than $35,000, DM_1=1 if household income is $35,000 to $75,000, and

DM_2=1 if household income is greater than $75,001.[5] Using the most general specification with separate slope coefficients for each mode and income category, the final empirical specification of the probability of not fishing and mode choice from equations (11) and (12) can be written as

$$(14) \qquad \pi_i^{nf} = \exp\left\{ -\sum_{m=1}^{M} \exp\left[\begin{array}{l} -\left(\sum_{j=1}^{5} \alpha_j Dwave_j \right) - \alpha_7 Dredsn - \alpha_8 Exper - \alpha_9 Dboat \\ +\alpha_{0m} + \gamma CR_m - \left(\beta_{0m} DM_0 + \beta_{1m} DM_1 + \beta_{2m} DM_2 \right) P_{mi} \end{array} \right] \right\}$$

and

$$(15) \qquad \pi_{mi}^{f} = 1 \Big/ \sum_{s=1}^{M} \exp\left[\begin{array}{l} \alpha_{0s} - \alpha_{0m} + \gamma(CatchRate_s - CatchRate_m) \\ -(\beta_{0s} DM_0 + \beta_{1s} DM_1 + \beta_{2s} DM_2) P_{si} \\ +(\beta_{0m} DM_0 + \beta_{1m} DM_1 + \beta_{2m} DM_2) P_{mi} \end{array} \right].$$

Note that the intercept term, α_{0m}, captures the difference between intercept in the non-fishing and mode-*m* utility function, i.e. $\alpha_{0m} = \alpha_m - \alpha_0$ in (5), (6), (8) or (9). With π_i^{nf} and π_{mi}^{f} defined by (14) and (15), the parameters of the unrestricted model are found by maximizing (4) with respect to the parameters. Equivalently, the restricted models, (5), (6), and (8), are estimated by making the suitable restrictions in the equations for V_{0ti} and V_{mti}.

C. Estimation Results

Estimation results for participation and mode choice model are presented in Table 3.3.[6] The alternative models associated with different specifications of the price coefficient are presented. We estimated four different models corresponding to equations (5), (6), (8) and (9), models 1 through 4. Only one price coefficient is used in model 1, mode-specific price coefficients are used in model 2, income specific coefficients are estimated in model 3, and both mode and income specific price coefficients are estimated in model 4. Our focus is here on testing the slope coefficients in the utility difference equations vary across both mode and income. Based on the likelihood ratio test, we reject at the 1% level all restrictions on the model. That is, we reject the hypothesis that the price coefficient is constant across modes, (5)=(6), that it is constant across income levels, i.e., (5)=(8), or both of these restrictions simultaneously, (5)=(9). Following our model specification tests, we focus the remainder of our discussion on the preferred and most general model, Model 4, in which the price coefficient is allowed to vary for each mode and income group.

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[5] Note that the dummy variable trap is avoided because there no default coefficient.

[6] The standard errors that yield the t statistics in Table 3 are computed from analytic second derivatives (Newton) supplied by the econometrics program TSP.

Table 3.3: Estimation Results of Participation-Mode Choice Model

Parameter	Model 1 One Price coefficient Estimate	Model 2 Mode-specific Price coefficients Estimate	Model 3 Income Specific Price coefficients Estimate	Model 4 Mode and Income specific Price coefficients Estimate
α_{0Ch}	3.3865	1.6558	3.4031	2.9852
(Constant)	(28.62)	(23.73)	(26.01)	(23.60)
α_{0Pr}	3.9828	4.7467	3.9821	4.0196
(Constant)	(94.60)	(54.05)	(93.12)	(51.07)
α_{0Sh}	2.6163	3.2589	2.6127	3.3132
(Constant)	(67.55)	(58.40)	(62.04)	(55.17)
γ	0.0473	0.0856	0.0467	0.0886
(CatchRate)	(4.86)	(13.78)	(4.72)	(14.44)
β_{0Ch} †	0.0111	0.0061	0.0110	0.0085
(Price Low)	(27.79)	(28.70)	(19.39)	(28.90)
β_{1Ch} †			0.0117	0.0079
(Price Middle)			(25.95)	(25.01)
β_{2Ch} †			0.0099	0.0070
(Price High)			(20.96)	(25.70)
β_{0Pr} †		0.0307		0.0242
(Price Low)		(17.45)		(16.56)
β_{1Pr}				0.0195
(Price Middle)				(14.47)
β_{2Pr}				0.0205
(Price High)				(12.96)
β_{0Sh} †		0.0419		0.0379
(Price Low)		(19.88)		(16.13)
β_{1Sh}				0.0467
(Price Middle)				(14.87)
β_{2Sh}				0.0597
(Price High)				(10.52)
α_1	0.2139	0.2129	0.2146	0.2157
(Dwave1)	(7.29)	(7.27)	(7.32)	(7.36)
α_2	-0.2539	-0.2441	-0.2547	-0.2378
(Dwave2)	(-10.31)	(-9.92)	(-10.33)	(-9.66)
α_3	-0.2641	-0.2561	-0.2660	-0.2553
(Dwave3)	(-11.34)	(-11.00)	(-11.42)	(-10.96)
α_4	-0.1349	-0.1289	-0.1358	-0.1300
(Dwave4)	(-5.22)	(-4.99)	(-5.25)	(-5.03)
α_5	-0.1125	-0.0988	-0.1130	-0.0935
(Dwave5)	(-4.67)	(-4.11)	(-4.69)	(-3.88)
α_7	0.4891	0.4820	0.4968	0.4639
(Dredsn)	(5.72)	(5.65)	(5.80)	(5.43)
α_8	-0.0011*	-0.0015	-0.0011*	-0.0015
(Experience)	(-2.22)	(-2.89)	(-2.21)	(-2.87)
α_9	-0.1507	-0.1698	-0.1532	-0.1964
(Dboat)	(-9.96)	(-11.16)	(-9.88)	(-12.58)

Table 3.3 (continued)

	Model 1	Model 2	Model 3	Model 4
Log Likelihood	-26938.4	-26712.5	-26931.1	-26645.9
Schwarz BIC	26991.8	26774.1	26992.7	26732.1
Degrees of Freedom	3681	3679	3679	3673

Notes: Variable names and t-statistics in parentheses. Ch=Charter, Pr=Private, Sh=Shore, and Low, Middle, and High indicate income groups, respectively. All price terms enter the model with a minus sign, so a positive sign is consistent with the usual expectation of the price coefficient in demand models.
* Significant at 5%, all other estimates are significant at 1%.
† In models 1 and 3 the price coefficients are not mode specific. In model 2 the price coefficients are for all income levels.

The signs on the estimated coefficients for the prices are all negative and significant with exception of the charter price. They appear to be positive because in estimation all are subtracted from other terms (see equation (9)). Hence, an increase in trip costs, such as through the imposition of a user fee, would be expected to lead to a reduction in the probability of using that mode. Comparing the price coefficients across income levels, e.g., β_{0Ch}, β_{1Ch}, and β_{2Ch}, we find relatively little difference, with the largest differences being within the shore angler mode group, where the high income category coefficient (0.06) is 37% larger than the low income category coefficient (0.038). Across the modes, however, there is striking difference in the responsiveness to price, indicating greatly different slopes depending on the mode of fishing. The charter coefficients are very small, but the private coefficients are about three-times larger and the shore coefficients are over two times larger than private ones. As we discuss in more detail below, these differences across modes indicate that anglers who participate in shore fishing are much more responsive to price changes than other fishermen.

All mode characteristic constant terms in the mode decision (α_{0Ch}, α_{0Pr}, and α_{0Sh}) are significant and positive, implying that anglers can get utility benefit from fishing trips. The positive estimate of the catch rate variable indicates that anglers will likely choose a mode that provides them with more catches. The coefficients in the probability of not fishing equation (14), i.e., α_0, to α_9, are also significant and give us appropriate interpretation. If the signs of these estimates are negative, it implies that anglers are more likely to go fishing instead of staying at home. For example, with negative signs of the experience variable and the dummy variable of owning a boat, more experienced anglers and/or anglers who own a boat will have higher possibility of taking a trip. Finally, all the coefficients on Dredsn are significantly greater than zero, indicating that the demand for trips that target red snapper is slightly greater than for the average across all other species.

Evaluating the estimated probabilities at the means of all explanatory variables, Table 3.4, the predicted number of recreational trips to the Gulf states and probabilities of choosing modes by using the estimates are presented. The expected number of trips over the period are equal to $61\times(1-\pi_i^{nf})$, and the expected trips for each mode are calculated by $61\times(1-\pi_i^{nf})\times(\pi_{mi}^{f})$. The probability of not fishing on any given day is estimated at 97.1 percent, on average. The number of trips that a representative angler would take to catch red snapper over the two-month

period is estimated at 1.76 trips, and on average 1.15 of these would be from a private boat. Charter boat fishing is much less frequently done, with only 0.44 trips on average over the observed period.[7]

Table 3.4: Predicted Trips per Two-Month Period and Daily Probabilities of Choosing Mode and Not Fishing

Trips	Total	Charter	Private	Shore
Mean	1.755	0.164	1.152	0.439

Probability	Not Fish	Charter	Private	Shore
Mean	0.971	0.250	0.656	0.094

Note: In this table and hereafter all trips are defined as recreational trips per two-month period *to catch red snapper* (Dredsn =1).

D. The Effects of Income, Season, and Price on Trips, across Modes

Using the estimated coefficients, we predicted the number of trips in each mode for the different income categories, *i*.e., low (L), middle (M), and high (H) income groups, in Table 3.5 Notice that the demand for fishing trips actually falls slightly as income rises from a high of 1.79 trips/two-month period for people in the low income group, to 1.68 trips for those in the higher group.[8] Although one might expect fishing to be a luxury good (suggesting that trips rise as income rises), there are clearly other economic factors at play that are not captured in the model. The negative effect of income on fishing demand may be due to omitted choices. Thus, the set of feasible alternative recreational options increases as income rises. More noticeable are the differences in the modes chosen across income groups. Although we predict that individuals of all income will primarily take trips on private boats, only higher income people are predicted to prefer charter fishing, (0.157 (L) to 0.211(H) on average), while shore fishing is preferred by lower income people (0.555(L) to 0.265(H) on average). Hence, the model predicts substantial variability in choices made depending on income level.

[7] The estimated number of trips for red snapper trips from shore are presented for comparision, though as noted in the next chapter, the demand for shore trips is not included in the simulation analysis.

[8] To obtain the average number of trips, on would need to be weight the values in this table by the number of people in each income group in the sample.

Table 3.5: Predicted Trips per Two-Month Period and Daily Probabilities for Different Income Categories

Average Predicted Trips		Total	Charter	Private	Shore
Low Income	less than $35,000	1.791	0.157	1.079	0.555
Middle Income	$35,001 to $75,000	1.782	0.163	1.237	0.382
High Income	greater than $75,001	1.678	0.211	1.202	0.265

Probabilities		Not Fish	Fish (probabilitiy of each mode on a trip)		
			Charter	Private	Shore
Low Income	less than $35,000	0.9706	0.088	0.602	0.310
Middle Income	$35,001 to $75,000	0.9708	0.092	0.694	0.214
High Income	greater than $75,001	0.9725	0.126	0.716	0.158

The predicted number of trips across two month fishing periods are tabulated in Table 3.6. The expected number of trips is the largest during the months of May and June. March and April are also preferred months and the least preferred fishing season is winter in the months of January to February.[9]

Table 3.6: Average Predicted Trips across Waves

Trip	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Charter	0.116	0.182	0.185	0.164	0.158	0.144
Private	0.894	1.398	1.422	1.257	1.213	1.106
Shore	0.311	0.487	0.495	0.438	0.422	0.385
Total	1.321	2.066	2.102	1.858	1.793	1.635

[9] As above, the values in Table 3.6 cannot be used to directly to calculate calculate the averages since the average must be weighted based on the distribution of trips over the year.

E. Fee Impacts

We now use the model to predict how fees can be used to reduce recreational fishing effort, which in turn, may reduce adverse impacts on the fishery. Suppose a day-based fishing permit fee were imposed on those who go fishing, equally charged to all anglers no matter what mode they use. Table 3.7 shows that the model predicts that fishing behavior would be quite sensitive to such an increase in the cost of a fishing day. We estimate that a $5 fee would lead to a 12% reduction in total fishing effort and a $20 fee is predicted to reduce trips by 38% which is 1.1 trips every two months. Among modes, charter boat fishing demand is least affected and shore fishing is most affected. If the fee is increased to over $15, the model predicts that half of the least expensive mode, shore fishing, will be eliminated. In contrast, the same increase in costs for charter fishermen has a relatively small effect.

Table 3.7: Predicted Trips per Two-Month Period for Various Fee Levels

	Trips per two-month period			
Daily Fee	Total	Charter	Private	Shore
$0	1.755	0.164	1.152	0.439
	0%	0%	0%	0%
$5	1.541	0.157	1.031	0.352
	-12.2%	-4.1%	-10.5%	-19.8%
$10	1.361	0.151	0.926	0.284
	-22.5%	-7.8%	-19.6%	-35.4%
$15	1.208	0.146	0.834	0.229
	-31.1%	-11.1%	-27.6%	-47.9%
$20	1.079	0.141	0.753	0.185
	-38.5%	-14.0%	-34.7%	-57.9%
$25	0.968	0.137	0.681	0.150
	-44.8%	-16.6%	-40.8%	-65.8%

Note: Percentage Declines in Parentheses. Values are averages across the six two-month periods during a year.

The distribution of these impacts across the modes make intuitive sense; as a percentage of the trip price that they already face, a five dollar fee has much greater significance to shore fishermen than to charter fishermen. We find, therefore, that a price instrument such as a fee and TRs to rationing would have the effect of favoring charter fishing, the pastime of the wealthy, relative to shore fishing which is the choice for the lower income anglers.

User fees are particularly attractive from an efficiency perspective because they restrict fishing opportunities in a way that those who value the resource most (in terms of willingness to pay) are the ones who end up using the resource. Such a policy would also tend to reduce fishing by those vessels that haverst the fewest fish per trip. Fees are more efficient than the current policy of closures and based on our results, we find that a user fee can be very effective in reducing fishing effort. However, we find that such a policy may not be desirable on equity

grounds. A flat fee will work by reducing fishing pressure by the lower income participants who use the least expensive mode, essentially excluding this group from access to the resource. Balancing efficiency and equity in practice is a challenge, but ignoring the issues either explicitly or implicitly through the choice of the model, will not make this challenge go away.

F. Consumer Surplus

Because our utility function is assumed to be linear in income (or budget) and catch rates, consumer surplus of taking a trip using mode *m* is equal to compensating variation (CV). If we assume taking a trip can not cause an individual to jump income categories, i.e., low income to middle income group, this welfare measure will be same as equivalent variation (EV). Our interest is in measuring how much an angler can benefit when taking a trip to catch red snapper using mode *m*. Expected per-day (per-trip) consumer surplus (CS) when an angler takes a trip using mode *m* is defined implicitly by the equation

$$U_m(B - P_m - CS_m) = U_0(B),$$

and empirical expression using estimates is

$$E(CS_m)/day = \frac{\alpha_m - \alpha_0 + \gamma \cdot CR_m}{\beta_m} - P_m,$$

where β_m is price parameter for each mode *m*, and other parameters and variables are same as defined above. Gross per-day CS for mode *m* when an angler take a trip using mode *m* is approximate as $(\alpha_m - \alpha_0 + \gamma \cdot CR_m)/\beta_m$, and net per-trip CS can be measured by subtracting the cost of fishing from the gross CS. Because estimated marginal utility of income varies by income group, we can compute the welfare measures by both income group and mode. Per-day CS estimates calculated by using the estimated parameters for each mode and by evaluating variables at the mean are presented in Table 3.8. The values found are in the range of values estimated by by Gillig (1999), who used the same data set but used a count-model rather than RUM model as we do here.

Table 3.8: Expected Consumer Surplus per Day across Modes

	Gross E(CS)/Day			Net E(CS)/Day		
Income Group	Charter	Private	Shore	Charter	Private	Shore
Low	398.2	179.5	93.6	135.4	127.1	63.6
Middle	426.7	223.2	76.0	163.9	170.8	46.0
High	479.7	211.5	59.4	216.9	159.1	29.4
Weighted Average	418.3	201.1	82.8	155.5	148.7	52.8

Expected per-trip CS is biggest when a charter boat trip is taken while it is smallest when shore fishing is chosen in both gross and net terms. Whenever an angler takes a charter boat trips, he can get $156 for his welfare benefit. If an angler takes a trip using his private boat or fishes at shore, his welfare gain will be $149 and $53, respectively. The reason the difference of

CS between charter and private boats is not significantly large is that the fixed (or sunk) cost of owning a private boat is not captured when we calculate the price. If we could appropriately add this fixed cost to the price of taking a private boat trip, the net CS for private boat trip would diminish.

Table 3.9: Expected Consumer Surplus per Day across Two-Month Periods

Gross E(CS)/Day	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Charter	378.4	434.3	436.5	421.0	416.5	405.0
Private	184.6	205.4	206.2	200.4	198.8	194.5
Shore	73.9	84.3	84.7	81.8	81.0	78.8
Weighted Average	167.3	187.1	187.9	182.4	180.8	176.7

Net E(CS)/Day	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Charter	115.6	171.5	173.7	158.2	153.7	142.2
Private	132.2	153.0	153.8	148.0	146.4	142.1
Shore	43.9	54.3	54.7	51.8	51.0	48.8
Weighted Average	111.3	131.2	131.9	126.4	124.8	120.8

Because α_0 captures seasonal dummy variables, CS can be measured for each 2-month period (Table 3.9). If the marginal utility of income is constant over the range of the price change, β_m for each mode m can be calculated by the weighted average of marginal utility by income category. When an individual take a trip in May and June, she can get the highest per-day CS for all modes. When taking a trip using charter boat, private boat, and at shore in this period an angler can get $174, $154, and $55, respectively. On the other hand, January and February are least desirable period because anglers obtain the smallest welfare gain.

VI. Concluding Remarks

Overfishing is a serious problem in fisheries throughout the world and there is increasing recognition that recreational as well as commercial fishing must be controlled. Standard economic logic suggests that limiting catch using a price mechanism would be more efficient than other rationing mechanisms. However, a price instrument, such as an access fee or a transferable right, would raise the price of fishing to all anglers. Such a policy would clearly have more significance to those on the lower end of the income distribution than to those on the upper end. Furthermore, a flat fee or price increase would also affect the types of modes equally, but the impact would differ widely. Compared to the normal costs of day trip, a small fee can amount to a high percentage tax on some modes and a relatively small tax on others.

Using results from an econometric model that allows for differing price responses across modes and income groups, we consider the consequences of a per day user fee on recreational fishing in the Gulf of Mexico. The model used for this analysis is based on the approach taken by MSR (1991), which is appropriate when complete trip data are not available, but our model

extends the MSR (1991) approach in that it allows the price coefficient to vary across incomes and modes. We find income to be an important determinant of mode choice. Our results indicate that a user fee would have much greater impacts on low income groups, than on higher ones and would affect low-cost fishing modes much more than it would modes that are relatively expensive.

We also compute per-day CS across modes and two-month periods. When an angler takes a trip using charter boat he will get the largest welfare gain. Per-day CS varies by seasons. A trip in May and June will allow anglers to have the biggest CS while a trip in January and February is lease preferable in terms of welfare measures. For the case of the recreational fishery of the Gulf of Mexico, we estimate a model that provides information that can help guide a policy based on both efficiency and equity. In the next chapter we will use this model in order to simulate the impact of a recreational TR program.

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Chapter 4: Simulation Analysis of Transferable Rights Program*

I. Introduction

The purpose of this chapter is to develop a simulation model that will be used to conduct an economic analysis of transferable rights (TR) program aimed at reducing over-use of the Gulf of Mexico red snapper (GRS) fishery and rationalizing fishing effort. A TR program can play a role in restricting the harvest of recreational red snapper fisheries, thereby increasing the red snapper stock to a level which will ensure its sustainability. It also could allow for recreational fishermen to fish when they want, rather than during the increasingly restricted times when the fishery is currently open. We also explore the possibility of allowing a TR program in which the recreational sector is allowed to purchase rights from the commercial sector or vice versa.

A simulation approach is adopted to evaluate both biological and economic effects of the TR policy on the fishery. We will use the General Bioeconomic Fisheries Simulation Model (GBFSM) as a simulation tool. As discussed in chapter 2 of this report, we consider feasible a program in which rights to fish are based on the right to a day of fishing. This is the program that will be simulated. The demand for recreational fishing is based on the econometric analysis presented in chapter 3.

II. Conceptual Model of Transferable Rights Program

The simulation model of the TR programs is carried out by adding a new module to GBFSM. The basic features of GBFSM are described in chapter 1 of this report and Appendix A. In this section we provide the conceptual underpinnings for the simulation modelling.

As we reviewed in chapter 2, TR programs have been used in various areas to protect environment and resources. These programs specify a predetermined total level of quotas (permits) within a specified region. Permits equal to the permissible TAC are distributed among fishermen in the region. Such programs could include both the recreational and commercial fishing sectors. To ensure that such permits serve their purpose as incentives to achieve socially desired levels, total harvesting levels within a given region are limited so that the permits become valuable. Economic efficiency can be increased through trading of rights within the sector or across sectors. Our application is made to the red snapper fishery in the Gulf of Mexico.

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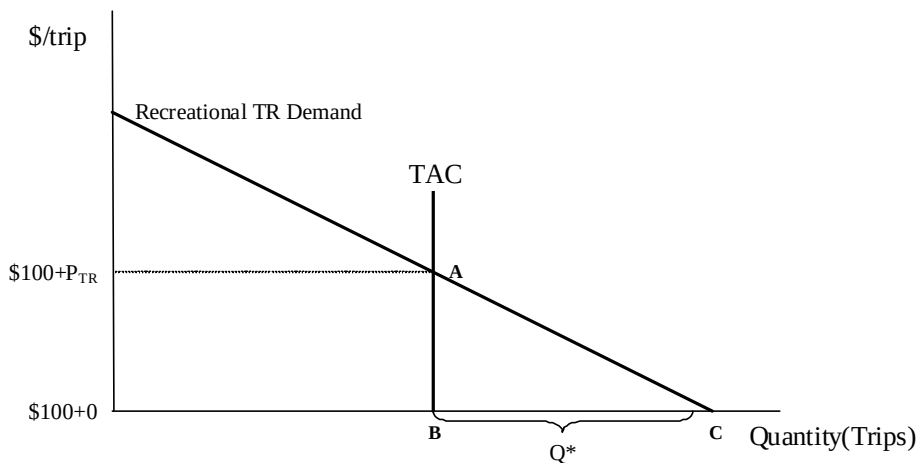
* This chapter builds upon Chapter V in Kim (2007). It benefited by comments from David W Carter, Vishwanie Maharaj and participants at the PERC Political Economy Forum, Evolving Approaches to Managing Marine Recreational Fisheries. Any remaining errors are the responsibility of the authors.

A. Transferable Rights Program in Only Recreational Sector

In this section we elaborate how the recreational TR program works to achieve a given TAC goal. The standard model of recreation demand (see Hanley et al. 2007) is one in which a representative angler's demand for fishing trips is a function of travel cost. This prototypical model is presented in Figure 4.1. In this figure we present the aggregate recreation demand curve is downward sloping. The horizontal axis is fixed at the average cost to travel and participate in a day of fishing, $100. This would lead to a demand for C trips, where the marginal benefit to the marginal angler is equal to the cost of a day of fishing. If, however, the harvest obtained at C is in excess of the total allowable catch (TAC), then a reduction in fishing effort can be achieved by artificially raising the price of a day of fishing. As seen in the figure if anglers pay P_{TR} to purchase a right to participate in a day of fishing, then the TAC goal can be achieved.

Figure 4.1: Recreational Transferable Permit Demand and the Substitution Effect



The analysis in Figure 4.1 assumes that it is possible to convert a day of fishing effort into pounds of fish. We assume that a constant conversion rate will be used for making this conversion. This assumption is made for simplicity (and lack of better data) and is quite strong. It ignores the reality that the behavior of the average angler may change as a result of the TR program. Anglers have incentives to respond to policies (Woodward and Griffin, 2003) and if they have paid a substantial fee for a day of fishing, their catch rates may increase. The simulation results presented below should, therefore, be interpreted as a first approximation of a TR program for the red snapper fishery and our analysis is probably biased since catch rates will tend to increase in a predictable fashion.

Because we consider a case in which there is a TR program only for red snapper, it is likely that implementing such a program will result in some degree of substitution away from red snapper. A substitution effect is defined as the percentage of anglers who will give up catching one species and switch their target to other species. With substitution effect, the demand curve in Figure 4.1 will shift down and the possible optimum of the price of TRs will be decided between

points A and B. Hereafter in this chapter the estimated demand curve will incorporate the substitution effect. Unfortunately, because most travel-cost data do not distinguish costs targeting red snapper from costs targeting other fisheries, no substitution effect between species is found in the standard recreation demand models (including that estimated in the previous chapter). We explain below how we approximate a substitution effect for our simulation model.

III. Net Benefit of Transferable Rights Program

Closures are mainly used for the current policy to manage the number of trips of the GRS fishery. The length of the GRS fishery is exemplary. The number of days available to recreational fishermen has shrunk sharply in recent years (Table 4.1). This policy will lead to an inefficient outcome because, as we have seen in chapter 3, recreational anglers demand to go fishing during the closed season. Under a TR program they can go fishing whenever they want with the permit purchased.

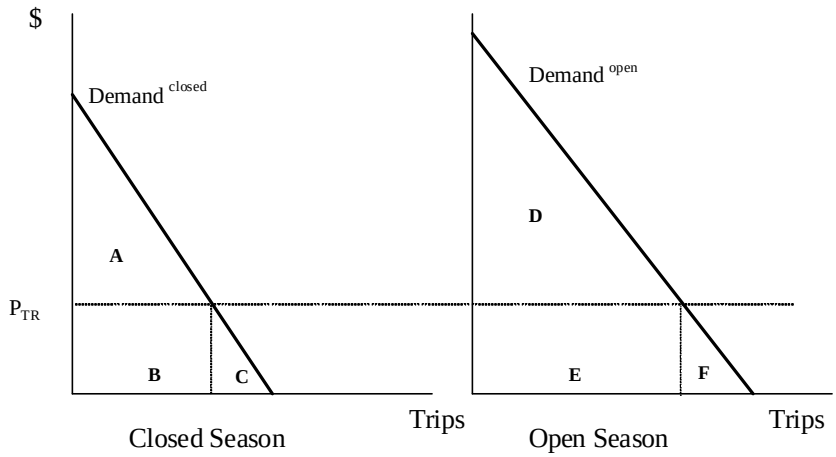
Table 4.1: Changes in recreational red snapper regulations

Year	Size Limit (Inches TL)	Daily Bag Limit (Number of Fish)	Season Length (days)	Recreational Allocation/Quota (MP)
1991	13	7	365	1.96
1992	13	7	365	1.96
1993	13	7	365	2.94
1994	14	7	365	2.94
1995	15	5	365	2.94
1996	15	5	365	4.47
1997	15	5	330	4.47
1998	15	4	272	4.47
1999	15	4	240	4.47
2000	16	4	194	4.47
2001	16	4	194	4.47
2002	16	4	194	4.47
2003	16	4	194	4.47
2004	16	4	194	4.47
2005	16	4	194	4.47
2006	13	4	194	4.47
2007	13	2	194	3.18
2008	13	2	66	3.18
2009	13	2	122	2.45

Source: History of red snapper management in federal waters of the U.S. Gulf of Mexico -1984-2004: 2004 Red Snapper SEDAR, NOAA Fisheries, SEDAR7-DW-40 (Hood and Steele, 2004). Figures for 2004 and 2005 are from Vivian Matter (Personal Communication, 8/15/2006)

The welfare gains that can be obtained by using a TR program as opposed to a closure can be seen in Figure 4.2. In the figure we present demands with the substitution effect in both closed and open seasons. For simplicity we use the Marshallian demand to calculate welfare measures.[1] Suppose a simple two-period demand system in which the fishery is closed during the first season, the left panel of Figure 2, and open during the second season, the right panel. Initially, under the closure, the angler receives no surplus when the fishery is closed. So the initial surplus is D+E+F. Under the TR program, surplus is possible in both periods and at the price P_{TR}, the angler's surplus after the TR program is A+D, but notice that whoever sells the permits (be it the government or others who are given the initial allocation) receive revenue equal to B+E. Hence, total surplus generated by the TR program now becomes A+B+D+E. Under the closure policy, it is always true that net benefits can be increased by a marginal increase in the number of days during the closed period and reducing the number of days in the open period. Hence, within this simple framework, it holds unequivocally that net benefits to the sector are increased by the TR policy.

Figure 4.2: Efficiency Gain of Transferable Rights Program



IV. Transferable Rights Program in both Recreational and Commercial Sectors

Although some negative consequences of transfer of the rights between commercial and recreational sector are discussed in chapter 2, allowing trading between sectors can lead to an efficiency gain (Arnason, 2009; Arnason and Pearse, 2009). In this section we will explain why

[1] Consumer surplus, which is a Marshallian measure, has dominated applied work because of the difficulty of obtaining Hicks Ian measures which are often called "exact" measures; utility functions are difficult to observe in the real world.

the efficiency gain by trading rights between sectors arises and how the new price and allocation are determined.

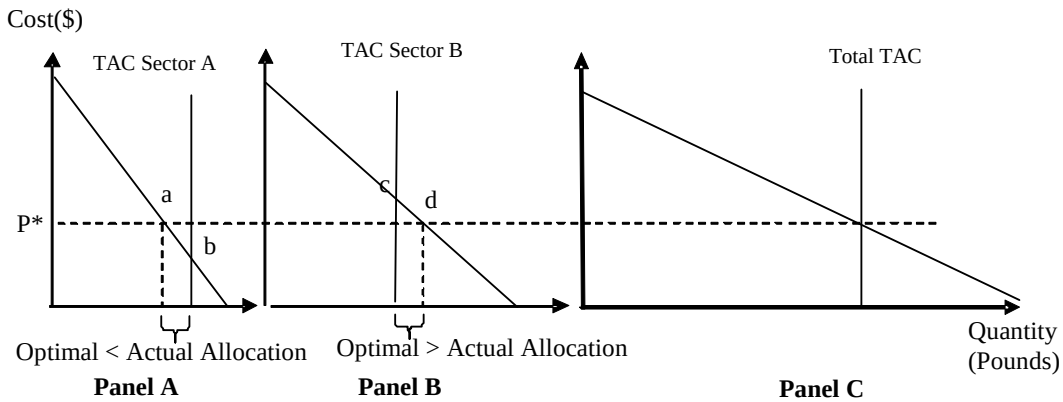
With no tradable permit market, initial allocation of the TAC between sectors matters. Efficiency is only achieved if the TAC allocation is set such that the marginal net benefit of the last unit of catch to each sector is the same. Before we move on to the full model of TR programs in both recreational and commercial sectors, we consider appropriate initial allocation of TR quotas (permits) between commercial and recreational harvesters to insure that the public's resources are used efficiently. The main problem is how to allocate the TAC between two sectors. For economic efficiency, those who value the fish most should obtain more of the TAC. The values for the fish can be captured by demand such as trip demand and quantity demand.

In the recreational sector, as we explored above, a recreational demand model can be used to derive the demand for the TAC. For the commercial sector, demand for the TAC is a function of the profits that can be obtained from the sector's share. In the simplest case, considered here, the demand would be determined by the marginal profits that could be generated by the TAC, $\pi(q) = p(q) - c(q)$, where q is the TAC allocated to the commercial sector, $p(q)$ is the inverse demand curve for red snapper and $c(q)$ is the marginal cost of harvesting. Even if $c(q)$ is constant, the downward sloping demand curve will cause the sector's demand for TAC to be downward sloping.

Demand for a share of the TAC by each sector would typically be downward sloping so that an increase in the trip cost would lead to decease in fishing effort directed toward red snapper. Commercial and recreational demand relationships would capture how much the two sectors are willing to pay for a marginal increase in their share of the TAC. Once the TAC is set, it can be interpreted as a fixed supply curve.

Graphical representation to determine how we allocate the total TAC between two sectors is shown in Figure 4.3. The negatively sloped curves of Panel A to C are demand for two sectors, A and B, and an aggregate demand curve which is the horizontal aggregation of demands A and B. The point where the aggregate demand curve meets total TAC in Panel C provides the marginal value of the TAC to the economy under an optimal allocation. Thus, this establishes a procedure for measuring total benefits, and a means of identifying the efficient allocation between the two sectors.

Figure 4.3: Initial Allocation of TAC between two sectors



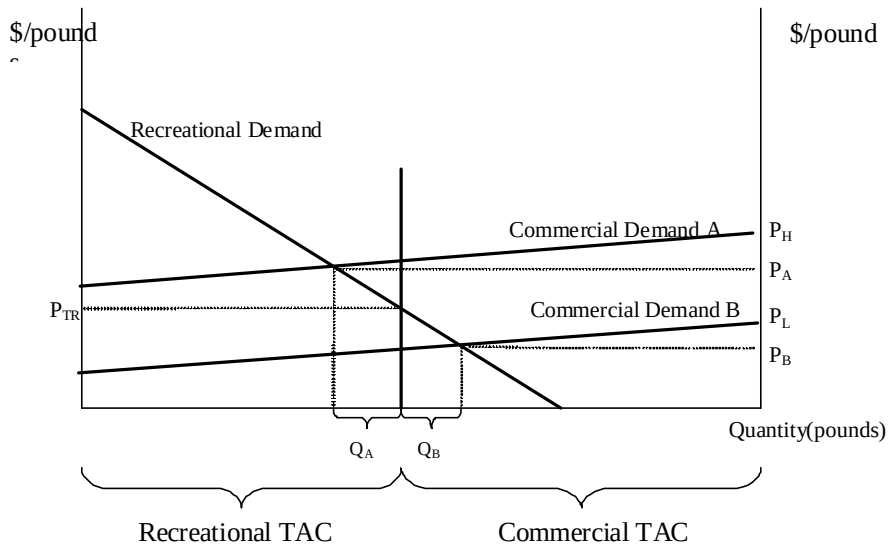
The optimal allocation for sector A occurs at point *a* where the sector's demand corresponds to the given level of cost, *P**, obtained in panel C. In the same fashion, optimal allocation for sector B is determined at point *d* where demand meets *P**. However, if the actual allocation for each sector is made at points *b* and *c*, then the result will be inefficient. In this example, sector A needs to have a smaller allocation and sector B needs to have a greater allocation to achieve maximum of total surplus. However, the result of allocation is dependent on the slope and intercept of each curve.

Montgomery (1972) showed that the initial allocation of permits is not a significant problem under the tradable market system with assumption of zero transaction costs and a competitive market. Stavins (1995) and Arnason and Pearse (2009) show that with transaction costs, this does not hold. Numerous other papers (e.g., Hahn, 1984) have shown that other imperfections in the market can lead to inefficiencies of one form or another. For our analysis we lack the kind of detailed data that would be necessary to estimate transaction costs and we assume a perfectly competitive TR market. Hence, to some degree, we overestimate the extent to which efficiency gains could be achieved.

Figure 4.4 suggests how to allocate red snapper TAC between sectors. By using recreational and commercial fishing demand, we can predict the optimal allocation between two sectors under the TR program in both sectors. The lines in Figure 4.4 depict the recreational and commercial demand toward quotas (permits) for each of the two sectors. The recreational demand is read from left to right and the commercial demand is to be read the other way around. In order to achieve a TAC goal given to the recreational sector, recreational angers should pay $\$P_{TR}$ to purchase a TR permit. Suppose the marginal cost to commercial fishermen is constant at C. Two possible demand curves are shown, one in which the choke price is high, $\overline{P}_H = P_H - C$, and a second for a lower choke price, $\overline{P}_L = P_L - C$. These different red snapper prices lead to the two demand curves for the TAC as shown with choke prices P_H and P_L. If the price of red snapper is high the equilibrium price per unit of the TR (P_A) is above P_{TR}, then commercial fishermen will want to buy more permits from the recreational sector. The maximum of permit transfer from recreational to commercial sector is Q_A. On the other hand, if the price of red

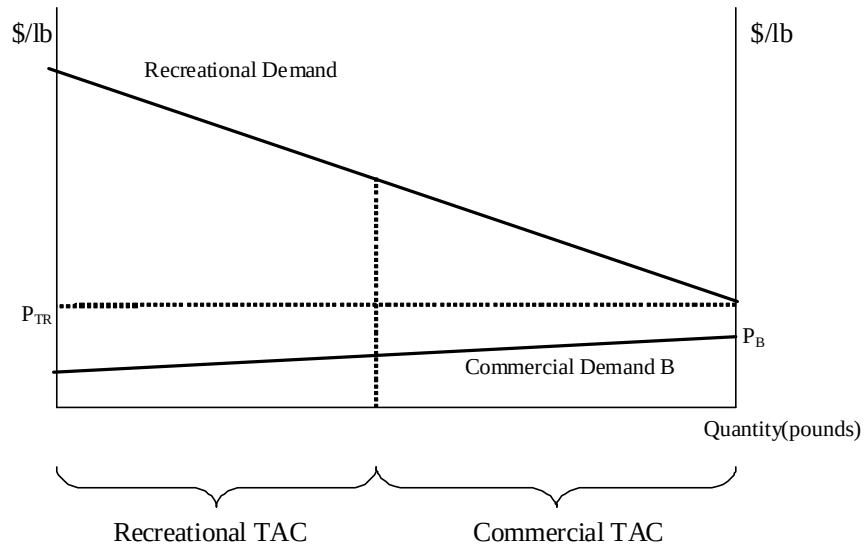
snapper is low, the new equilibrium price of the TR is determined below P_{TR}, commercial fishermen will sell their permits to recreational anglers rather than harvest red snapper. No matter what share of the TAC is initially allocated, both sectors can achieve the objective of maximizing the net benefit following the above mechanism to the equilibrium price in the permit market.

Figure 4.4: Optimal and Actual Allocation of TAC between Sectors



In Figure 4.5 we present the case in which the recreational sector purchases all the available rights from the commercial sector. What happens here is that the marginal value of a right to go recreational fishing is much greater than the value of that fish in the commercial sector. As a result, the commercial fishermen are unable to compete for the rights and the recreational sector will purchase all the available permits. In this case the equilibrium price will exceed the most that the commercial sector would be willing to pay, indicated by P_B in the figure. As we see below, based on our estimates in the Gulf red snapper fishery, this type of relationship may be what would happen in the event that transferability across the two sectors were allowed. This does not necessarily mean that the commercial fishermen are worse off. If they receive grandfathered rights, and if a result like Figure 4.5 occurs, then fishermen are better off selling those rights than they would be selling the fish.

Figure 4.5: Optimal and Allocation of TAC between Sectors Under a Corner Solution



V. Submodel for Transferable Rights Program

Using the conceptual presentation above, in this section we describe the empirical issues that must be addressed to construct a simulation submodel of the TR program for the GRS fishery. Empirical representation of the recreational demand by fishing mode and assumptions that we use are introduced. We assume that there is a Gulf-wide market that would permit anglers anywhere to purchase a right to fish. The specific assumptions about the demand from the recreational and commercial sectors are spelled out below.

A. Recreational Demand and Assumptions

In chapter 4 we estimate a discrete choice model of marine recreational fishing demand, allowing for differing price/fee responses across fishing modes and monthly seasons. This econometric model is an important piece of the submodel we develop to simulate a recreational TR program. The trip demand is directly equivalent to the day-based TR demand as shown in the chapter 3. According to that model, the number of trips taken by a representative angler during month *i* can be written

$$Trip_{im} = \left\{1-\pi_i^{nf}\left(p_m + p_{TR}\right)\right\} \cdot \pi_m^f\left(p_m + p_{TR}\right) \cdot \left(1 - SR(p_{TR})\right) \cdot Day_i, \qquad (1)$$

where p_m is the price of trip, p_{TR} is the price of TR, 1-$\pi_i^{nf}(p_m)$ is the probability of fishing to target the red snapper in *i* month, $\pi_m^f(p_m)$ is the probability of taking a *m* mode trip estimated in

chapter 4,[2] $SR(p_{TR})$ is the substitution rate switching targets from red snapper to other species, and Day_i is the number of possible fishing days in *i* month (e.g., 31 in January).

The assumptions that we used to develop the TR demand are as follows:

1. The recreational fishing trip demands and mode choice structures are same for all Gulf States.
2. Because we estimate the demand for two-month periods we assume the probabilities of taking a trip in two months in the same wave as defined in chapter 4 are same (e.g., π_i^{nf} in January and Feb is same).
3. Because red snapper cannot be easily caught inshore we dropped shore fishing mode. Head boat trips are added because the GBFSM contains this type of mode (vessel class). Our approach to simulating this sector is described below.
4. For the purposes of the TR market simulation, we assume that the head and charter boats sectors are perfectly competitive so that all rents generated by the TR market accrue to the anglers.
5. The substitution rate is same for all fishing modes. This too is discussed in more detail below

B. Demand of Head Boat

Because the 1997 MRFSS data do not include angler who used head boats, we were forced to approximate the demand from this sector. To approximate head boat demand, we use a weighted average between estimated coefficients of charter boat and private boat. Intercept and slope coefficients of charter and private boats are estimated in chapter 4.

$\alpha_{HB} = \gamma \cdot \alpha_{CB} + (1-\gamma) \cdot \alpha_{PB}$, and

$\beta_{HB} = \theta \cdot \beta_{CB} + (1-\theta) \cdot \beta_{PB}$,

[2] Because the probability of taking a trip using *m* mode ($\pi_m^f(p_m)$) does not vary by species, our econometric model overestimates the percentage of using private boat and underestimates the percentage of using head and charter boats. In case of red snapper for-hire boats are more likely used for recreational trips.[the previous sentence is awkward] In order to well predict the probability of taking a trip using each mode compared with the red snapper historical data, adjustment weights are used. Decision criterion for the weights was the seven year averages (1993-2001) of red snapper catches for each mode.

where α_{HB}, α_{CB}, and α_{PB} are intercept parameters for head, charter, and private boats, respectively, and γ is the weight of its parameter. Similarly, β_{HB}, β_{CB}, and β_{PB} are slope (price) parameters for each mode, and θ is its weight. The optimal weights (γ and θ) were found by minimizing sum of squared error (SSE) of the percentage ratio of head boat, charter, and private-rental modes. We used average percentages of fishing efforts (trips)[3] for 7 years and chose γ and θ to minimize SSE.

$$\underset{\gamma,\theta}{SSE} = \sum_{m} \left(\hat{\pi}_m(\alpha_m, \beta_m; \gamma, \theta) - \overline{\pi}_m \right)^2 ,$$

where $\hat{\pi}_m(\cdot)$ is the predicted probability of taking a trip using *m* mode, and $\overline{\pi}_m$ is the average of the probability of using *m* mode. Predicted parameters, α_{HB} and β_{HB}, that minimize the SSE will be incorporated into the recreational demand model. The demand model has three modes: head, charter, and private boats.

C. Substitution Rate

The substitution away from a species with a TR program is a potentially important effect that cannot be estimated using data from a situation without a TR program. As noted above, because we consider a case in which there is a TR program only for red snapper, it is likely that implementing such a program will result in some degree of substitution away from red snapper. The substitution rate, *SR*(*p*), is defined as the percentage of anglers who give up fishing red snapper and target other species instead. For example, if *SR* equals to 0.1 then 10% of red snapper trips will switch into trips to target other species. The substitution rate is in addition to the standard reduction in demand, which is movement along a demand curve. In order to have the substitution effect in the model, we need a cross-price elasticity that tells us how the demand for trips targeting other species will change with respect to the price of taking a red snapper trip. Such cross-price elasticity is not estimated in our recreation demand model and we could not find this estimated elsewhere in the literature.

However, we were able to estimate this variable using the results from Gentner (2004). Gentner estimates target substitution elasticities for the catch rate changes in one species using the MRFSS data including the Gulf coasts. The cross-price elasticity is not available, but he does provide substitution of species with respect to the catch rate which we can build on to derive our cross-price measure. Gentner (2004) provides substitution elasticities with respect to catch rate as follows:

$$\frac{\text{\% change in trips of other species}}{\text{\% change in catch rate of red snapper}} = -\varepsilon_1$$

[3] The GRS recreational fishing data are obtained from the National Marine Fishery Service (NMFS) MRFSS data, the NMFS Head Boat Survey data, the Texas Wildlife and Park Department, and the NMFS Southeast Regional Office.

$$\frac{\text{\% change in trips of red snapper}}{\text{\% change in catch rate of red snapper}} = \varepsilon_2 \cdot$$

From the prediction of our model, we can have the own price elasticity

$$\frac{\text{\% change in trips of red snapper}}{\text{\% change in price of red snapper}} = -\hat{\varepsilon}_3 \cdot$$

Finally, the cross-price elasticity can be written

$$\frac{\text{\% change in trips of other species}}{\text{\% change in price of red snapper}} = \frac{-\varepsilon_1}{\varepsilon_2} \cdot (-\hat{\varepsilon}_3) \cdot \qquad (2)$$

Using this cross-price elasticity of trips in other species with respect to the price of red snapper trips, we can incorporate the substitution effect into the model and predict how much percentage of anglers who used to target red snapper would go fishing for other species if there is an increase in the price only for the red snapper. The substitution rate, which is a function of permit price (P_{TR}), will be $\left\{\frac{-\varepsilon_1}{\varepsilon_2} \cdot (-\hat{\varepsilon}_3) \cdot \frac{\overline{\mathrm{Q}}_{\mathrm{other}}}{\overline{P}_{RS}} \cdot \frac{1}{\overline{\mathrm{Q}}_{\mathrm{RS}}}\right\} P_{TR}$, where $\overline{Q}_{other}$ is the number of trips for other species, $\overline{Q}_{RS}$ is the number of trips for red snapper, and $\overline{P}_{RS}$ is the price of taking a trip for red snapper.

The parameters needed to estimate equation (2) are taken from Gentner (2004, Table VI). Quoting from that document:

> The first scenario in Table VI uses the policy attribute model, first setting the current regulations across all species and then reducing the bag limit by two red snapper. Table VI indicates that this 50% reduction will reduce grouper trips by 1.05% and red snapper trips 5.18%, increase king mackerel and dolphin trips by 1.83% and 2.51% respectively, and 1.90% would not take any trip.

He finds therefore that red snapper and grouper are complements (in the sense of the catch per trip), while red snapper and king mackerel are substitutes. Because we are interested in the substitution effect here, we use the parameter value for king mackerel. The ratio of the elasticities, $\frac{-\varepsilon_1}{\varepsilon_2}$, therefore, equals $1.83/5.18$. The remaining terms, $\frac{\overline{\mathrm{Q}}_{\mathrm{other}}}{\overline{P}_{RS}} \cdot \frac{1}{\overline{\mathrm{Q}}_{\mathrm{RS}}}$, are taken from the recreation demand model estimated in chapter 3, with parameters evaluated at the means.[4]

[4] The resulting product is (-0.2073588)*(5755449/(131.06*439139).

D. Commercial Demand

As noted above, efficiency is increased if it is possible to trade TRs between the recreational and commercial sectors. The problem is how precisely we can estimate the commercial demand. However, it would be quite difficult to estimate commercial fishing demand because it needs to be a multi-equation system demand model between species to reduce estimation biases. The commercial snapper demand was previously estimated by Park (1996) in his Ph.D. dissertation at North Carolina University using 1977-1992 National Marine Fisheries Service (NMFS) data. The study analyzes six broad types of commercial fisheries: Groupers, Porgies, Snappers, Jacks, Tilerfishes, and Sea basses.

As in previous versions of GBFSM, we adopt Park's commercial snapper demand and its corresponding price flexibility as a proxy of the commercial red snapper demand in the Gulf. Following Park's results from the synthetic inverse demand system (SIDS) model, the price flexibility of snappers is -0.0341. That indicates 1 % increase in red snapper landings would result in a 0.0341 % decline in its price. This price flexibility implies a highly elastic commercial demand, a result that seems inconsistent with observed price variation in the fishery in recent years. In light of this inconsistency, sensitivity analysis will be carried out with respect to the price flexibility.

For the purpose of calculating the market price, a constant elasticity demand curve is used. This curve would take the form $Q = kP^{\beta}$, where Q is the aggregate quantity demanded, P is the wholesale price of red snapper per pound, and β is the elasticity. Rewriting as an inverse demand curve we obtain $P = KQ^{\gamma}$ where $\gamma = \beta^{-1}$ is the price flexibility and $K = k^{\gamma}$. With a given price-quantity combination and an assumed value of the price flexibility, it is possible to recover K to obtain the complete demand curve.

E. Solving for Recreational TR Market Demand and Equilibrium

In this section we describe the process that is used to find the equilibrium in a TR market involving recreational fishermen. We use a seven-step process.

1. Calculate the number of harvest that, according to GBFSM using historical data, would be "desired" by the recreational sector without closures or a TR program, say Q_D.

2. Dividing the recreational sector's TAC by the desired harvest, we find the TAC as a percent of the desired catch, say R= TAC/Q_D. This is then adjusted by the percent by which the actual recreational harvests in the previous year deviated from the TAC.[5]

[5] The maximum adjustment allowed here is 20% as we found that complete adjustments tended to result in highly oscillating recreational harvests over time. The adjusting over time seems like a plausible approximation of how such a program might be implemented.

3. Using the recreational demand functions, (1) evaluated at the means of the variables and using the catch per unit effort from the body of GBFSM, it is possible to calculate the weighted average number of days that would be sought across all months by the anglers as a function of the TR price, say $T(P_{TR})$. The weighted average number of trips that would be sought in the absence of any policy would be $T(0)$.

4. The substitution rate as a function of the price is calculated, $S(P_{TR})$, leading to final weighted average number of trips, $\left(1-S\left(P_{TR}\right)\right)T\left(P_{TR}\right)$.

5. The price of the TR is then changed until the predicted number of trips is reduced by the same level as would be the needed reduction in harvests, i.e. $\frac{\left(1-S\left(P_{TR}\right)\right)T\left(P_{TR}\right)}{T\left(0\right)}=R$.

6. Because of the substitution effect, there is also an increase in effort going to other reef fish. These are assumed to be distributed to those fish in proportion to landings of the other reef species in the model.

7. The resulting reduction in red snapper demand will affect each mode and month differently. This is introduced into the body of GBFSM by reducing the effective recreational effort in each month-vessel class combination. This process is assumed to take place at the end of a year, with the implications for harvests occurring in the following year.

Because equation (1) is quite complicated and nonlinear, there is no analytical solution to obtain the price in step 5. However, because the demand curve is monotonically decreasing in price for all modes, it is easy to find the solution using Newton's method. In this case, it is possible to program analytical representations of the first derivatives of the demand with respect to P_{TR}, so the root-finding algorithm converges very quickly to the global optimum.

Step 7 in the process above is how the TR program is actually introduced into GBFSM affecting catch, harvests, welfare and other the biological systems. As indicated, we incorporate the TR process by adjusting down effective effort in GBFSM. This is done through a parameter known as the catchability coefficient. These coefficients vary by fishing modes (vessel class), months, and age levels. Recreational harvest of *j* species in *a* age group can be defined as

$$h_{ja}=\sum_{m} q_{ajm}\cdot T_m ,$$

where *m*=mode, and T_m=trips for all species by mode. Under the closure policy of red snapper fishery, the catchability coefficient, q_{ajm}, is the weighted average of the percentage of open days (γ):

$$q_{ajm}=\gamma\cdot q_{ajm}^{1}+\left(1-\gamma\right)q_{ajm}^{0}=\gamma\cdot q_{ajm}^{1}+\left(1-\gamma\right)q_{j}^{closed}q_{ajm}^{1},$$

where q_{ajm}^{1} is the catchability coefficient when the season is open and q_{ajm}^{0} is the catchability coefficient when it is closed. q_{j}^{closed} is an adjustment factor in the closed season and is a small number reflecting bycatch of red snapper.

Under the TR program, γ is always equal to one, meaning that we can go fishing for red snapper all days of all months. The catchability coefficient q_{ajm}^{1} is adjusted downward by the rate that the number for trips would be adjusted down for that month-vessel combination because of the TR price that the fishermen now need to purchase in order to go fishing.

F. Solving for the Equilibrium in the Joint Recreational-Commercial TR program

The approach outlined above solves for the allocation of effort across the different modes of recreational fishing for a given TAC for that sector. We also need to model the case in which effort is moved from the recreational to the commercial sector or vice versa. As noted above, we assume that the commercial rents will increase as the price of red snapper increases, which happens as the commercial harvests fall. In short, a reduction in the commercial TAC, leads to an increase in the price, leading to an increase in the marginal rents available to the commercial sector, and increasing the price that that sector will pay for a TR.

We assume that each year a conversion rate is calculated to convert from recreational to a commercial TR. This is set equal to the average CPUE across all modes. For example, if the average recreational trip harvest a 3 lbs fish, then a recreational fisherman would need to purchase 3 lbs of commercial TR in order to have the right to one day of fishing.

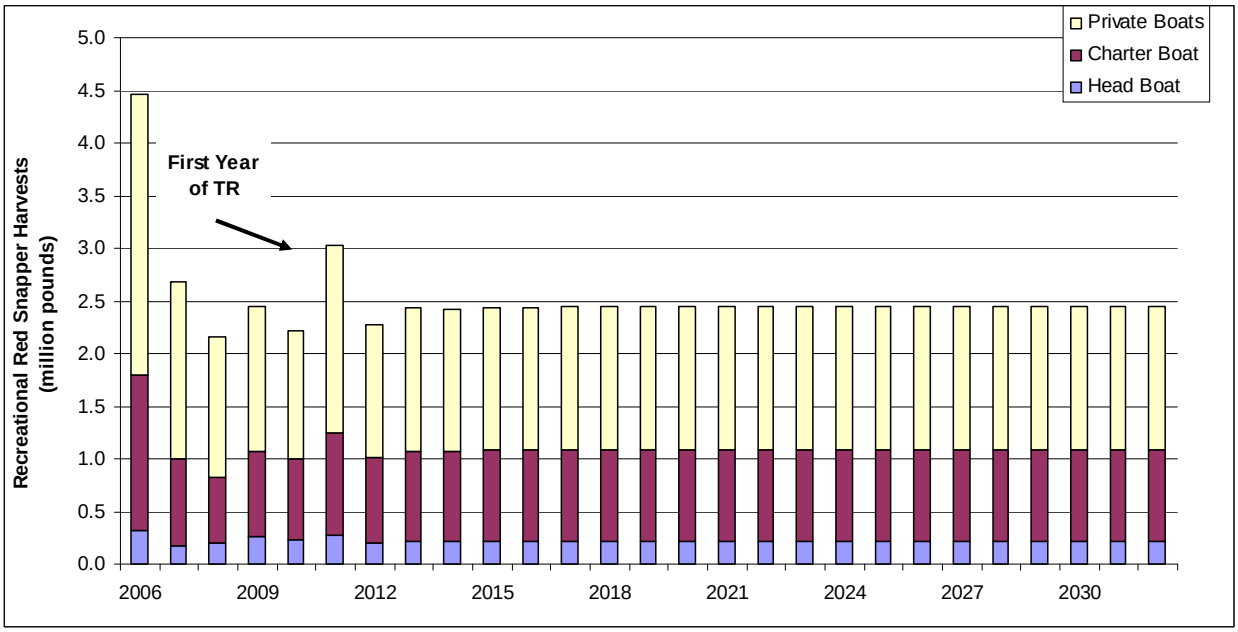
Let P_{TR}^{C} and P_{TR}^{R} be the prices for the TR for the commercial and recreational sectors respectively. The commercial TR would equal the marginal rents, P-C, where P is the price paid to commercial vessels for a pound of fish and C is the marginal cost of harvesting that pound, which we assume to be constant and equal to the average cost. An interior market equilibrium in the TR market, is achieved if there is an allocation such that the marginal rents in the commercial sector is equal to the marginal willingness to pay for a day of recreational harvests after using the conversion factor so that the units are equivalent.

VI. Results

A. A Model with Trading Only in the Recreational Sector

We now evaluate the impact of a recreational transferable rights program in which the fishery is run following the baseline policies from 2006 – 2009. At the end of 2009 it is assumed that a recreational transferable rights program is introduced. This then affects fishing and harvests from that point onward. We assume that a bag limit of 4 fish per recreational trip is allowed during the policy period. This relaxation from the current policy of two fish per trip seems reasonable if an alternative approach to controlling the catch is possible.

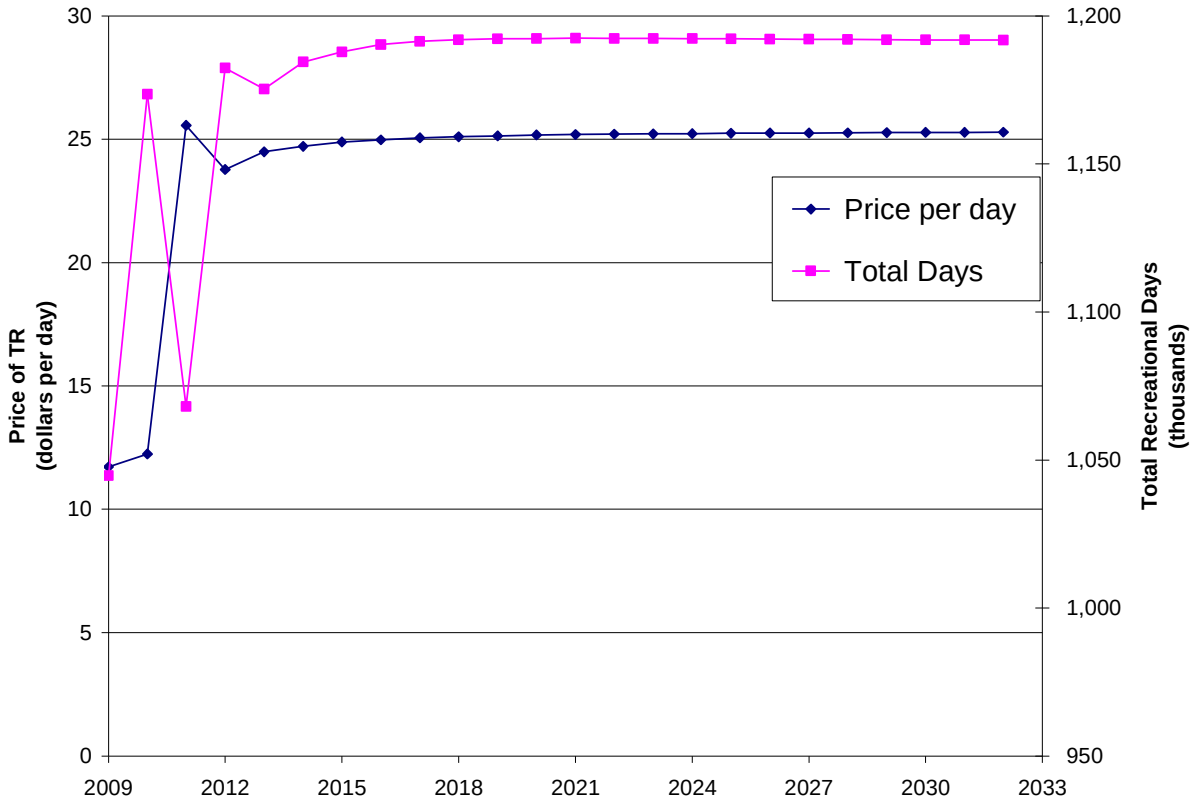
Figure 4.6: Simulated Recreation Harvest Under a TR Program Involving Only the Recreational Sector (5 M lbs. total TAC, 2.45 M lbs. for Recreational Sector)



In Figure 4.6 we present the total simulated harvests by the recreational sector during the period 2006-2032. Harvests during the first three years decline sharply due to the policies that have been put in place reducing the season length. The jump in harvests in 2009 is due to the fact that we simulate a relaxation of the bag limit in 2009, prior to the introduction of the TR program. The first round of TR trading is assumed to occur at the end of 2009, affecting harvests in 2010. As simulated, the number of licenses sold in 2010 leads to harvests in below the TAC in that year and, following the algorithm noted above, the number is increased the following year. Over the next several years the landings oscillate, leveling off at a level such the TAC is achieved almost exactly.

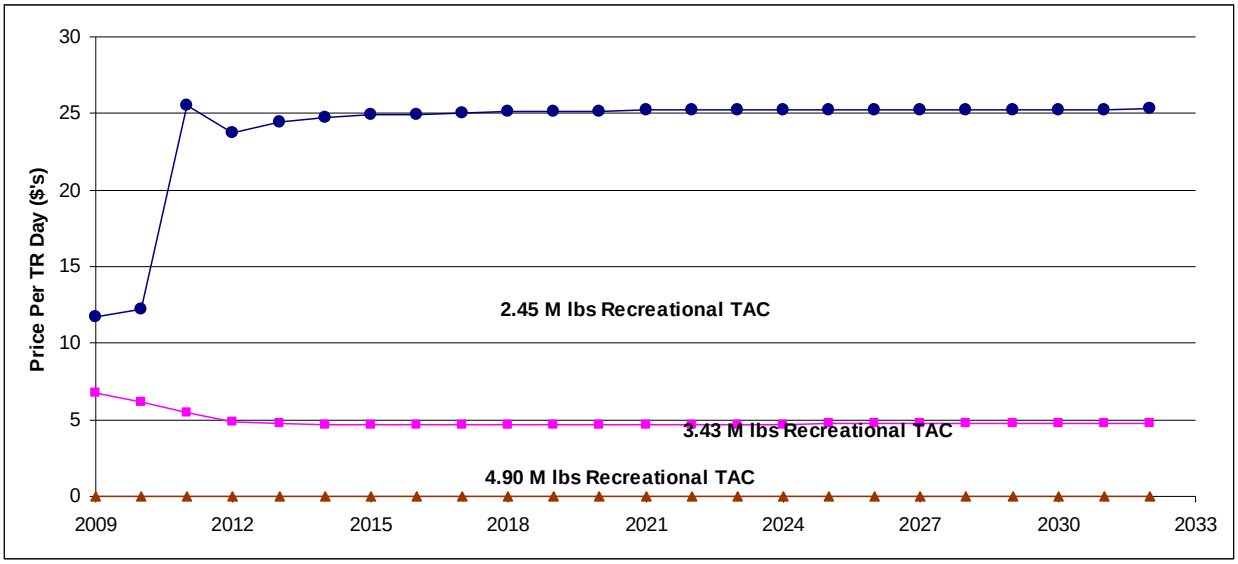
There are two effects of the TR program that are evident in Figure 4.6. First is the fact that the TR program is able to reduce the total harvests to very nearly the recreational sector's TAC. Second is that the distribution of the harvest across the different modes of fishing changed sharply as a result of the TR program. In the four years prior to the TR program the distribution of harvests were as follows: headboats, 8%, charter boats, 31%, and private boats 60%. After the TR program is introduced the charter boats' share of the TAC increases to 36% while the private boats' share drops to 55%. The headboats' share remains nearly constant. As discussed in chapter 3, this shift occurs because the high-paying charter boat fishermen are more likely to pay the additional fee to purchase the right to a day of fishing.

Figure 4.7: Market Clearing TR Price and Number of TR Days Available (Recreational TAC of 2.45 million lbs.)



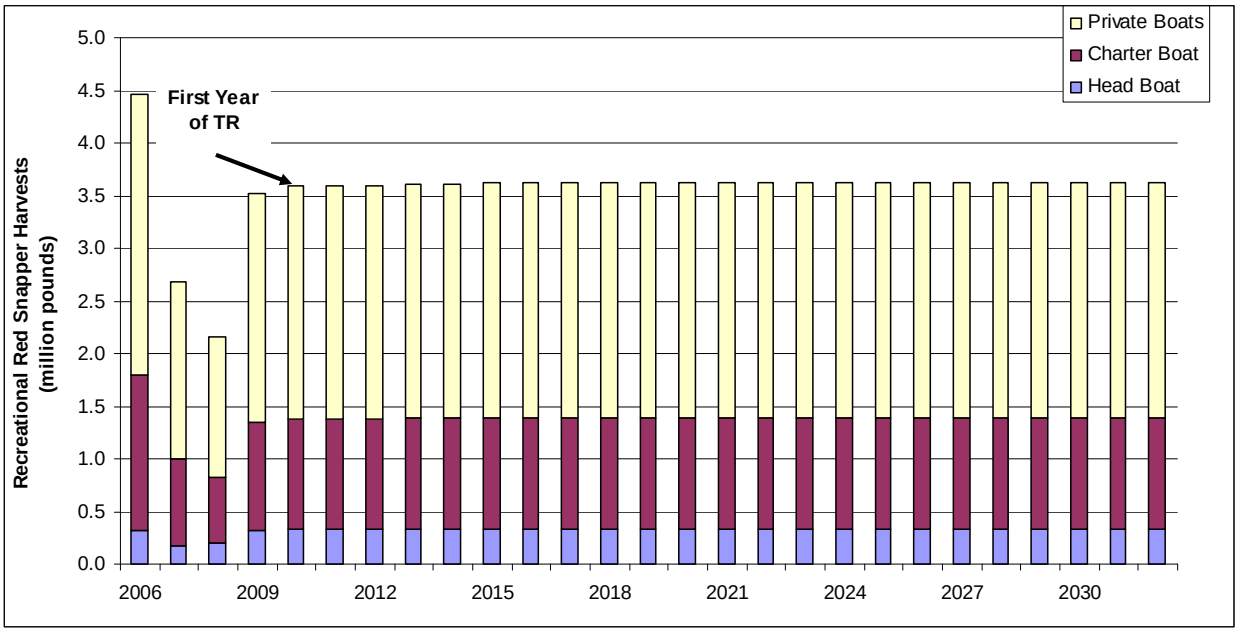
The simulated price of the TR under the TAC of 2.45 million lbs. is presented in Figure 4.7. We predict that under this TAC the market clearing price would level off after several years at slightly less than $30 per day for a total of over almost 1.15 million recreational days. As simulated, the supply of recreational days varies somewhat in the early years. While this is a result of the numerical approach used to simulate the TR market in each year, it is also consistent with what might be seen in practice since managers may need a number years to find the correct cap on the number of recreational days needed to satisfy the TAC.

Figure 4.8: TR Price for Recreational TACs of 2.45, 3.43 and 4.9 M lbs



In Figure 4.8 we present the simulated prices for a day of recreational fishing for three different levels of the recreational TAC, corresponding to a total red snapper TAC of 5, 7 and 10 million pounds with 49% allocated to the recreational sector. As economic theory would predict, the price that would be paid by anglers for a right to fish decreases as the TAC available to the recreational sector increases. Overall, the demand for the TR is quite elastic–when we simulate a 50% increase in the TAC from 2.45 to 3.43 million pounds, the price that clears the market falls by over half. And when the recreational TAC increases to 4.9 million pounds the price falls to zero in the long term as the TAC constraint becomes non-binding in this scenario. The fall in the price occurs because of two interacting forces. First, the increase in the available supply of fishing days. Second, as the TAC increases the biomass declines, putting downward pressure on catch per unit effort, which then decreases demand for the right to catch red snapper.

Figure 4.9: Simulated Recreation Harvest Under a TR Program Involving Only the Recreational Sector (10 M lbs. total TAC, 4.90 M lbs. for Recreational Sector)



In Figure 4.9 we present the distribution of red snapper landings across the vessel types under a 10 million lb. TAC. In this case the share of landings by the different modes changes very little. Since the TR price equals zero, it is not suprising that the policy has almost no effect on the distribution of harvests. Fisheries managers are likely interested not only in the biology of the fishery and the aggregate economic consequences; they probably care also about distributional consequences and whether a wide range of anglers are able to enjoy the resource. This type of analysis can be helpful in evaluating such policies.

B. A Model with Trading Between the Recreational and Commercial Sectors

We now consider a model in which we allow the recreational and commercial sectors to trade. At an interior equilibrium, the recreational sector would purchase rights to days of fishing up until the point where the price of commercial red snapper increases so much that the marginal net revenue of the commercial fleet justifies their purchasing of rights from the recreational sector. In Table 4.2, we see that using the base-case parameters, under a 5 million lb. TAC the recreational demand is such that the sector purchases over 70% of the TAC by the end of the program. However, as the total TAC increases, the proportion that the recreational sector demand falls, and when the total TAC is 10 million pounds, the commercial sector actually purchases a portion of the share from the recreational sector. Interestingly, as the TAC increases to 10 million lbs, the eventual total number of days purchased by the recreational sector actually falls, a result of the effect that the declining stock has on CPUE and, therefore, demand by the recreational sector.

Table 4.2: Price and Share of Total Allocation Purchased by Recreational Sector

	5 M lb. TAC		7 M lb TAC		10 M lb TAC	
Year	Price per day	%Rec	Price per day	%Rec	Price per day	%Rec
2009	4.90	58%	4.98	51%	5.06	36%
2010	5.07	58%	5.26	50%	5.28	33%
2011	5.48	79%	5.32	49%	5.47	30%
2012	5.38	76%	5.38	47%	5.28	30%
2013	5.41	73%	5.39	47%	5.53	30%
2014	5.43	71%	5.43	47%	5.23	30%
2015	5.45	71%	5.41	47%	5.60	29%
2016	5.46	71%	5.45	47%	5.16	30%
2017	5.46	71%	5.42	48%	5.69	29%
2018	5.46	71%	5.47	47%	5.05	30%
2019	5.47	71%	5.41	48%	5.80	28%
2020	5.47	71%	5.49	47%	4.91	29%
2021	5.47	71%	5.39	48%	5.90	27%
2022	5.47	71%	5.52	47%	4.74	28%
2023	5.48	71%	5.37	48%	5.91	26%
2024	5.47	71%	5.56	47%	4.56	27%
2025	5.48	71%	5.33	48%	5.82	25%
2026	5.47	71%	5.63	47%	4.41	25%
2027	5.48	71%	5.27	48%	5.67	23%
2028	5.47	71%	5.72	47%	4.31	24%
2029	5.48	71%	5.18	48%	5.54	23%
2030	5.47	71%	5.86	46%	4.26	23%
2031	5.49	71%	5.08	47%	5.46	23%
2032	5.47	71%	6.03	45%	4.24	23%

Recall that the demand for commercial share of the TAC is critically influenced by the wholesale price. However, because the demand curve is so elastic, even dramatic reductions in the commercial harvests lead to only slight increases in the commercial price. Even if the harvests of the sector are reduced to nearly zero, the commercial price of red snapper rises to only $4.11 from an estimated initial level of $2.96. As seen in Table 4.2, at 7 million pounds the price paid by the commercial sector per pound of the TR does not change much across the different TAC levels, in part because the price per pound of red snapper varies so little across the different simulation runs. As the total TAC increases, the price per TR measured in pounds falls slightly, as does the simulated wholesale price of red snapper. The bigger effect, however, is on the recreational sector, for which the demand curve is much steeper and, therefore, more sensitive to changes in the supply of rights to harvest red snapper.

Table 4.3: Price per TR in Pounds and Wholesale Price of Red Snapper Per Lb

	5 M lb. TAC		7 M lb TAC		10 M lb TAC	
Year	Price per TR (lbs)	Price per lb of Red Snapper	Price per TR (lbs)	Price per lb of Red Snapper	Price per TR (lbs)	Price per lb of Red Snapper
2009	2.05	2.89	2.10	2.89	2.15	2.87
2010	2.20	2.89	2.24	2.89	2.27	2.85
2011	2.27	2.97	2.25	2.89	2.35	2.87
2012	2.22	2.95	2.26	2.89	2.27	2.84
2013	2.22	2.94	2.26	2.89	2.39	2.87
2014	2.22	2.93	2.27	2.89	2.26	2.84
2015	2.23	2.93	2.26	2.89	2.42	2.88
2016	2.23	2.93	2.27	2.89	2.23	2.83
2017	2.23	2.93	2.26	2.88	2.47	2.89
2018	2.23	2.93	2.28	2.89	2.20	2.82
2019	2.23	2.93	2.25	2.88	2.53	2.90
2020	2.23	2.93	2.29	2.89	2.15	2.81
2021	2.23	2.93	2.25	2.88	2.60	2.91
2022	2.23	2.93	2.30	2.90	2.11	2.79
2023	2.23	2.93	2.24	2.88	2.67	2.93
2024	2.23	2.93	2.32	2.90	2.08	2.78
2025	2.23	2.93	2.22	2.87	2.69	2.93
2026	2.23	2.93	2.34	2.91	2.07	2.77
2027	2.23	2.93	2.20	2.86	2.69	2.92
2028	2.23	2.93	2.39	2.92	2.07	2.77
2029	2.24	2.93	2.17	2.85	2.68	2.91
2030	2.23	2.93	2.45	2.94	2.07	2.76
2031	2.24	2.94	2.13	2.84	2.66	2.90
2032	2.23	2.93	2.54	2.95	2.08	2.76

As we indicated above, the price flexibility coefficient is very small in absolute value, meaning that the demand curve for red snapper harvests from the Gulf is extremely flat. To evaluate how sensitive our results are to this statistic, we conducted sensitivity analysis on this parameter. In Table 4.4 we compare the results for the TR market for three values of the price flexibility parameter, equal to one, two and four times the original estimate form Park (1996). We see that the price flexibility coefficient makes little difference. Although the simulated price per day of fishing increases slightly for larger flexibilities, the share purchased by the sectors changes little. We find, therefore, that our qualitative results are robust to changes in this parameter.

Table 4.4: Sensitivity Analysis for Price Flexibility: Comparison of Equilibrium Prices and Percentage of Rights Purchased by Recreational Sector Under a 5 M lb TAC

	Price flexibility = -0.0341		Price flexibility = -0.0682		Price flexibility = -0.1364	
Year	Price of TR per day	% of TAC purchased by Rec. Sector	Price of TR per day	% of TAC purchased by Rec. Sector	Price of TR per day	% of TAC purchased by Rec. Sector
2009	4.90	58%	4.89	58%	4.91	58%
2010	5.07	58%	5.07	58%	5.11	58%
2011	5.48	79%	5.65	79%	6.02	78%
2012	5.38	76%	5.51	76%	5.82	76%
2013	5.41	73%	5.52	73%	5.77	72%
2014	5.43	71%	5.52	71%	5.74	70%
2015	5.45	71%	5.54	71%	5.76	70%
2016	5.46	71%	5.54	70%	5.76	70%
2017	5.46	71%	5.55	70%	5.77	70%
2018	5.46	71%	5.55	70%	5.77	70%
2019	5.47	71%	5.56	70%	5.78	70%
2020	5.47	71%	5.56	70%	5.78	70%
2021	5.47	71%	5.56	70%	5.79	70%
2022	5.47	71%	5.56	70%	5.78	70%
2023	5.48	71%	5.57	70%	5.79	70%
2024	5.47	71%	5.56	71%	5.78	70%
2025	5.48	71%	5.57	70%	5.80	70%
2026	5.47	71%	5.56	71%	5.78	70%
2027	5.48	71%	5.57	71%	5.80	70%
2028	5.47	71%	5.56	71%	5.78	70%
2029	5.48	71%	5.58	71%	5.81	70%
2030	5.47	71%	5.55	71%	5.77	70%
2031	5.49	71%	5.58	71%	5.82	70%
2032	5.47	71%	5.55	71%	5.76	70%

Table 4.5: Comparison of Cumulative Present Value ($1,000,000)
Under Policy Options

A	B	C	D	E	F	G	H	I	J
Cumulative Years 2009 to:	Shrimp Commercial (PS)	Red Snapper (PS)	Vermillion and Other Reef (PS)	Red Snapper Commercial (CS)	Red Snapper For-Hire (PS)	Vermillion and Other Reef For-Hire (PS)	Red Snapper Angler (CS)	Vermilion and Other Reef Angler (CS)	Total value of all TRs
				Base Case					
2013	538	14	76	5	71	221	581	2,650	0
2018	975	25	134	8	123	387	985	4,550	0
2028	1,517	38	206	12	186	589	1,473	6,874	0
2032	1,650	41	224	13	202	639	1,592	7,444	0
				TR - Recreation Only					
2013	538	15	76	1	74	214	547	2,640	111
2018	975	26	133	2	129	372	895	4,541	259
2028	1,517	38	203	3	195	564	1,318	6,864	560
2032	1,650	42	221	3	212	611	1,422	7,433	680
				TR - Trading between Recreational and Commercial Allowed					
2013	538	7	76	1	83	204	707	2,533	57
2018	975	9	134	1	149	348	1,273	4,287	118
2028	1,517	13	206	2	231	524	1,964	6,429	242
2032	1,650	13	223	2	251	567	2,133	6,954	291

C. Comparison of Policy Options

In this section we briefly compare the welfare consequences of the three main policy options considered.[6] In Table 4.5 we present the surpluses that accrue to the different sectors. We can see that there are some sectors that are essentially unaffected by the different options. The welfare of the shrimp sector does not change at all and the non-red snapper commercial fisheries are only slightly affected by the policy options.

Not surprisingly, the red snapper fisheries are greatly affected by the different policy options. Relative to the base-case scenario, we find that introducing the tradable permits among the recreational sector actually leads to a slight reduction in the estimated present value of surplus in that sector. Note, however, that the recreational surplus is calculated is in excess of the money spent for the TR permits by the recreational fishermen (column J). If the rights to fish were grandfathered to the sector, then the revenue in column J would actually be rents that would accrue to the sector making the anglers better off. Hence, the total surplus generated by the recreational sector (including columns H and J) increases relative to the base case. As indicated in chapter 2, we believe that an auction of the recreational TRs may be the most easily implementable system. Those revenues have a present value of $680 million over the period 2009-2032. However, if the simulation results are accurate, recreational anglers themselves will not benefit directly from the policy change. The for-hire red snapper sector sees a 5% increase in the present-value of its producer surplus, so this sector may indeed favor a TR program, even if the rights are auctioned by the government.

A move to a policy that allows for trading between the commercial and recreational sectors leads to sharp changes in the surplus picture. The recreational sector, which purchases over 70% of the TAC, increases its surplus relative to the base and recreation-only scenarios. The commercial red snapper fishery, on the other hand, suffers a dramatic reduction in its surplus. Again, taking into account how revenues are treated is important. Because the price of the TR falls so sharply, we estimate that the extension of the TR program to the commercial sector would result in a reduction in the total value of the rights. However, it is seems less likely that an auction system would be implementable if the commercial sector were involved – they do have a record of landings that could be used to grandfather allocations. If rights are grandfathered to the commercial sector, then we predict that in addition to the direct surplus from the use of the rights (column C), the sector would also earn revenues from the sale of its rights (column K). Combined, the commercial red snapper sector's welfare actually increases by 70% relative to the base case scenario.

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[6] Note that the base case in this analysis is not equivalent to the base case elsewhere in chapter 1 since a recreational bag limit of 4 fish per trip is assumed here while 2 fish per trip is used in chapter 1.

We also predict some less significant effects on the other reef fish fisheries. We predict that the surplus of both the for-hire and the recreational sectors will decline slightly under the TR programs. The cause of this is that the model assumes that any redirection of effort toward red snapper will lead to a reduction in the rate at which other species are targeted.

VII. Conclusions

In this chapter we have presented a simulation model for the use of transferable rights as a way to control recreational fishing for red-snapper in the Gulf of Mexico. We predict that this will lead to an increase in the recreational surplus, achieved by rationalizing the effort over the entire year, instead of the current policy of seasonal closures. This policy also leads to an increase in the cost of red snapper recreational fishing in the Gulf and the resulting situation would have much more of the total catch harvested by charter vessels at the expense of the head boat and private boat fishermen.

We also simulate a policy in which recreational fishermen can purchase licenses from the commercial fleet. For TACs of 5 or 7 million pounds, we predict that the recreational sector will purchase the vast majority of the rights. Only if the TAC is increased to 10 million pounds do we predict that the commercial red snapper fishery will begin to purchase rights to a portion of the TAC. The greatest increase in total surplus is achieved through a program that allows full transferability of the rights. If rights to the commercial sector are grandfathered, then we predict that the fishermen will actually earn more money from selling their rights to the recreational fishermen than they would have earned using those rights for fishing.

VIII. References

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Appendix A: Calibration of Biological Model

I. Model Dimensions

The dimensions of the BESS(GFBSM) model for this study are as follows:

Four species of fish:

Species 1: Shrimp
Species 2: Red snapper
Species 3: Vermillion snapper
Species 4: Other fish

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

Species:	Size 1	Size 2	Size 3
Shrimp (mm)	167.3	122.4	80
Red snapper (inch)	12	9	0
Vermillion snapper (inch)	10	5	0
Other fish (inch)	10	5	0

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

Size	Tail count/pound
1	20-up
2	21-50
3	> 51

The sizes of red snapper and vermillion snapper represent the following age classes:

Size	Age class
1	2 +
2	1
3	0-12 months

Two regions where landings occur:

Region 1: East gulf
Region 2: West gulf

Two areas fished:

Area 1: East gulf
Area 2: West gulf
(The gulf is divided into two regions/areas: east gulf and west gulf by Mississippi river.)

Eight vessel classes:

Vessel class 1: Shrimp vessels < 60 ft
Vessel class 2: Shrimp vessels >= 60 ft

Vessel class 3: RS_2000 Commercial
Vessel class 4: Hand Line Commercial Reef
Vessel class 5: Long Line Commercial Reef
Vessel class 6: Head Boat Recreational
Vessel class 7: Charter Boat Recreational
Vessel class 8: Private Recreational

Two depths fished:
Inshore/bay
Offshore

Number of cohorts:

Species:	Maximum age
Shrimp	2
Red snapper	35
Vermillion snapper	25
Other fish	25

II. Calibration of biological model for shrimp

The GBFSM is calibrated to the average effort and landings data for the period 2000-2005. The GBFSM has an incorporated optimization routine to aid calibrating. The optimizer, called POWELL, is used to determine the optimum values for various biological coefficients [TuneCoeff(i)], based on given criteria [TuneCriteria(j)]. That is, TuneCoeff(i) is optimized when the optimal TuneCoeff(i) minimizes the squared difference between actual and simulated values for TuneCriteria(j). This optimization technique is set up to do one area and one species at a time. As an example, TuneCoeff(1) is gross recruitment and TuneCriteria(12) is annual landings. POWELL will optimize gross recruitment based on annual landings. The different tuning coefficients and the tuning criteria used in calibrating GBFSM are given in Table A.1.

Table A.1

Number	TuneCoeff	TuneCriteria	Variable	Variable(s) changed
1	1	12	Gross recruitment	ICOF(1,NA,NSP)
2	13	5	Vul. index fish mort	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
3	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
4	23	15	Vulnerability index for IV range and ID range	FMAX(IA,IS,ID,1:NM,IV)
5	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
6	2	1	Altering recruitment	EDISTR(NA,NSP,NER)
7	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
8	3	5	Movement by depths	ERT(NSP,NSZ,ND,NA,NA)
9	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
10	2	1	Altering recruitment	EDISTR(NA,NSP,NER)
11	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
12	3	5	Movement by depths	ERT(NSP,NSZ,ND,NA,NA)
13	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
14	2	1	Altering recruitment	EDISTR(NA,NSP,NER)
15	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
16	3	5	Movement by depths	ERT(NSP,NSZ,ND,NA,NA)
17	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)
18	7	7	Adj. growth by size	VASV(NA,NSP,NSZ)
19	39	47	Gross recruitment & fishing mortality (F)	ICOF(1,NA,NSP) & AdjFvestyp(NA,NSP,NVT)

The Gulf of Mexico was divided into 2 areas fished by Mississippi river: East Gulf and West Gulf. The following 28 figures show the calibrating results for both areas. Figures 1 thru 14 are East Gulf, and Figures 15 thru 28 are West Gulf. The simulated data fit well during the 2000-2005 period. In Figures 13, the yield curve passes through the 2000-2005 data points as we expected. More data points lie above the yield curve because the earlier years have higher gross recruitment. In Figure 14, we demonstrate annual data back to 1965, but we do not expect the simulated data to fit the earlier years. The reason is that we hold the gross recruitment at the average level of 2000-2005, which is significantly lower than that in previous years.

1. Graphical Results For Shrimp in Area 1 (East Gulf), 2000-2005

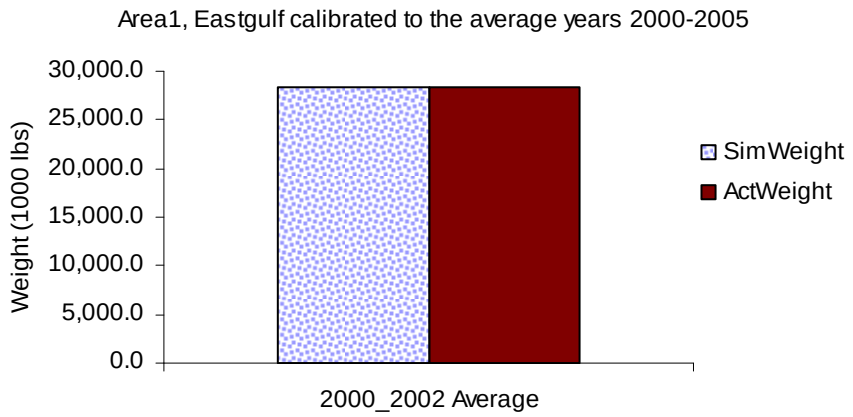


Figure Shr1. Comparison of fishing annual landings in East Gulf, calibrated to the average years 2000-2005.

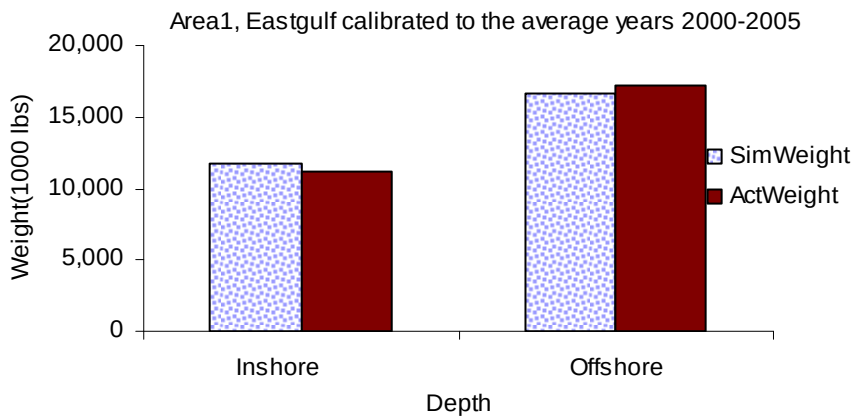
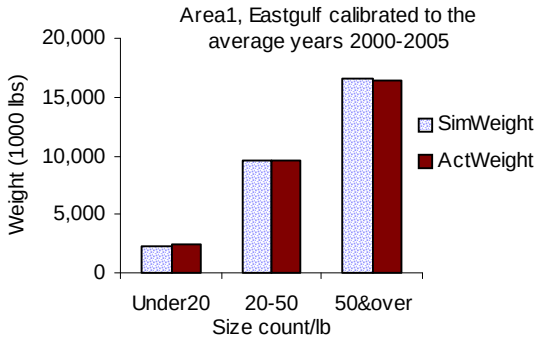


Figure Shr2. Comparison of landings by depth in state and federal waters in East Gulf, calibrated to the average years 2000-2005.



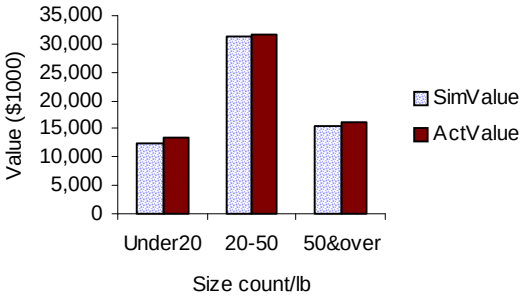


Figure Shr3. Comparison of landings and value of landings by count size in East Gulf, calibrated to the average years 2000-2005.

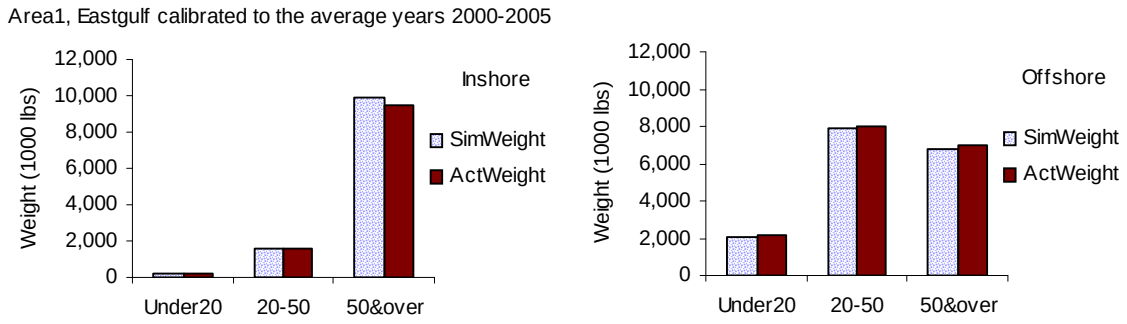


Figure Shr4. Comparison of landings by depth in state and federal waters and count size in East Gulf, calibrated to the average years 2000-2005.

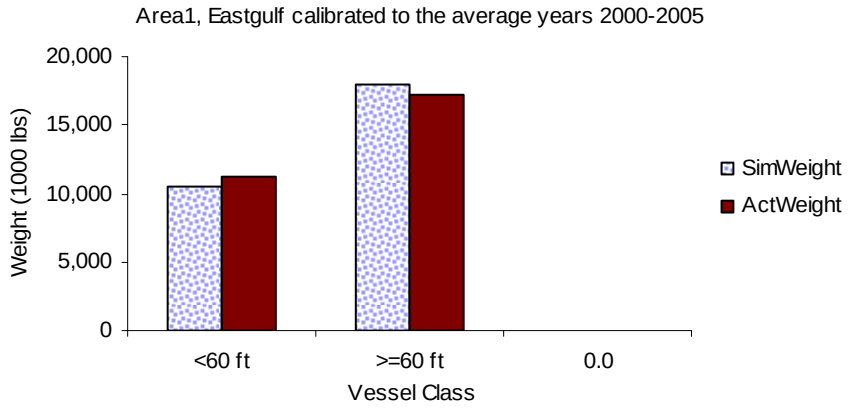


Figure Shr5. Comparison of landings by vessel length in East Gulf, calibrated to the average years 2000-2005.

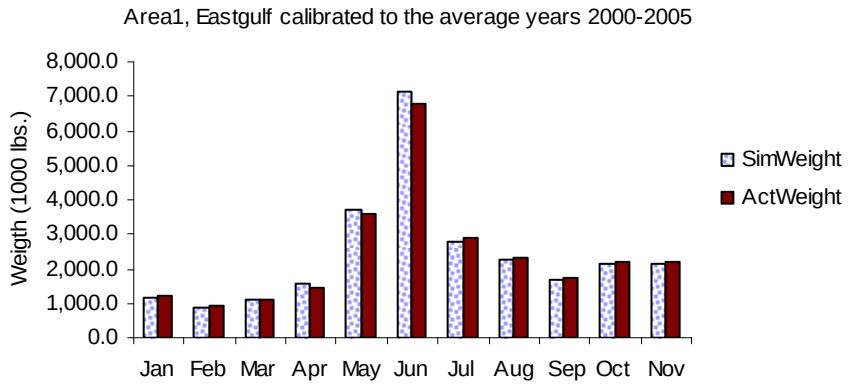


Figure Shr6. Comparison of landings by month in East Gulf, calibrated to the average years 2000-2005.

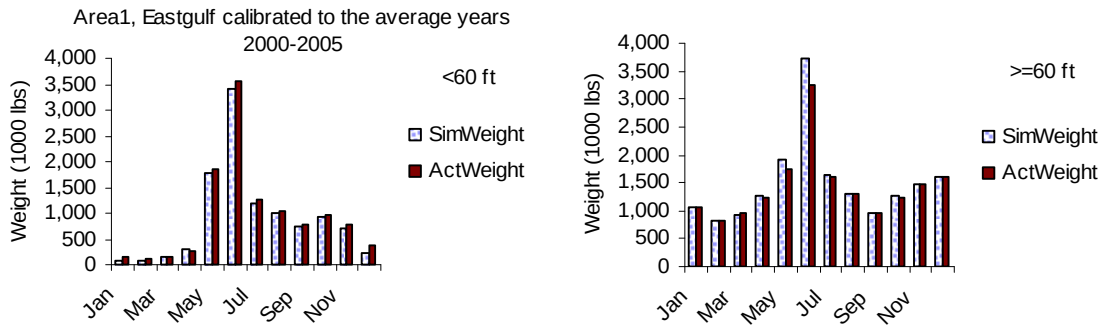


Figure Shr7. Comparison of landings by vessel length and month in East Gulf, calibrated to the average years 2000-2005.

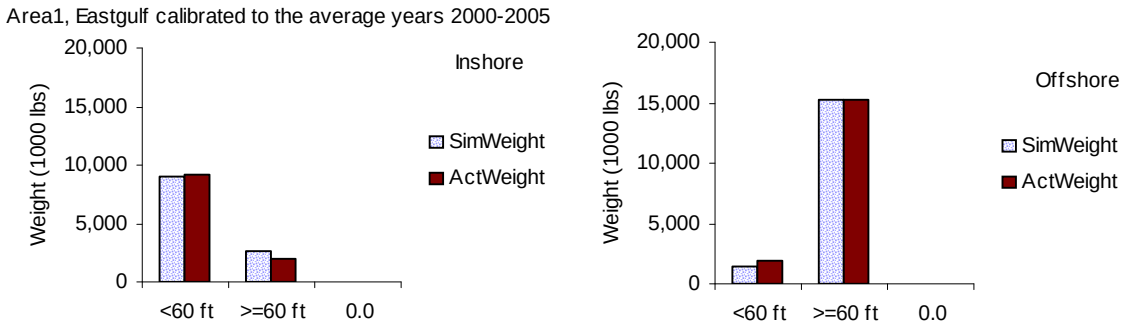


Figure Shr8. Comparison of landings by depth in state and federal waters and vessel length in East Gulf, calibrated to the average years 2000-2005.

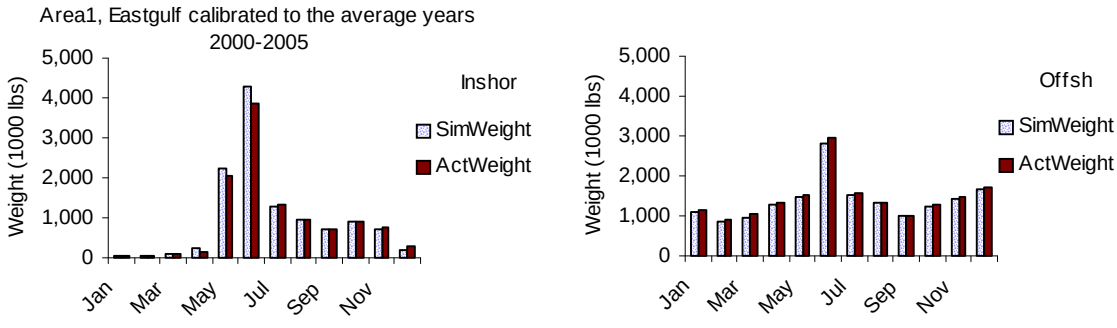


Figure Shr9. Comparison of landings by depth in state and federal waters and month in East Gulf, calibrated to the average years 2000-2005.

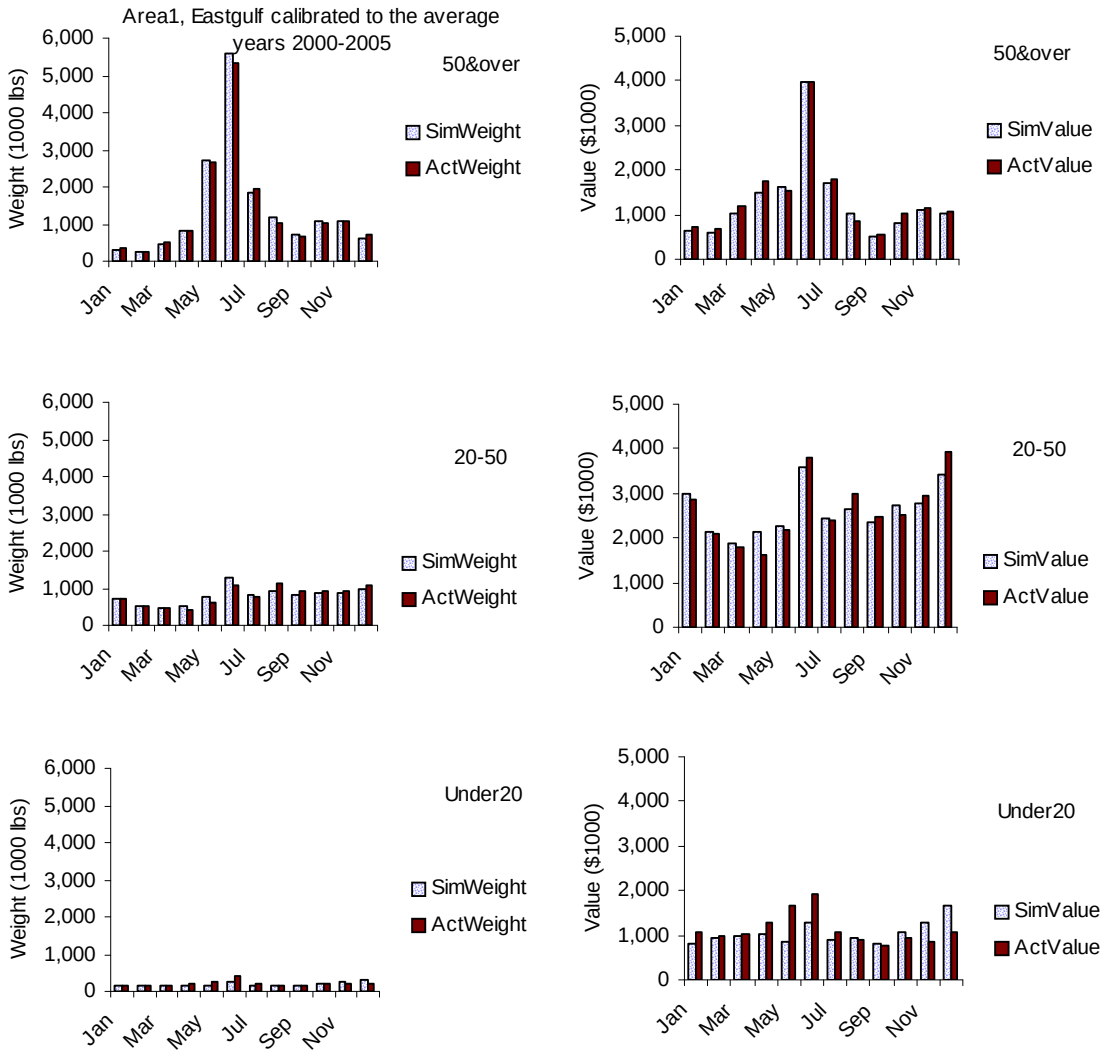


Figure Shr10. Comparison of landings and value of landings by count size and month in East Gulf, calibrated to the average years 2000-2005.

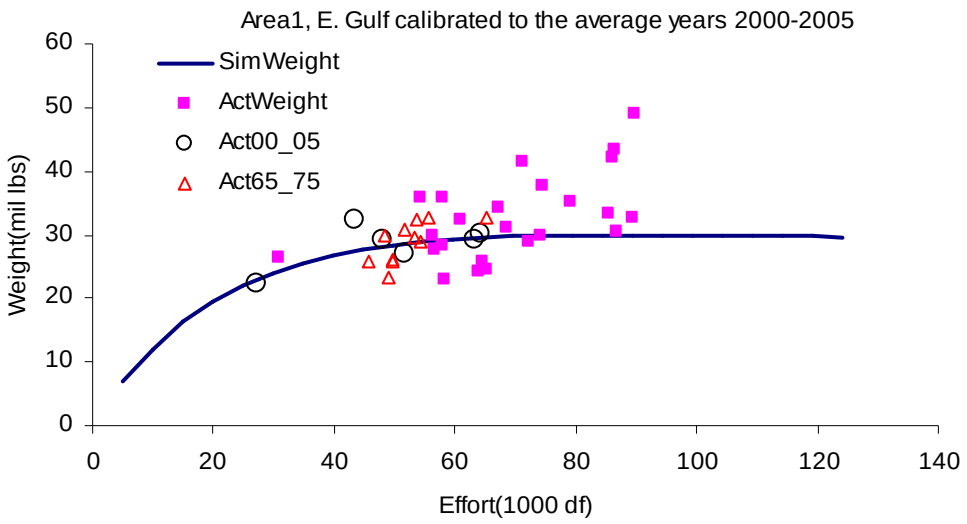


Figure Shr11. Simulated yield curve compared to annual landings 1965-2005 in East Gulf, calibrated to the average years 2000-2005.

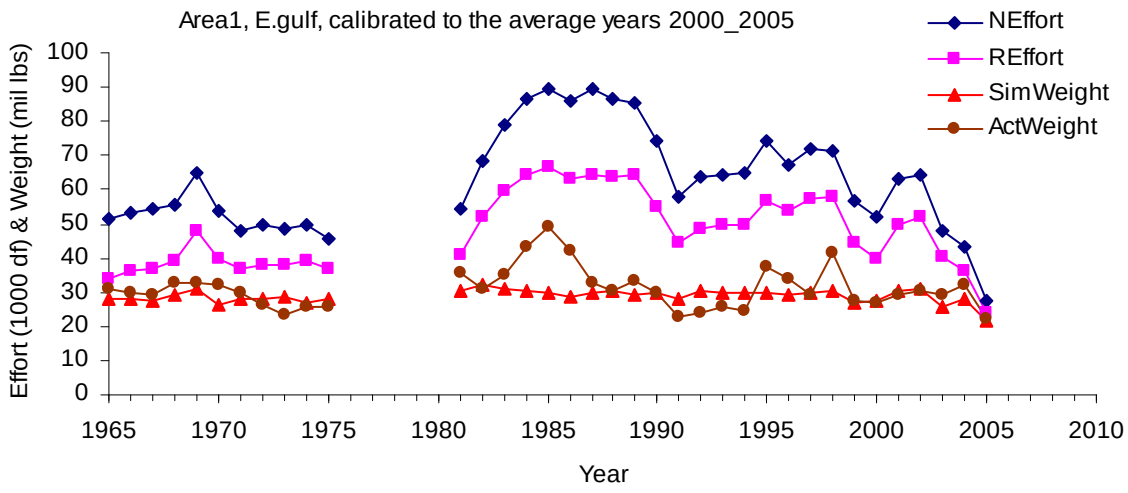


Figure Shr12. Simulated landings compared to actual landings, and nominal and real effort 1965-2005 in East Gulf, calibrated to the average years 2000-2005.

A. 2. Graphical Results For Shrimp in Area 2 (West Gulf), 2000-2005

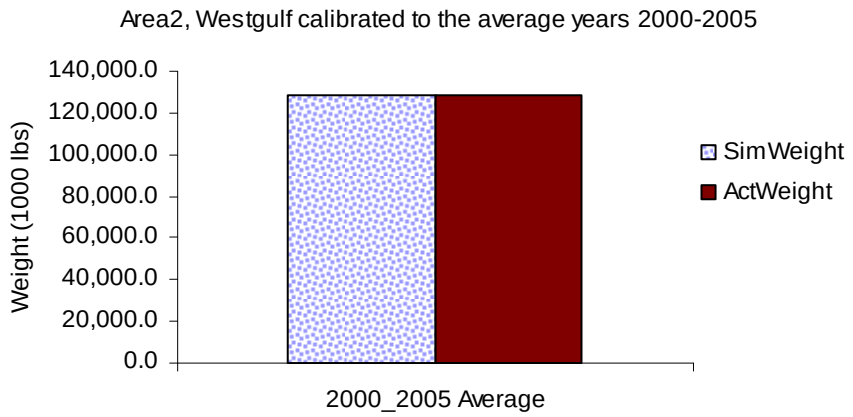


Figure Shr13. Comparison of fishing annual landings in West Gulf, calibrated to the average years 2000-2005.

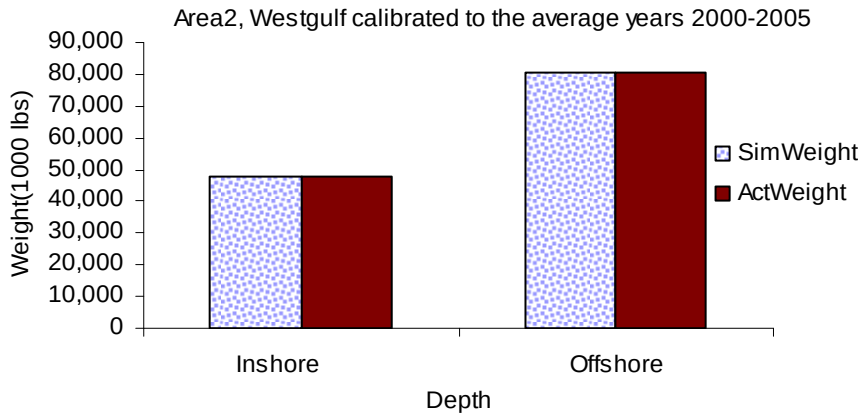
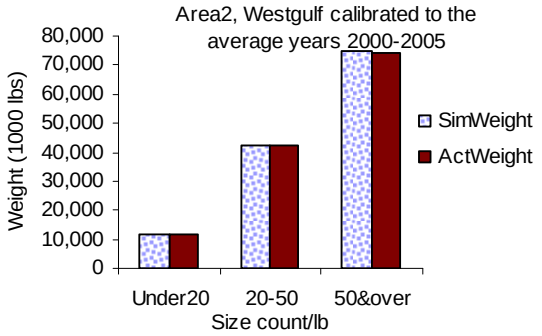


Figure Shr14. Comparison of landings by depth in state and federal waters for West Gulf, calibrated to the average years 2000-2005.



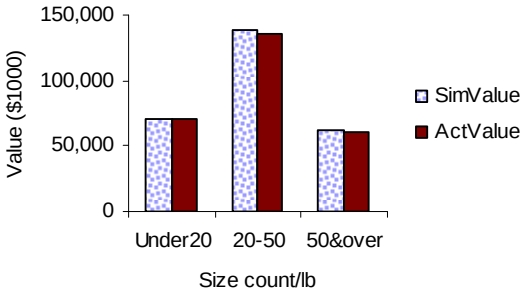


Figure Shr15. Comparison of landings and value of landings by count size in West Gulf, calibrated to the average years 2000-2005.

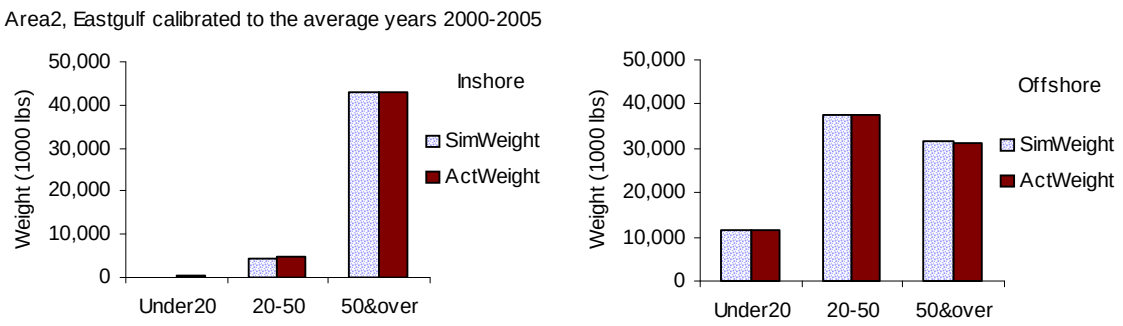


Figure Shr16. Comparison of landings by depth in state and federal waters and count size in West Gulf, calibrated to the average years 2000-2005.

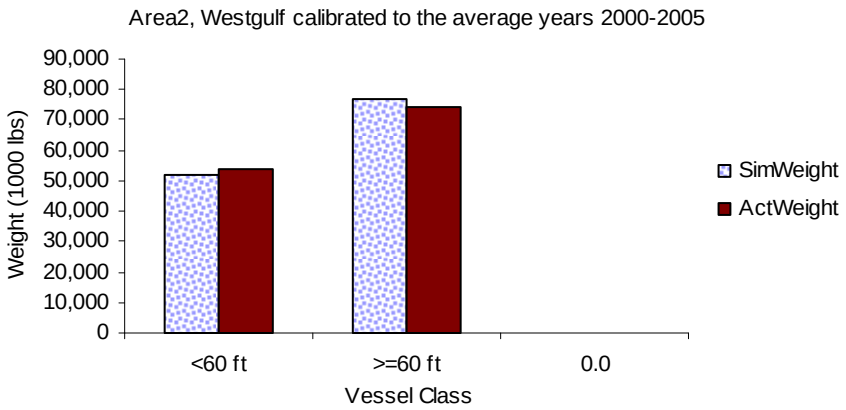


Figure Shr17. Comparison of landings by vessel length in West Gulf, calibrated to the average years 2000-2005.

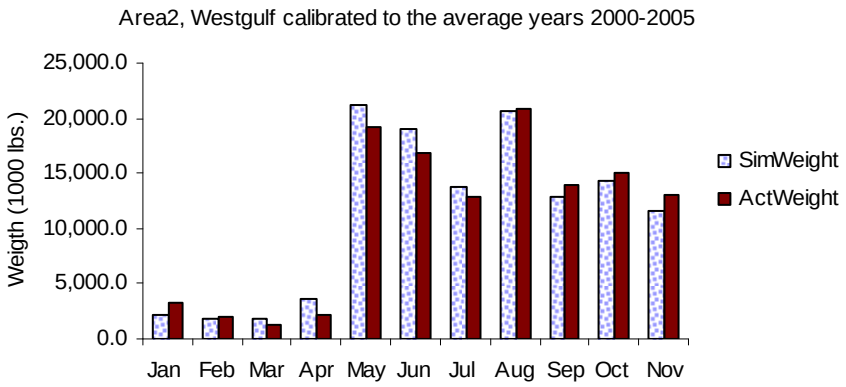


Figure Shr18. Comparison of landings by month in West Gulf, calibrated to the average years 2000-2005.

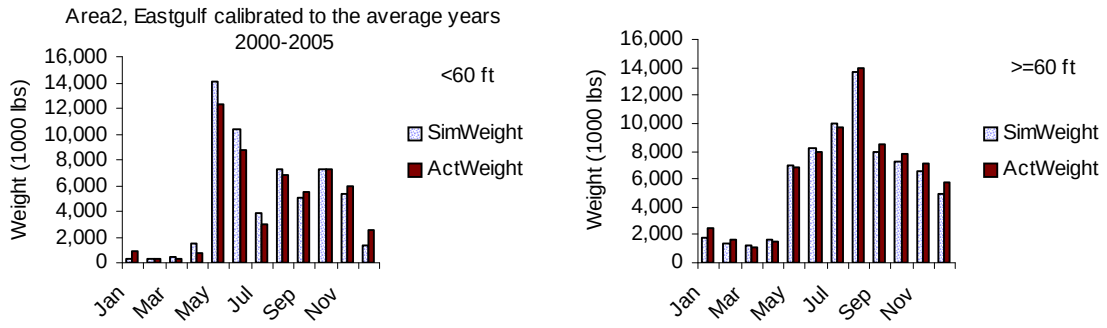


Figure Shr19. Comparison of landings by vessel length and month in West Gulf, calibrated to the average years 2000-2005.

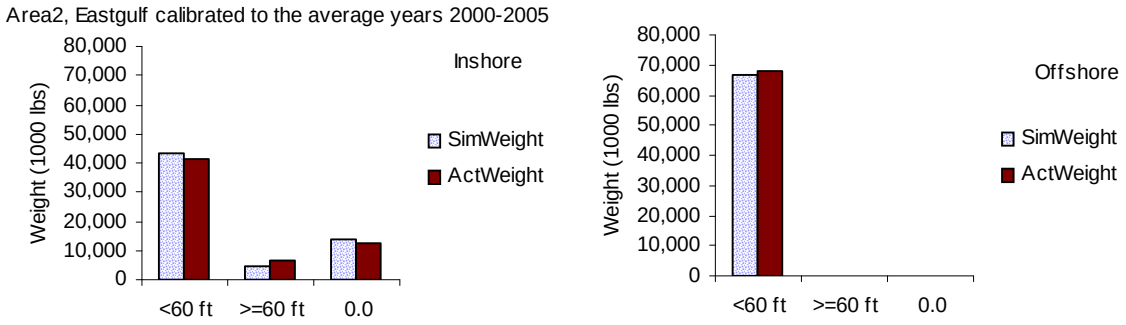


Figure Shr20. Comparison of landings by depth in state and federal waters and vessel length in West Gulf, calibrated to the average years 2000-2005.

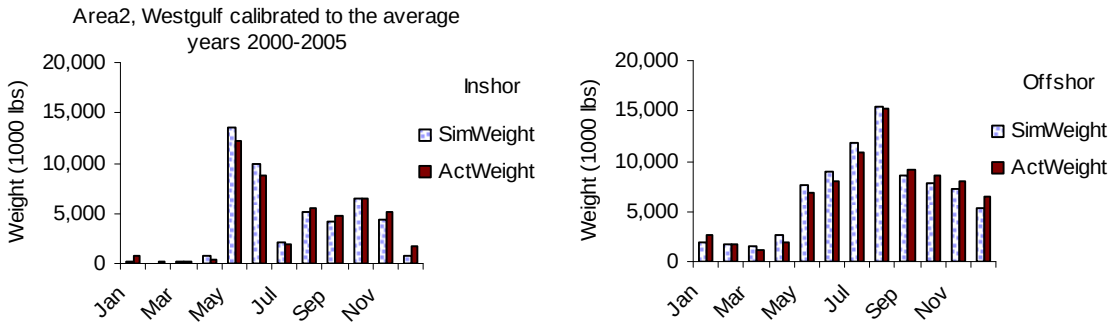


Figure Shr21. Comparison of landings by depth in state and federal waters and month in West Gulf, calibrated to the average years 2000-2005.

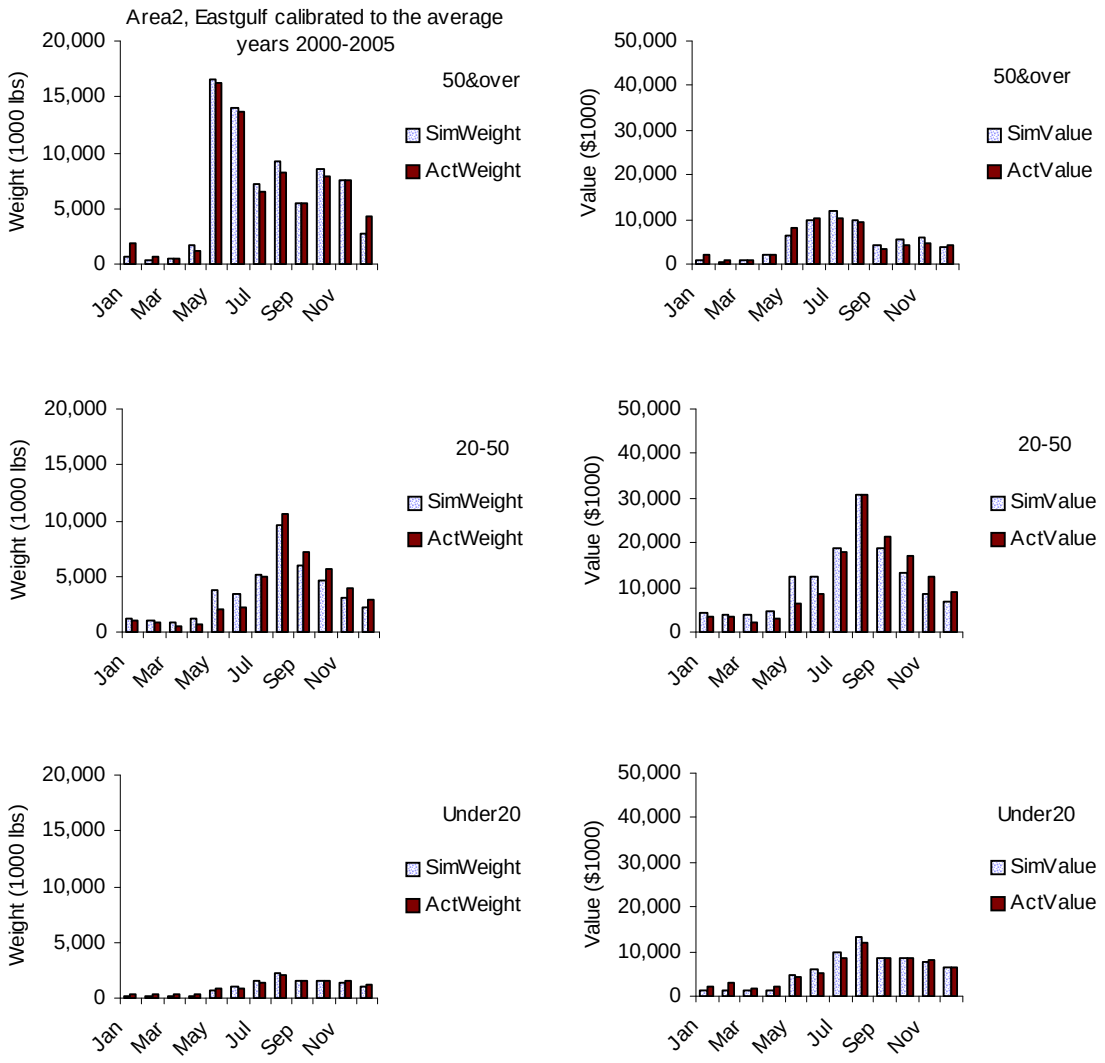


Figure Shr22. Comparison of landings and value of landings by count size and month in West Gulf, calibrated to the average years 2000-2005.

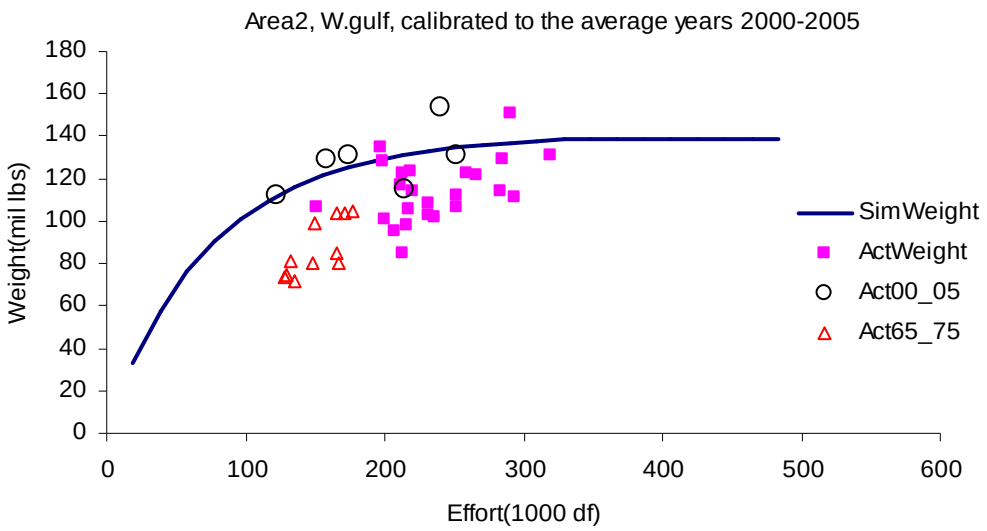
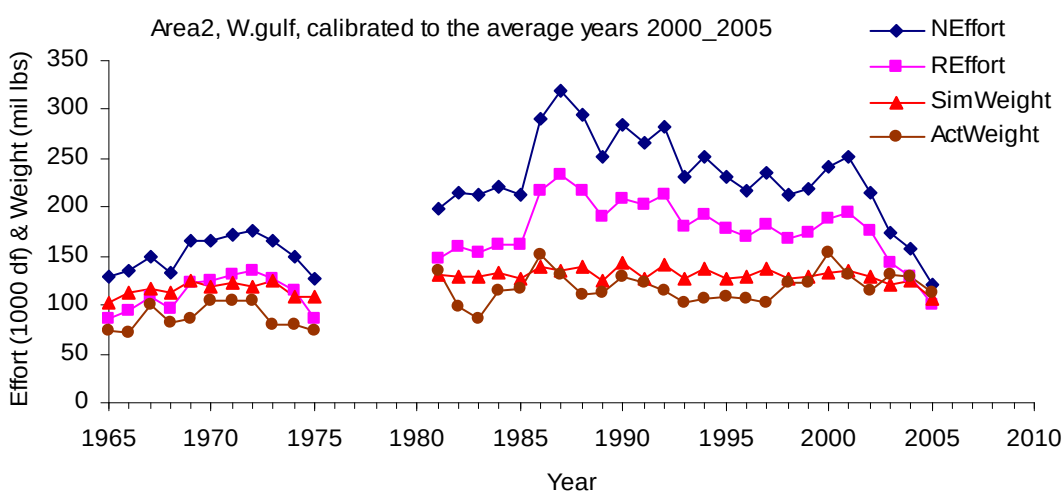


Figure Shr23. Simulated yield curve compared to annual landings 1965-2005 in West Gulf, calibrated to the average years 2000-2005.

B.

C.



D.

Figure Shr24. Simulated landings compared to actual landings, and nominal and real effort 1965-2005 in West Gulf, calibrated to the average years 2000-2005.

E. 3. Entry/Exit calibration

The following figures show the actual and simulated results by region and vessel class, where shrimp prices and unit cost are held constant by year and entry/exit coefficients are calibrated using the optimization procedure in the GBFSM. The time period 1997-2005 was chosen so that there would be both favorable and unfavorable economic conditions. Greater confidence can be put in the simulation results if the entry and exit of vessels (effort) tracks actual entry and exit of vessels. We used a longer period of time (1997-2005) then calibrating of the biological coefficients (2000-2005) because wanted to have a more number of years where the economics conditions were favorable then the 2000-2005 data had.

Each set of figures below contain the following graphs beginning at the top right:

1. Effort in thousand days fished. The optimization procedure in the GBFSM minimizes the difference squared of simulated and actual effort.
2. Weight landed in million pounds.
3. Value of shrimp landed in million dollars.
4. Price receives in dollars per pound.
5. Shares in million dollars. This is the net share paid to the crew; crew revenue less crew costs.
6. Variable costs in million dollars. This is all other cost per unit of effort and does not include shares or fuel costs.
7. Fuel cost in million dollars.
8. Total variable costs which includes which includes the variable costs in 6 above and fuel costs but does not include share costs.
9. Fixed costs in million dollars. Basically this includes cash costs such as insurance, docking fees, etc.
10. Opportunity costs in million dollars.
11. Total fixed and opportunity costs in million dollars.
12. Total costs in million dollars. This includes all costs mentioned above.
13. Revenue above variable costs in million dollars. This includes variable cost, fuel costs and shares.
14. Profit in million dollars. This is the variable used to determine if vessels will entry of exit the fishery.

Based on the figures presented below we have confidence that the simulation model as calibrated will do a good job of determining whether vessels will enter or leave the fishery in both favorable and unfavorable economic circumstances.

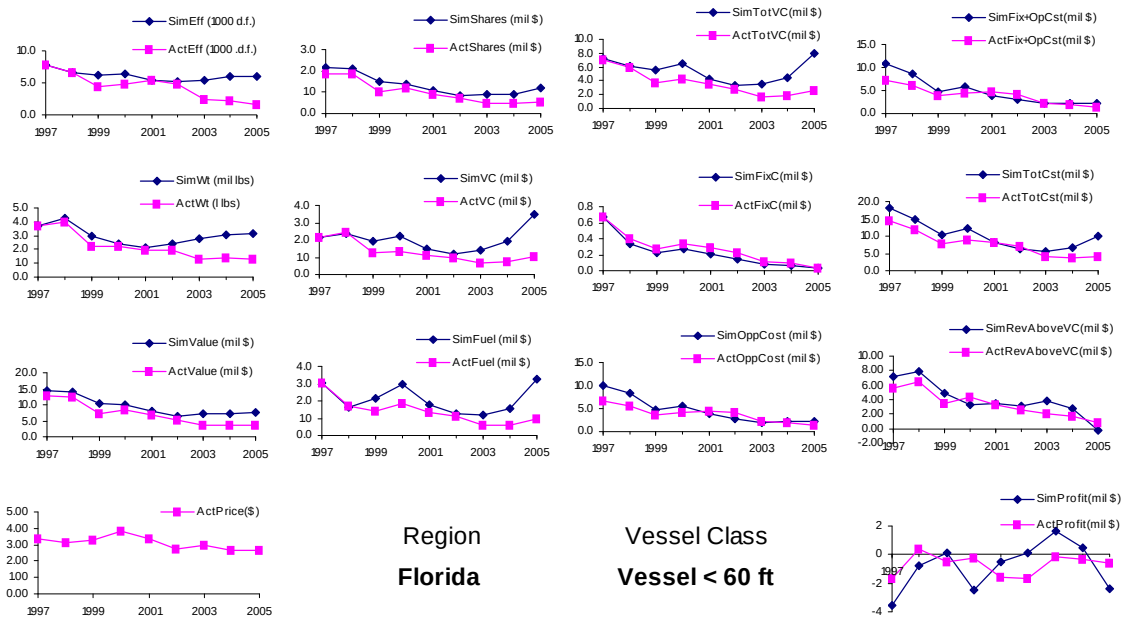


Figure Shr25. Results of entry exit calibration for small vessels in region 1.

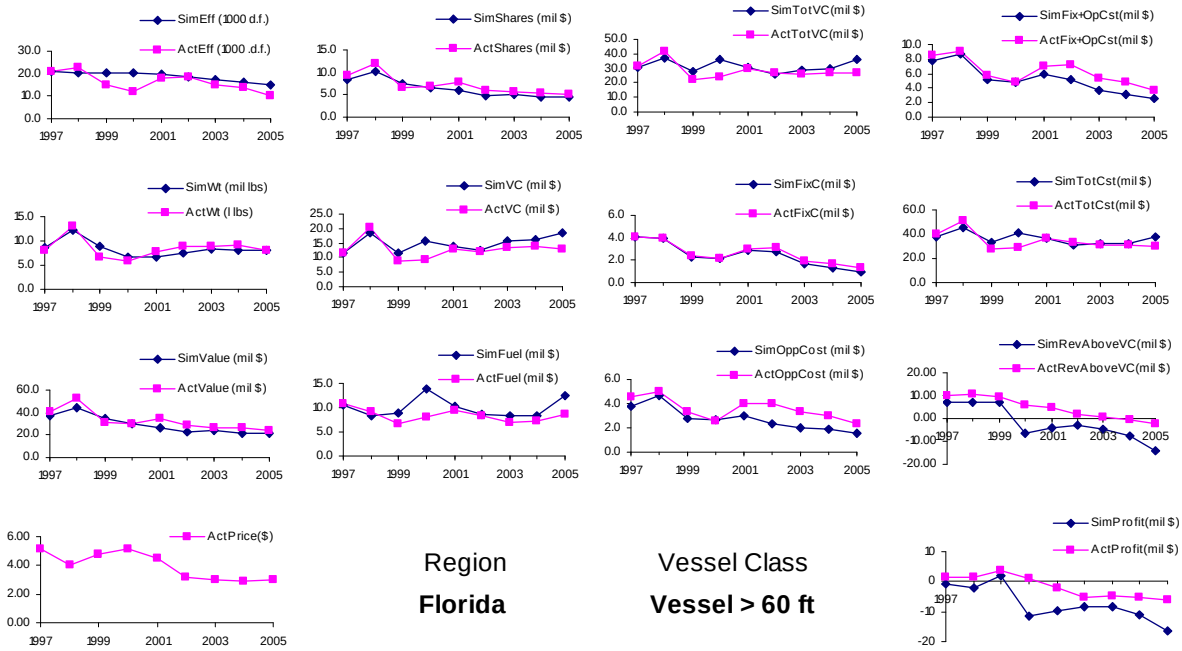


Figure Shr26. Results of entry exit calibration for large vessels in region 1.

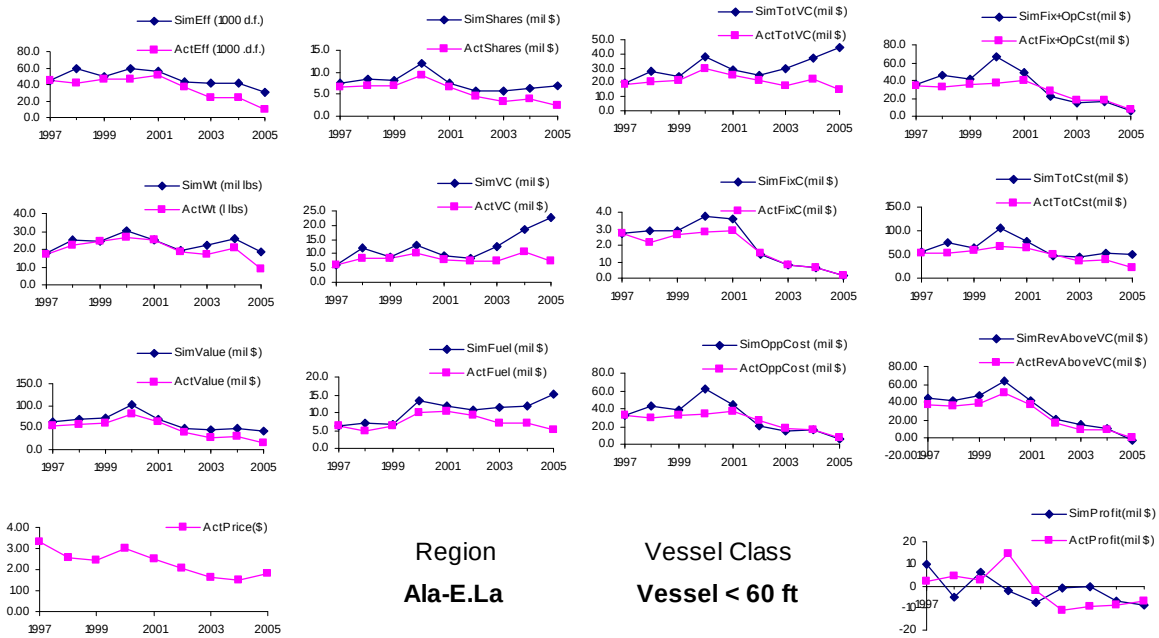


Figure Shr27. Results of entry exit calibration for small vessels in region 2.

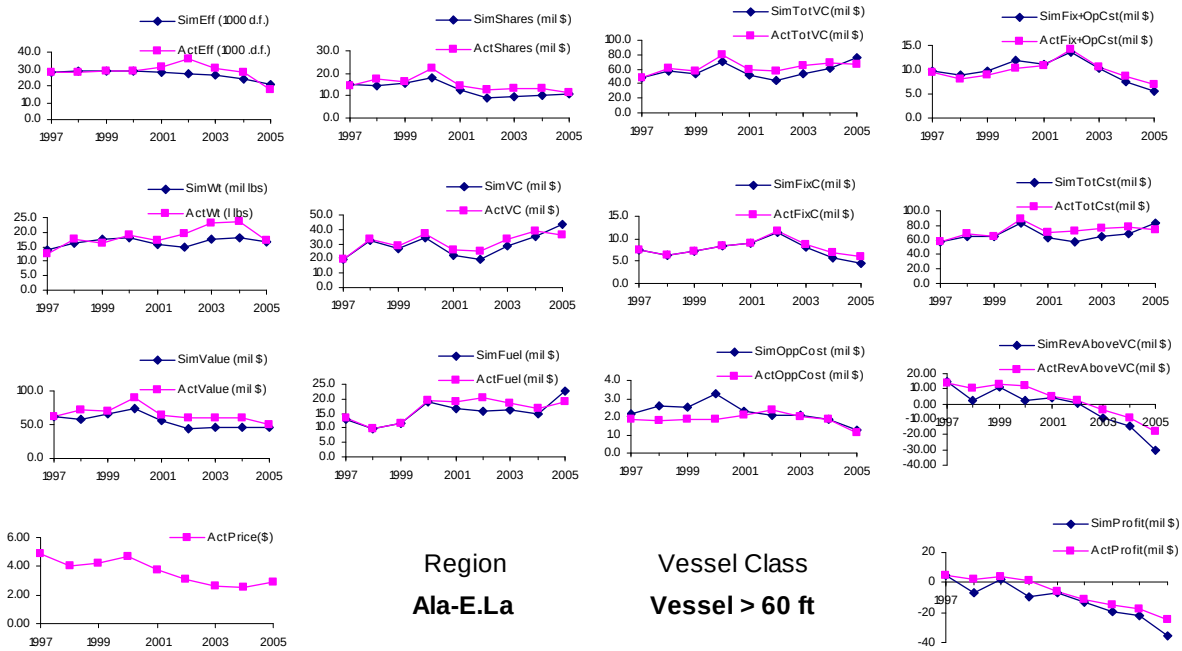


Figure Shr28. Results of entry exit calibration for large vessels in region 2.

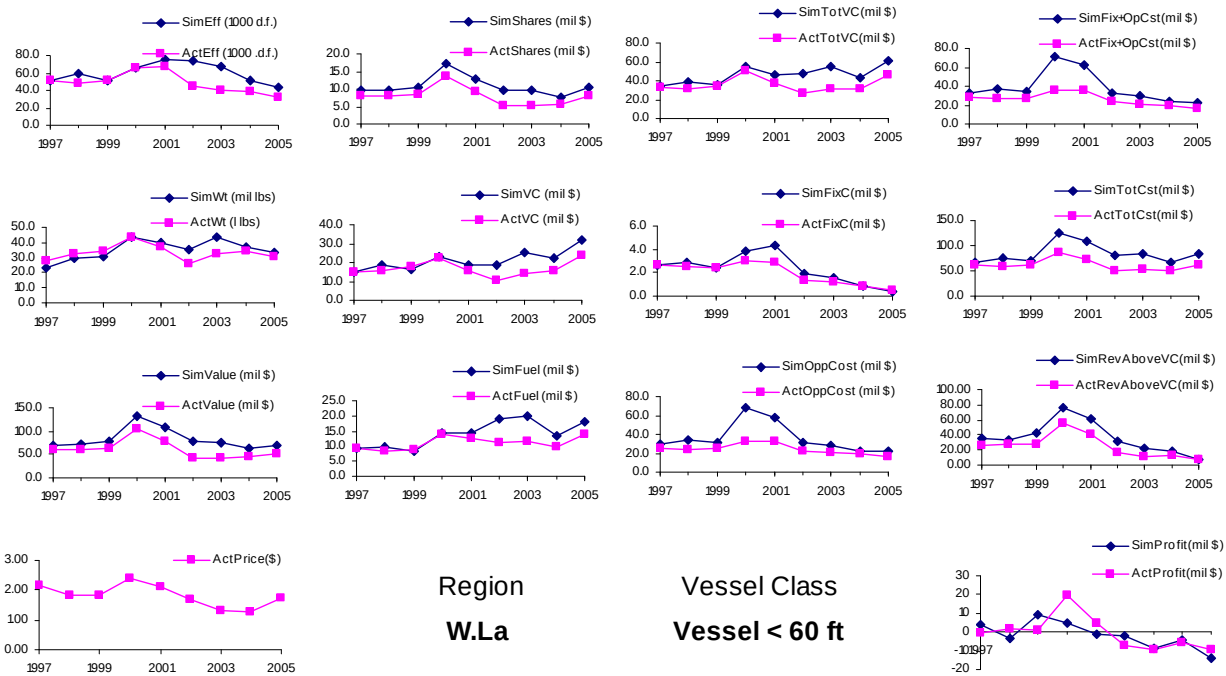


Figure Shr29. Results of entry exit calibration for small vessels in region 3.

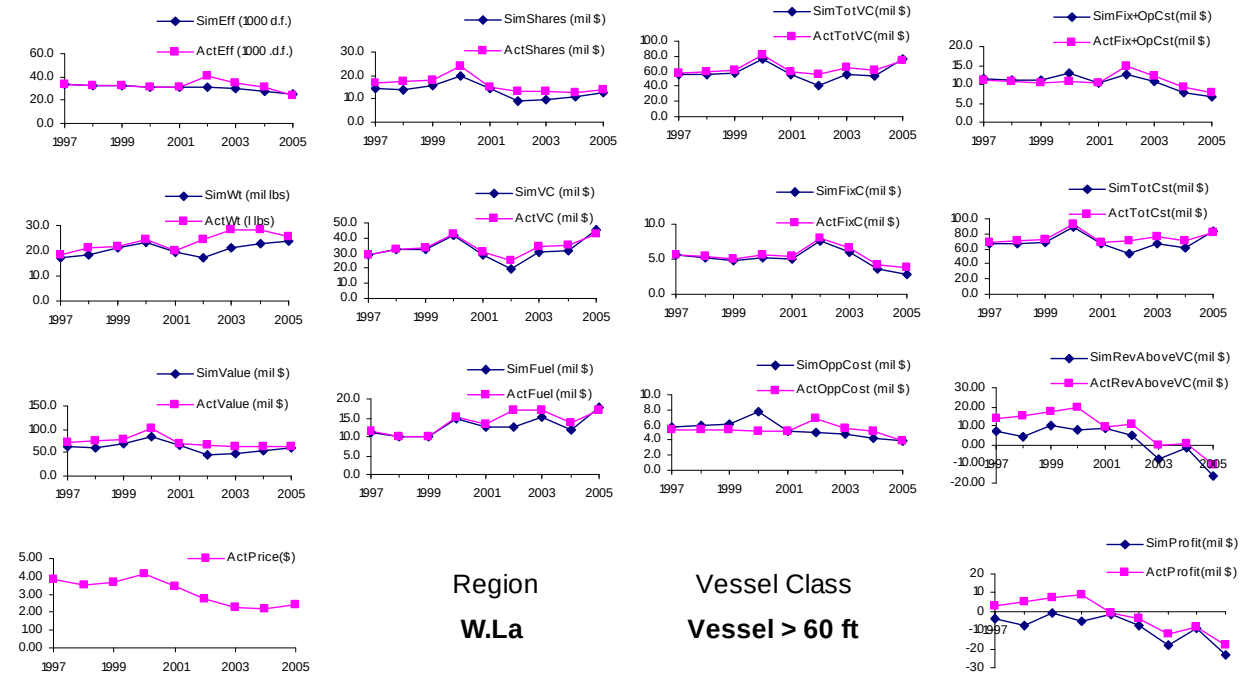


Figure Shr30. Results of entry exit calibration for large vessels in region 3.

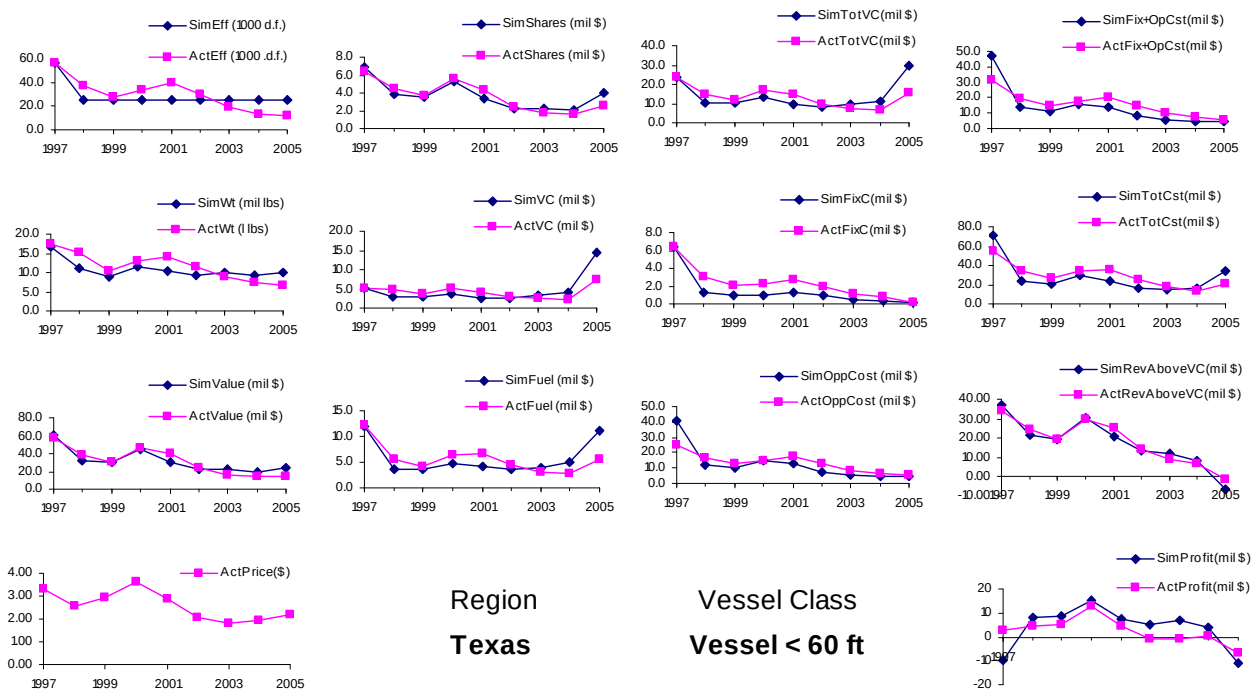


Figure Shr31. Results of entry exit calibration for small vessels in region 4.

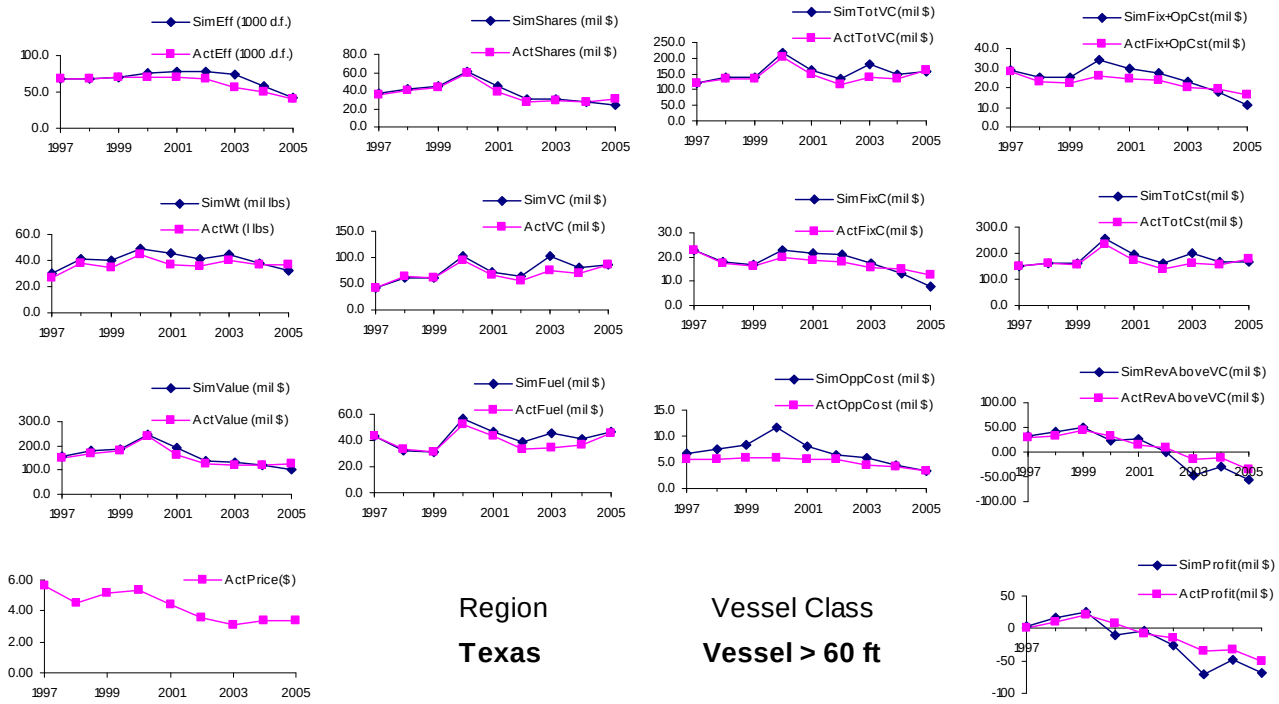


Figure Shr32. Results of entry exit calibration for large vessels in region 4.

III. Calibration of biological model for red snapper

To calibrate four different species (shrimp, red snapper, vermilion snapper, and other reef fish) in a single model, we select January 1 as the beginning of a year in GBFSM. Further, we simulate all fish at actual age instead of year classes as does SEDAR assessments, which may contribute to some of the differences between our results and those of previous research. We also use a density dependent model where as the SEDAR 7 assessment did not (although it was recommended). Gazey et.al. (2008) have shown that red snapper are density dependent. More importantly, unlike SEDAR 7, we incorporate the applicable fishing policies in our tuning process, to obtain more realistic estimations. That is, for each year we imposed the policies that were in effect for at year.

1. Data for red snapper

In BESS(GBFSM), red snappers are grown in total length (*TL*) in inches, converted to weight (*W*) in pounds, and then converted to weight sold in pounds. The length to weight relationship is the one used in the stock assessment SEDAR 7, Red Snapper Data Workshop Report, equation 1:

$$W = 0.00044*[(TL)^{3.056}]$$

The growth curves were derived by "eye-balling" the distribution of points in Figure 6 of Guillermo, Porch, and Ortiz (2004). The form of the growth equations used in the BESS(GBFSM) is:

$$TL = a[1- e^{b(\text{Age}-c)}].$$

In BESS(GBFSM), one cohort can be introduced every timestep, and each cohort can contain multiple sub-cohorts. In the case of red snapper, we have 12 timesteps a year, and 12 sub-cohorts in a cohort; thus there can be up to 144 sub-cohorts per year. Each sub-cohort has its growth curve, recruitment size, and number of fishes recruited. The coefficients of the growth equations for all sub-cohorts are given in Table RS1.

BESS(GBFSM) provides 3 recruitment models for researchers to choose. They are the Ricker model, the Beverton and Holt model, and the Gazey model, and all three of them are density dependent models. We select the Gazey model for our tuning process, because it is the simplest among the three, and it works the best with our data. The model in BESS(GBFSM) is:

$$R_{asdcs} = E_{skt}/(\alpha_\kappa * E_{skt} + \beta_\kappa),$$

where

R_{asdcs} is the age 0 recruits in area (*a*), for species (*s*), at depth (*d*), in cohort (*c*) and subcohort (*h*);

E_{skt} is the total number of eggs for species (*s*) and stock (*k*) in time period *t*;

α_κ and β_κ are respectively the density independent and density dependent parameters for stock *k*.

The distribution of recruitment by months is shown in Table RS2 and Figure RS2. The seasonal adjustment for recruitment by month is derived through "eye-balling" the graphs in Figure 2 in Gazey, Gallaway, Cole, and Fournier (2008). The initial size of recruits per sub-cohort and the

distribution of recruits among the sub-cohorts are shown in Table RS2 and Figure RS3. The growth curves are shown in Figure RS4 and are based on Figure 6 in Guillermo, Porch, and Ortiz (2004).

We consider four cases of natural mortalities in our calibration process, as shown in the Table RS3. Case 1 is used in SEDAR 7 and yield Shrimper Fishing Index of 1. Gazey, Gallaway, and Fournier (2008) have suggested that M_0 is much higher for red snapper and they estimated a value of $M_0 = 2.03$ and $M_1 = 1.25$. Wells, Cowan, Patterson, and Walters (2008) have estimated that M_0 could range from 2.6 to 11.0 depending on the circumstances; i.e., trawled or non-trawled and sand or shell. As the natural mortality of red snappers increases for age 0 and age 1 groups, from Case 1 to Case 4, the Shrimper Fishing Index decreases from 1 to 0.05926. This relationship suggests that the impacts of Shrimpers on red snapper fishing industry mitigates while the natural mortality of juvenile red snappers rises.

Table RS3. Natural Mortality by Age

Age	0	1	2+	A	Shrimper Fishing Index	Remark
Case 1	0.98	0.59	0.1	2.25	1	SEDAR 7, 2005
Case 2	2.03	1.25	0.1	0.71	0.36074	Gazey, Gallaway, and Fournier
Case 3	4	1.25	0.1	0.09	0.08519	Intermediate case
Case 4	7.665	1.25	0.1	0.05	0.05926	Wells, Cowan, Patterson, and Walters

Gazey, Gallaway, and Fournier report in their estimation that age-0 mortality exceeds 2.03 and age-1 mortality exceeds 1.25 at a probability of 95%. Consequently, we select Case 2 for the calibrating our model. In BESS(GBFSM), we adopt the definition:

$$Z = M + F,$$

where

Z is the total mortality,
M is a function of mortality rates and adjustment factors (by age),
F is a function of fishing effort, the catchability coefficient (q), and vulnerability indexes.

To get M at different ages, we first turn off fishing mortality, then select the appropriate mortality rates and adjustment factors (by age) that will give us the appropriate M at different ages.

Our model also provides evidence to the proposition that SEDAR 7 exaggerates Shrimpers impacts on red snapper fishing industry. By under estimating natural mortality for age 0 and age 1 fish, the SEDAR 7 assessment bears an over estimate of shrimp bycatch, which is the foundation of over severe policies for shrimpers.

A. 2. Calibrating Areas Fished

In this analysis, we decide to treat red snappers east and west of the Mississippi River as separate stocks. The commercial effort (Trips) and landings data are logbook data, provided by Jim Waters, NMFS Beaufort, and NC, for the period of 1993 to 2005. The recreational data are from

MRFSS, headboat and Texas Parks and Wildlife Department, and they are provided by Patty Phares, NMFS Miami, FL for the period of 1993 to 2002.

We define the period of 1993 to 2002 as our "historical" era, and use the generated data for this period to set up BESS(GBFSM). Considering the maximum age of red snappers of 35 years, we also adopt a "prehistoric" period (1935-1984) to get the old fishes in the model. Our data base is sufficient to generate a quasi prehistoric data set of the 1935-1984 period, and will be "used as a burn in to scale the model results", which is a procedure similar to that adopted by SEDAR9 Section III, Assessment Workshop Report. This prehistoric period allows us to "get the appropriate number of old fish in the model at the appropriate length and weight"[1]. Having done this we will calibrate the model to predict the historic period, 1985-2002. Once the model is calibrated we will be able to analyze realistic policy analysis beyond 2002. During our calibration, S/S_0 is above 0.5 in the east Gulf of Mexico, and 0.36 in the west Gulf of Mexico.

1. East Gulf of Mexico

We start the simulation in 1935 and introduce age 0 red snapper at a constant rate for two years. Then in 1937 we activate the stock recruitment relationship. We also use the appropriate management regulations in each year they were enforced. Figure RS5 shows the number of effective spawners, the number of fish that reach age 1 and the number of fish that reach age 2. The number of effective spawners reaches a maximum of about 1.3 million fish around 1972 in the east Gulf of Mexico. Figure RS6 shows that without any shrimp fishing mortality the maximum number of effective spawners would have reached approximately 1.35 million spawners in the east Gulf of Mexico.

Figure RS7 shows the effective spawners' numbers for no fishing effort by any vessel types compared with no fishing by individual vessel type in the east Gulf of Mexico by years. Figure RS8 shows recruit of age 2 red snappers under the same conditions. Notice that when recreational F=0 there is no drop in the curves in the 1980s. In Figure RS8 there is a severe drop in age 2 recruits in 1983 except when Recreational F=0. As shown in Figure RS7 commercial Handline fishermen have the second greatest impact on the effective number of spawners after 1982. Shrimpers, and Longliners have very little impact on the effective number of spawners in the east Gulf of Mexico. The decrease in effective number of spawners and age 2 recruits since 1995 is due to the recreational fishery.

The numbers of red snapper discarded by shrimp trawls, Longline, Handline, and recreation in the east Gulf of Mexico are shown in Figure RS9. The distribution of the bycatch of red snapper by shrimp vessels in the east Gulf of Mexico are shown in Figure RS10. This distribution is derived from onboard observer data for shrimp trawlers. We used the optimizing procedure in BESS (GBFSM) so that it would produce basically the same distribution.

Figure RS11 shows the total pounds landed of red snapper by all commercial and recreational fishermen in the east Gulf of Mexico. It also shows the total number of red snapper landed by recreation, because the actual pounds landed by recreation are not available before 1985. We choose annual adjustment factors for the catchability coefficients that reproduce close data to the

[1] Our model is and cohort model not a age structured model. We prefer this since actual sample data is in length of fish not age. Therefore we calibrate the model to the length of the fish and not the age of the fish. We keep track of the age of the fish and can report result by age, which we use actual age and not year-class age as does SEDAR 7.

actual landings for the prehistoric period. The model simulation results from 1985 to 2002 does a very good job of predicting the actual annual landings in pounds by commercial and recreational reef fish fishermen.

Figure RS12 shows the simulated and actual distribution of landings of red snapper by inch and vessel class in the east Gulf of Mexico. It should be pointed out that our concern is making sure that the model fits the length distribution and we are unconcerned with the age distribution. The reason is the length distribution is actual sampling data where as the age information produced by the SEDAR assessments has to estimate age for the length sampling data so that they can use their age-structured model. Ours is a cohort model and we keep track of results in both length and age and can report it either way.

Figures RS13 through RS16 show the results of calibrating the model for the average period 1993-2002. Figure RS13 shows the average annual simulated and actual landings of red snapper in the east Gulf of Mexico. Figure RS14 shows the average annual simulated and actual landings of red snapper by vessel classes in the east Gulf of Mexico. Figure RS15 shows the simulated and actual landings of red snappers by vessel class and year. It is easy to see that the charter and private recreational fishermen harvest the greatest landings. Figure RS16 shows the average monthly simulated and actual landings of red snapper by month and vessel class in the east Gulf of Mexico. All four figures show that BESS generate accurate simulations in the prehistoric era.

2. West Gulf of Mexico

Figure RS17 shows the number of effective spawners, the number of fish that reach age 1 and the number of fish that reach age 2. The number of effective spawners reaches a maximum of about 1.7 million fish around 1965 and declined to about 1.1 million fish by 2002 in the west Gulf of Mexico. Figure RS18 shows that without any shrimp fishing mortality the maximum number of effective spawners would have reached approximately 2.5 million spawners and declined to about 1.7 million fish by 2002 in the west Gulf of Mexico.

Figure RS19 shows the effective spawners' numbers for no fishing effort by any vessel types compared with no fishing by individual vessel type in the west Gulf of Mexico by years. Notice the shrimpers have to greatest impact on the effective number of spawners through the period. Handline fishermen have the second greatest impact however recreational fishermen have the same impact as Handline fishermen from 1985 to 1998. Longline fishermen are basically irrelevant in the west Gulf of Mexico. Figure RS20 shows recruit of age 2 red snappers under the same conditions. The recruitment of age 2 fish is most affected shrimp trawlers and second most by recreational fishermen. Handline fishermen have almost no impact on the recruitment of age 2 red snapper. The reason recreational fishermen impact recruitment age 2 recruitment and Handline fishermen don't is that recreational fishermen catch on average a smaller red snapper (Figure RS24).

The numbers of red snapper discarded by shrimp trawls, Longline, Handline, and recreation in the west Gulf of Mexico are shown in Figure RS21. The distribution of the bycatch of red snapper by shrimp vessels in the west Gulf of Mexico are as shown in Figure RS22. This distribution is derived from onboard observer data for shrimp trawlers. We used the optimizing procedure in BESS (GBFSM) so that it would produce basically the same distribution.

Figure RS23 shows the total pounds landed of red snapper by all commercial and recreational fishermen in the west Gulf of Mexico. It also shows the total number of red snapper landed by recreation, because the actual pounds landed by recreation are not available before 1985. We choose annual adjustment factors for the catchability coefficients that reproduce close data to the actual landings for the prehistoric period. The model simulation results from 1985 to 2002 does a very good job of predicting the actual annual pounds landings by commercial and recreational reef fish fishermen.

Figure RS24 shows the simulated and actual distribution of landings of red snapper by inch and vessel class in the west Gulf of Mexico. It should be pointed out that our concern is making sure that the model fits the length distribution and we are unconcerned with the age distribution. The reason is the length distribution is actual sampling data where as the age information produced by the SEDAR assessments has to estimate age for the length sampling data so that they can use their age-structured model. Ours is a cohort model and we keep track of results in both length and age and can report it either way.

Figures RS25 through RS28 show the results of calibrating the model for the average period 1993-2002. Figure RS25 shows the average annual simulated and actual landings of red snapper in the west Gulf of Mexico. Figure RS26 shows the average annual simulated and actual landings of red snapper by vessel classes in the west Gulf of Mexico. Figure RS27 shows the simulated and actual landings of red snappers by vessel class and year. Figure RS28 shows the average monthly simulated and actual landings of red snapper by month and vessel class in the west Gulf of Mexico. It is easy to see that the Handline fishermen with the 2000 pound endorsement harvest the largest pounds of red snapper in the west Gulf of Mexico then any other type fishing vessel. All four figures show that BESS generate accurate simulations in the prehistoric era.

Tables

Table RS1. Coefficients *a*, *b*, and *c* for the growth equation for each sub-cohort per timestep.

Subcohort	*a*	*b*	*c*
1	0.0158	31.5	0
2	0.0161	32.05	0
3	0.0163	32.6	0
4	0.0166	33.15	0
5	0.0168	33.7	0
6	0.0171	34.25	0
7	0.0173	34.8	0
8	0.0176	35.35	0
9	0.0178	35.9	0
10	0.0181	36.45	0
11	0.0183	37	0
12	0.0186	37.55	0

Table RS2. Seasonal distribution by month, initial size of recruits, and distribution of recruits among sub-cohorts.

Month/Sub-cohort	Distribution of seasonal recruitment	Initial size of new recruits in sub-cohort (inches)	Distribution of recruits among sub-cohorts
1	0	0.9685	0.0148
2	0	1.1654	0.0326
3	0	1.3622	0.0613
4	0	1.5591	0.0984
5	0	1.7559	0.1349
6	0	1.9528	0.158
7	0.1	2.1496	0.158
8	1	2.3465	0.1349
9	3	2.5433	0.0984
10	1	2.7402	0.0613
11	0	2.937	0.0326
12	0	3.1339	0.0148

B. 1. Graphical Results For Red Snapper in Area 1 (East Gulf)

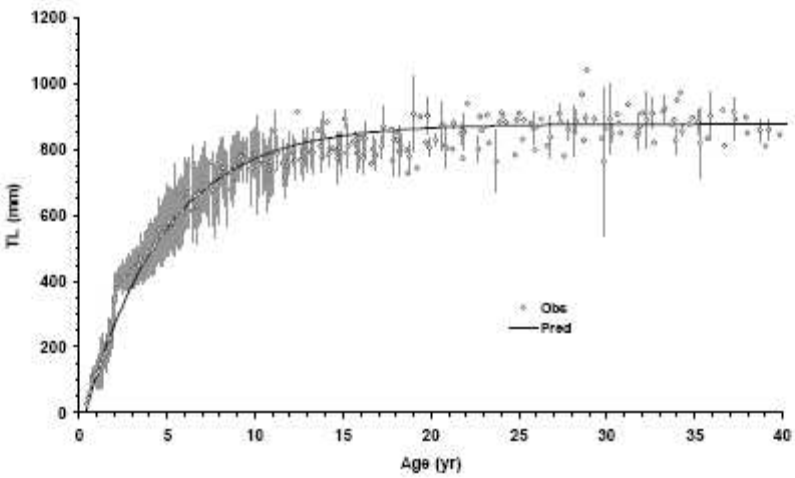


Figure 6: Observed average length-at-age of the landings and predicted length-at-age of the catch (all data sets combined). The von Bertalanffy growth parameters of the predicted curve are given in Table 1. Vertical lines around the observed average lengths correspond to the standard deviation.

Figure RS1. Source: Porch and Cass-Calay. 2001.

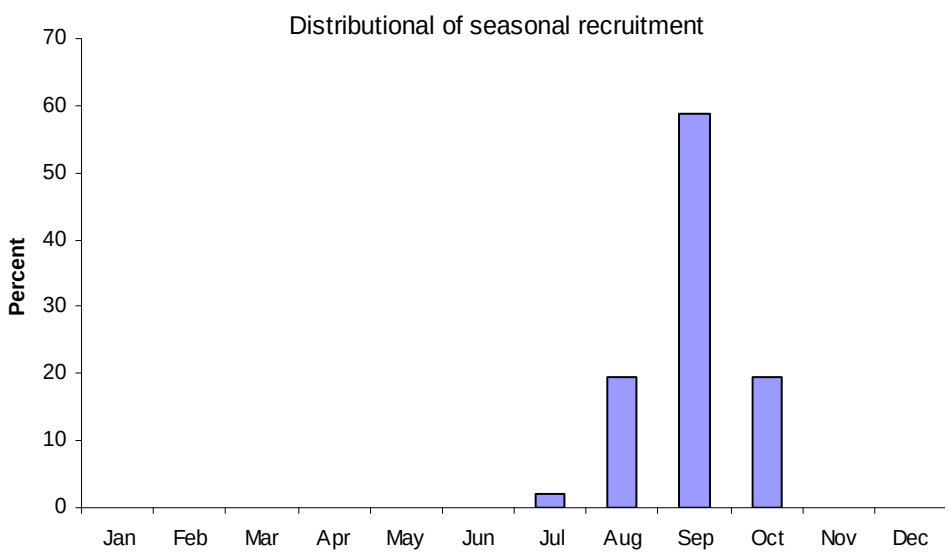


Figure RS2. Distribution of recruits by month.

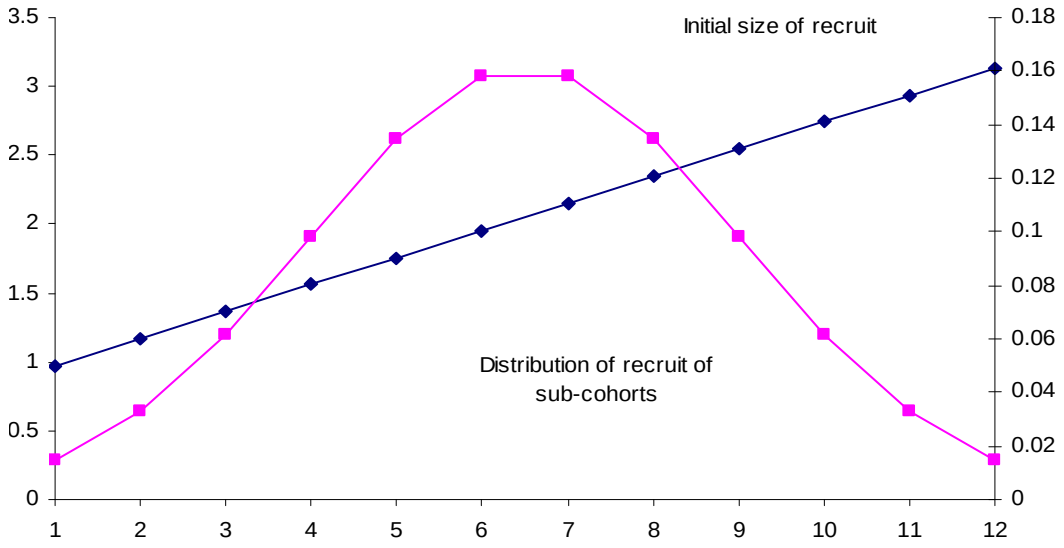


Figure RS3. Initial size of recruits and distribution of recruits among cohorts.

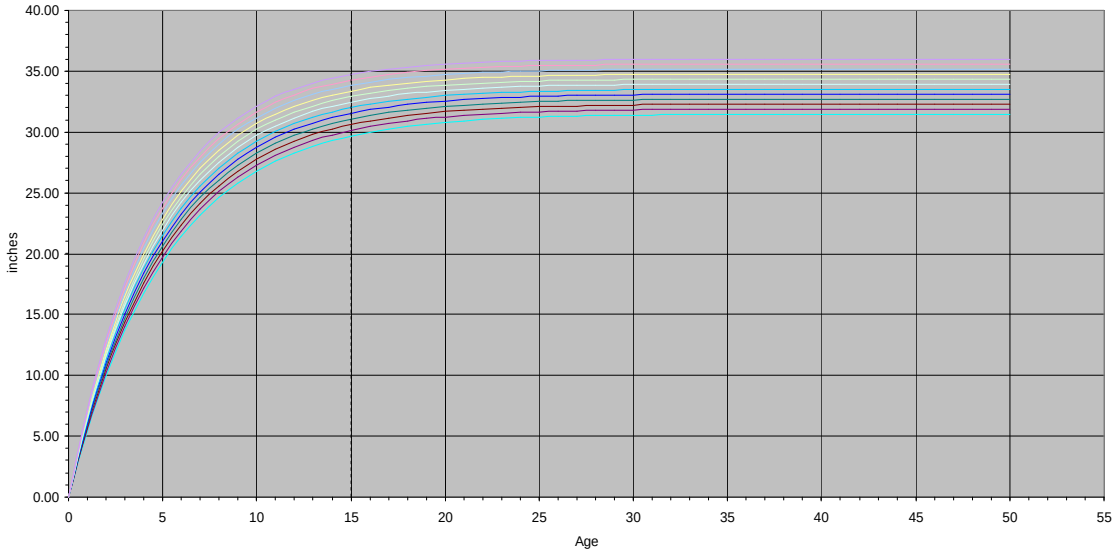


Figure RS4. Growth curves for red snapper sub-cohorts compared with Figure 6 from Porch and Cass-Calay (2001).

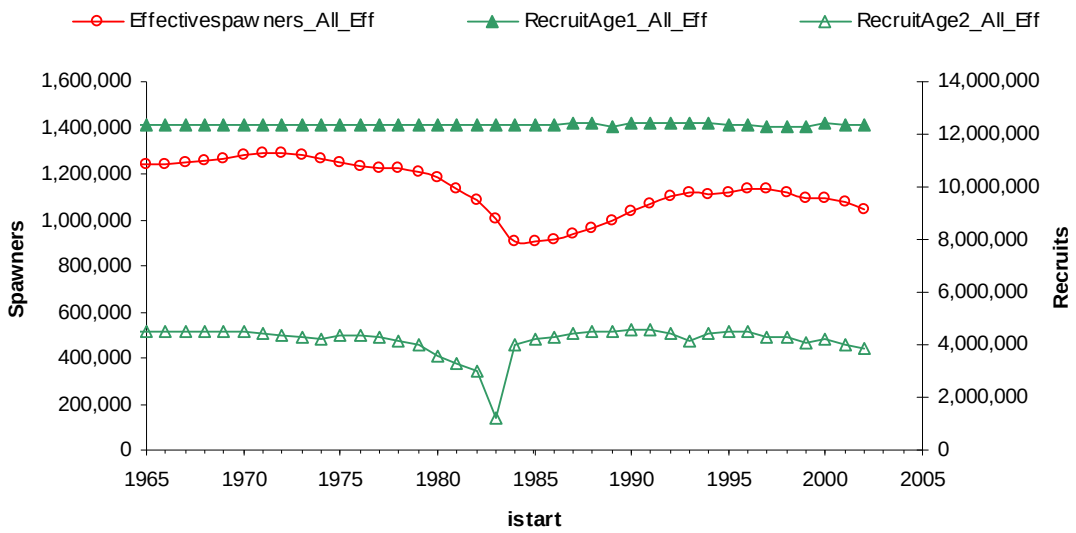


Figure RS5. Developing the prehistoric and historic stock in the red snapper fishery in the east Gulf of Mexico using BESS(GBFSM).

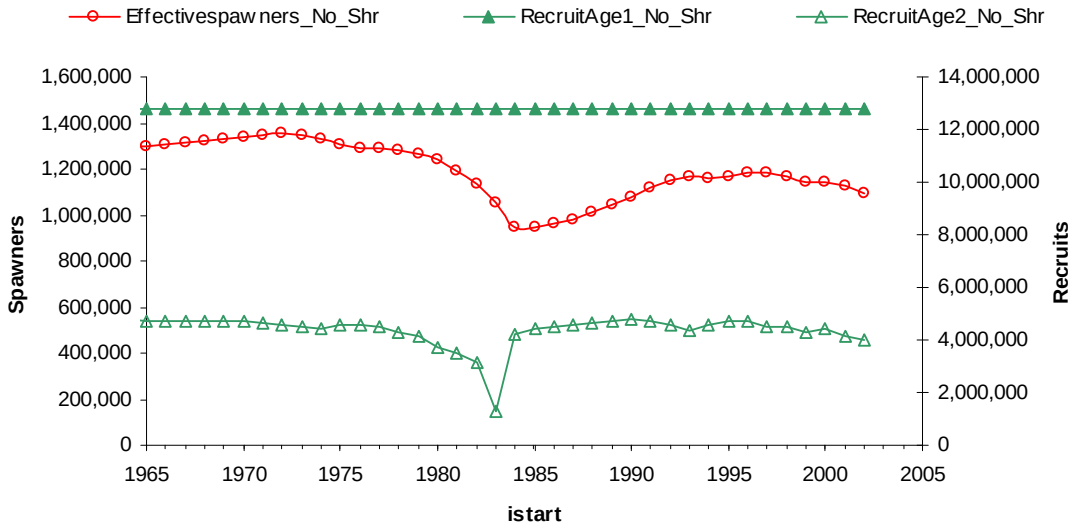


Figure RS6. Developing the prehistoric and historic stock in the red snapper fishery using BESS(GBFSM) without shrimping (i.e., F=0) east Gulf of Mexico.

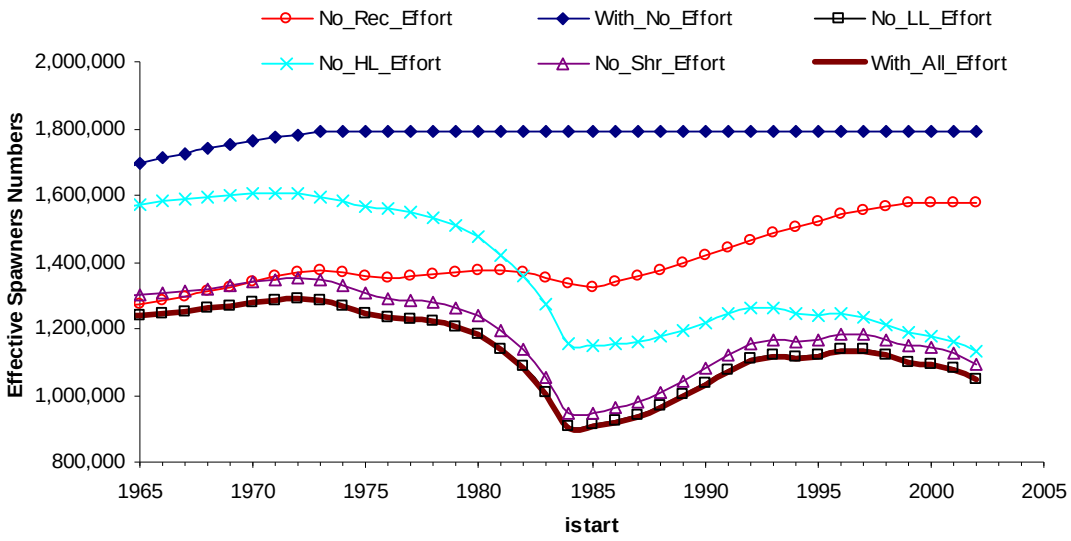


Figure RS7. Effective Spawners Numbers for no fishing effort by any vessel (all F=0) compared with no fishing by individual vessels in the east Gulf of Mexico by years.

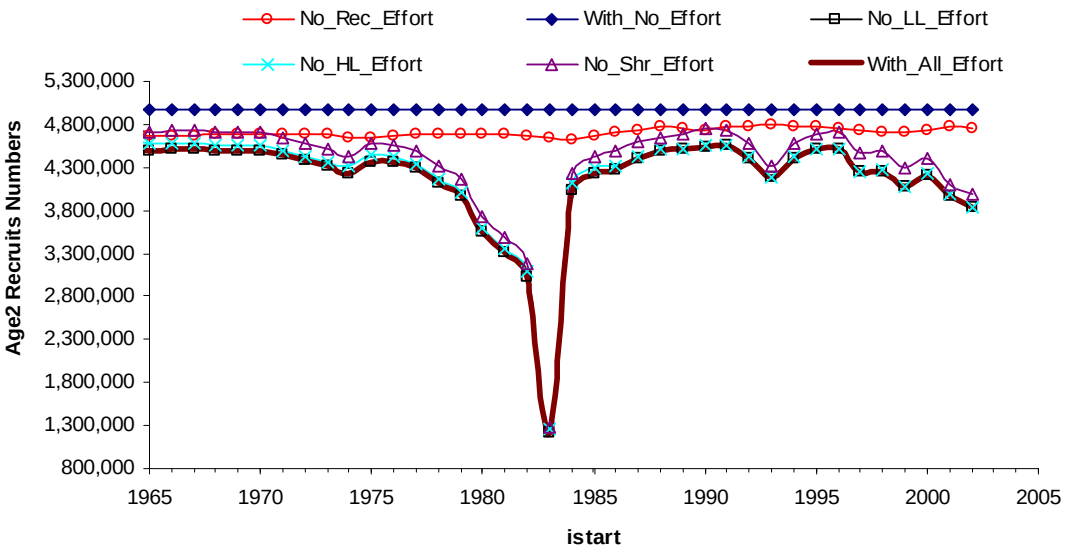


Figure RS8. Recruit of Age 2 Red Snapper for no fishing effort by any vessel (all F=0) compared with no fishing by individual vessels in the east Gulf of Mexico by years.

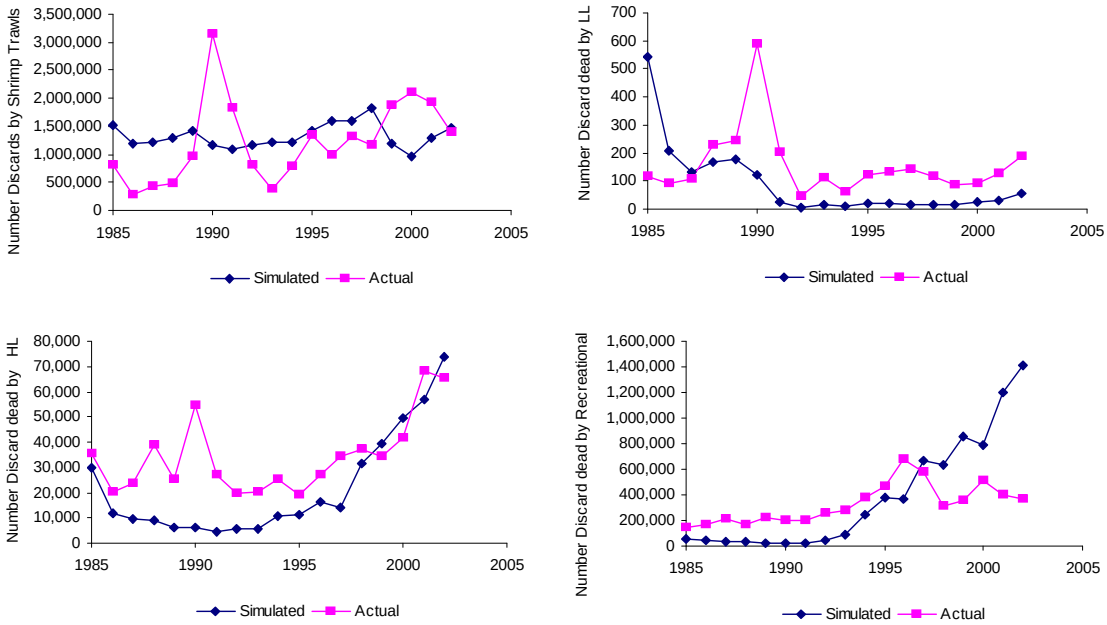


Figure RS9. Number of Discards by shrimp trawlers, handline, longline, and recreation using BESS(GBFSM) in the east Gulf of Mexico by years.

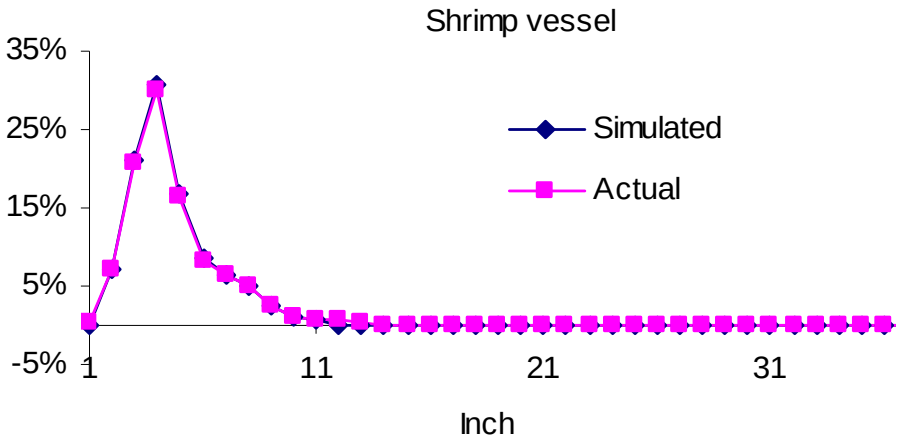


Figure RS10. Length frequency distribution of the bycatch of red snapper by the offshore shrimp fleet in the east Gulf of Mexico.

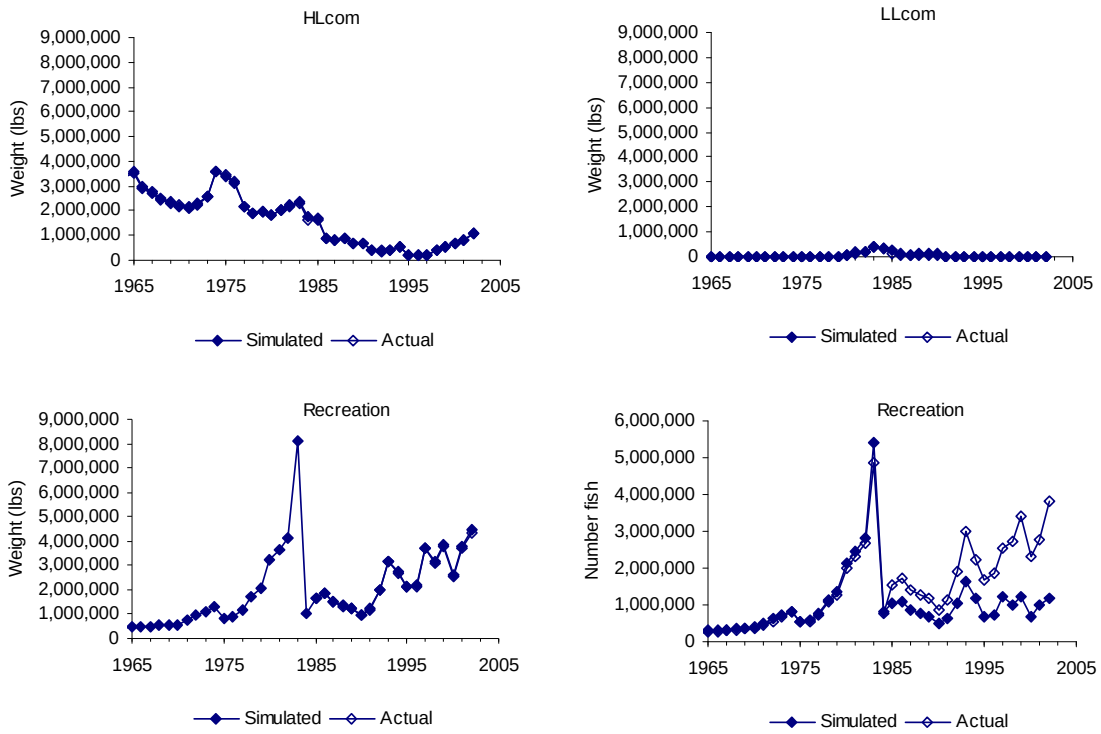


Figure RS11. Total pounds landed of red snapper by handline and longline commercial fishermen as well as pounds and numbers by recreation in the east Gulf of Mexico.

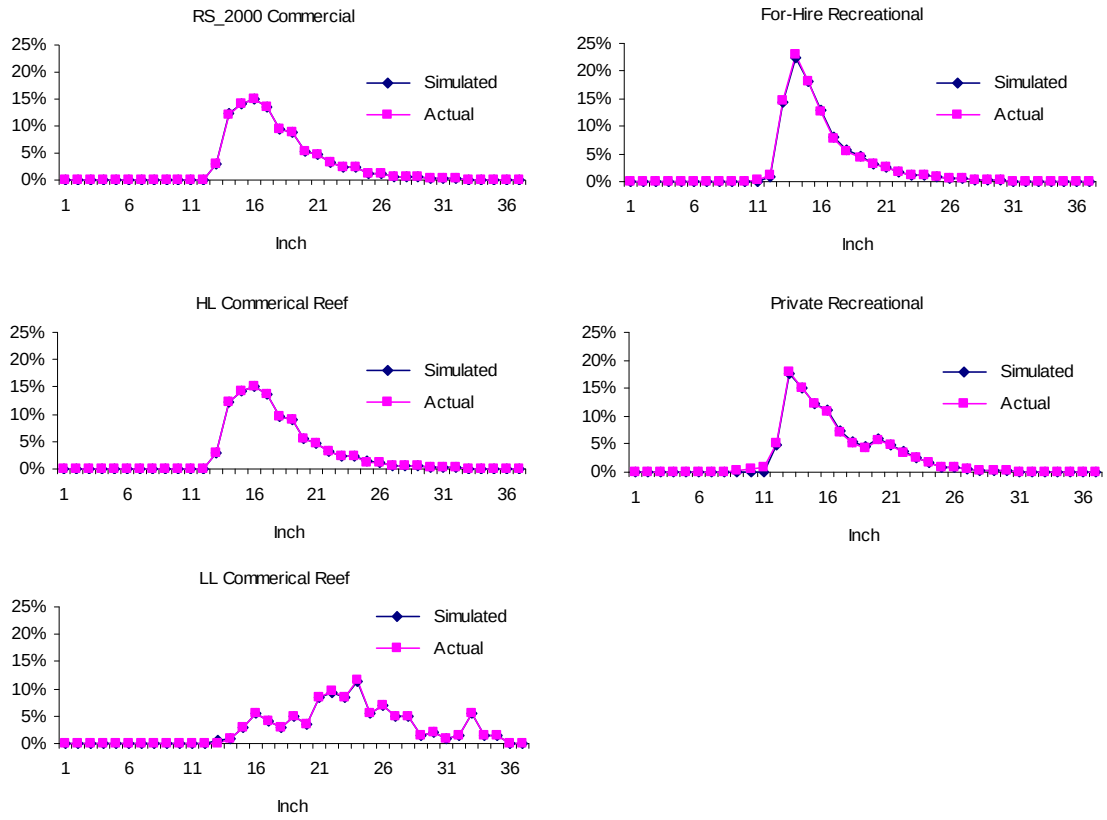


Figure RS12. Simulated and actual distribution of landings of red snapper by inch and vessel class in the east Gulf of Mexico.

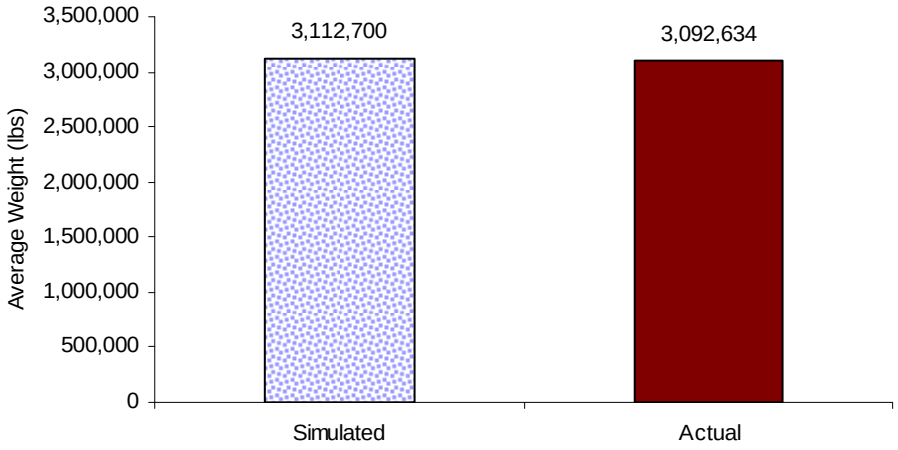


Figure RS13. Average 1993-2002 annual simulated and actual landings of red snapper by reef fish fishermen in the east Gulf of Mexico.

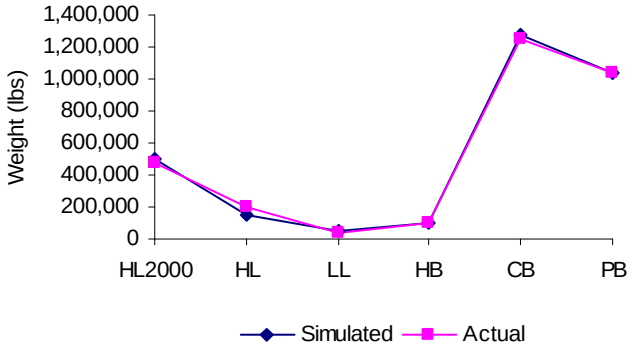


Figure RS14. Average 1993-2002 annual simulated and actual landings of red snapper by vessel class in the east Gulf of Mexico.

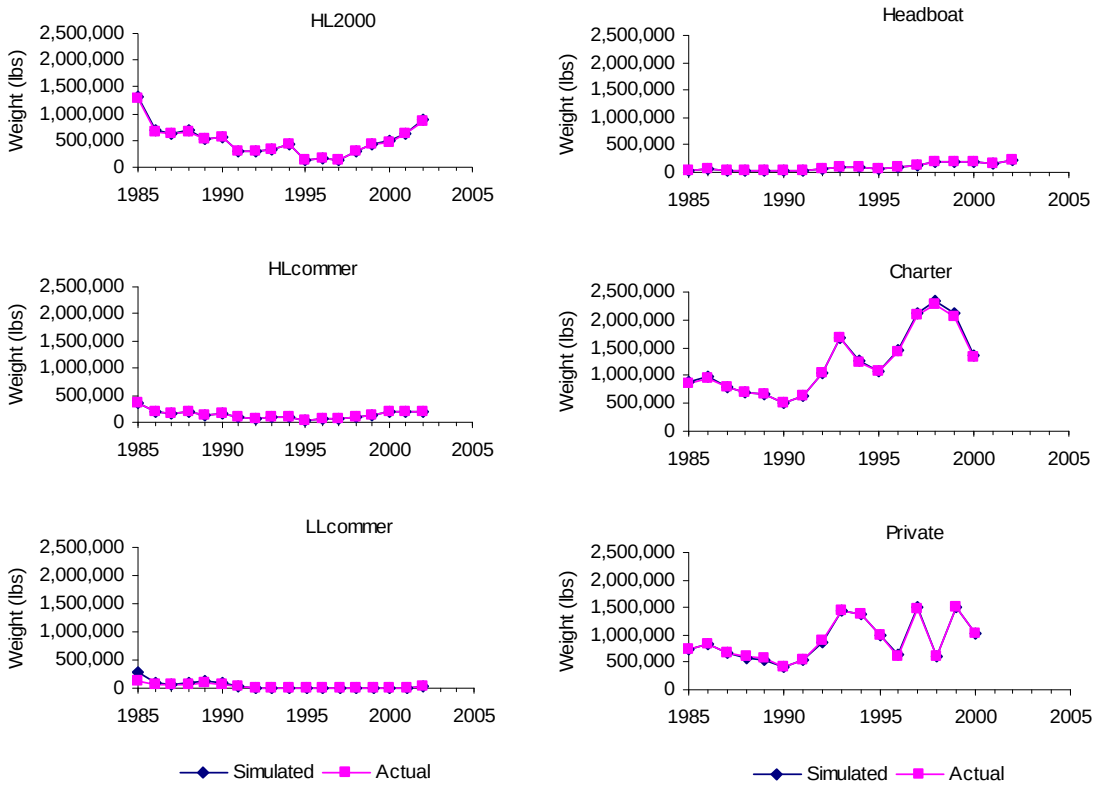


Figure RS15. 1993-2002 annual simulated and actual landings of red snapper by vessel class in the east Gulf of Mexico.

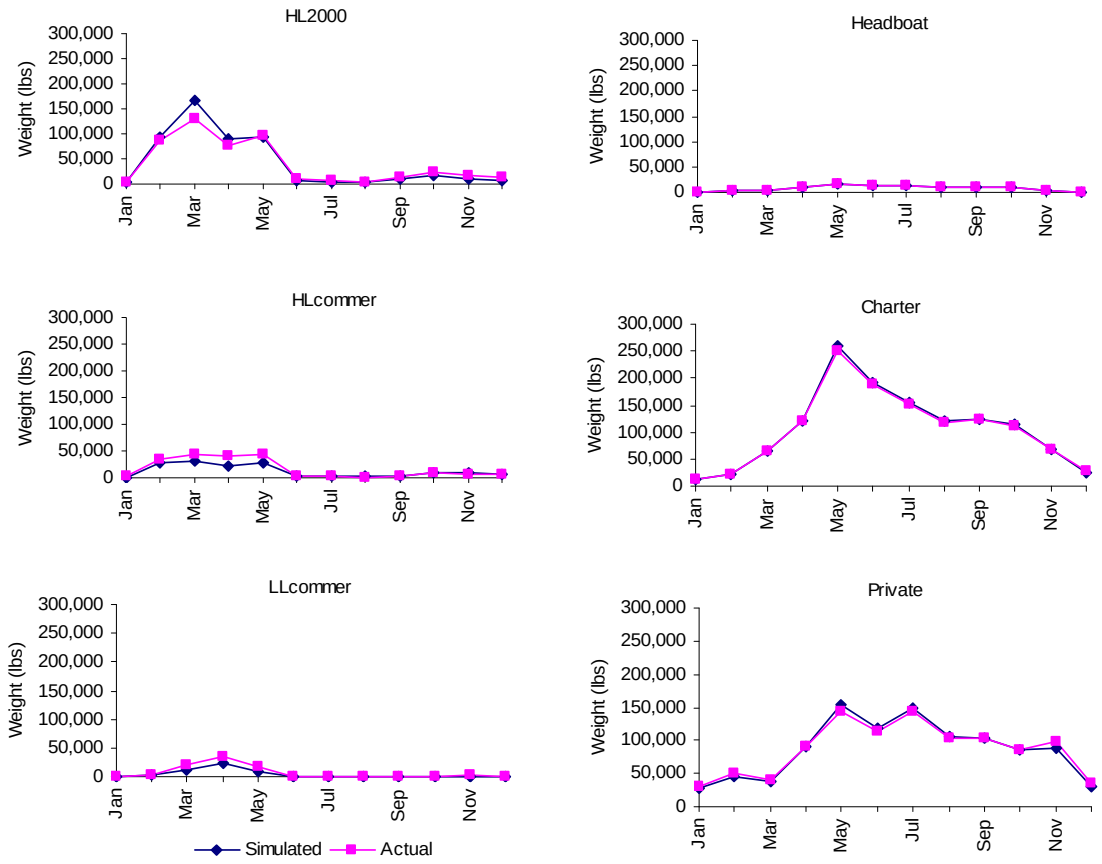


Figure RS16. Average 1993-2002 monthly simulated and actual landings of red snapper by month and vessel class in the east Gulf of Mexico.

C. 2. Graphical Results For Red Snapper in Area 2 (West Gulf)

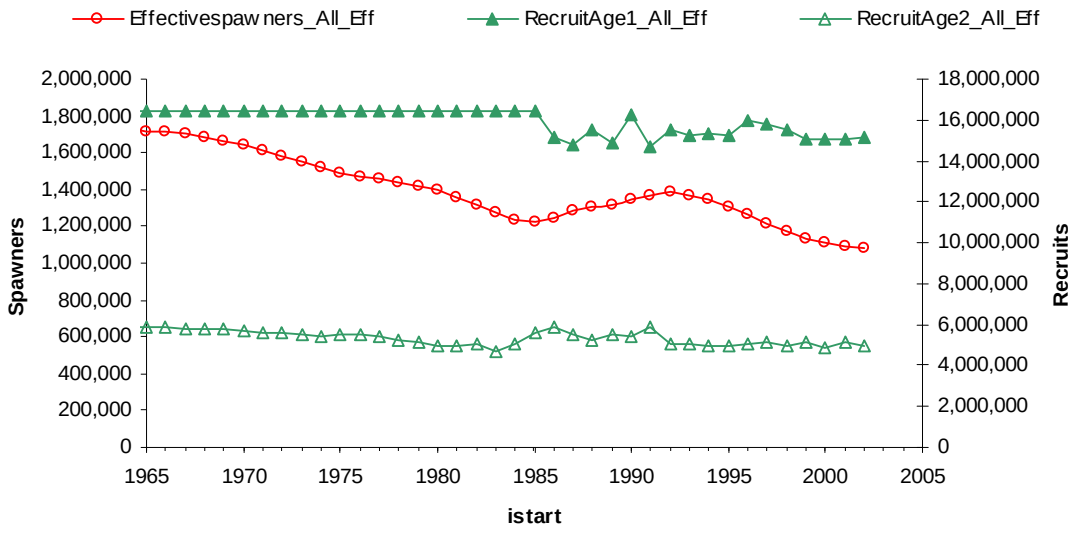


Figure RS17. Developing the prehistoric and historic stock in the red snapper fishery in the west Gulf of Mexico using BESS(GBFSM).

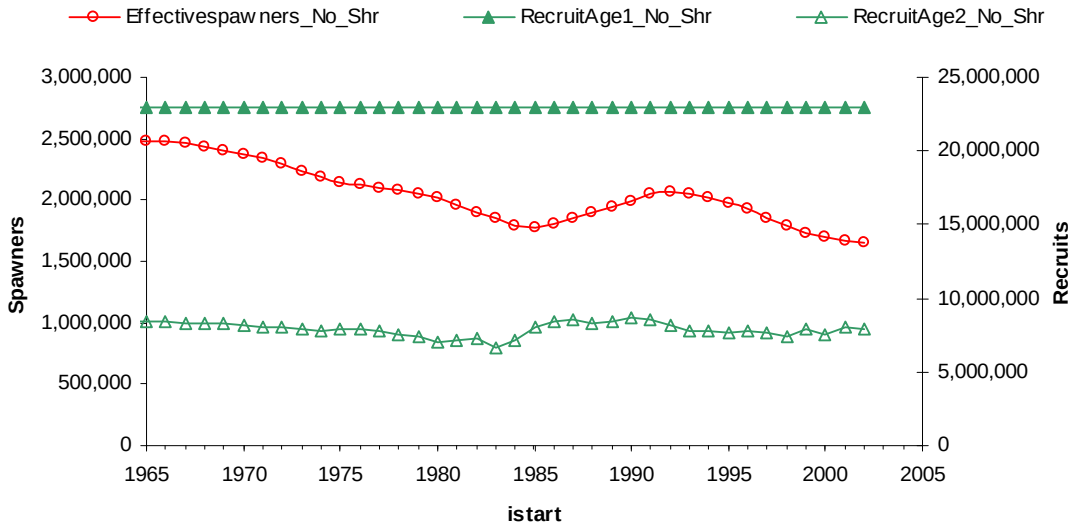


Figure RS18. Developing the prehistoric and historic stock in the red snapper fishery using BESS(GBFSM) without shrimping (i.e., F=0) west Gulf of Mexico.

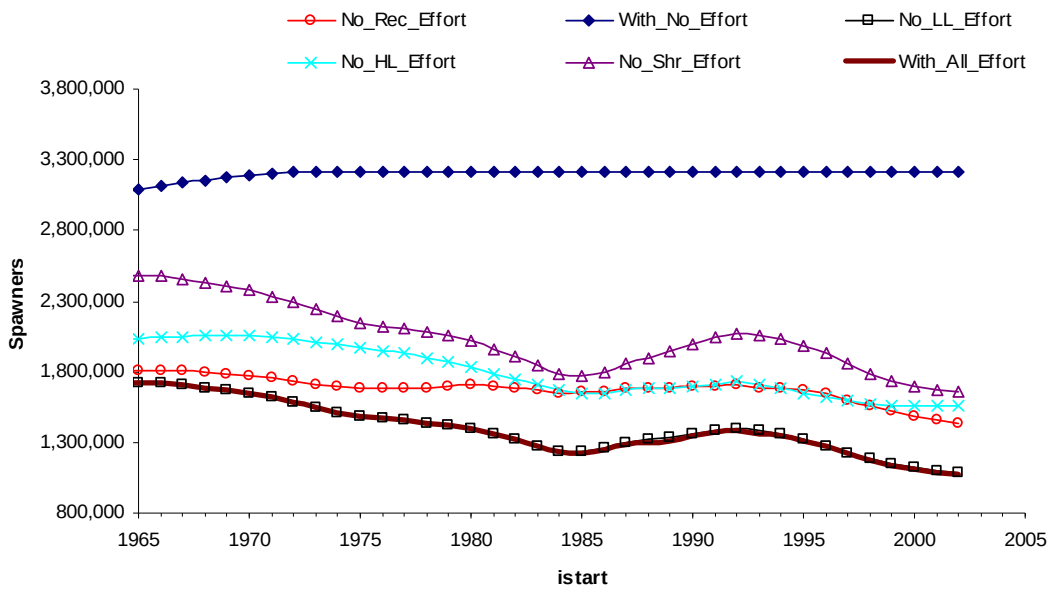


Figure RS19. Effective Spawners Numbers for no fishing effort by any vessel (all F=0) compared with no fishing by individual vessels in the west Gulf of Mexico by years.

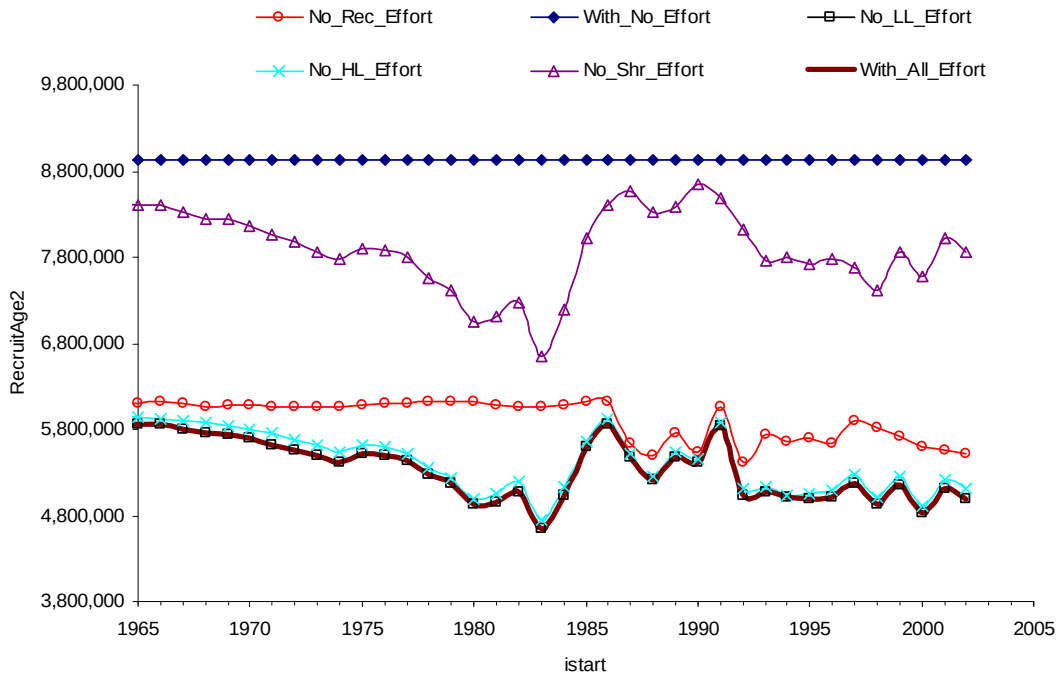


Figure RS20. Recruit of Age 2 Red Snapper for no fishing effort by any vessel (all F=0) compared with no fishing by individual vessels in the west Gulf of Mexico by years.

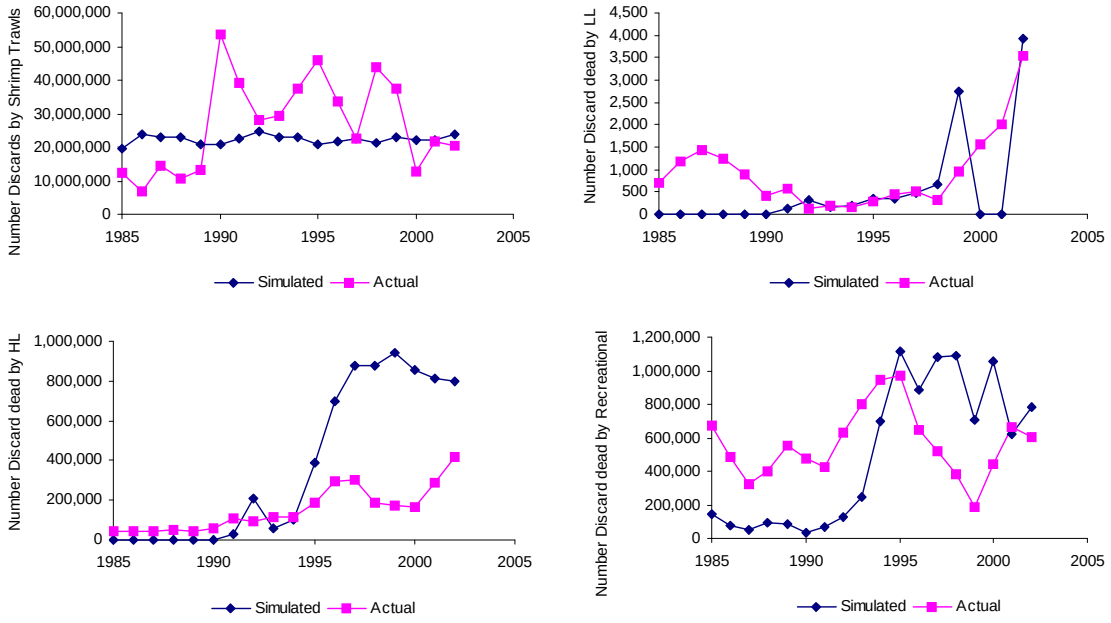


Figure RS21. Number of Discards by shrimp trawlers, handline, longline, and recreation using BESS(GBFSM) in the west Gulf of Mexico by years.

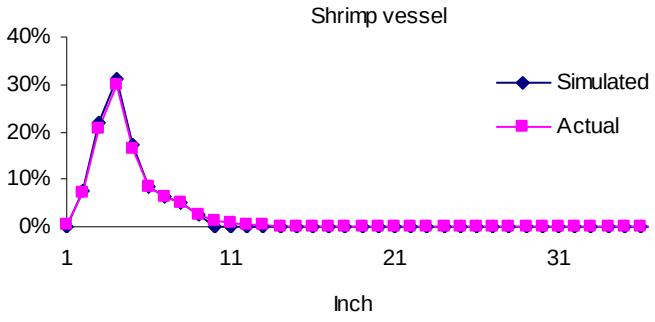


Figure RS22. Length frequency distribution of the bycatch of red snapper by the offshore shrimp fleet in the west Gulf of Mexico.

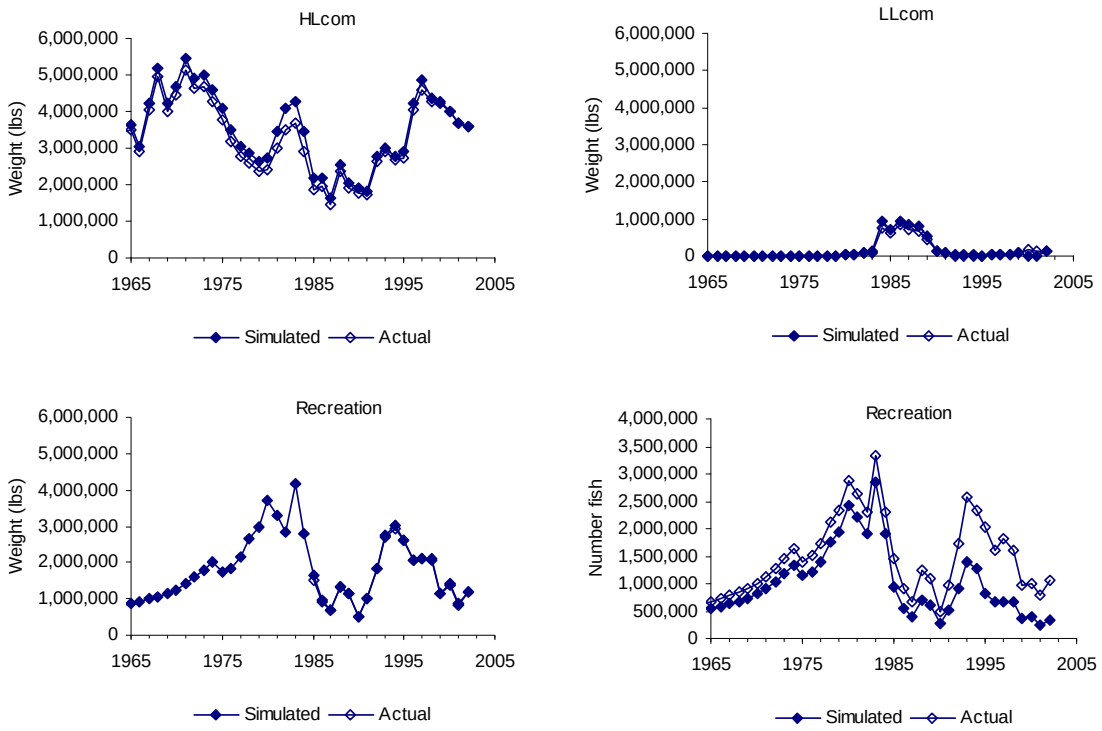


Figure RS23. Total pounds landed of red snapper by handline and longline commercial fishermen as well as pounds and numbers by recreation in the west Gulf of Mexico.

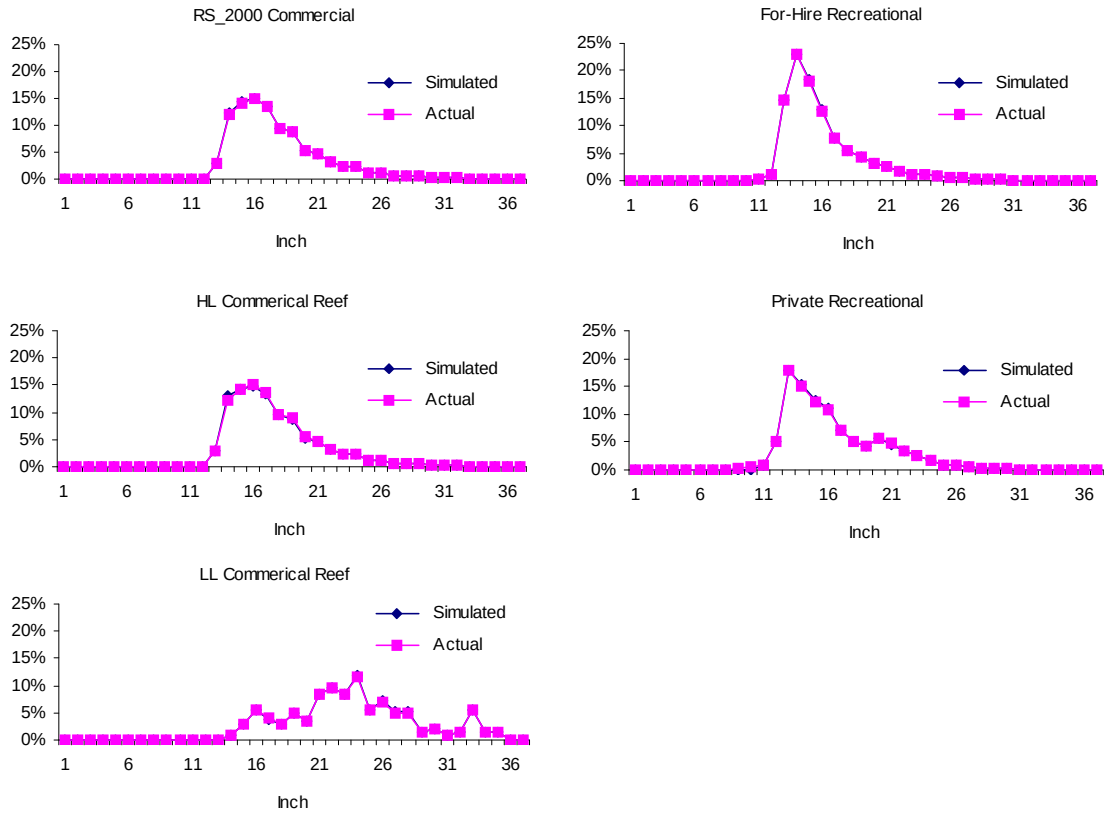


Figure RS24. Simulated and actual distribution of landings of red snapper by inch and vessel class in the west Gulf of Mexico.

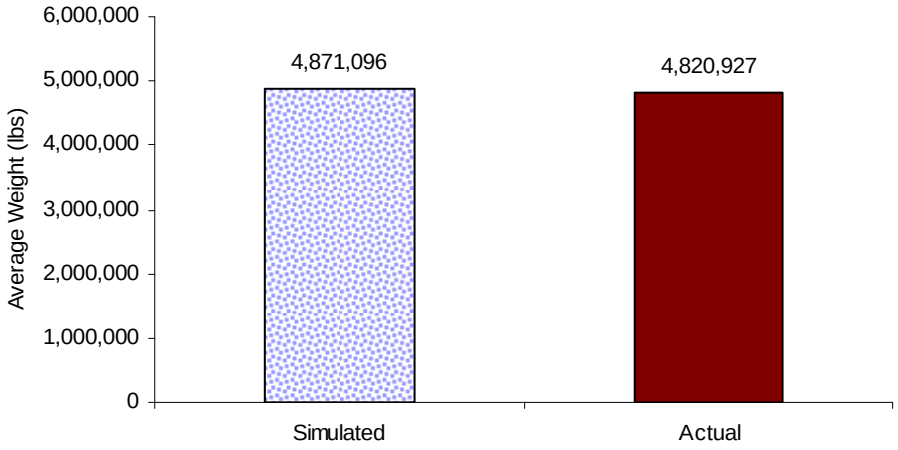


Figure RS25. Average 1993-2002 annual simulated and actual landings of red snapper by reef fish fishermen in the west Gulf of Mexico.

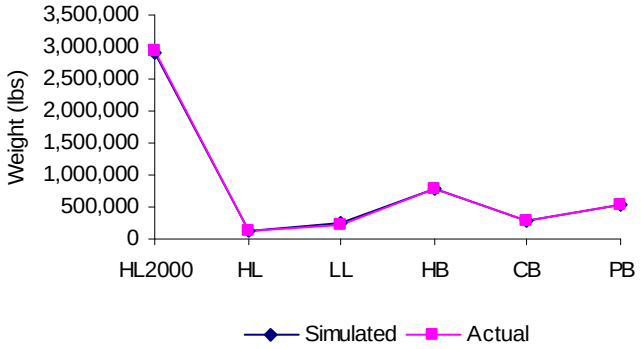


Figure RS26. Average 1993-2002 annual simulated and actual landings of red snapper by vessel class in the west Gulf of Mexico.

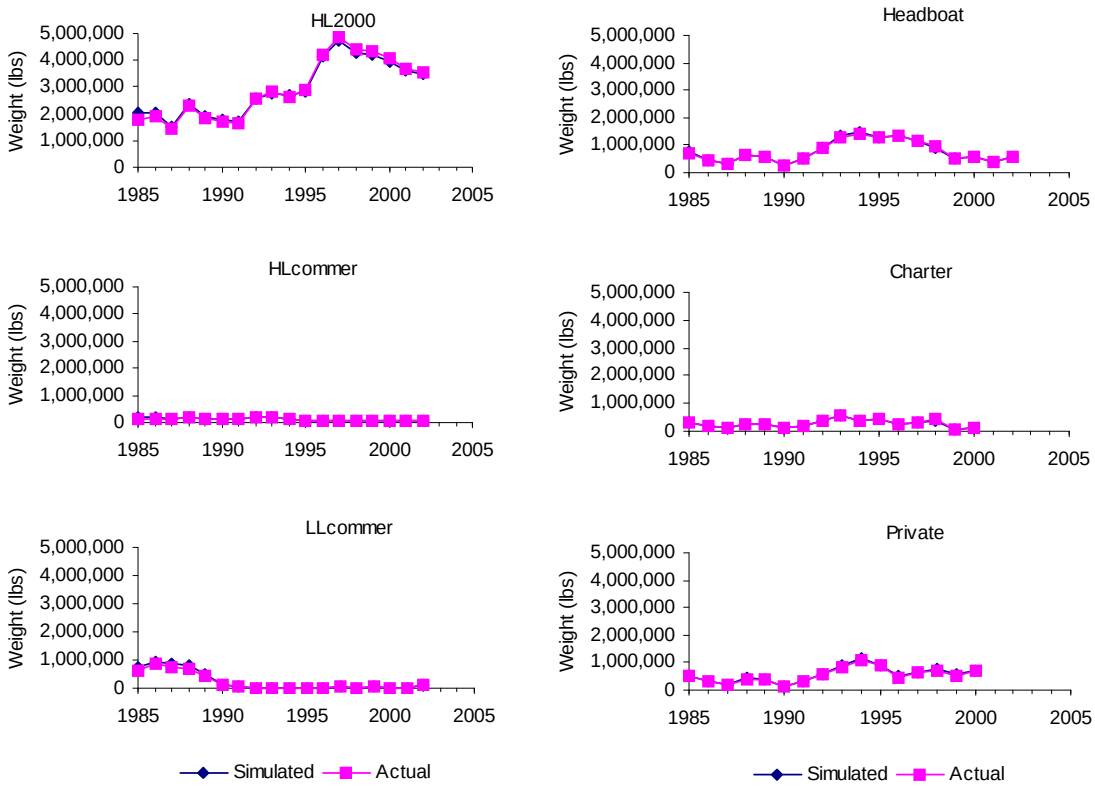


Figure RS27. 1993-2002 annual simulated and actual landings of red snapper by vessel class in the west Gulf of Mexico.

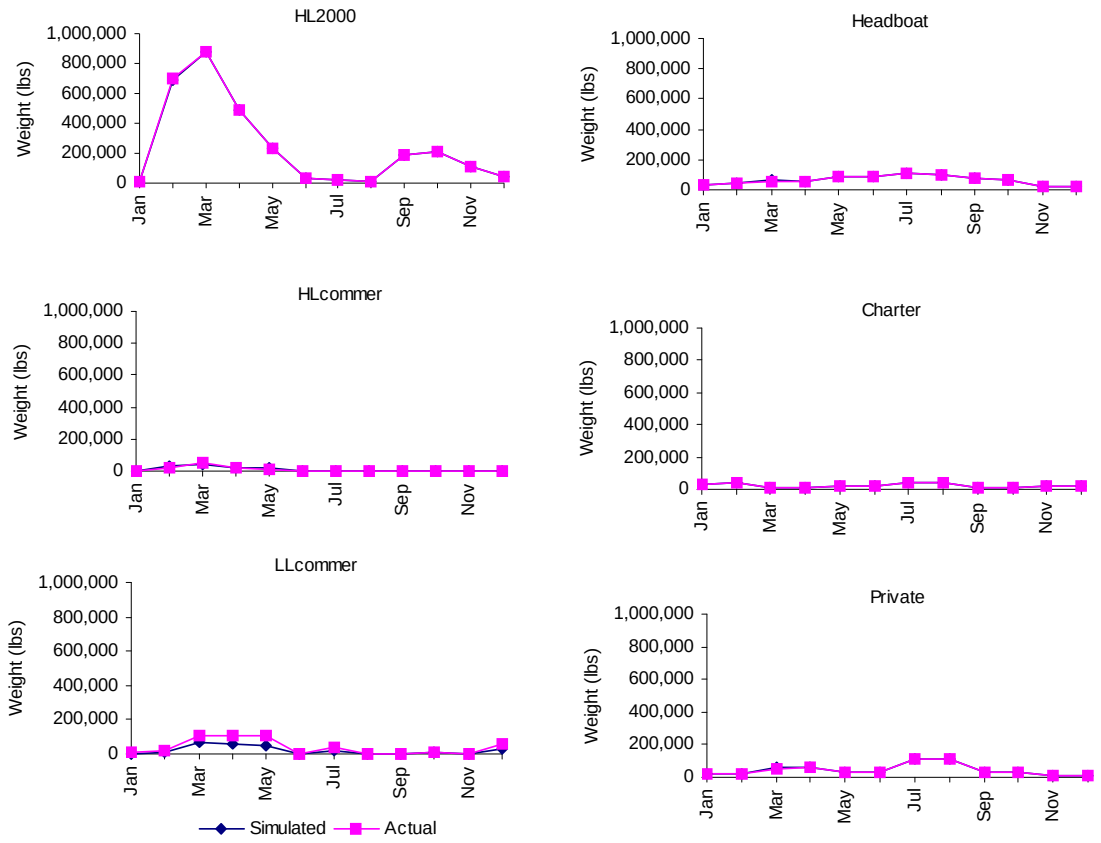


Figure RS28. Average 1993-2002 monthly simulated and actual landings of red snapper by month and vessel class in the west Gulf of Mexico.

IV. Calibration of biological model for vermilion snapper

A. 1. Data for vermilion snapper

The beginning of a year in the BESS(GBFSM) is January 1 since we are putting four different species in the same model. We use actual age for vermilion snapper rather than year class as does stock assessment 5 and the SEDAR9 assessment (Porch and Cass-Calay, 2001; SEDAR9, 2006).

In the BESS(GBFSM) vermilion snapper are grown in total length (*TL*) in inches, converted to weight (*W*) in pounds, and then converted to weight sold in pounds. The length to weight relationship is the one used in the stock assessment 5.0 (Porch and Cass-Calay, 2001) which is

$$W = 0.000595TL^{2.87}.$$

The growth curves were derived by "eye-balling" the distribution of points in Figure VS1 which is from Figure 4 of Porch and Cass-Calay (2001). The form of the growth equations used in the GBFSM was:

$$TL = a[1- e^{b(\text{Age-}c)}].$$

In the BESS(GBFSM) one cohort can be introduced each timestep where each cohort can have multiple sub-cohorts. For vermilion snapper we have 12 sub-cohorts; thus in a year with 12 timesteps there can be up to 144 sub-cohorts per year. Each sub-cohort then can have its own growth curve, recruitment size and number fish recruited. The coefficients for the growth equations for each sub-cohort are given in Table VS1.

BESS(GBFSM) can use one of 3 models which the researcher selects. There is Ricker model,the Beverton and Holt model and the Gazey model. All three are density dependent models. We chose the Gazey model because it is density dependent, it is simplest to use, and works extremely well. The model in BESS(GBFSM) is:

$$R_{asdcs} = E_{skt}/(\alpha_\kappa * E_{skt} + \beta_\kappa),$$

where R_{asdcs} is the age 0 by area (*a*), species (*s*), depth (*d*), cohort (*c*) and subcohort (*h*)recruits, E_{skt} is the total number of eggs for species (*s*) and stock (*k*) in time period *t*, eggs, α_κ and β_κ parameters for stock *k*.

The distribution of recruitment by months is shown in Table VS2 and Figure VS2. The seasonal adjustment for recruitment by month was taken from Table 2 in Lyczkowski-Shultz and Hanisko where we used the combined Bongo and Neuston samples lagged one month. The initial size of recruits per sub-cohort and the distribution of recruits among the sub-cohorts are shown in Table VS2 and Figure VS3. The growth curves are shown in Figure VS4 along with the growth curves of Porch and Cass-Calay (2001).

The natural mortality used in SEDAR9 and Porch and Cass-Calay (2001) for all ages was 0.25 yr^{-1}. It seems only logical that age 1 fish would have a higher natural mortality than age 2 and older fish and age 0 would be higher than age 1 fish. By under estimating natural mortality for age 0

and age 1 fish it will result in an over estimate of shrimp bycatch relative to the total number of age 0 and age 1 fish recruited into the fishery. Therefore, given no other guidance from the literature, we use a natural mortality for age 0 of 1.0 yr^{-1}, age 1 of 0.5 yr^{-1} and age 2 and above of 0.25 yr^{-1}. In the BESS(GBFSM) we use $Z = M + F$ where Z is total mortality, M is a function of mortality rates and adjustment factors (by age) and F is a function of fishing effort, the catchability coefficient (q), and vulnerability indexes. To get M at age, we turn off fishing mortality then select the appropriate mortality rates and adjustment factors (by age) that will give us the appropriate M at age.

B. 2. Calibrating Areas Fished

In this analysis we have chosen to treat vermilion snapper east and west of the Mississippi River as separate stocks. The commercial effort (Trips) and landings data is logbook data and was provided by Jim Waters, NMFS Beaufort, NC for the years 1993 to 2005. The recreational data is from MRFSS, headboat and Texas Parks and Wildlife Department and was provided by Patty Phares, NMFS Miami, FL for the period 1993 to 2002. So the data set used to calibrate the GBFSM was 1993 to 2002. Following the terminology of SEDAR 9, since we allow vermilion snapper to grow to a maximum age of 25, we needed a prehistoric (1935-1992) period to go with our greater historical data set (1993-2002) to get the old fish in the model and the model working properly. Through data found in SEDAR 9 we found annual data that was sufficient to generate a quasi prehistoric data set "used as a burn in to scale the model results" (SEDAR9 Section III. Assessment Workshop Report); or as we prefer to say, "get the appropriate number of old fish in the model at the appropriate length and weight"[2] so that realistic policy analysis can be conducted beyond 2002.

We start the simulation in 1935 and introduce age 0 vermilion snapper at a constant rate for two years. Then in 1937 we activate the stock recruitment relationship. We also use the appropriate management regulations in years they were enforced. The graphic results shown here is from 1965 to 2002. Little is known about vermilion snapper data prior to 1985 therefore the data in the graphs will be mostly constant from 1965 to 1984.

In Figure VS5 we show the effective number of spawners, the number of fish that reach age 1 and the number of fish that reach age 2. The number of effective spawners is about 1.015 million fish in 1965 in the eastern Gulf of Mexico. Figure VS6 shows that without any shrimp fishing mortality the maximum number of effective spawners would have reached approximately 1.56 million spawners in the eastern Gulf of Mexico. Notice in Figure VS5 that the number of effective spawners hit a local minimum in of about 0.65 million fish in 1995 and then began to increase. Without any shrimp effort the still hit a low of about 0.85 million fish.

Figure VS7 shows the effective spawners' numbers for no fishing effort by any vessel types compared with no fishing by individual vessel type in the east Gulf of Mexico by years. Figure VS8 shows recruit of age 2 vermilion snappers under the same conditions. It is obvious that shrimp have the greatest impact on the effective number of spawners and the number of fish that

[2] Our model is and cohort model not a age structured model. We prefer this since actual sample data is in lenget of fish not age. Therefore we calibrate the model to the length of the fish and not the age of the fish. We keep track of the age of the fish and can report result by age, which we use actual age and not year-class age as does SEDAR 9.

reach age 2. Because the low natural mortality used in the model for age 0 and age 1, the shrimp effort may appear much more important than it actually is. For the directed fishery, the commercial HL and recreational fishermen both cause a decrease in the effective number of spawners; however beginning in 1994 commercial HL have a greater impact then recreational fishermen. Commercial LL basically has no impact on the effective number of spawners.

The number of vermilion snapper bycatch by Gulf shrimpers is shown in Figure VS9. The distribution of the bycatch of vermilion snapper by shrimp vessels are as shown in Figure VS10. This distribution is from Figure 14 in Porch and Cass-Calay (2001). There distribution is in fork length (FL) which we converted to TL. We produce the same bimodal distribution with BESS(GBFSM).

Figure VS11 shows the total pounds landed of vermilion snapper by all commercial and recreational fishermen and total number landed by recreational fishermen in the east Gulf of Mexico. The actual weight data for recreational fisherman is available since 1985. Up until 2002 the model will seem to fit perfectly since we are choosing annual catchability coefficients that will reproduce the actual landings for the prehistoric period and the historic period; that is we are burning in to scale the model results. The model simulation results does a very good job of predicting the actual annual landings by commercial and recreational reef fish fishermen.

Figure VS12 shows the simulated and actual distribution of landings of vermilion snapper by inch and vessel class in the east Gulf of Mexico. It should be pointed out that our concern is making sure that the model fits the length distribution and we are unconcerned with the age distribution. The reason is the length distribution is actual sampling data whereas the age information produced by the SEDAR assessments have to estimate age for the length sampling data so that they can use their age-structured model.

Figures VS13 through VS16 show the results of calibrating the model for the average period 1993-2000 in the east Gulf of Mexico. As can be seen in these graphs the BESS(GBFSM) does a very good job of simulation the actual data.

Figure VS17 shows the effective number of spawners, the number of fish that reach age 1 and the number of fish that reach age 2. The number of effective spawners is about 0.94 million fish from 1965 to 1979 and then drop to about 0.75 million since 1992 in the western Gulf of Mexico. Age 1 recruits and age 2 recruits remain fairly constant before 1986 at 7.7 million and 4.1 million, respectively.

Figure VS18 shows that without any shrimp fishing mortality the maximum number of effective spawners is just under 1.4 million spawners in the western Gulf of Mexico. Without shrimp effort the age 1 recruits would increase about 2.3 million fish and the age 2 fish would have increased about 1.9 million fish. We would caution however that we don’t know what the natural mortality is for the age 0 and age 1 vermilion and that a higher natural mortality for these age levels would decrease the impact that shrimpers have on the effective number of spawners.

Figure VS19 shows the effective spawners’ numbers for no fishing effort by any vessel types compared with no fishing by individual vessel type in the west Gulf of Mexico by years. Figure VS20 shows recruit of age 2 vermilion snappers under the same conditions. For the directed fisheries the commercial HL fishermen have some impact on the effective numbers after 1984. Commercial LL and recreational fisheries have no impact on the effective number of spawners. Commercial HL, LL and recreational fisheries have no impact on age 2 recruits.

The number of vermilion snapper bycatch by Gulf shrimpers is shown in Figure VS21. The distribution of the bycatch of vermilion snapper by shrimp vessels are as shown in Figure VS22. This distribution is from Figure 14 in Porch and Cass-Calay (2001). Their distribution is in fork length (FL) which we converted to TL. We produce the same bimodal distribution with BESS(GBFSM). We produce the same bimodal distribution with BESS(GBFSM).

Figure VS23 shows the total pounds landed of vermilion snapper by all commercial and recreational fishermen and total number landed by recreational fishermen in the west Gulf of Mexico. The actual weight data for recreational fisherman is available since 1985. In the figure for the commercial HL the simulated data is greater than the actual data. This actual data come from Table 2.2 of the SEDAR 9 Data Workshop Report I Vermilion Snapper. The data which we calibrated the model comes from the commercial logbook data (see Figure VS27 below).

Figure VS24 shows the simulated and actual distribution of landings of vermilion snapper by inch and vessel class in the west Gulf of Mexico. It should be pointed out that our concern is making sure that the model fits the length distribution and we are unconcerned with the age distribution. The reason is the length distribution is actual sampling data where as the age information produced by the SEDAR assessments has to estimate age for the length sampling data so that they can use their age-structured model.

Figures VS25 through VS28 show the results of calibrating the model for the average period 1993-2000 in the west Gulf of Mexico. As can be seen in these graphs the BESS(GBFSM) does a very good job of simulation the actual data.

C. 3. Calibration of Cost and Revenue 1993-2005

The figures below (C&R1-C&R6) are the result of calibrating GBFSM for costs and revenue for the period 1993 to 2005. Actual effort is read in as is actual unit cost and prices by year. After calibrating the biological model of GBFSM, we run the model through 1992 and write out the write the biological information into files. Now we can begin the model in 1993 by reading in the biological information that was stored and the end of 1992. We then run the model from 1993 to 2005 to calibrate the cost and revenue data. After being satisfied that the model is working properly we write out the biological information at the end of 2005. Our policy analysis will begin in 2006 and we will use the actual yearly policies for 2006, 2007 and 2008. The actual policy analysis will be for the period 2009 through 2032.

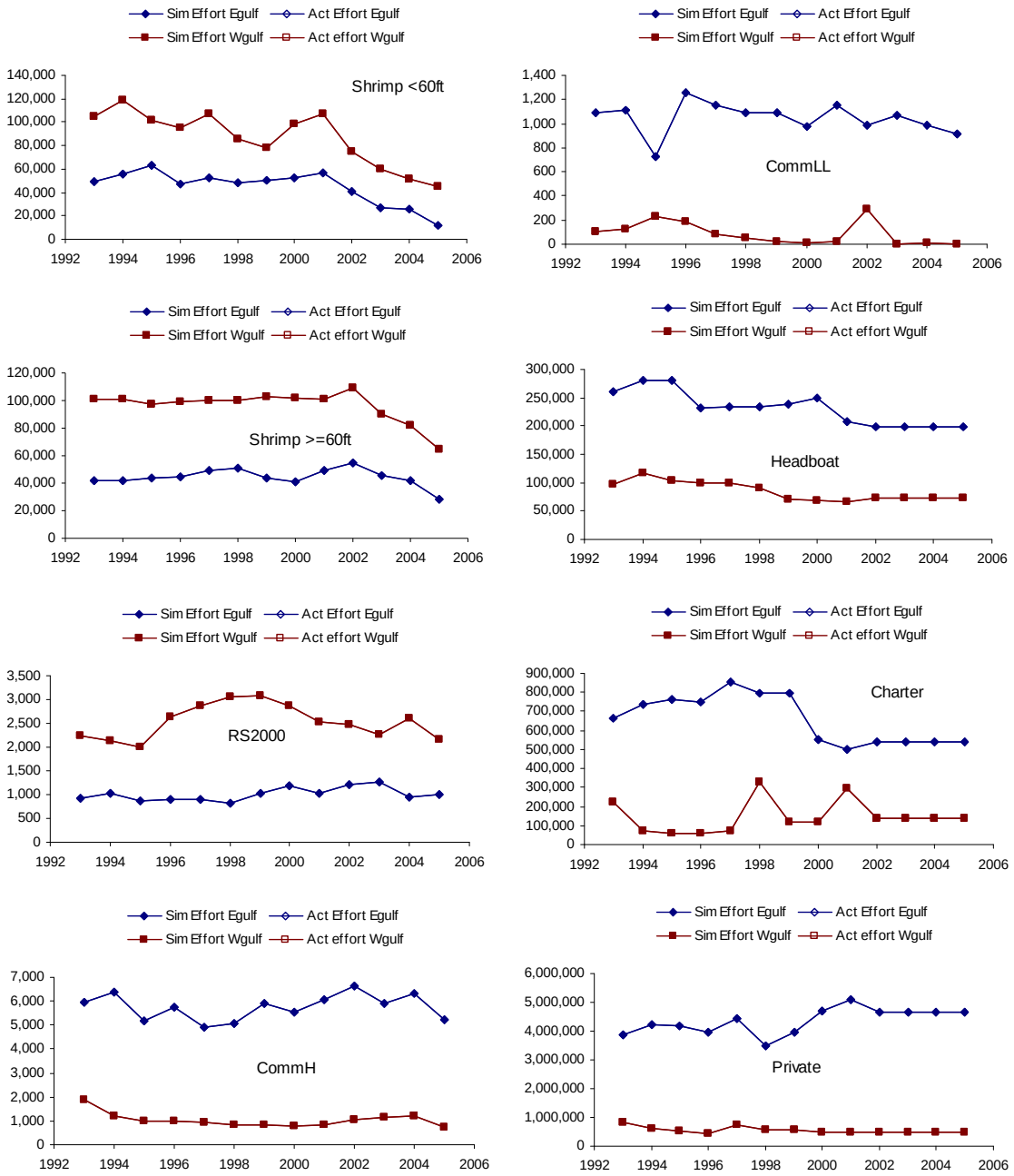


Figure C&R1. These Figures are a comparison of effort by vessel class and east and west gulf for the period 1993-2005.

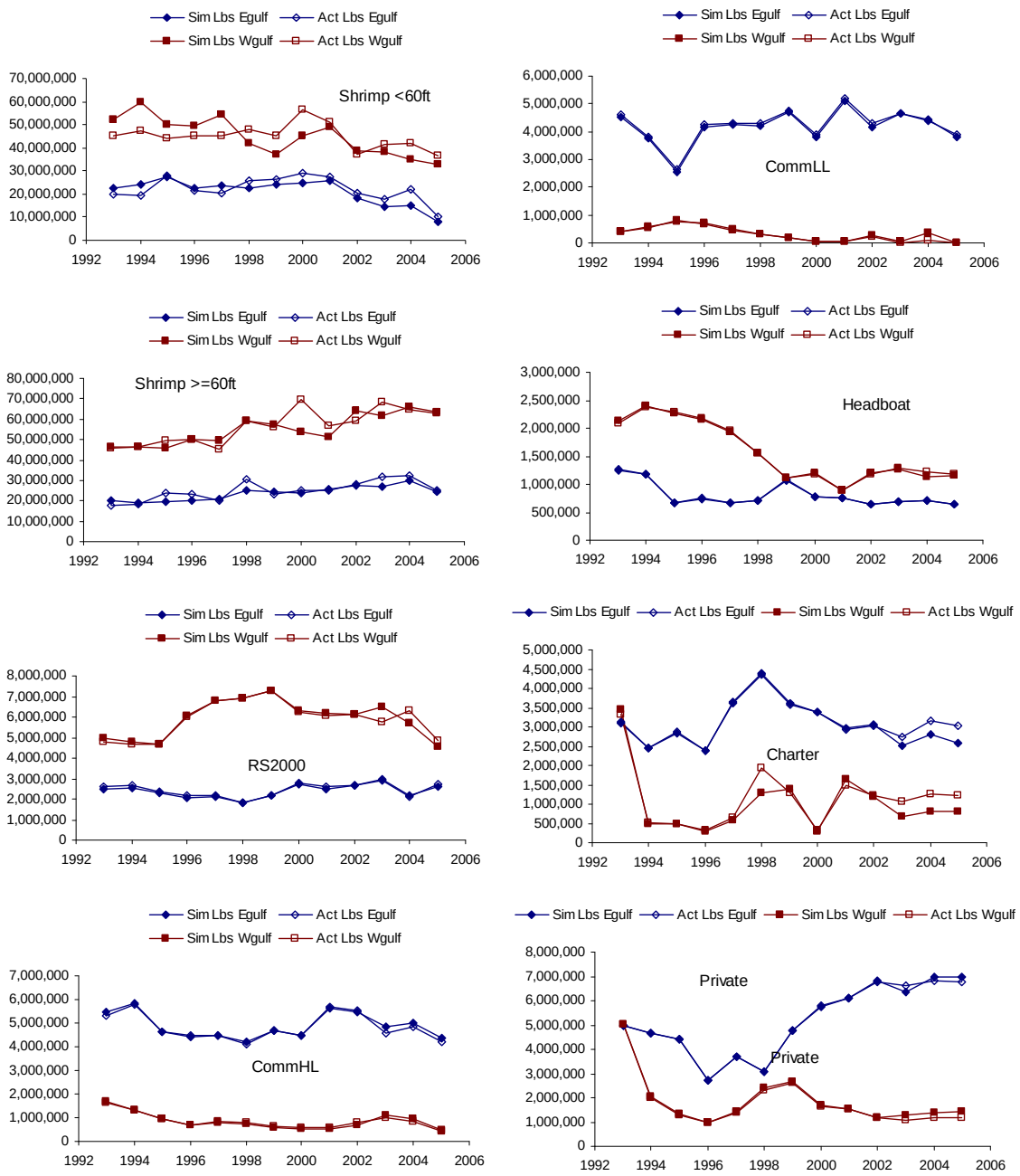


Figure C&R 2. Comparison of pounds landed by vessel class and east and west gulf for the period 1993-2005.

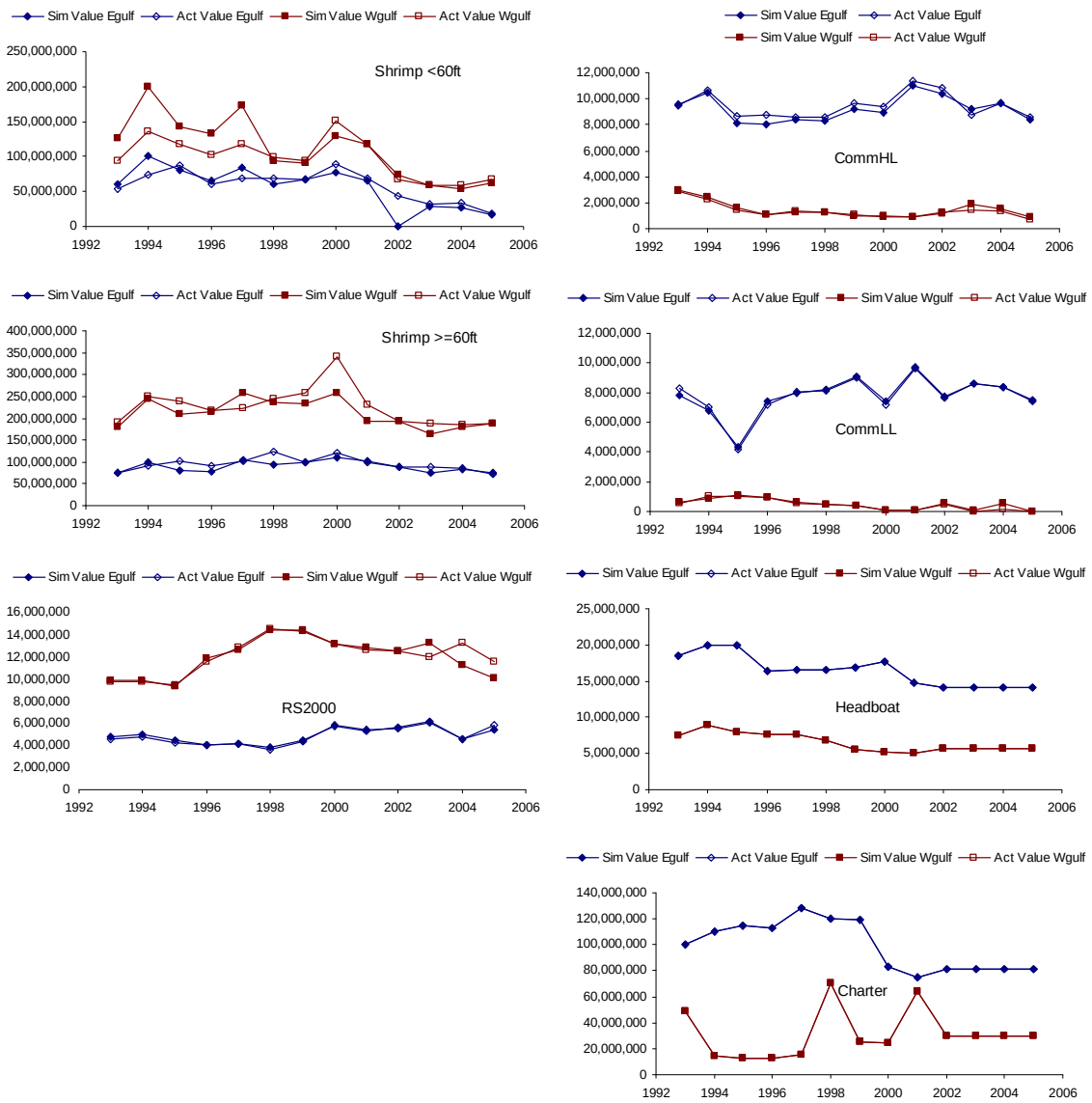


Figure C&R 3. Comparison of revenue by vessel class and east and west gulf for the period 1993-2005.

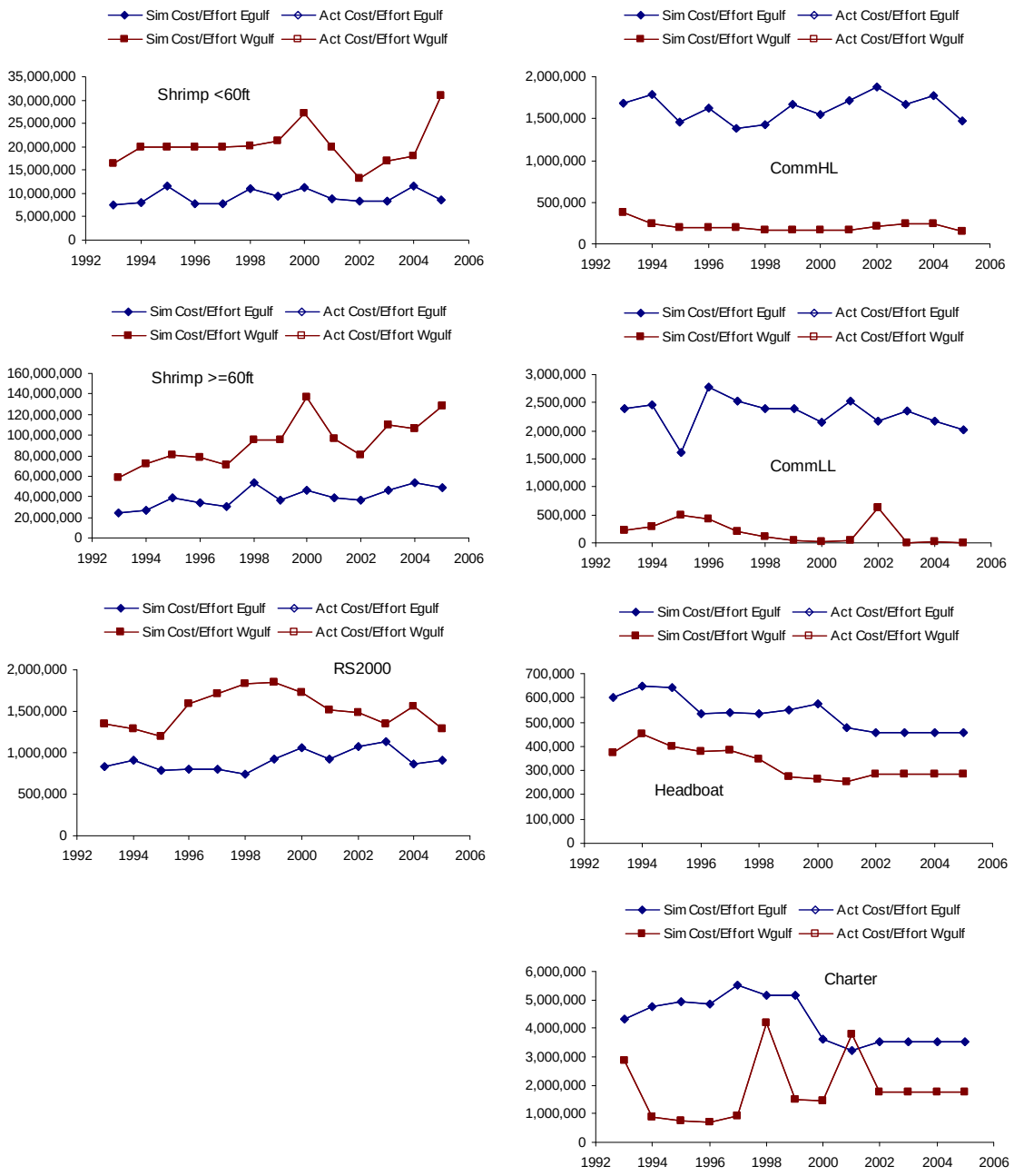


Figure C&R 4. Comparison of variable effort cost by vessel class and east and west gulf for the period 1993-2005. This excludes fuel costs and shares of the crew.

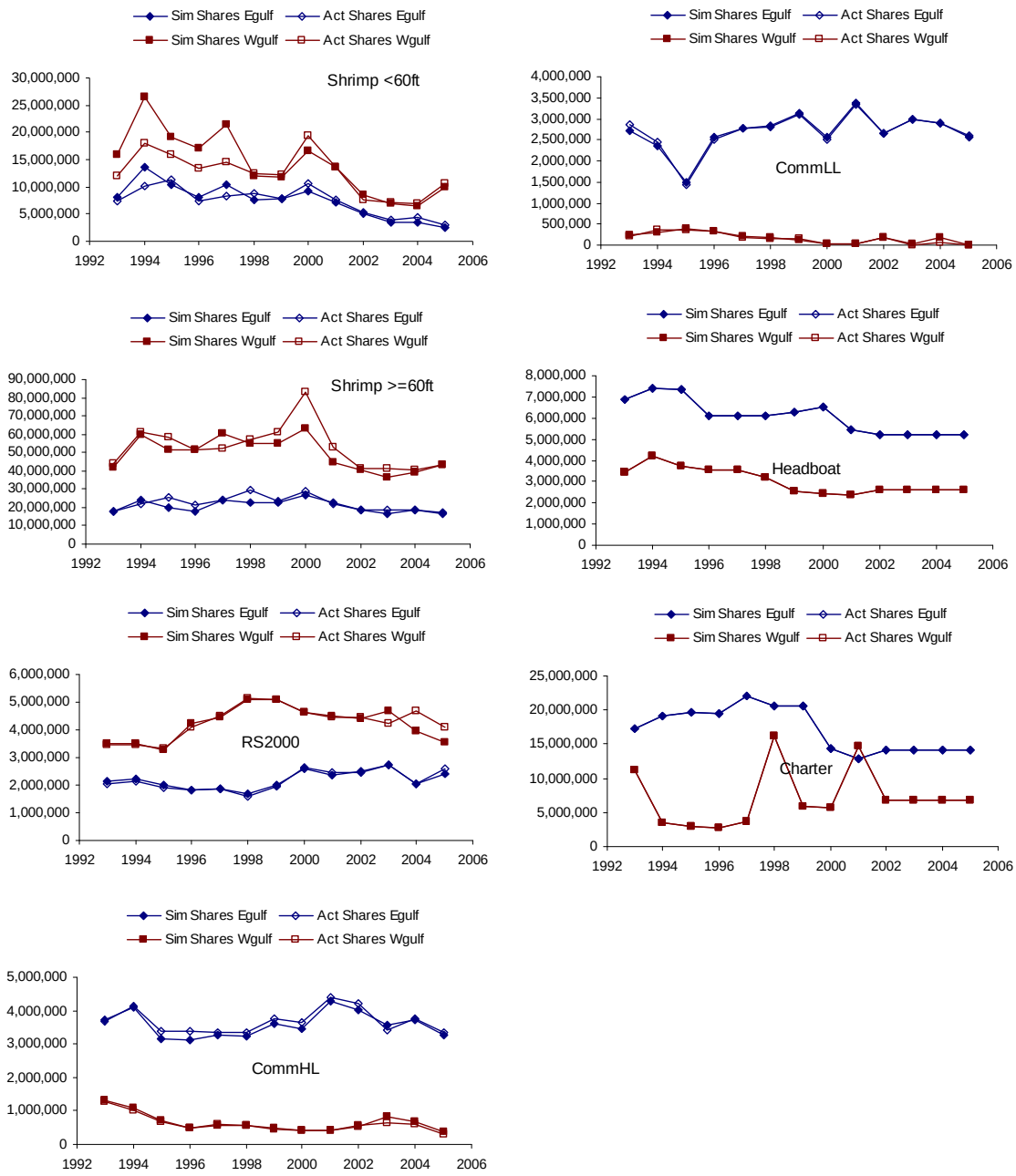


Figure C&R 5. Comparison of share costs by vessel class and east and west gulf for the period 1993-2005.

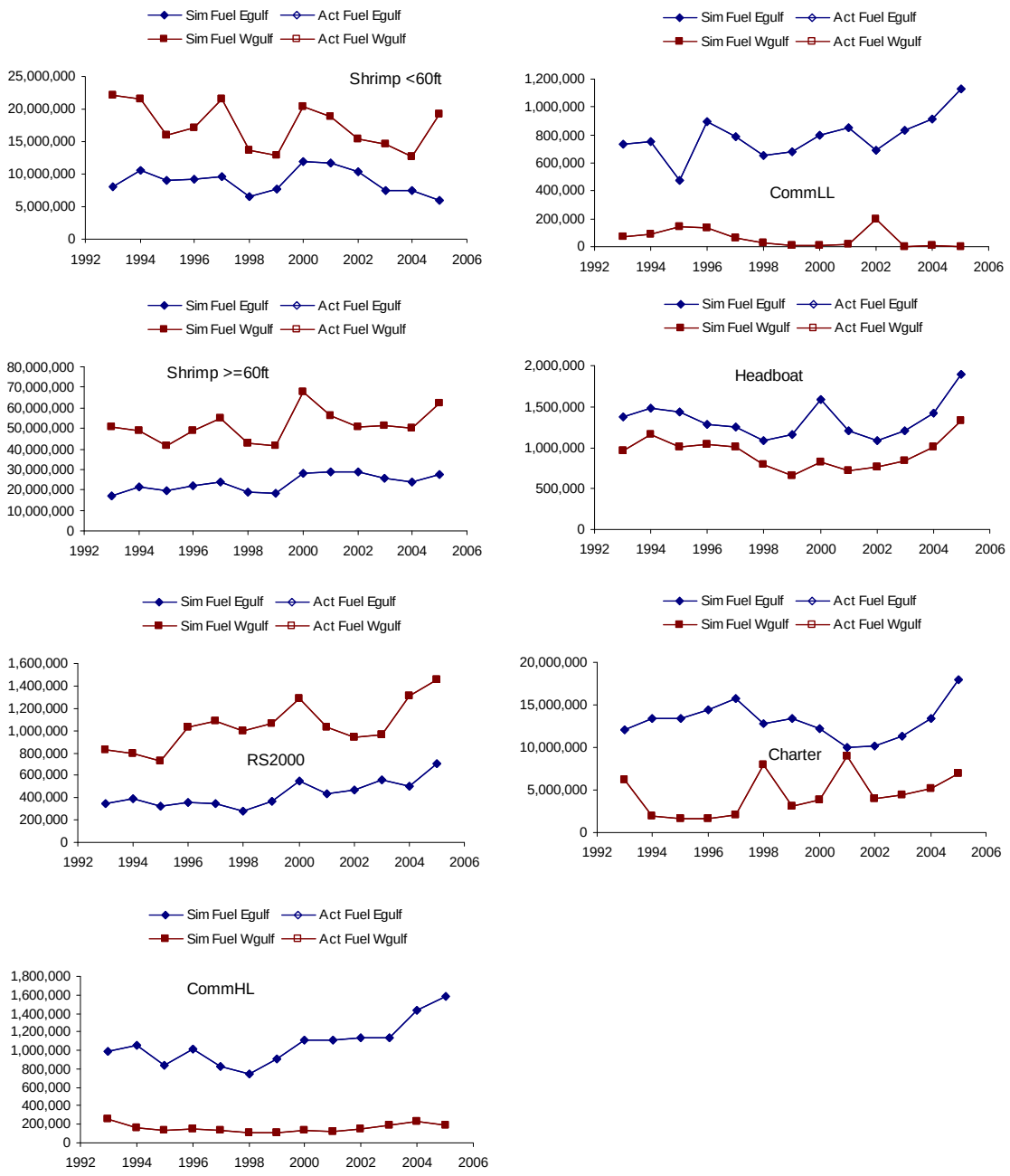


Figure C&R 6. Comparison of fuel costs by vessel class and east and west gulf for the period 1993-2005.

D. 4. Vermilion Snapper Tables

Table VS1. Coefficients *a*, *b*, and *c* for the growth equation for each sub-cohort per timestep.

Sucohort	*a*	*b*	*C*
1	0.030	11.00	-6.00
2	0.031	12.10	-5.95
3	0.032	13.20	-5.90
4	0.033	14.30	-5.85
5	0.034	15.40	-5.80
6	0.035	16.50	-5.75
7	0.036	17.60	-5.70
8	0.037	18.70	-5.65
9	0.038	19.80	-5.60
10	0.039	20.90	-5.55
11	0.040	22.00	-5.50
12	0.041	23.10	-5.45

Table VS2. Seasonal distribution by month, initial size of recruits, and distribution of recruits among sub-cohorts.

Month/Sub-cohort	Distribution of seasonal recruitment	Initial size of new recruits in sub-cohort (inches)	Distribution of recruits among sub-cohorts
1	0	0.7473	0.0049
2	0	0.9656	0.0166
3	0	1.1906	0.0442
4	0	1.4220	0.0921
5	0.0037	1.6595	0.1503
6	0.0634	1.9028	0.1920
7	0.0376	2.1517	0.1920
8	0.0246	2.4058	0.1503
9	0.1308	2.6649	0.0921
10	0.5764	2.9286	0.0442
11	0.1591	3.1969	0.0166
12	0.0043	3.4693	0.0049

E. 5. Graphical Results For Vermilion Snapper in Area 1 (East Gulf)

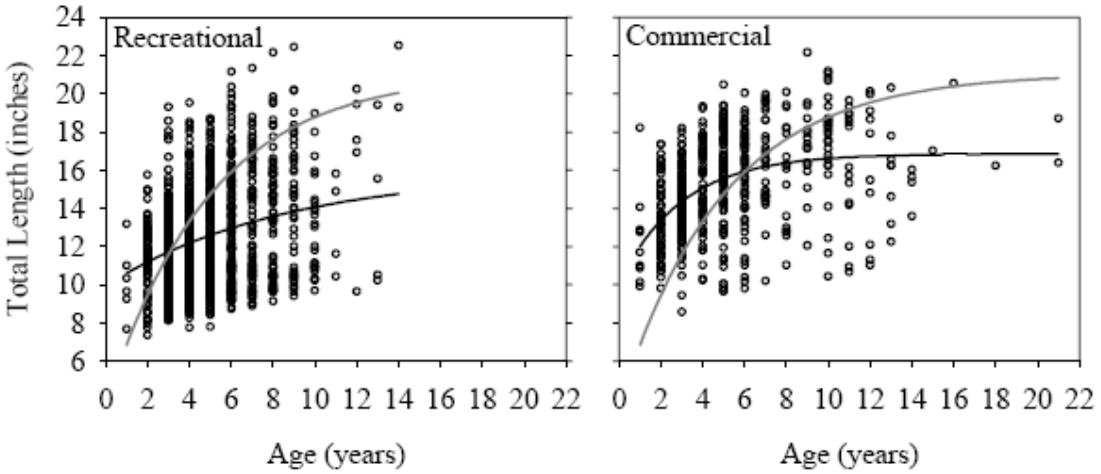


Figure 4. Age-length observations of vermilion snapper collected from recreational and commercial landings from 1994 to 2000 with fitted von Bertalannfy curves (black lines) and Schirripa's (1992) curve (gray line).

Figure VS1. Source: Porch and Cass-Calay. 2001.

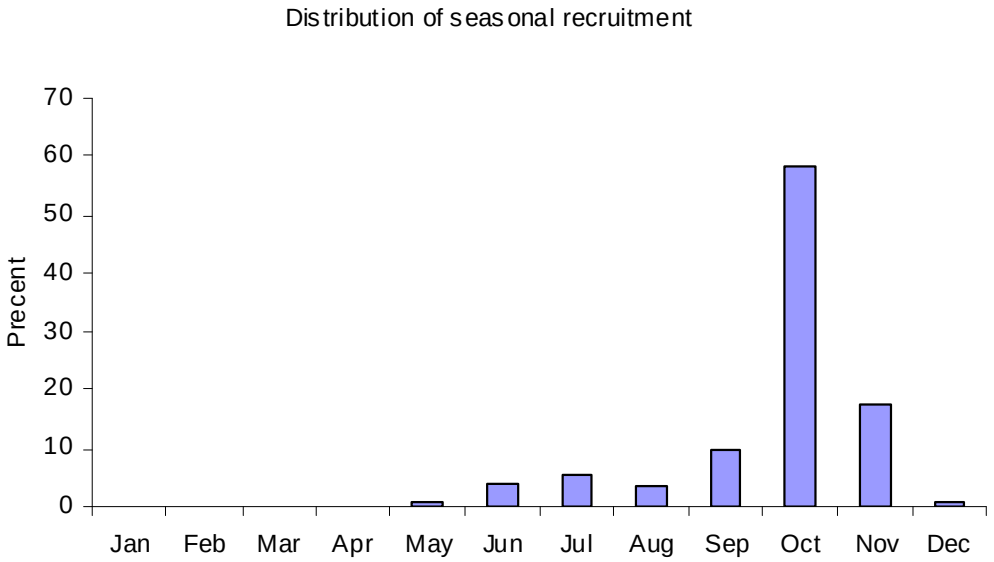


Figure VS2. Distribution of recruits by month.

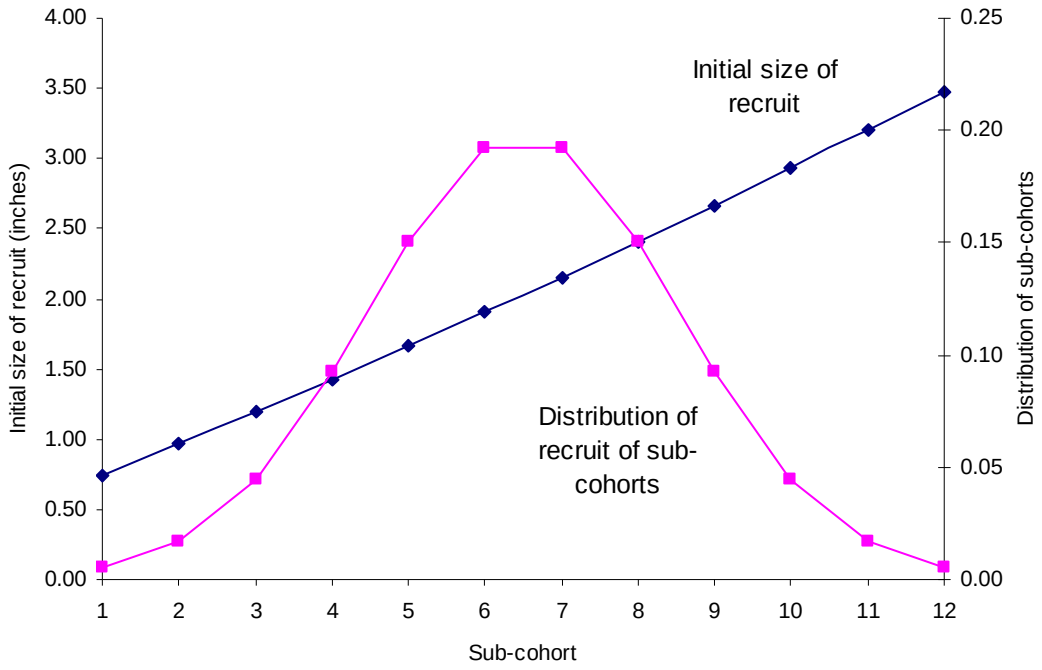


Figure VS3. Initial size of recruits and distribution of recruits among cohorts.

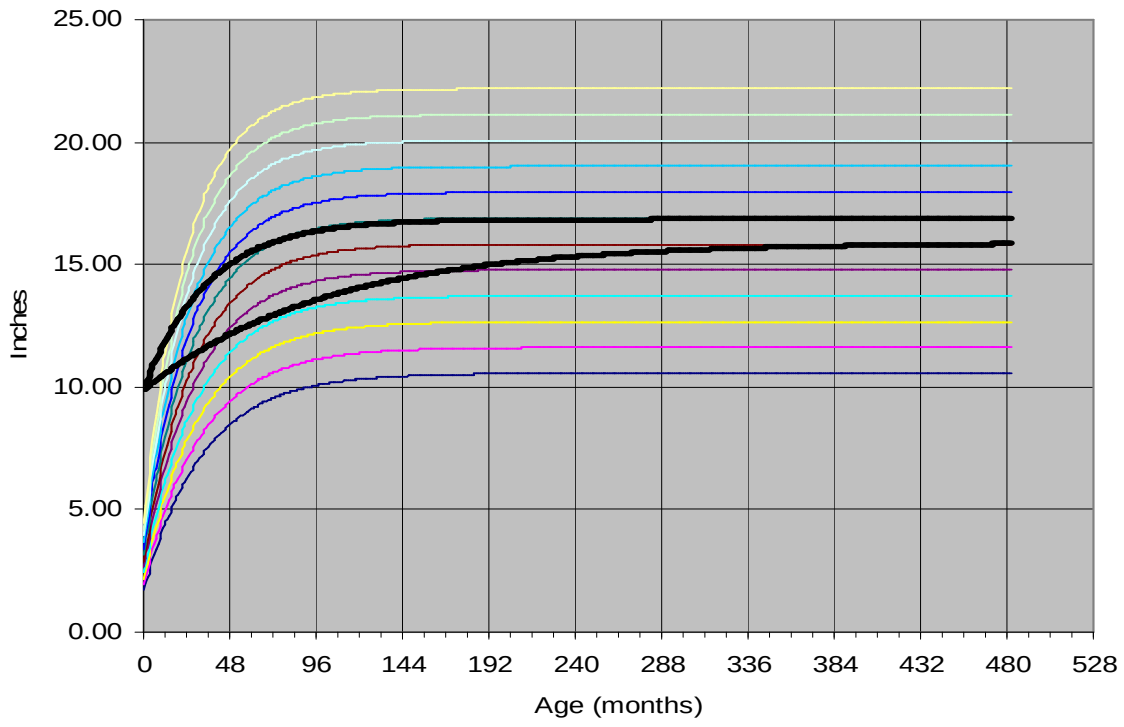


Figure VS4. Growth curves for vermillion snapper sub-cohorts compared with Figure 6 from Porch and Cass-Calay (2001).

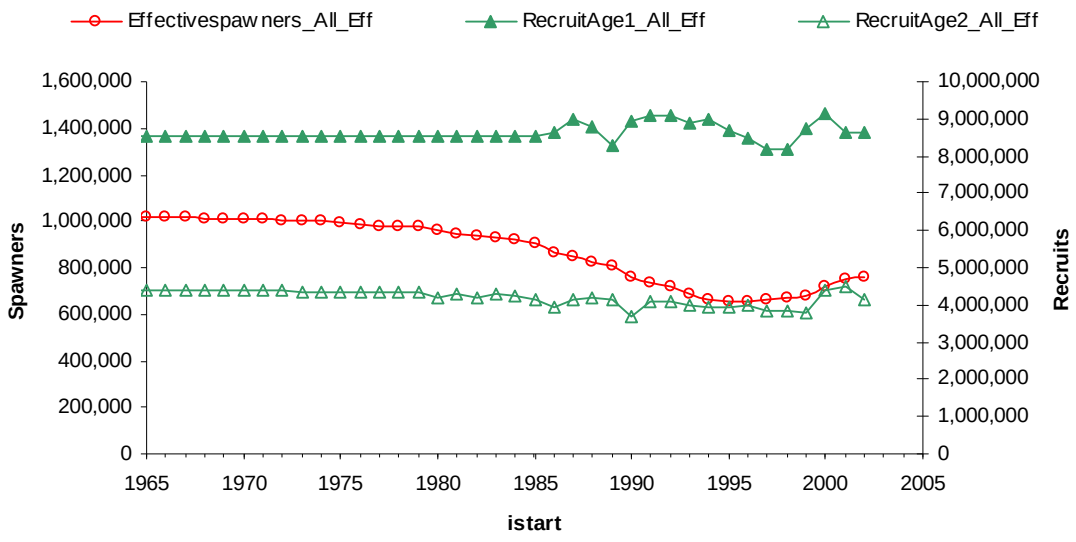


Figure VS5. Developing the prehistoric and historic stock in the vermillion snapper fishery in the east Gulf of Mexico using BESS(GBFSM).

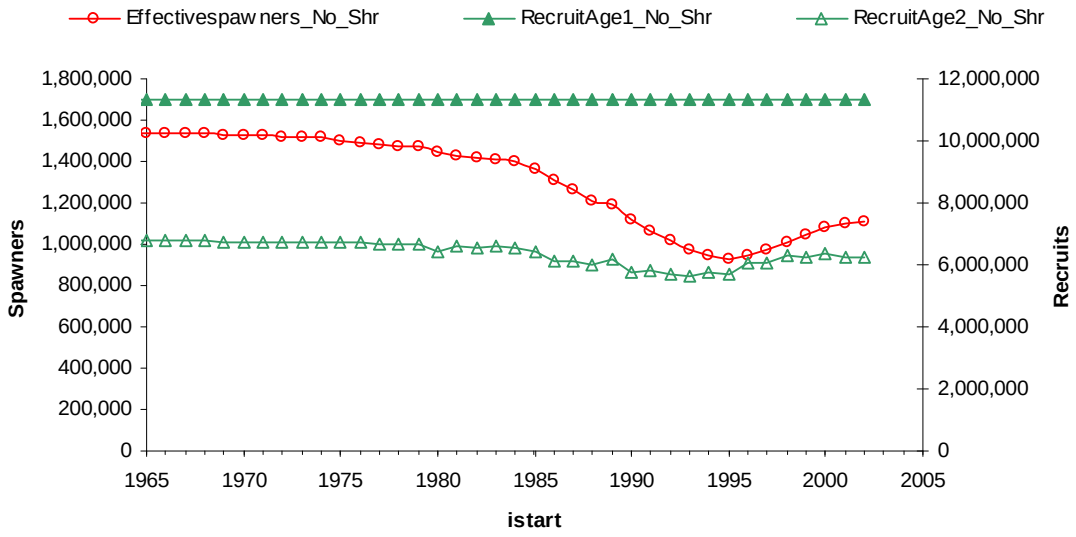


Figure VS6. Developing the prehistoric and historic stock in the vermillion snapper fishery using BESS(GBFSM) without shrimping (i.e., F=0) east Gulf of Mexico.

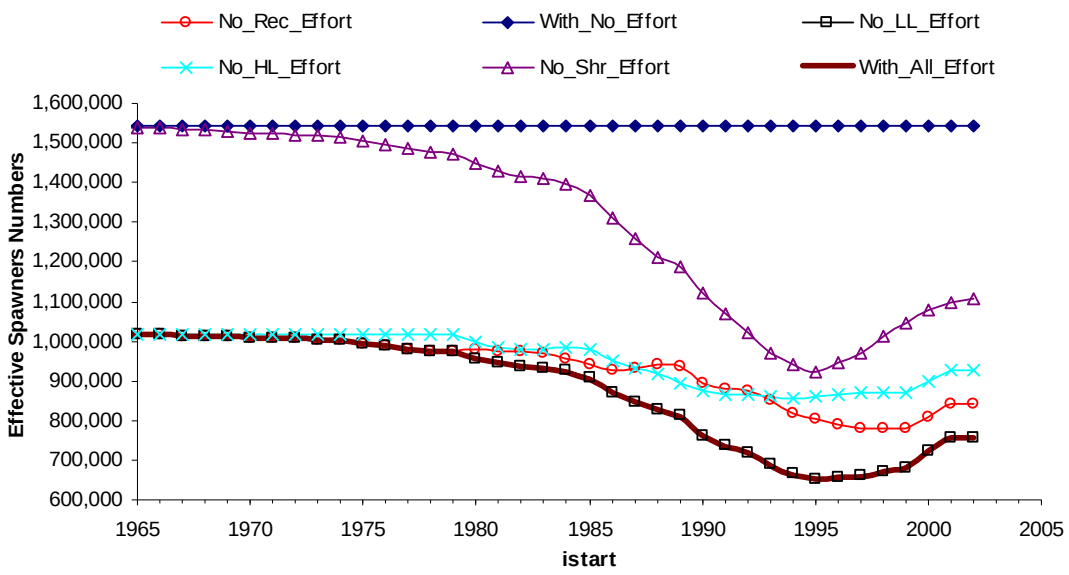


Figure VS7. Effective Spawners Numbers for no fishing effort by any vessel (all F=0) compared with no fishing by individual vessels in the east Gulf of Mexico by years.

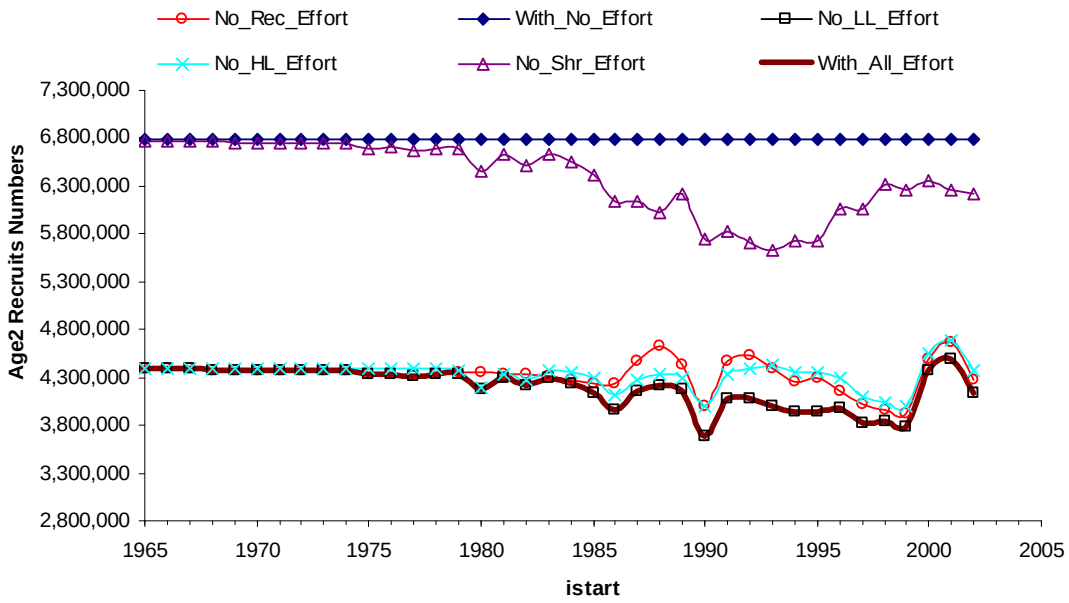


Figure VS8. Recruit of Age 2 Vermillion Snapper for no fishing effort by any vessel (all F=0) compared with no fishing by individual vessels in the east Gulf of Mexico by years.

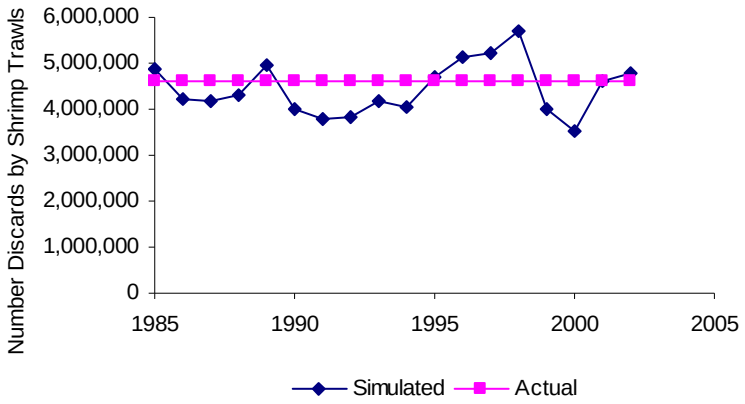


Figure VS9. Number of Discards by shrimp trawlers using BESS(GBFSM) in the east Gulf of Mexico by years.

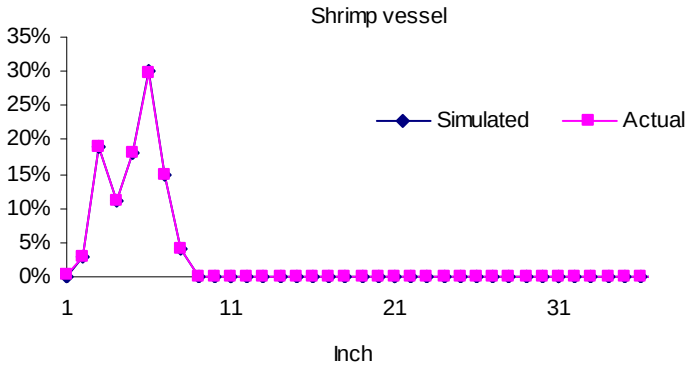


Figure VS10. Length frequency distribution of the bycatch of vermillion snapper by the offshore shrimp fleet in the east Gulf of Mexico.

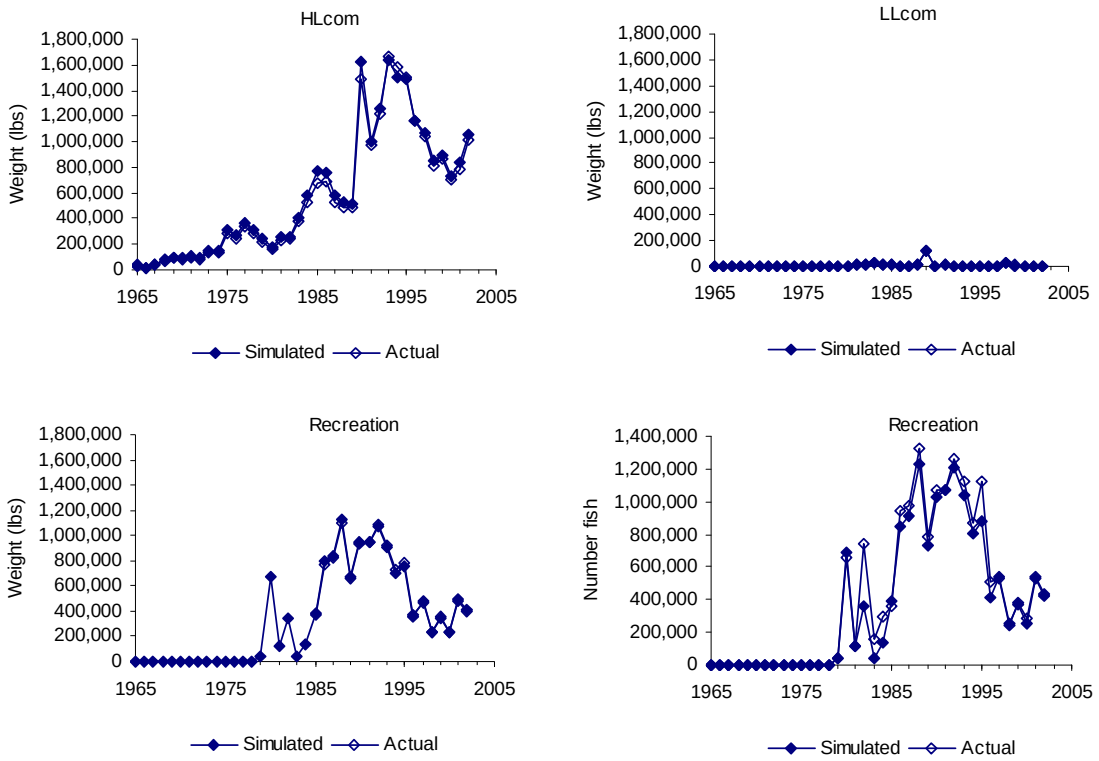


Figure VS11. Total pounds landed of vermillion snapper by handline and longline commercial fishermen as well as pounds and numbers by recreation in the east Gulf of Mexico.

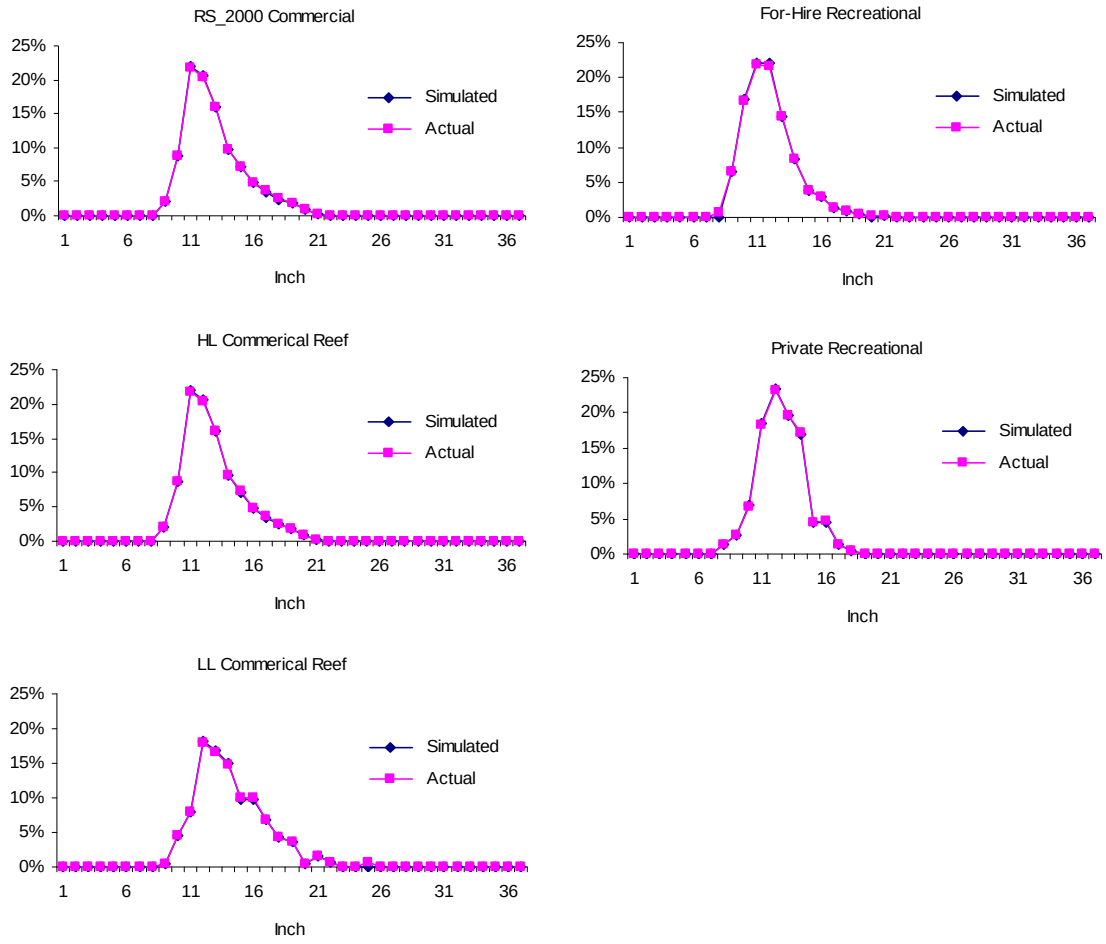


Figure VS12. Simulated and actual distribution of landings of vermillion snapper by inch and vessel class in the east Gulf of Mexico.

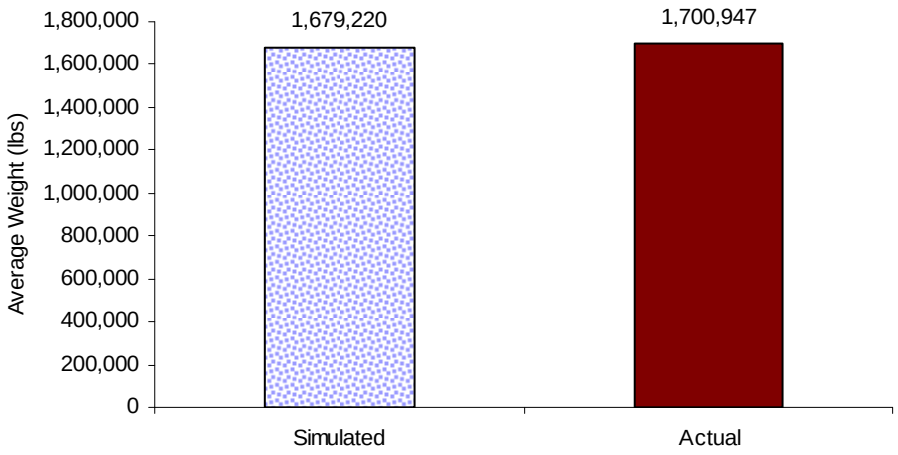


Figure VS13. Average 1993-2002 annual simulated and actual landings of vermillion snapper by reef fish fishermen in the east Gulf of Mexico.

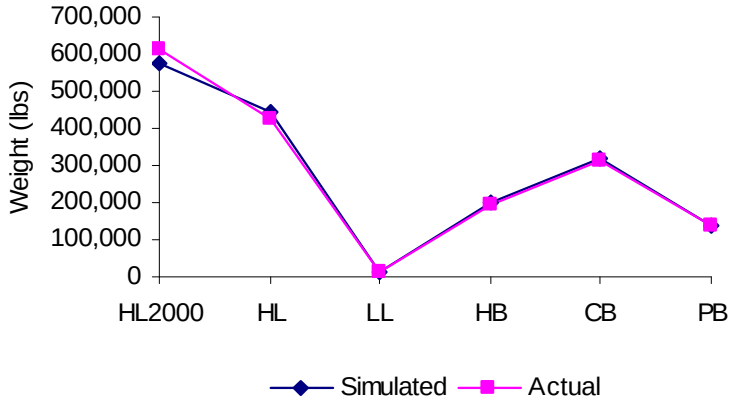


Figure VS14. Average 1993-2002 annual simulated and actual landings of vermillion snapper by vessel class in the east Gulf of Mexico.

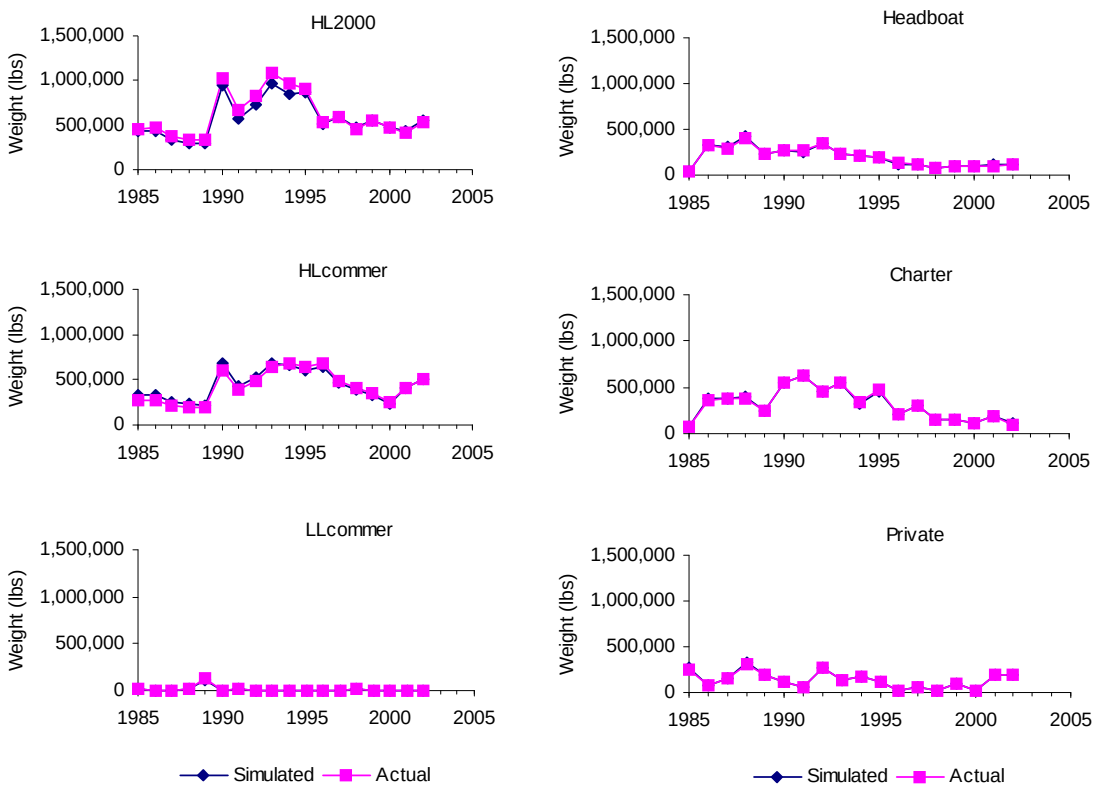


Figure VS15. 1993-2002 annual simulated and actual landings of vermillion snapper by vessel class in the east Gulf of Mexico.

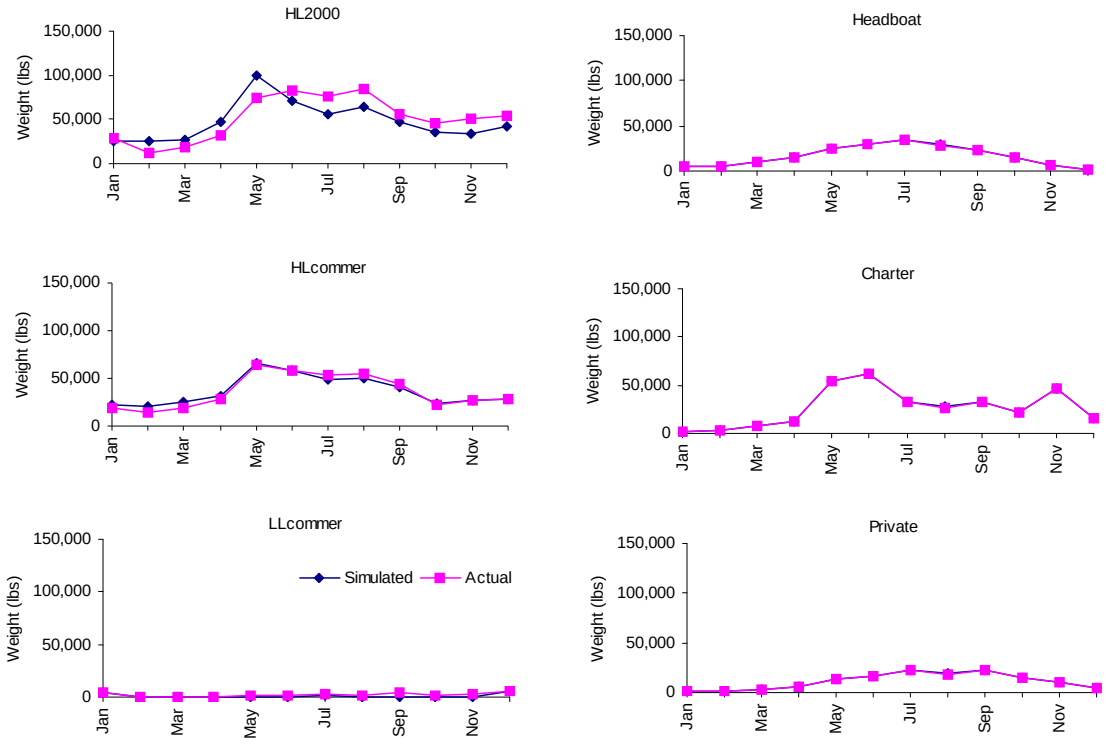


Figure VS16. Average 1993-2002 monthly simulated and actual landings of vermillion snapper by month and vessel class in the east Gulf of Mexico.

F. 6. Graphical Results For Vermilion Snapper in Area 2 (West Gulf)

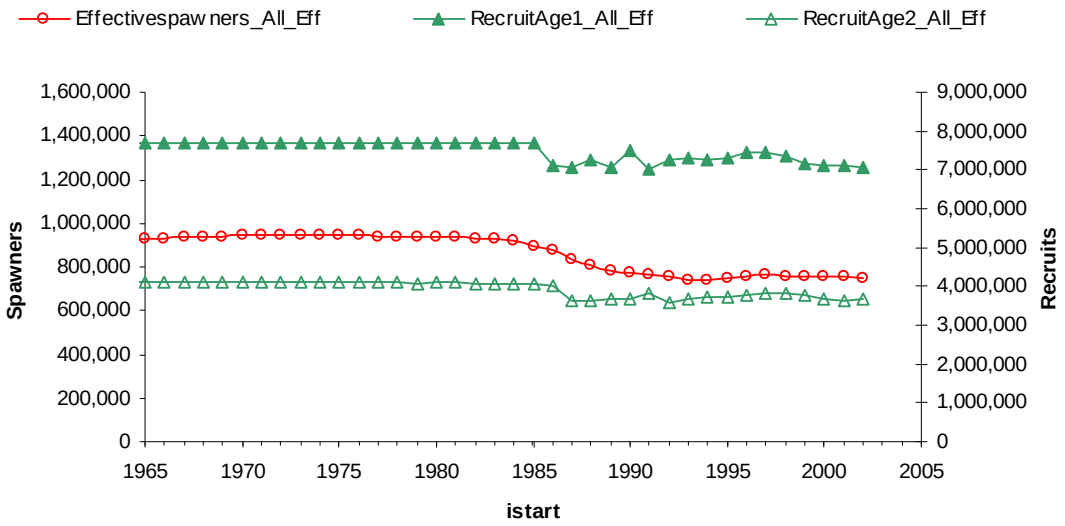


Figure VS17. Developing the prehistoric and historic stock in the vermillion snapper fishery in the west Gulf of Mexico using BESS(GBFSM).

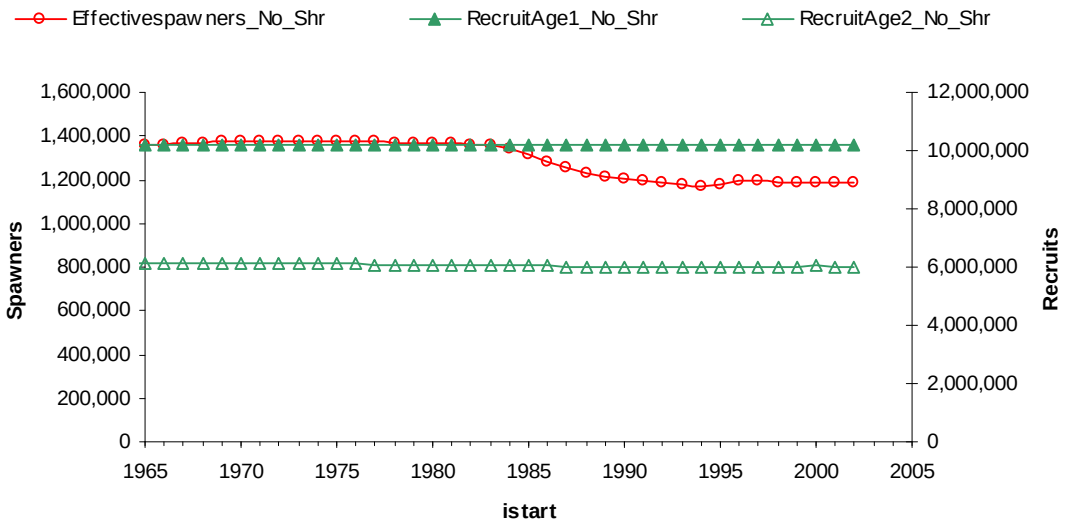


Figure VS18. Developing the prehistoric and historic stock in the vermillion snapper fishery using BESS(GBFSM) without shrimping (i.e., F=0) west Gulf of Mexico.

V. Calibration of Cost and Revenue 1993-2005

The figures below (C&R1-C&R6) are the result of calibrating GBFSM for costs and revenue for the period 1993 to 2005. Actual effort is read in as is actual unit cost and prices by year. After calibrating the biological model of GBFSM, we run the model through 1992 and write out the write the biological information into files. Now we can begin the model in 1993 by reading in the biological information that was stored and the end of 1992. We then run the model from 1993 to 2005 to calibrate the cost and revenue data. After being satisfied that the model is working properly we write out the biological information at the end of 2005. Our policy analysis will begin in 2006 and we will use the actual yearly policies for 2006, 2007 and 2008. The actual policy analysis will be for the period 2009 through 2032.

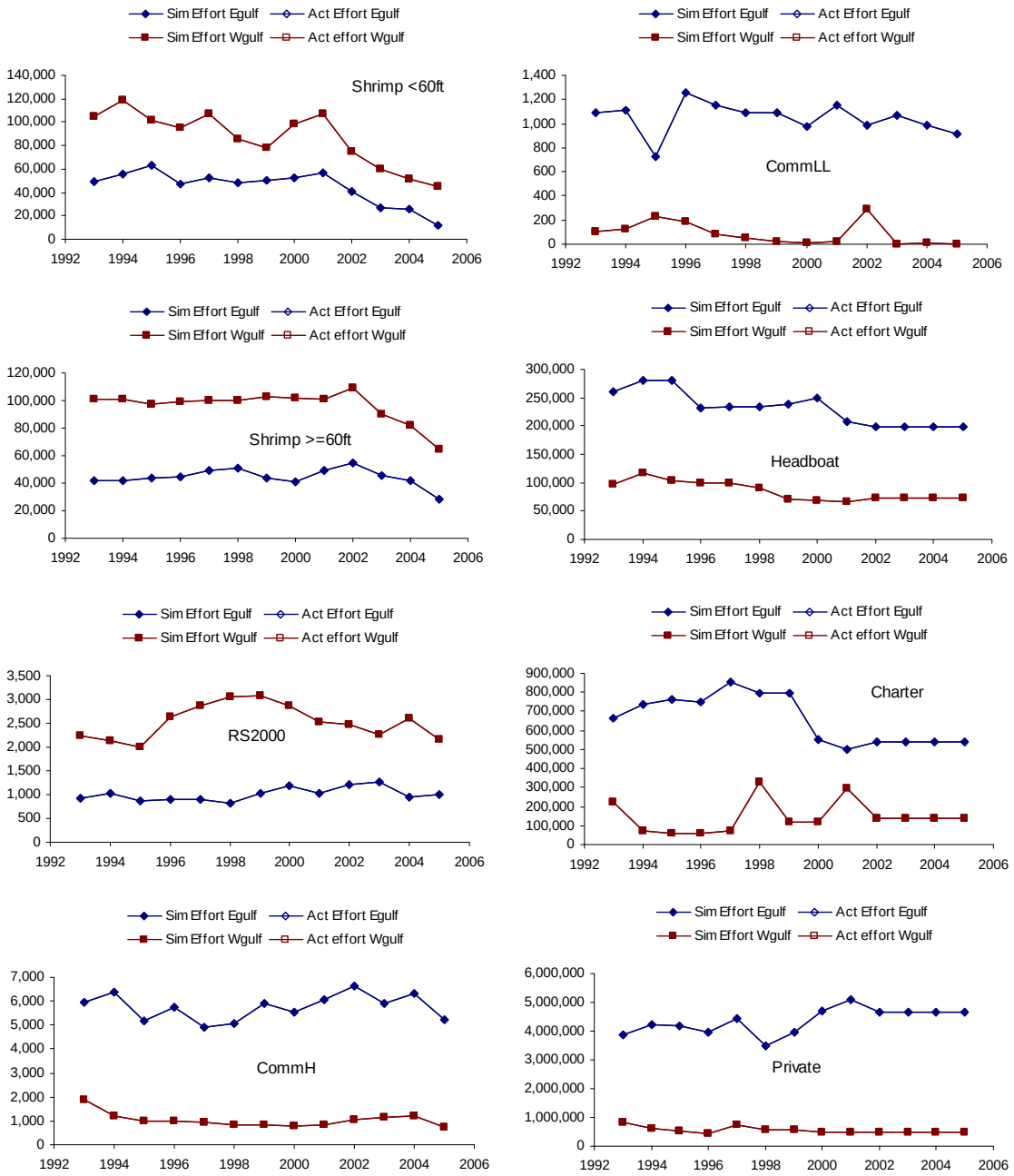


Figure C&R1. These Figures are a comparison of effort by vessel class and east and west gulf for the period 1993-2005.

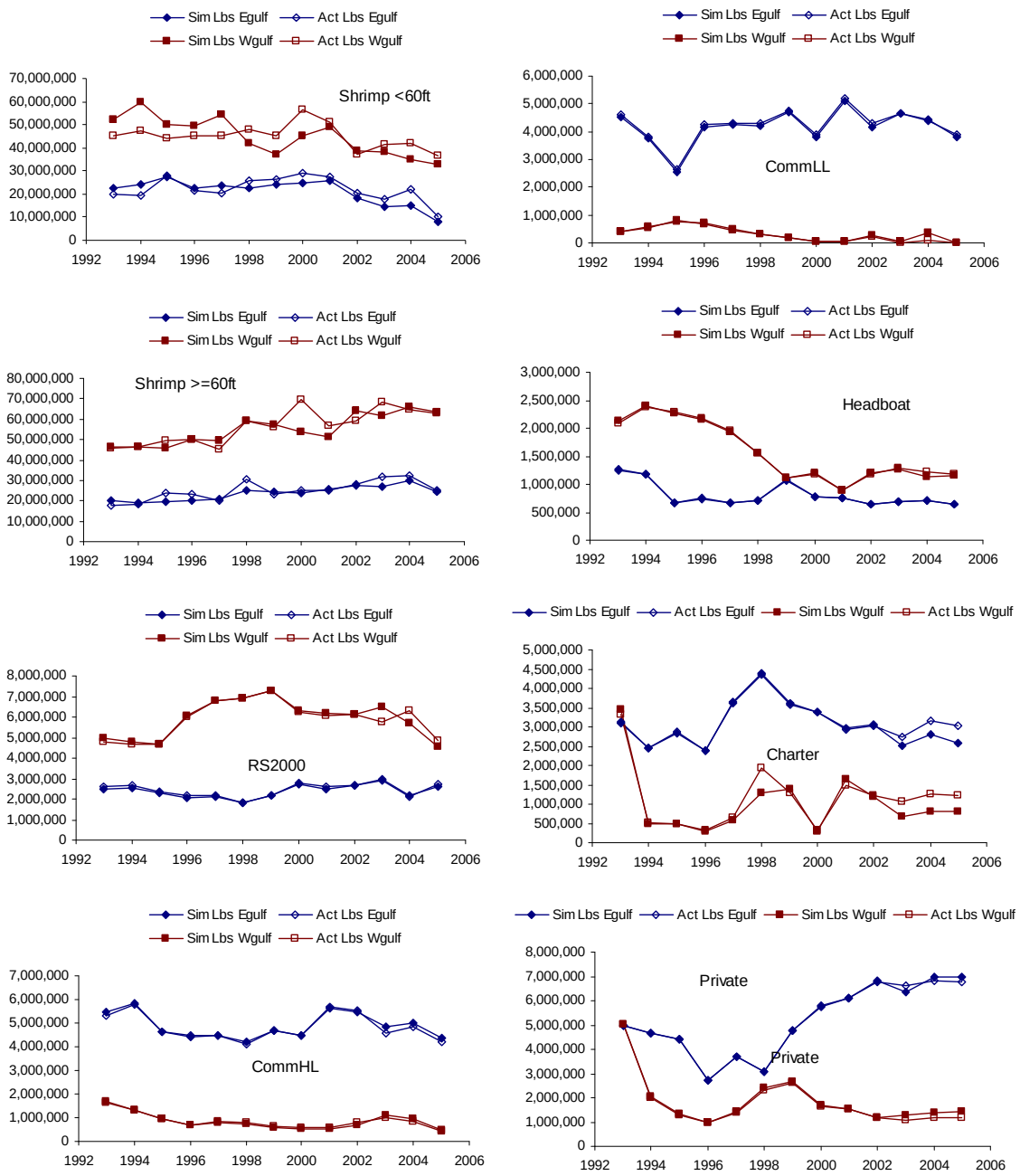


Figure C&R 2. Comparison of pounds landed by vessel class and east and west gulf for the period 1993-2005.

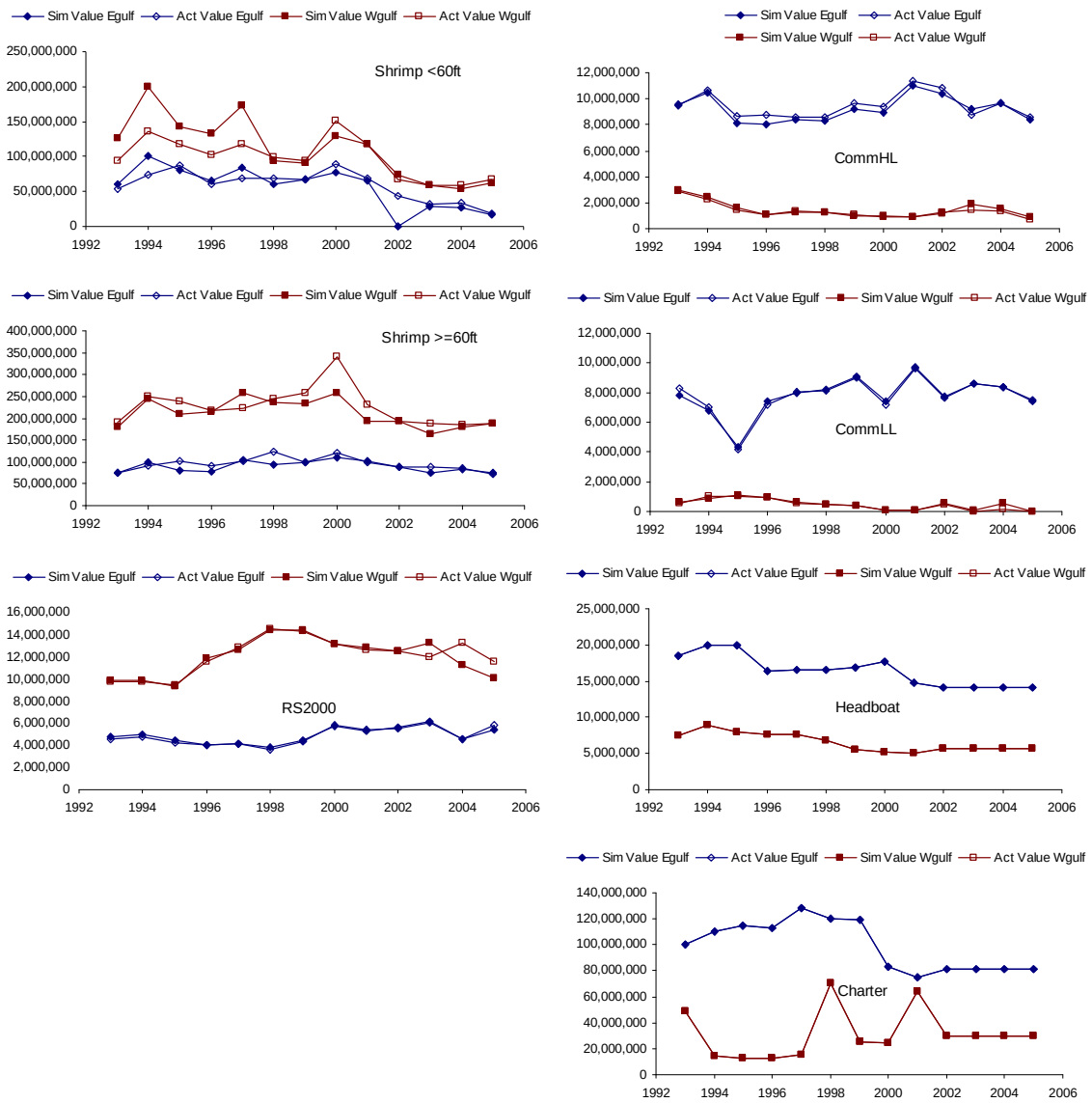


Figure C&R 3. Comparison of revenue by vessel class and east and west gulf for the period 1993-2005.

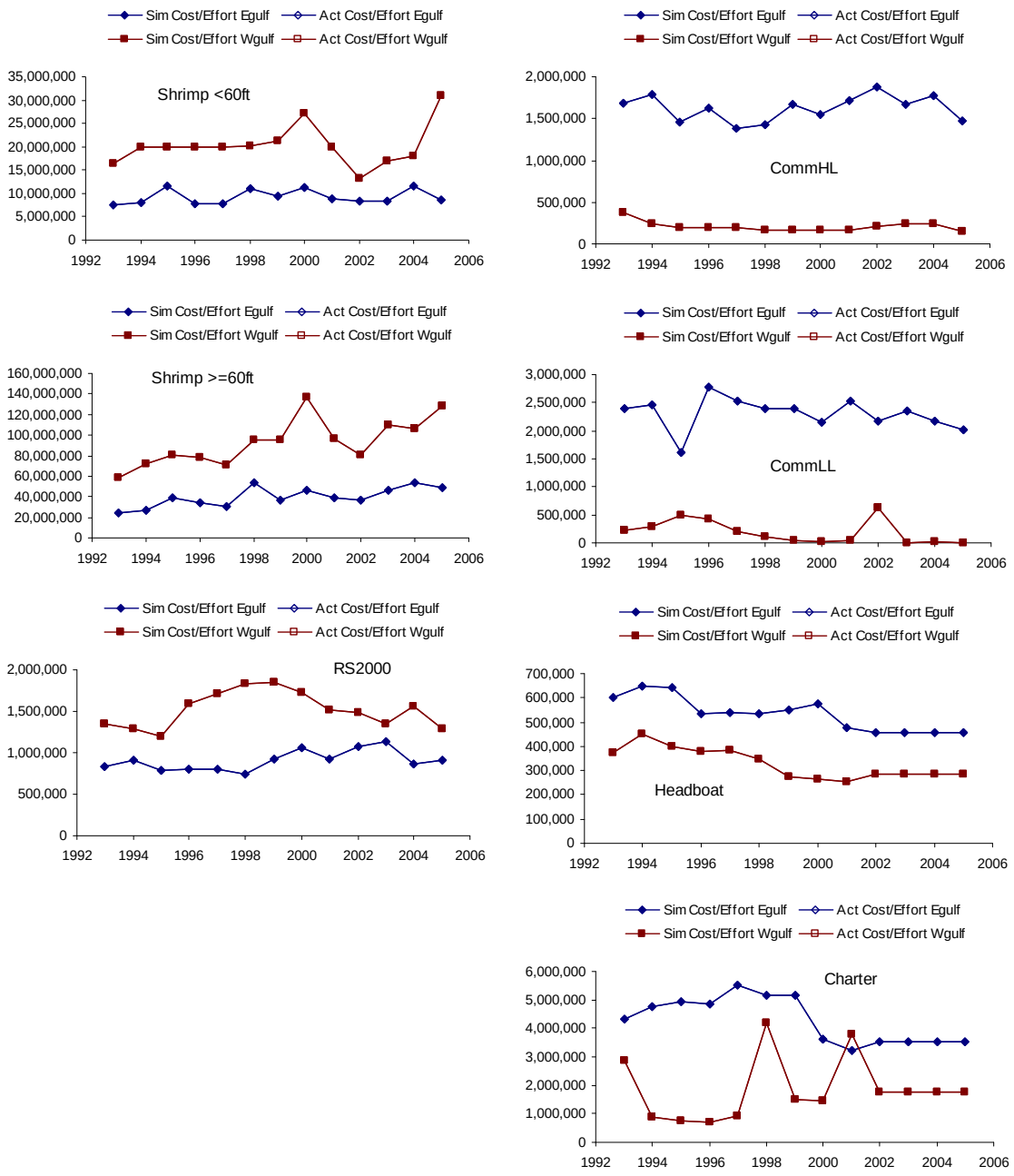


Figure C&R 4. Comparison of variable effort cost by vessel class and east and west gulf for the period 1993-2005. This excludes fuel costs and shares of the crew.

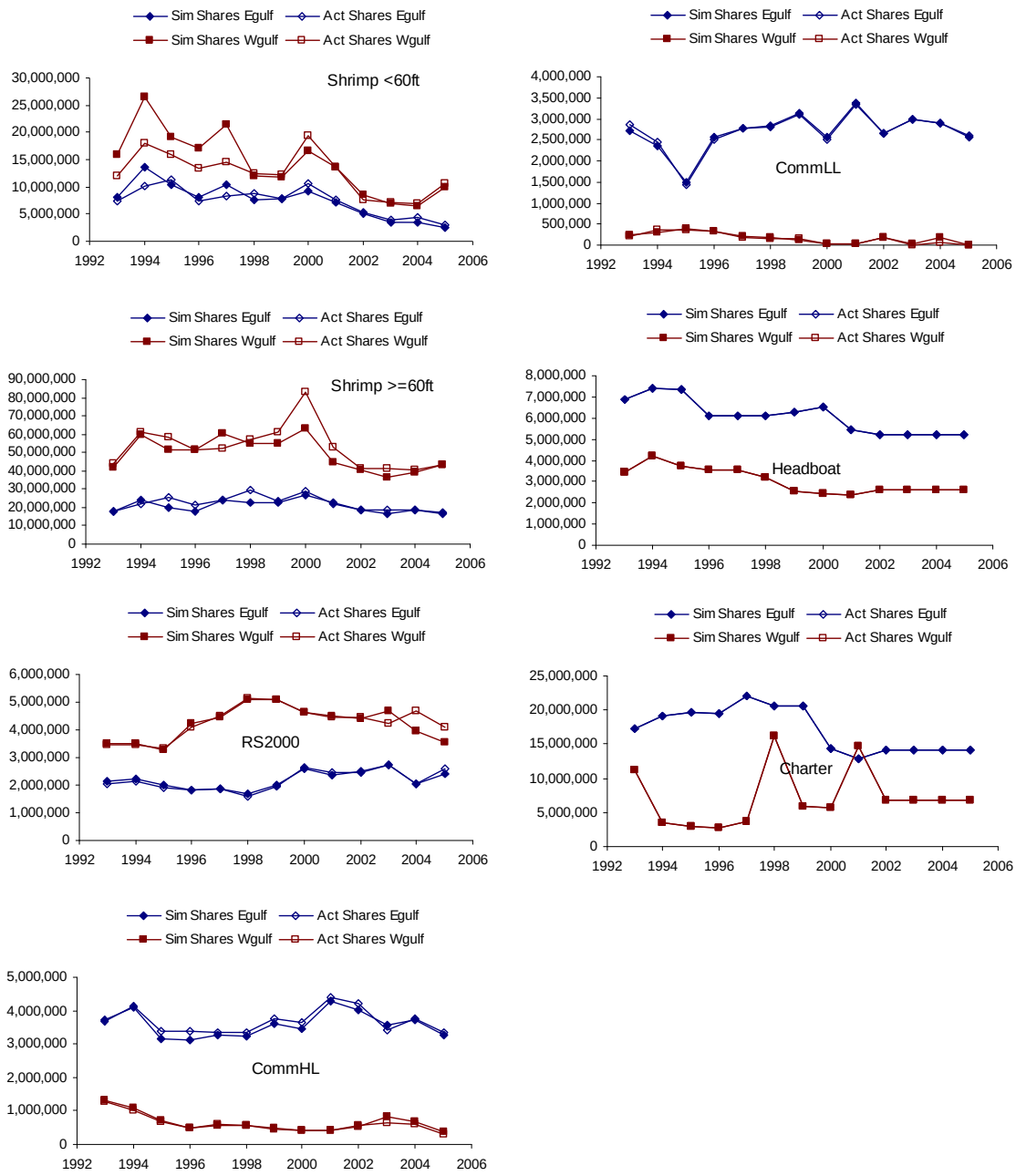


Figure C&R 5. Comparison of share costs by vessel class and east and west gulf for the period 1993-2005.

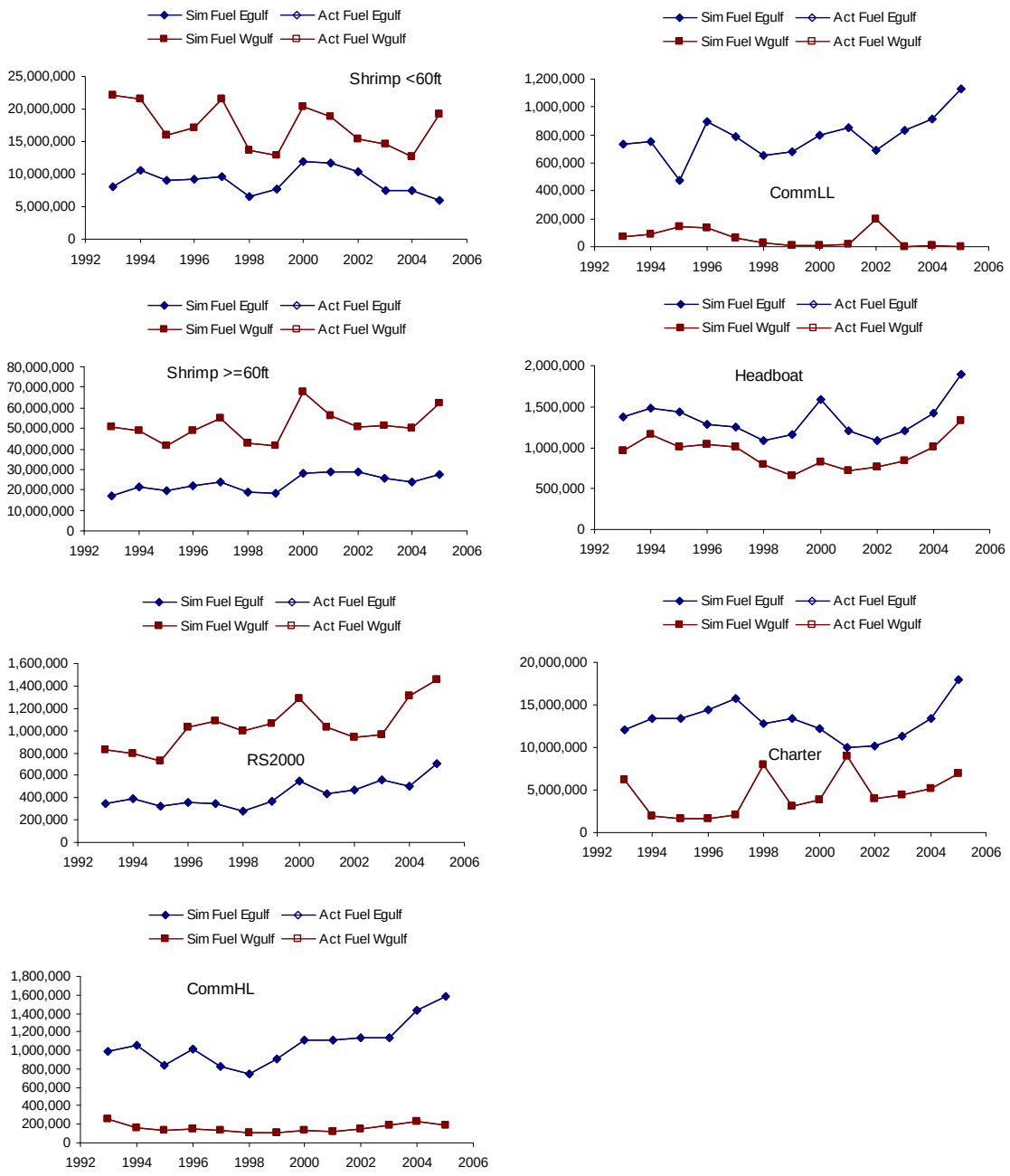


Figure C&R 6. Comparison of fuel costs by vessel class and east and west gulf for the period 1993-2005.

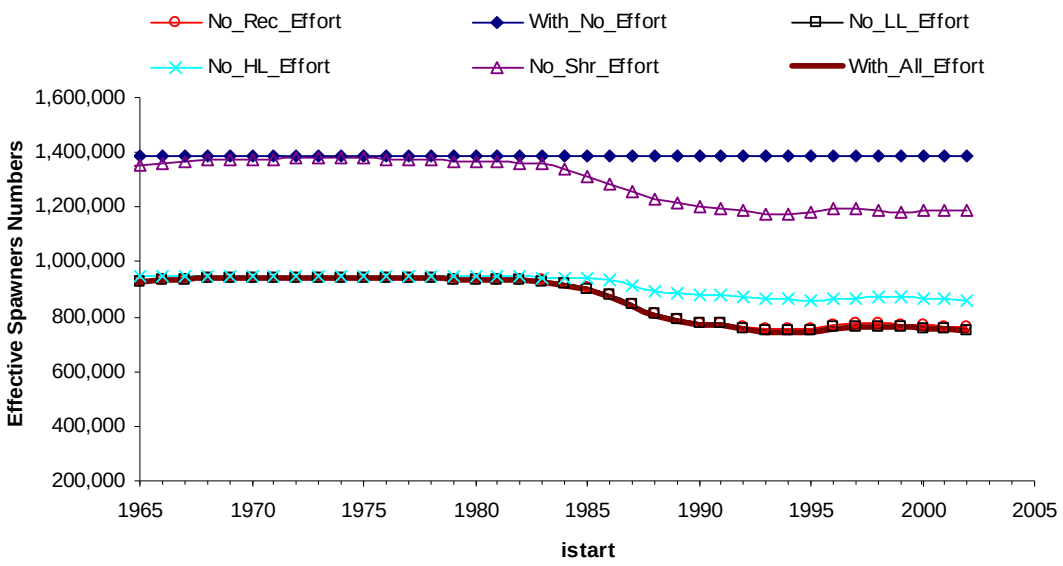


Figure VS19. Effective Spawners Numbers for no fishing effort by any vessel (all F=0) compared with no fishing by individual vessels in the west Gulf of Mexico by years.

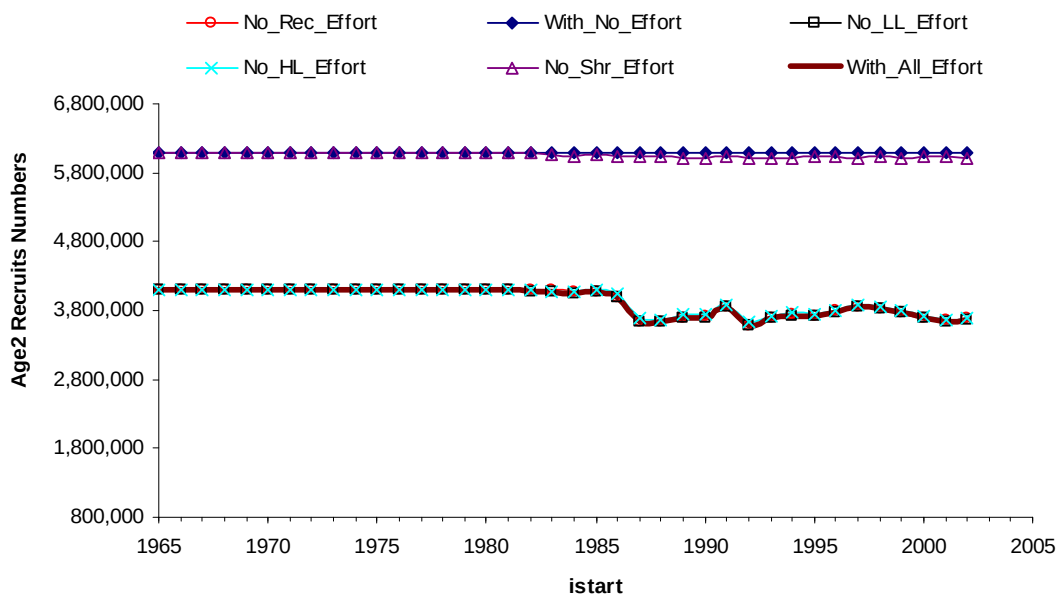


Figure VS20. Recruit of Age 2 Vermillion Snapper for no fishing effort by any vessel (all F=0) compared with no fishing by individual vessels in the west Gulf of Mexico by years.

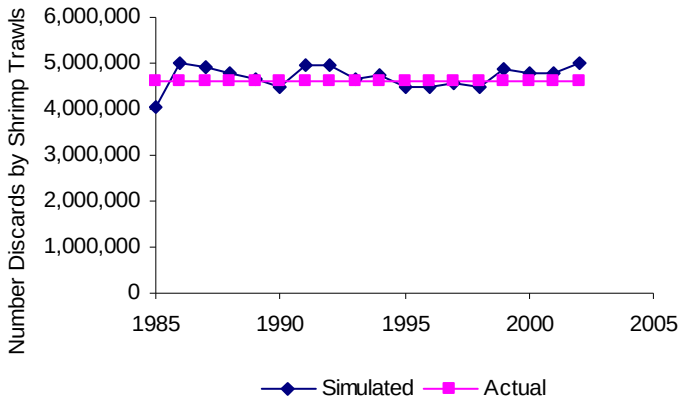


Figure VS21. Number of Discards by shrimp trawlers using BESS(GBFSM) in the west Gulf of Mexico by years.

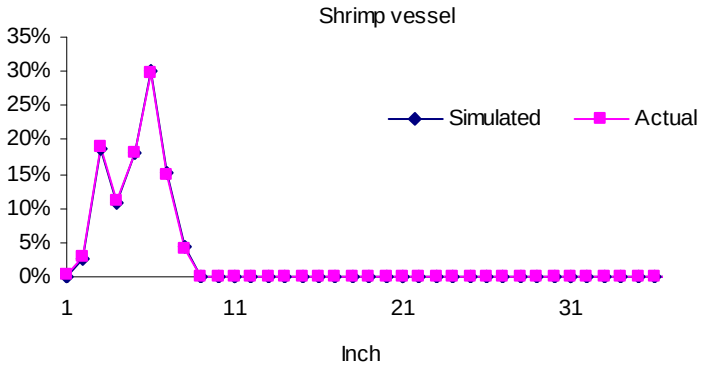


Figure VS22. Length frequency distribution of the bycatch of vermillion snapper by the offshore shrimp fleet in the west Gulf of Mexico.

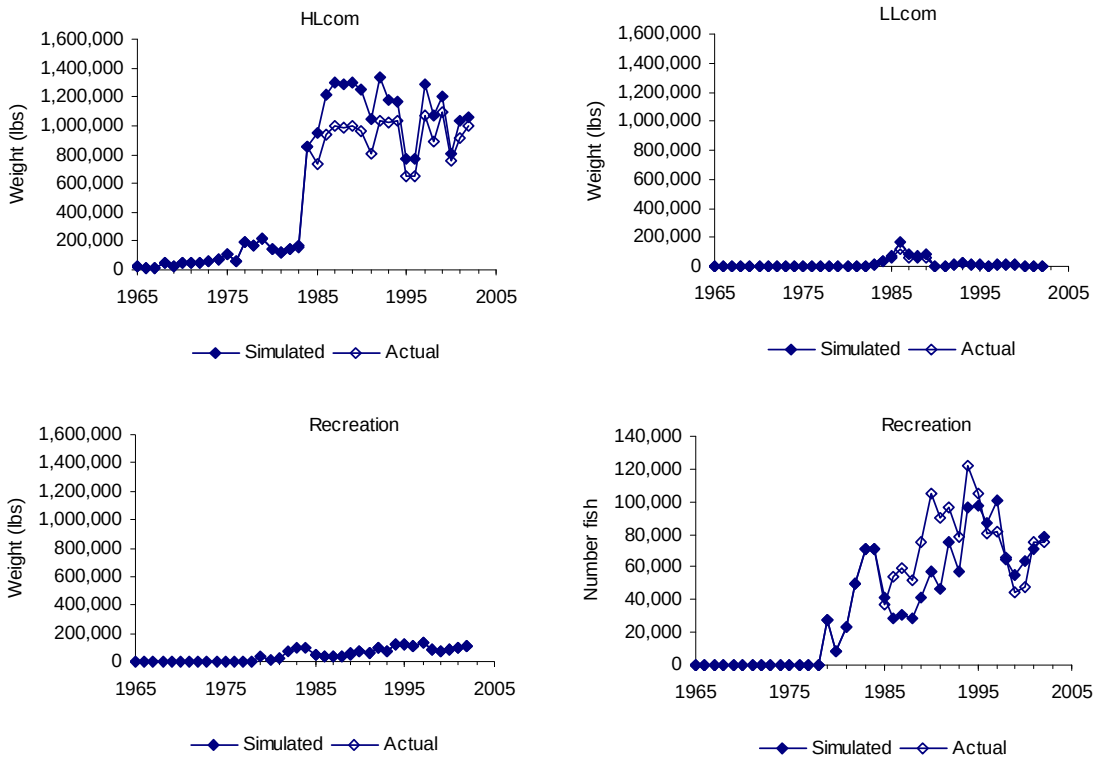


Figure VS23. Total pounds landed of vermillion snapper by handline and longline commercial fishermen as well as pounds and numbers by recreation in the west Gulf of Mexico.

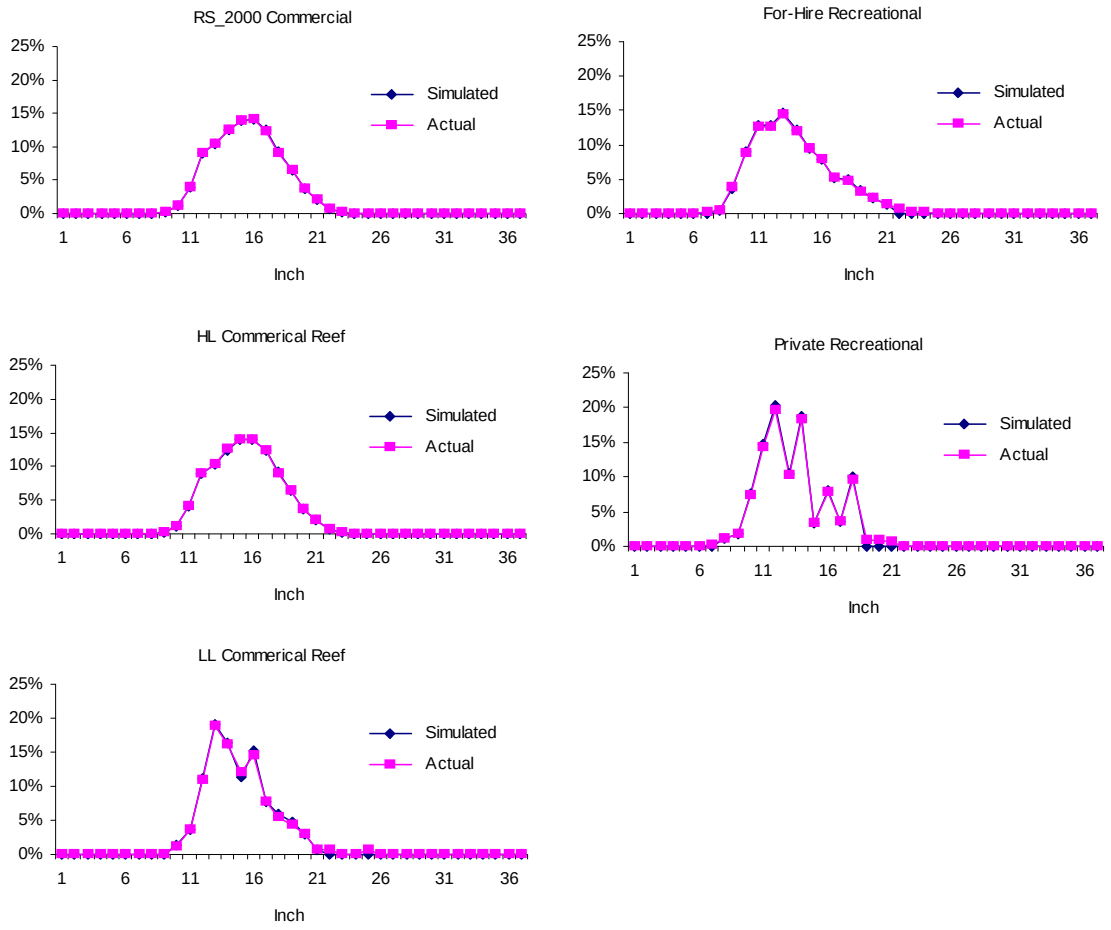


Figure VS24. Simulated and actual distribution of landings of vermillion snapper by inch and vessel class in the west Gulf of Mexico.

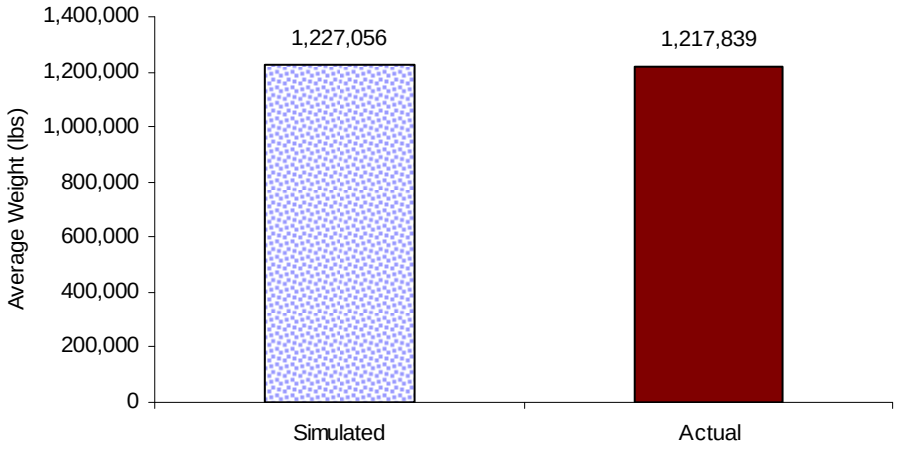


Figure VS25. Average 1993-2002 annual simulated and actual landings of vermillion snapper by reef fish fishermen in the west Gulf of Mexico.

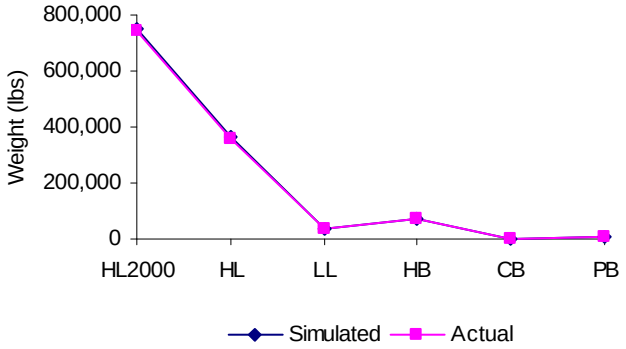


Figure VS26. Average 1993-2002 annual simulated and actual landings of vermillion snapper by vessel class in the west Gulf of Mexico.

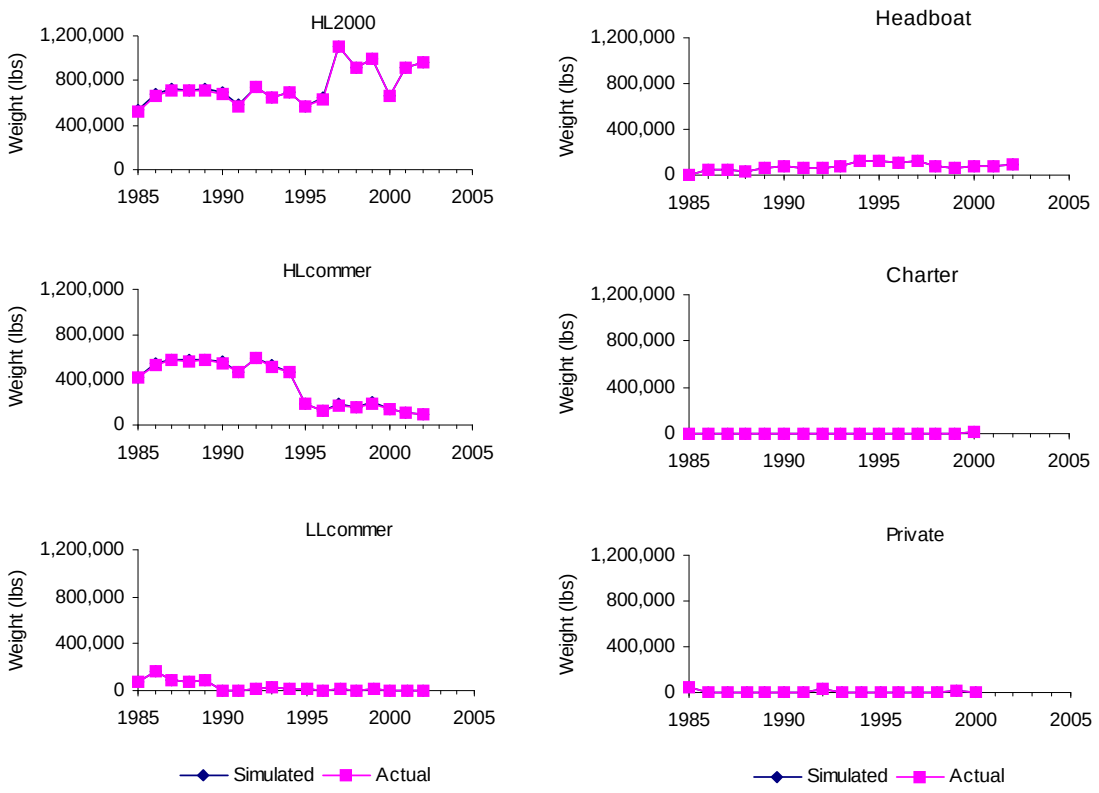


Figure VS27. 1993-2002 annual simulated and actual landings of vermillion snapper by vessel class in the west Gulf of Mexico.

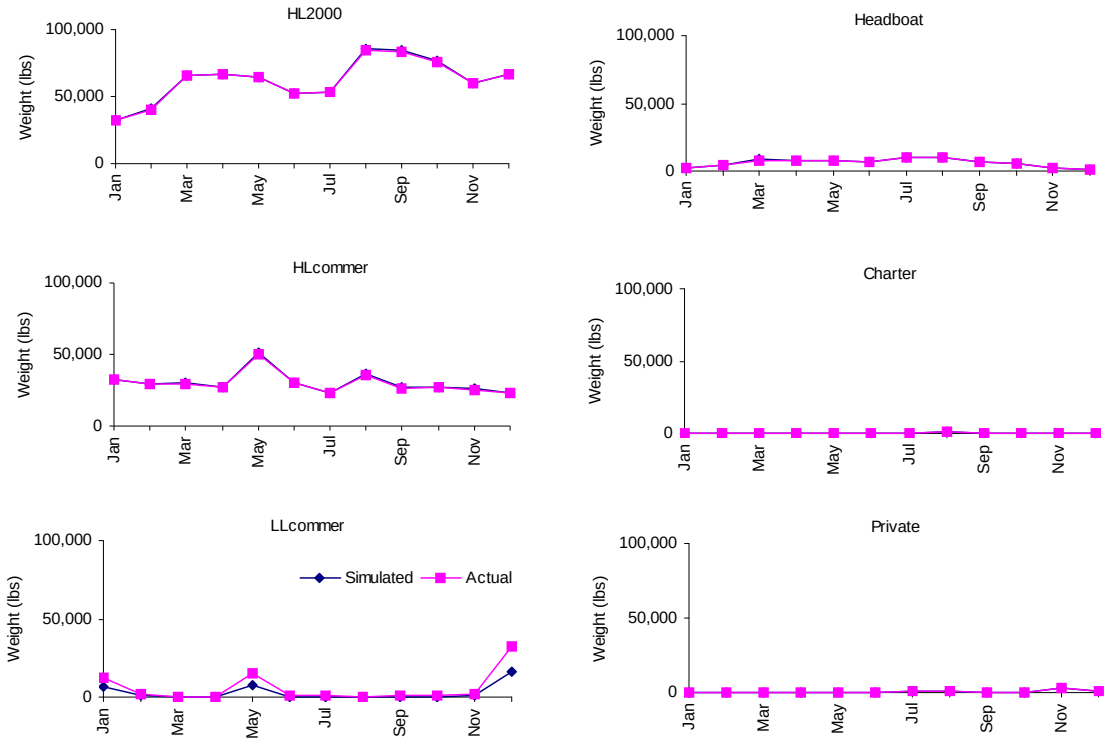


Figure VS28. Average 1993-2002 monthly simulated and actual landings of vermillion snapper by month and vessel class in the west Gulf of Mexico.

VI. Calibration of biological model for other reef fish

A. 1. Data for other reef fish

We put other reef fish in the model because they are part of the economics system. We have the actual data for effort (number of trips) and catch (landings), while we make a scientific guess for size and number.

For other reef fish we have 6 sub-cohorts; thus in a year with 12 timesteps there can be up to 72 sub-cohorts per year. Each sub-cohort then can have its own growth curve, recruitment size and number fish recruited.

The distribution of recruitment by months is shown in Figure OT1. The initial size of recruits per sub-cohort and the distribution of recruits among the sub-cohorts are shown in Figure OT2.

In the BESS(GBFSM) other reef fish are grown in total length (*TL*) in inches, converted to weight (*W*) in pounds, and then converted to weight sold in pounds. The length to weight relationship used is

$$W = 0.001TL^{2.5}.$$

The form of the growth equations used in the BESS(GBFSM) is:

$$TL = a[1- e^{b(\text{Age}-c)}].$$

The growth curves are shown in Figure OT3. Since this is an aggregate of all other reef fish the growth curves vary over a wide range which is simply our guess at what it might be. The coefficients for the growth equations for each sub-cohort are given in Table OT1.

We use the Gazey model for recruitment because it is density dependent, it is simplest to use, and works extremely well. The model in BESS(GBFSM) is:

$$R_{asdcs} = E_{skt}/(\alpha_\kappa * E_{skt} + \beta_\kappa),$$

where R_{asdcs} is the age 0 by area (*a*), species (*s*), depth (*d*), cohort (*c*) and subcohort (*h*)recruits, E_{skt} is the total number of eggs for species (*s*) and stock (*k*) in time period *t*, eggs, α_κ and β_κ parameters for stock *k*. We used a natural mortality of 1.0 for age 0 fish, 0.5 for age 1 fish and .25 for age 2+ fish.

B. 2. Calibrating Areas Fished

In this analysis we have chosen to treat other reef fish east and west of the Mississippi River as separate stocks. Figure OT4 shows the effective number of spawners, the number of fish that reach age 1 and the number of fish that reach age 2 in the eastern Gulf of Mexico. The number of effective spawners is about 4.23 million fish around 1965 in the eastern Gulf of Mexico.

The number of other reef fish bycatch by Gulf shrimpers in the eastern Gulf of Mexico is shown in Figure OT5. Figures OT6 through OT9 show the results of calibrating the model for the average period 1993-2000 in the east Gulf of Mexico. As can be seen in these graphs the BESS(GBFSM) does a very good job of simulation the actual data.

Figure OT10 shows the effective number of spawners, the number of fish that reach age 1 and the number of fish that reach age 2 in the western Gulf of Mexico. The number of effective spawners reaches a maximum of about 4.88 million fish around 1965 in the western Gulf of Mexico.

The number of other reef fish bycatch by Gulf shrimpers in the western Gulf of Mexico is shown in Figure OT11. Figures OT12 through OT15 show the results of calibrating the model for the average period 1993-2000 in the west Gulf of Mexico. As can be seen in these graphs the BESS(GBFSM) does a very good job of simulation the actual data.

C. 3. Other Reef Fish Tables

Table OT1. Coefficients *a*, *b*, and *c* for the growth equation for each sub-cohort per timestep.

Sucohort	*a*	*b*	*C*
1	0.030	10.00	0.00
2	0.032	14.00	0.00
3	0.034	18.00	0.00
4	0.036	22.00	0.00
5	0.038	26.00	0.00
6	0.040	30.00	0.00

D. 4. Graphical Results for Other Reef Fish in Area 1 (East Gulf)

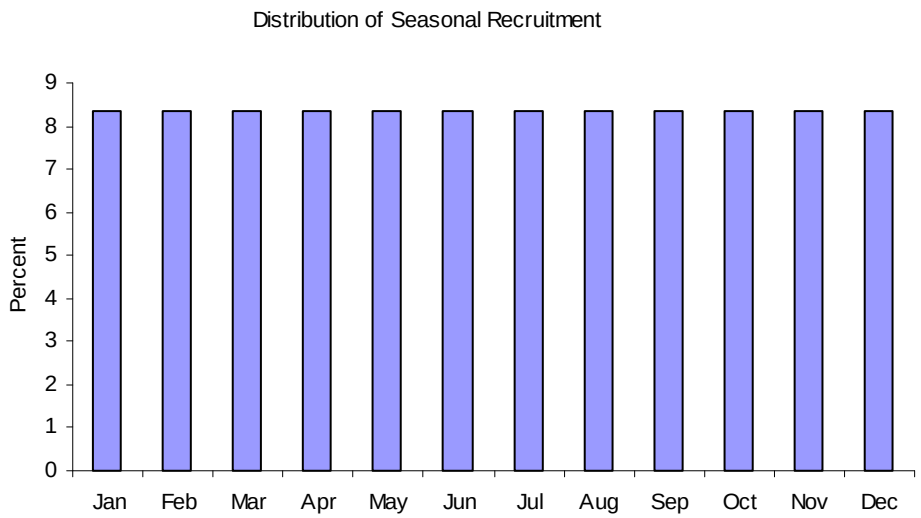


Figure OT1. Other reef fish distribution of recruits by month.

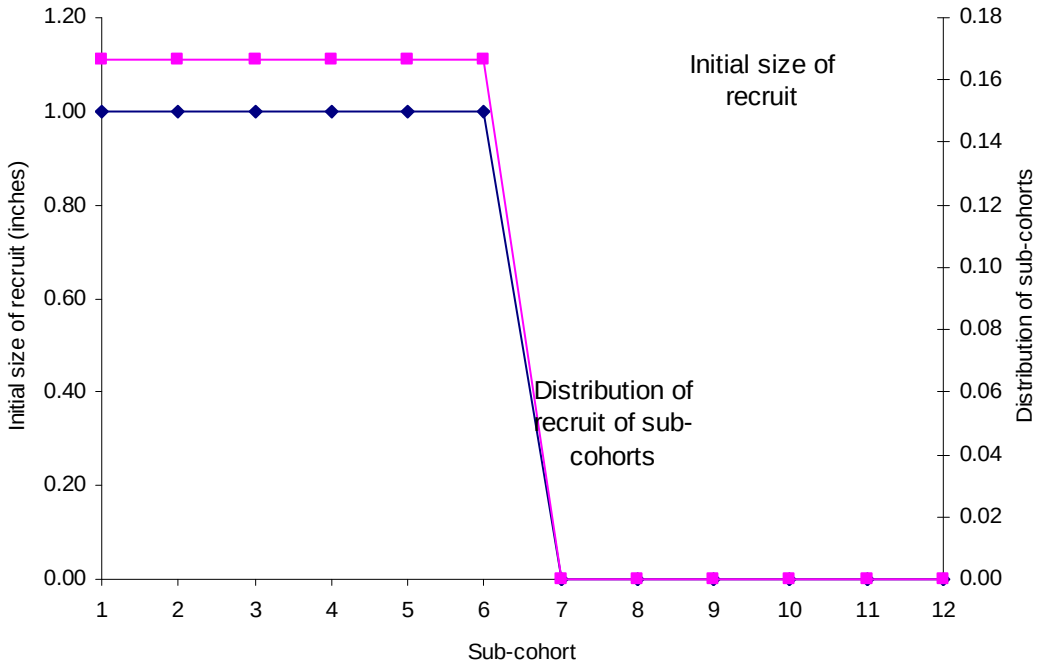


Figure OT2. Other reef fish initial size of recruits and distribution of recruits among sub-cohorts.

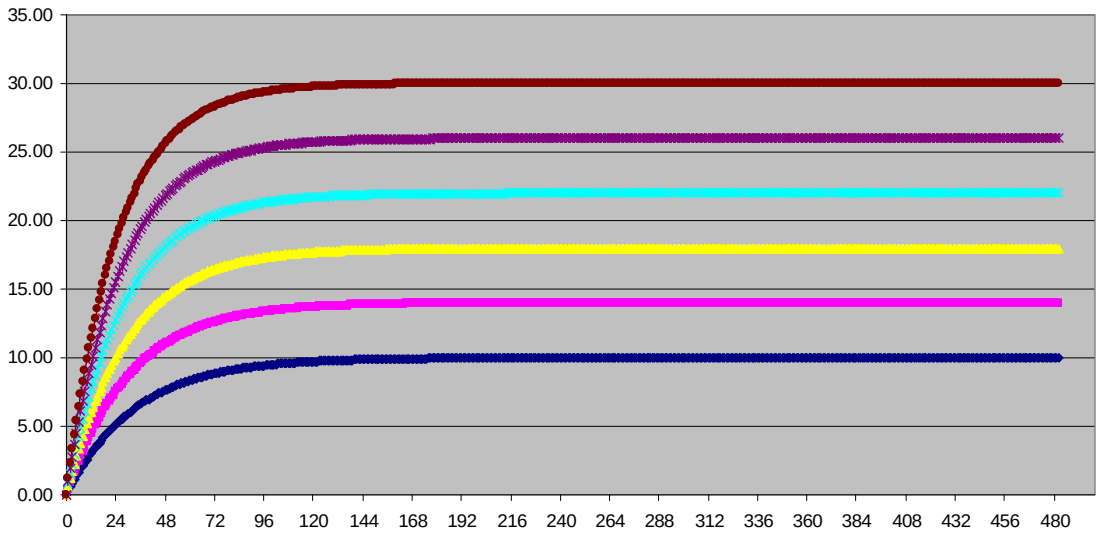


Figure OT3. Growth curves for Other Reef Fish sub-cohorts.

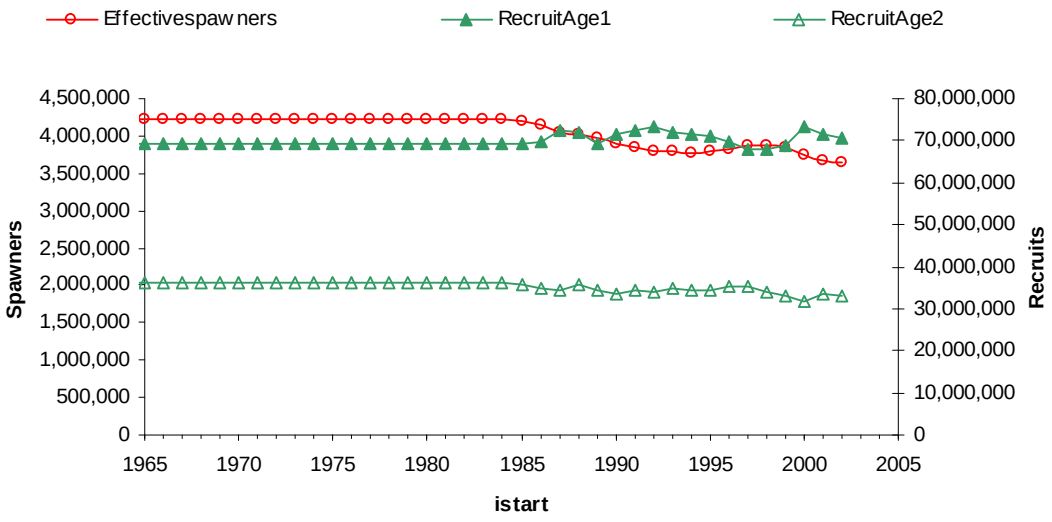


Figure OT4. Developing the prehistoric and historic stock in the Other Reef Fish fishery in the east Gulf of Mexico using BESS(GBFSM).

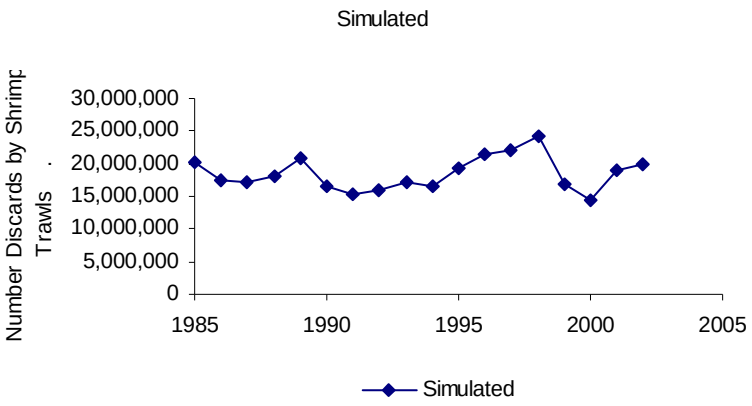


Figure OT5. Number of Discards by shrimp trawlers using BESS(GBFSM) in the east Gulf of Mexico by years.

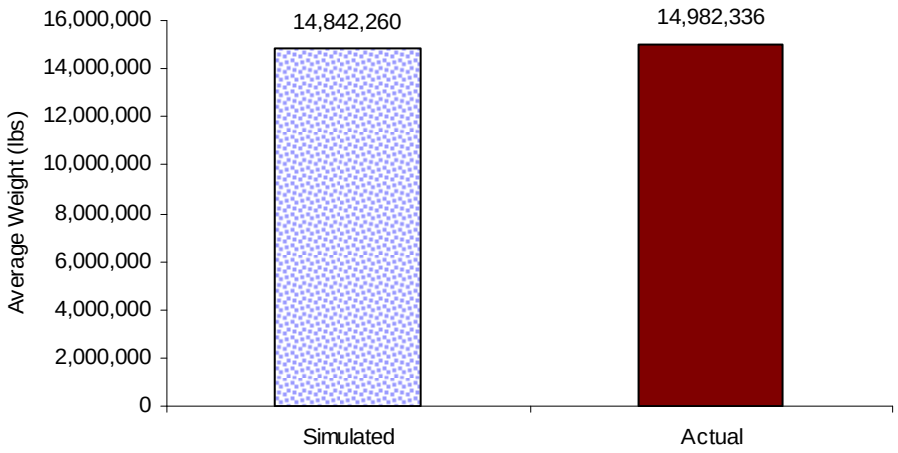


Figure OT6. Average 1993-2002 annual simulated and actual landings of Other Reef Fish by reef fish fishermen in the east Gulf of Mexico.

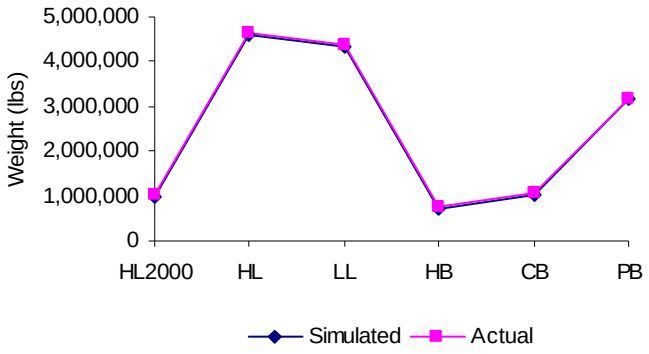


Figure OT7. Average 1993-2002 annual simulated and actual landings of Other Reef Fish by vessel class in the east Gulf of Mexico.

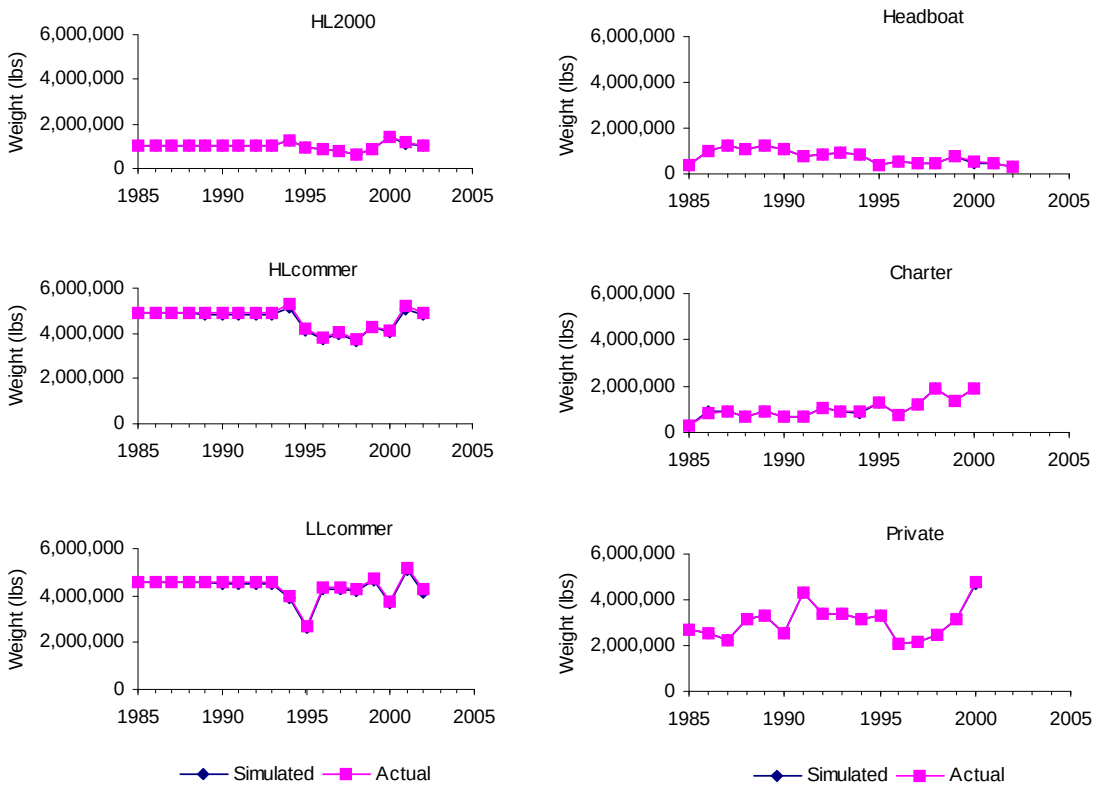


Figure OT8. 1993-2002 annual simulated and actual landings of Other Reef Fish by vessel class in the east Gulf of Mexico.

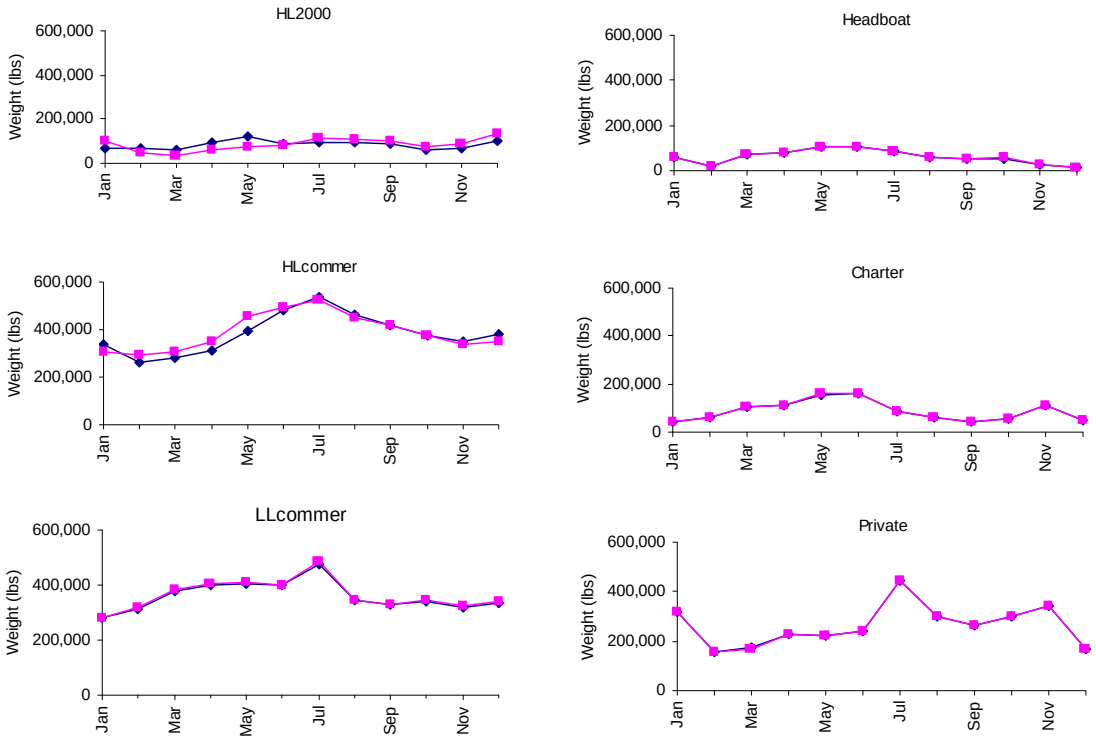


Figure OT9. Average 1993-2002 monthly simulated and actual landings of Other Reef Fish by month and vessel class in the east Gulf of Mexico.

E. 5. Graphical Results for Other Reef Fish in Area 2 (West Gulf)

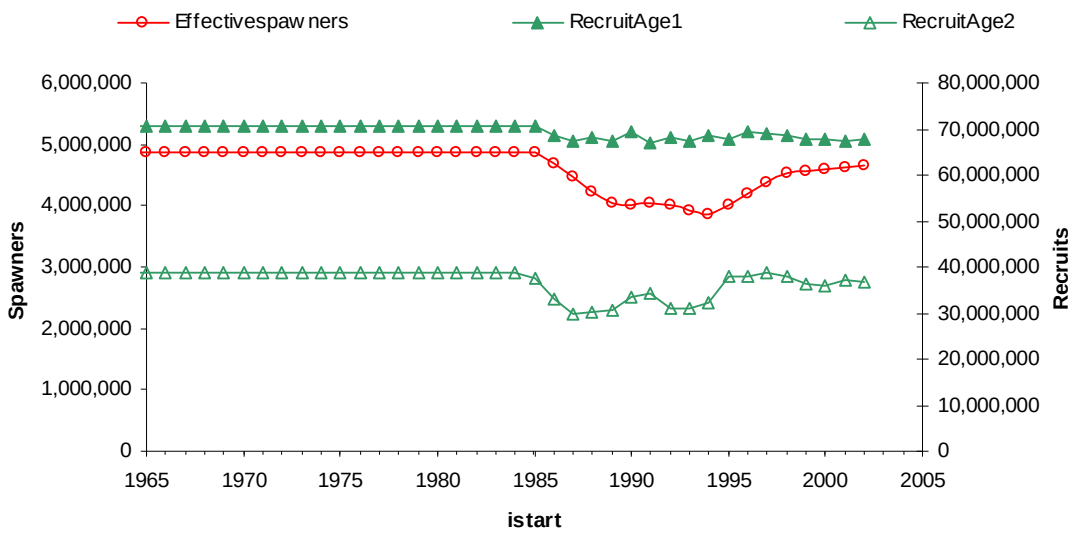


Figure OT10. Developing the prehistoric and historic stock in the Other Reef Fish fishery in the west Gulf of Mexico using BESS(GBFSM).

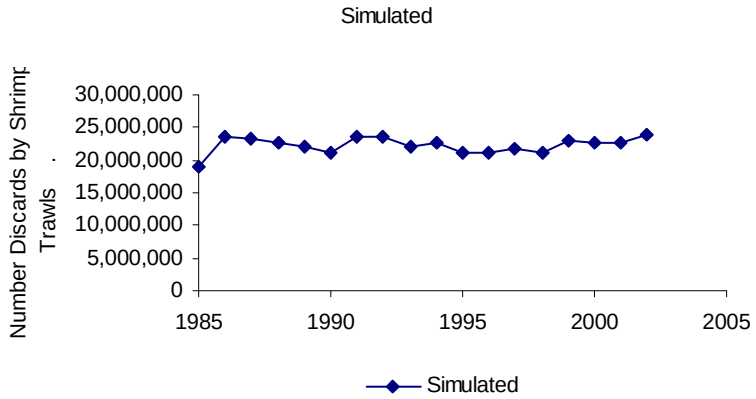


Figure OT11. Number of Discards by shrimp trawlers using BESS(GBFSM) in the west Gulf of Mexico by years.

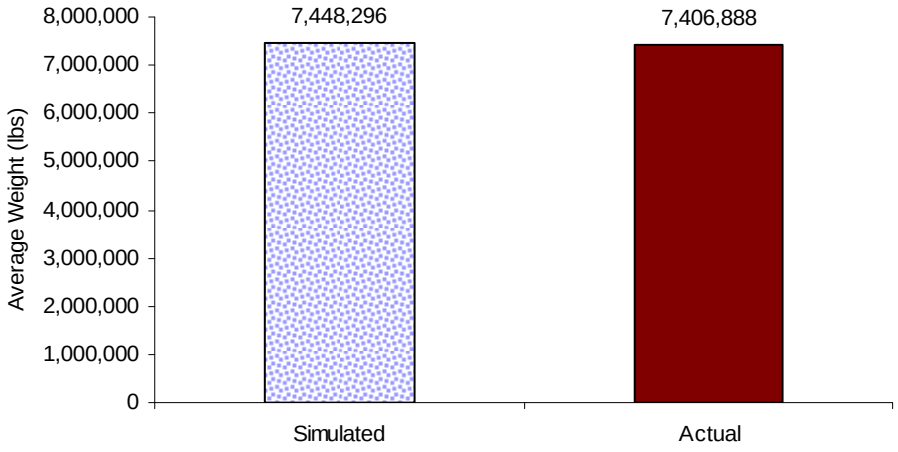


Figure OT12. Average 1993-2002 annual simulated and actual landings of Other Reef Fish by reef fish fishermen in the west Gulf of Mexico.

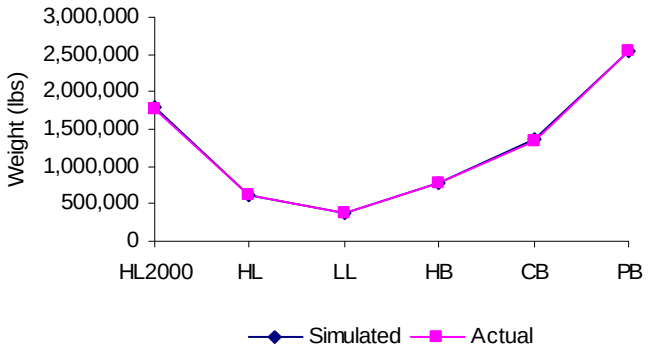


Figure OT13. Average 1993-2002 annual simulated and actual landings of Other Reef Fish by vessel class in the west Gulf of Mexico.

Figure OT14. 1993-2002 annual simulated and actual landings of Other Reef Fish by vessel class in the west Gulf of Mexico.

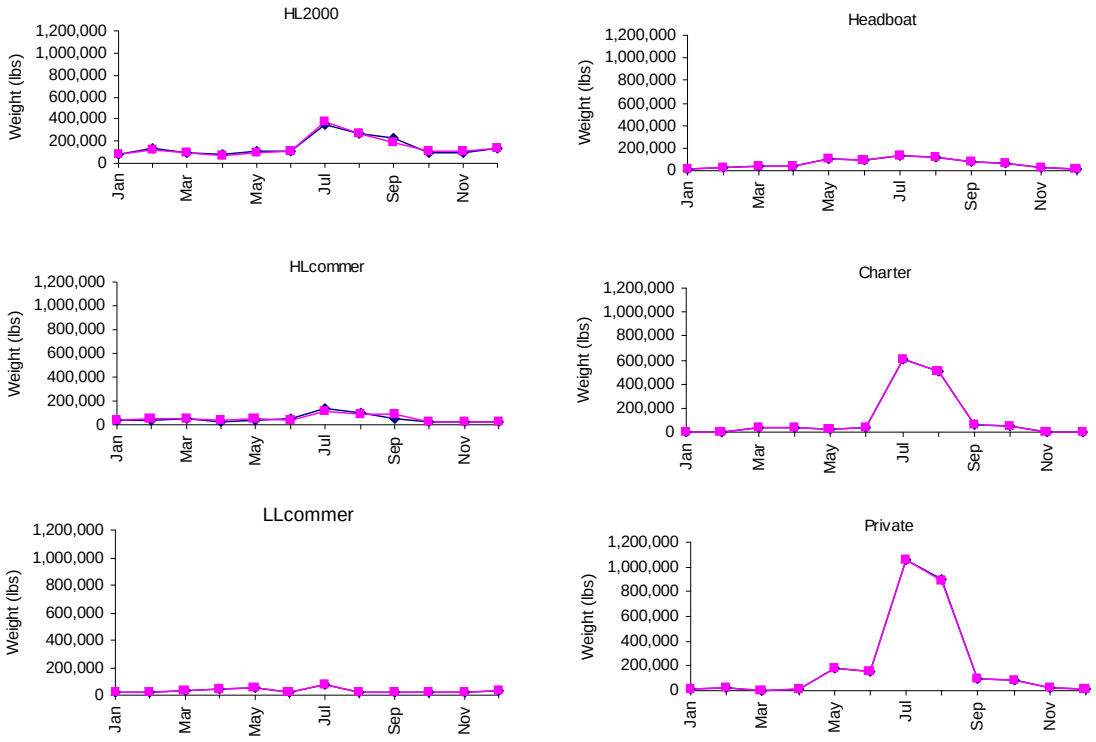


Figure OT15. Average 1993-2002 monthly simulated and actual landings of Other Reef Fish by month and vessel class in the west Gulf of Mexico.

VII. Calibration of Cost and Revenue 1993-2005

The figures below (C&R1-C&R6) are the result of calibrating GBFSM for costs and revenue for the period 1993 to 2005. Actual effort is read in as is actual unit cost and prices by year. After calibrating the biological model of GBFSM, we run the model through 1992 and write out the write the biological information into files. Now we can begin the model in 1993 by reading in the biological information that was stored and the end of 1992. We then run the model from 1993 to 2005 to calibrate the cost and revenue data. After being satisfied that the model is working properly we write out the biological information at the end of 2005. Our policy analysis will begin in 2006 and we will use the actual yearly policies for 2006, 2007 and 2008. The actual policy analysis will be for the period 2009 through 2032.

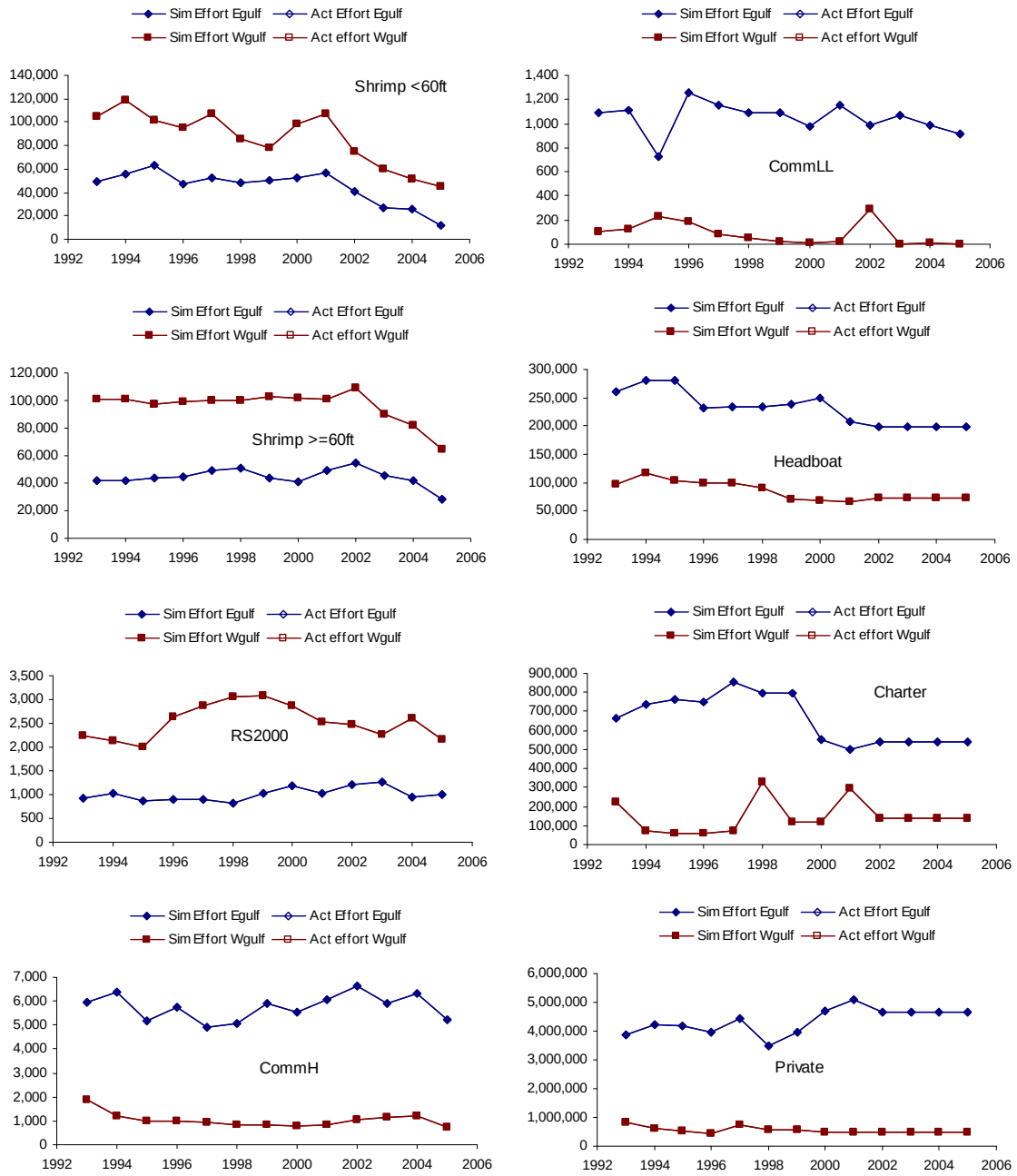


Figure C&R1. These Figures are a comparison of effort by vessel class and east and west gulf for the period 1993-2005.

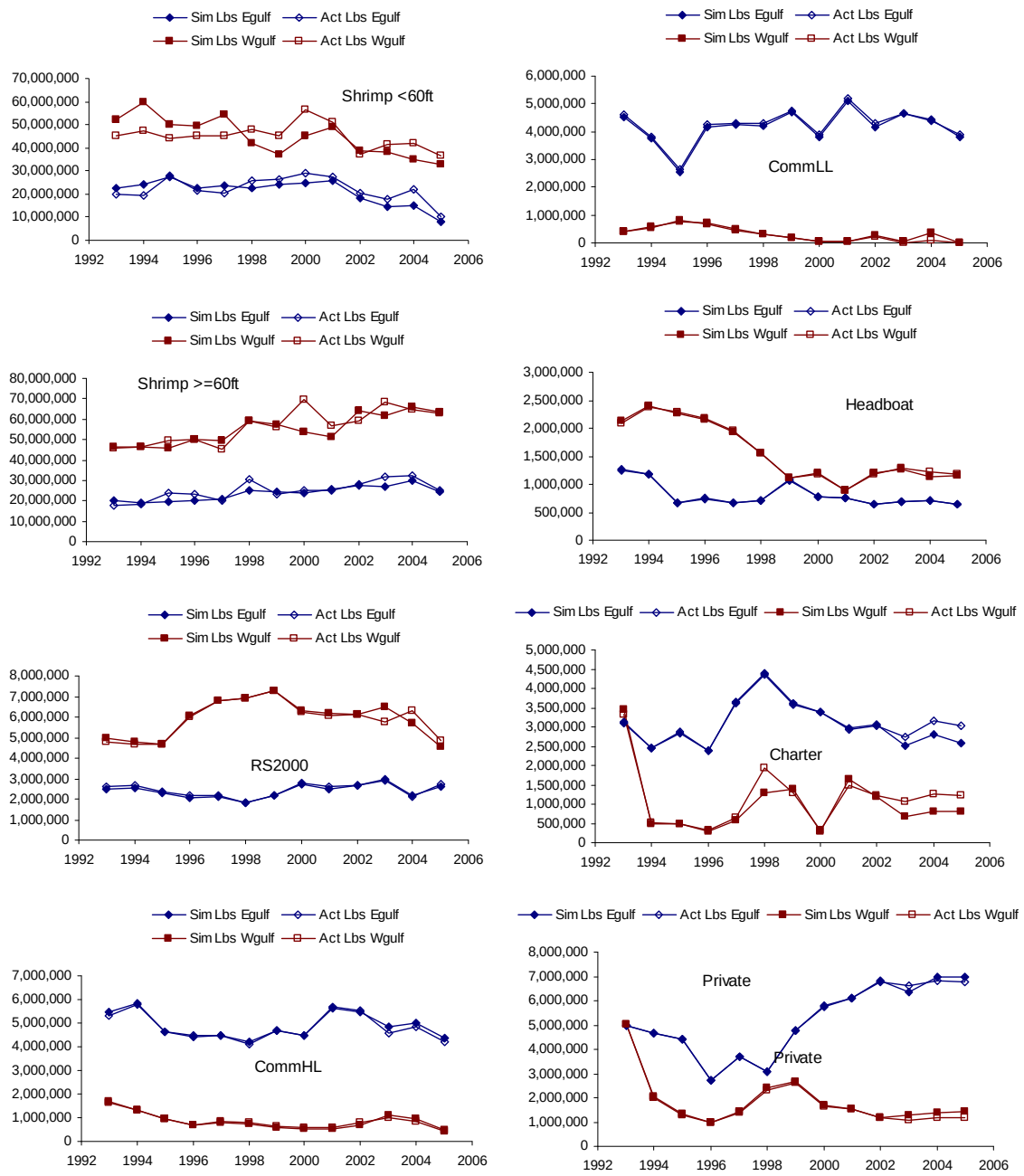


Figure C&R 2. Comparison of pounds landed by vessel class and east and west gulf for the period 1993-2005.

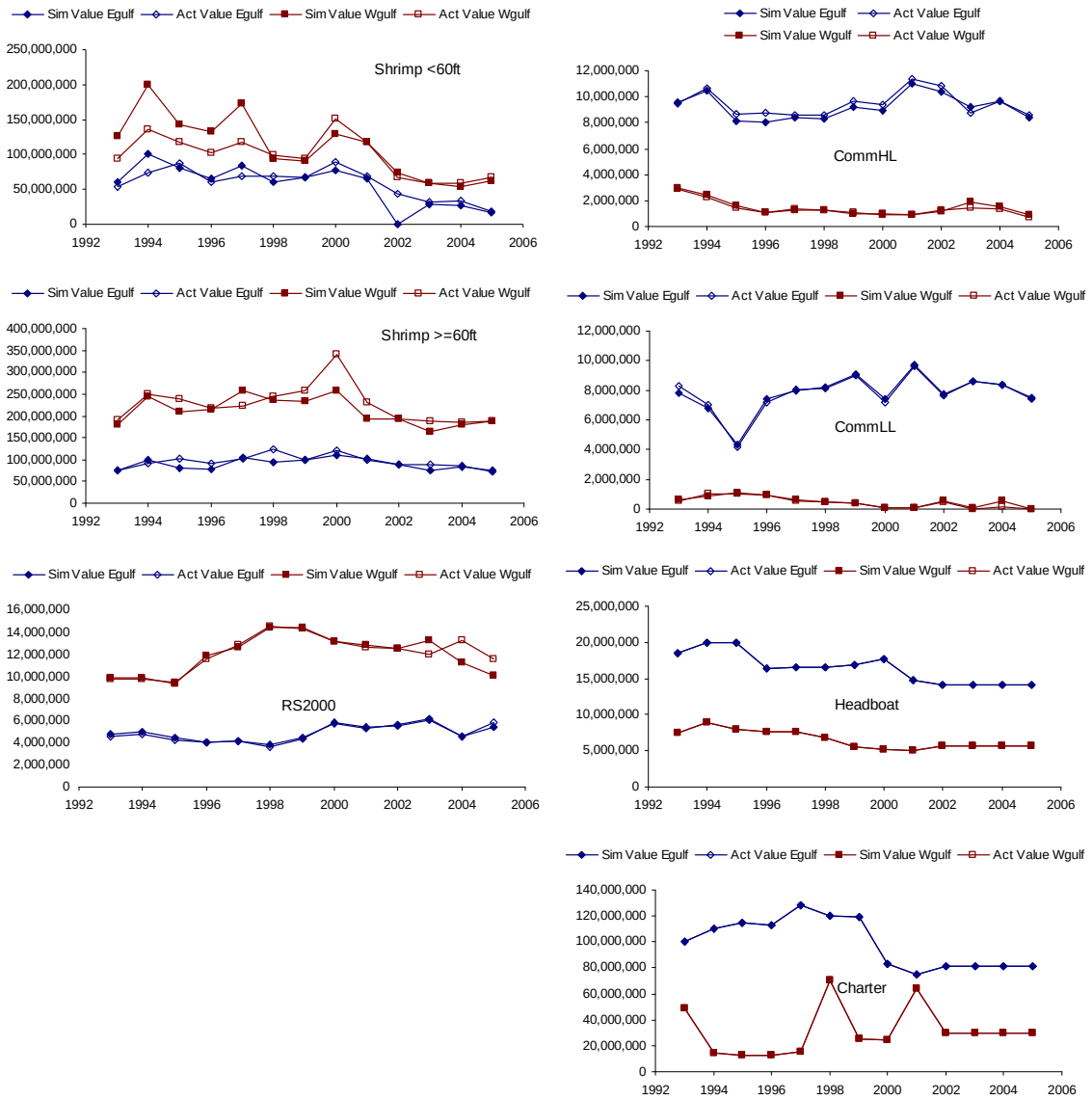


Figure C&R 3. Comparison of revenue by vessel class and east and west gulf for the period 1993-2005.

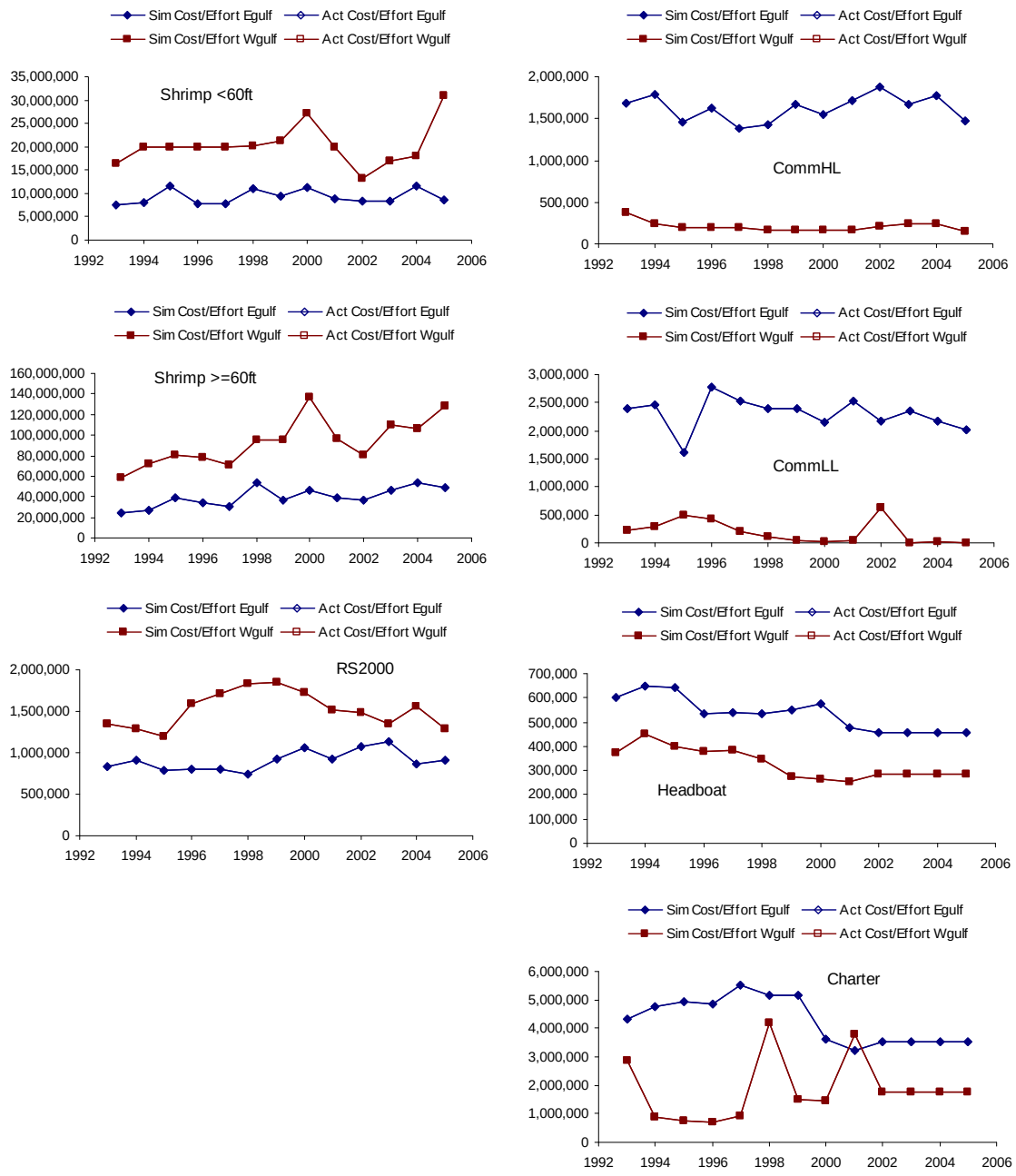


Figure C&R 4. Comparison of variable effort cost by vessel class and east and west gulf for the period 1993-2005. This excludes fuel costs and shares of the crew.

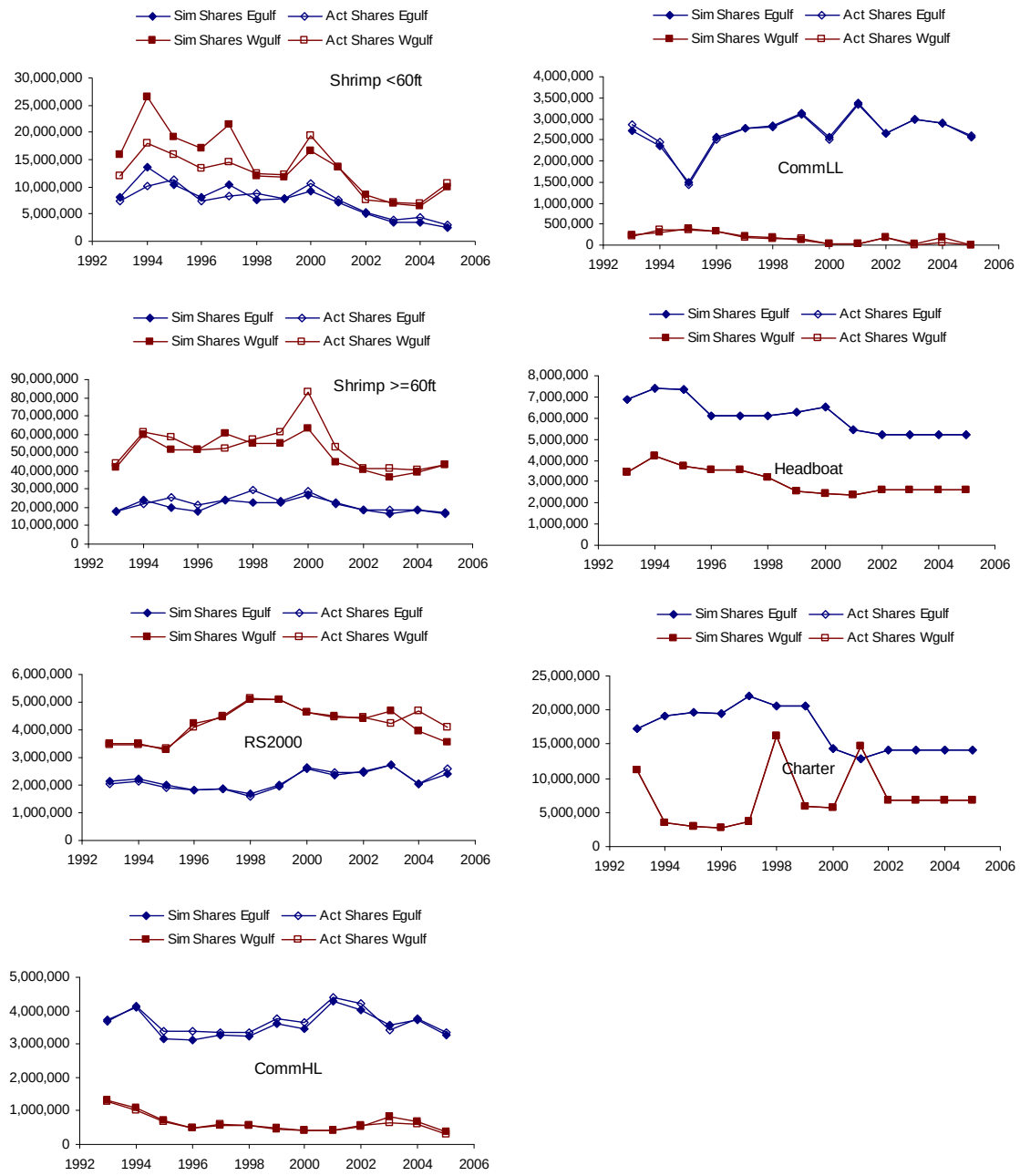


Figure C&R 5. Comparison of share costs by vessel class and east and west gulf for the period 1993-2005.

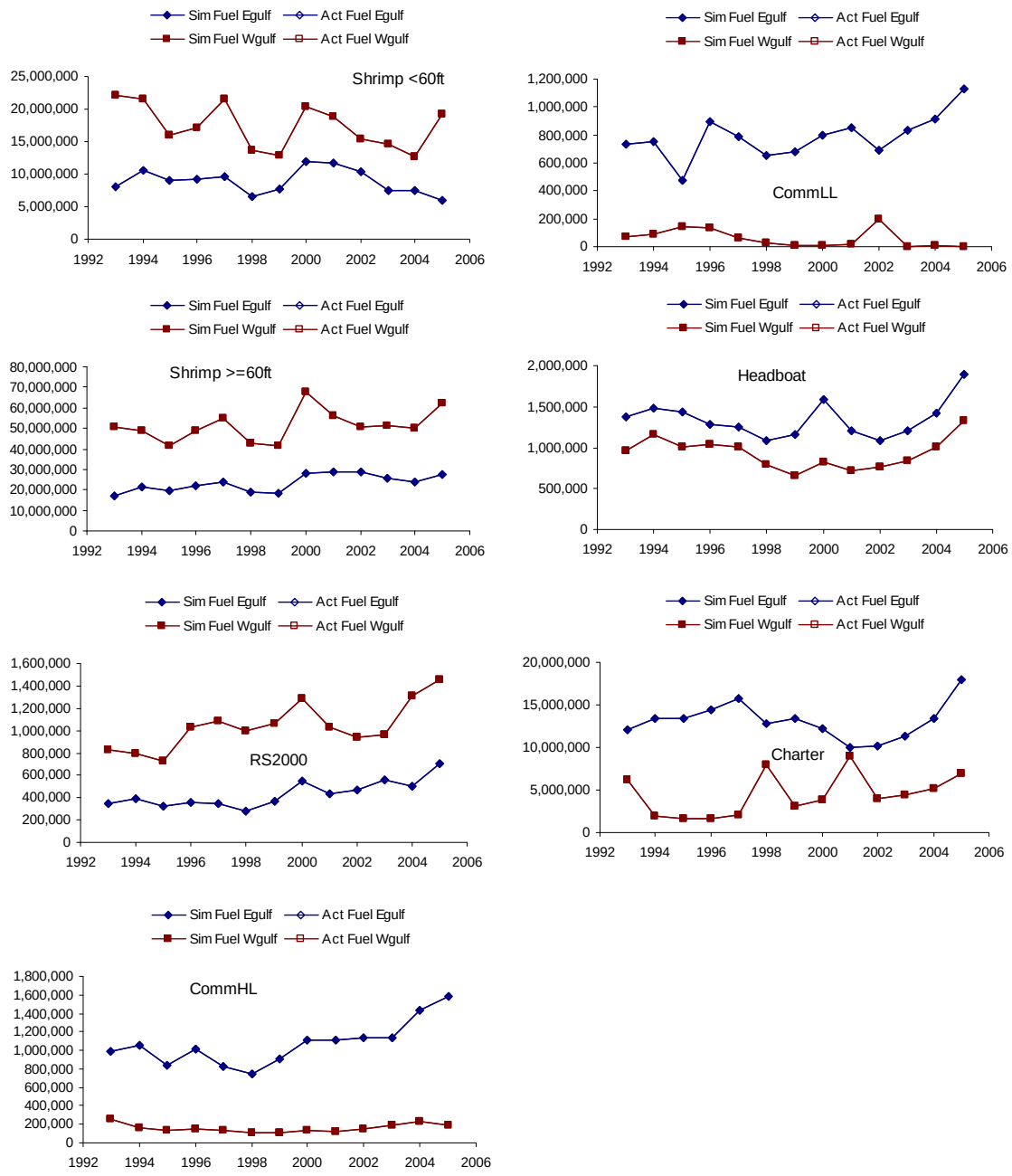


Figure C&R 6. Comparison of fuel costs by vessel class and east and west gulf for the period 1993-2005.

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Appendix B: Results from All Policy Simulations

Table B.1: Ranking Policies Based on Total = East RSS + West RSS + East TS + West TS) and Sum S/S0 (descending)

Rank	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
1	4	5	1	15	1	1	1	1	2	2	4	0.69	0.78	1.47	268	4	22	6
2	4	6	1	14	1	1	1	1	2	2	4	0.64	0.76	1.40	450	35	68	20
3	4	6	1	13	1	1	1	1	2	2	4	0.60	0.76	1.36	608	58	107	25
4	4	9	2	13	1	1	1	1	2	2	4	0.41	0.68	1.09	1,322	210	268	82
5	4	11	3	13	1	1	1	1	2	2	4	0.30	0.61	0.91	1,610	320	350	128
6	4	6	1	15	1	2	1	1	3	2	5	0.68	0.76	1.45	261	14	25	17
7	4	5	1	14	2	1	1	1	3	2	5	0.66	0.78	1.44	256	20	36	7
8	4	7	1	14	1	2	1	1	3	2	5	0.63	0.75	1.38	444	46	71	32
9	4	7	1	13	2	1	1	1	3	2	5	0.59	0.74	1.34	605	68	110	37
10	4	10	2	13	1	2	1	1	3	2	5	0.40	0.66	1.06	1,404	223	284	96
11	4	12	3	13	1	2	1	1	3	2	5	0.29	0.59	0.88	1,658	332	359	141
12	4	12	4	13	2	1	1	1	3	2	5	0.24	0.57	0.81	1,638	390	381	152
13	4	7	1	15	1	3	1	1	4	2	6	0.67	0.75	1.42	254	24	28	29
14	4	8	1	13	2	2	1	1	4	2	6	0.58	0.73	1.31	601	79	114	49
15	4	11	2	13	1	3	1	1	4	2	6	0.39	0.64	1.03	1,397	233	286	108
16	4	10	3	14	1	1	1	3	2	4	6	0.38	0.64	1.03	1,384	258	284	96
17	4	12	2	13	1	3	1	1	4	2	6	0.38	0.63	1.01	1,390	243	288	120
18	4	8	1	14	2	3	1	1	5	2	7	0.63	0.73	1.36	439	56	75	43
19	4	8	2	15	1	2	1	3	3	4	7	0.54	0.71	1.25	976	128	158	51
20	4	8	2	14	2	1	1	3	3	4	7	0.50	0.70	1.20	944	155	183	56
21	4	9	2	14	1	2	1	3	3	4	7	0.47	0.69	1.16	1,200	173	224	70
22	4	11	3	14	1	2	1	3	3	4	7	0.37	0.63	1.00	1,445	269	295	108
23	4	12	3	14	1	3	1	2	4	3	7	0.37	0.61	0.98	1,457	278	300	119
24	4	7	1	16	2	4	1	1	6	2	8	0.69	0.75	1.44	114	13	2	28
25	4	8	1	15	2	4	1	1	6	2	8	0.66	0.73	1.40	247	34	32	40
26	4	9	1	14	2	4	1	1	6	2	8	0.62	0.72	1.33	434	66	78	55
27	4	7	2	16	1	2	1	4	3	5	8	0.59	0.73	1.32	744	98	107	34
28	4	9	1	13	2	4	1	1	6	2	8	0.57	0.71	1.29	597	91	118	62
29	4	9	2	15	1	3	1	3	4	4	8	0.53	0.69	1.22	964	137	161	63
30	4	10	2	14	1	3	1	3	4	4	8	0.47	0.67	1.14	1,191	183	226	82

Table B.1: Continued

	Policies				Rating							S/So			Change in Surplus			
Rank	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
31	4	11	2	14	1	4	1	2	5	3	8	0.46	0.65	1.11	1,181	193	229	94
32	4	12	4	14	2	2	1	3	4	4	8	0.32	0.58	0.90	1,502	336	331	133
33	4	7	2	15	2	1	2	4	3	6	9	0.57	0.73	1.29	667	107	112	35
34	4	8	2	16	1	3	1	4	4	5	9	0.57	0.71	1.28	808	109	120	46
35	4	10	2	15	1	4	1	3	5	4	9	0.52	0.67	1.20	953	147	163	75
36	4	10	3	15	1	3	1	4	4	5	9	0.45	0.66	1.11	1,231	212	222	83
37	4	12	2	14	1	5	1	2	6	3	9	0.45	0.63	1.08	1,170	204	231	108
38	4	10	3	13	4	1	2	2	5	4	9	0.33	0.64	0.97	1,239	293	291	107
39	4	11	4	14	2	2	1	4	4	5	9	0.33	0.60	0.93	1,414	322	315	118
40	4	9	1	15	2	5	1	2	7	3	10	0.65	0.72	1.37	240	44	35	52
41	4	10	1	14	3	5	1	1	8	2	10	0.61	0.70	1.31	428	76	82	66
42	4	10	1	13	3	5	1	1	8	2	10	0.56	0.69	1.26	593	102	122	74
43	4	9	2	16	1	4	1	4	5	5	10	0.56	0.69	1.26	795	120	122	59
44	4	11	2	15	1	5	1	3	6	4	10	0.52	0.66	1.18	941	156	165	86
45	4	9	3	15	1	2	2	5	3	7	10	0.47	0.67	1.14	1,109	200	202	70
46	4	8	2	13	4	1	3	2	5	5	10	0.44	0.70	1.14	920	181	200	64
47	4	10	4	15	1	2	2	5	3	7	10	0.41	0.64	1.05	1,268	260	242	90
48	4	8	1	16	2	5	2	2	7	4	11	0.68	0.73	1.42	106	23	5	39
49	4	6	2	16	3	2	2	4	5	6	11	0.62	0.74	1.37	333	69	47	20
50	4	7	2	14	4	1	3	3	5	6	11	0.53	0.72	1.25	620	128	124	41
51	4	9	3	16	1	3	2	5	4	7	11	0.50	0.67	1.17	1,066	180	175	66
52	4	10	4	16	1	2	2	6	3	8	11	0.46	0.64	1.10	1,149	235	200	82
53	4	11	3	15	1	4	2	4	5	6	11	0.44	0.64	1.08	1,216	222	223	96
54	4	11	4	15	1	3	2	5	4	7	11	0.41	0.62	1.02	1,309	270	250	102
55	4	11	4	13	5	1	3	2	6	5	11	0.28	0.59	0.87	1,285	362	322	136
56	4	6	2	15	4	1	3	4	5	7	12	0.60	0.74	1.34	289	72	49	22
57	4	11	1	14	3	6	2	1	9	3	12	0.60	0.68	1.28	421	88	86	80
58	4	11	1	13	3	6	2	1	9	3	12	0.56	0.68	1.23	590	113	126	86
59	4	10	2	16	1	5	2	4	6	6	12	0.56	0.68	1.23	782	129	125	71
60	4	8	3	16	2	2	2	6	4	8	12	0.53	0.69	1.22	815	163	139	52

Table B.1: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
61	4	8	3	15	3	1	3	5	4	8	12	0.51	0.69	1.20	761	173	145	55
62	4	10	3	16	1	4	2	5	5	7	12	0.49	0.66	1.15	1,051	189	176	77
63	4	9	3	14	4	1	3	4	5	7	12	0.42	0.66	1.09	987	230	216	78
64	4	12	3	15	1	5	2	4	6	6	12	0.44	0.62	1.06	1,201	231	224	109
65	4	12	4	15	2	4	2	4	6	6	12	0.40	0.60	1.00	1,299	278	252	114
66	4	10	4	14	4	1	3	4	5	7	12	0.37	0.63	1.00	1,093	298	262	100
67	4	6	1	16	1	3	8	1	4	9	13	0.70	0.77	1.47	121	3	-2	16
68	4	9	1	16	3	6	2	2	9	4	13	0.68	0.72	1.39	98	33	9	50
69	4	10	1	15	3	6	2	2	9	4	13	0.65	0.70	1.35	233	53	39	63
70	4	11	1	15	3	7	2	1	10	3	13	0.64	0.69	1.32	225	63	42	74
71	4	12	1	13	4	6	2	1	10	3	13	0.55	0.66	1.21	586	123	129	98
72	4	12	2	15	2	6	2	3	8	5	13	0.51	0.64	1.15	929	165	167	98
73	4	11	3	16	2	4	2	5	6	7	13	0.48	0.64	1.13	1,036	198	177	89
74	4	10	1	16	3	7	2	2	10	4	14	0.67	0.70	1.37	90	42	12	61
75	6	6	2	15	4	3	3	4	7	7	14	0.60	0.75	1.35	295	29	56	14
76	4	12	1	15	4	7	2	1	11	3	14	0.63	0.67	1.30	216	74	46	87
77	4	12	1	14	4	7	2	1	11	3	14	0.59	0.67	1.25	415	98	89	92
78	4	11	2	16	2	6	2	4	8	6	14	0.55	0.66	1.21	769	138	127	83
79	4	12	2	16	2	7	2	3	9	5	14	0.54	0.65	1.18	756	147	129	94
80	4	9	4	16	3	2	3	6	5	9	14	0.48	0.66	1.14	945	219	172	68
81	4	9	4	15	4	1	3	6	5	9	14	0.46	0.66	1.12	886	232	182	72
82	4	12	3	16	2	5	3	4	7	7	14	0.48	0.63	1.10	1,019	207	179	102
83	6	6	2	16	4	4	3	4	8	7	15	0.63	0.75	1.38	159	14	25	13
84	4	11	1	16	4	7	2	2	11	4	15	0.66	0.69	1.35	82	52	15	73
85	4	7	3	16	4	2	4	5	6	9	15	0.56	0.71	1.28	444	128	79	37
86	6	7	2	14	5	3	3	4	8	7	15	0.53	0.72	1.25	507	72	117	33
87	4	8	4	16	4	1	4	6	5	10	15	0.52	0.68	1.20	603	189	117	54
88	4	11	4	16	2	4	3	6	6	9	15	0.45	0.62	1.07	1,131	244	201	96
89	4	12	4	16	2	5	3	5	7	8	15	0.44	0.61	1.05	1,114	252	202	108
90	4	9	3	13	7	1	5	2	8	7	15	0.36	0.65	1.02	868	255	221	92

Table B.1: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
91	4	10	4	13	7	1	5	2	8	7	15	0.31	0.61	0.93	920	319	253	119
92	4	12	1	16	4	7	3	2	11	5	16	0.65	0.67	1.32	73	61	19	84
93	6	7	3	16	4	3	3	6	7	9	16	0.57	0.72	1.29	402	76	78	28
94	6	8	2	14	5	4	3	4	9	7	16	0.52	0.71	1.23	502	82	120	46
95	4	7	2	13	7	1	5	3	8	8	16	0.47	0.71	1.18	528	142	129	49
96	6	9	3	14	5	3	3	5	8	8	16	0.44	0.68	1.12	777	158	193	66
97	6	10	3	13	6	3	4	3	9	7	16	0.36	0.64	1.00	942	212	242	94
98	6	11	4	13	6	3	4	3	9	7	16	0.31	0.60	0.91	1,039	283	284	121
99	4	6	3	16	6	2	5	4	8	9	17	0.61	0.74	1.34	83	69	15	24
100	6	7	2	15	5	4	3	5	9	8	17	0.59	0.73	1.33	288	38	59	26
101	6	6	2	14	7	2	4	4	9	8	17	0.56	0.74	1.30	234	53	73	18
102	6	7	3	15	5	3	3	6	8	9	17	0.54	0.72	1.26	494	95	107	32
103	6	8	2	13	6	3	4	4	9	8	17	0.45	0.70	1.15	658	114	161	54
104	4	8	3	14	6	1	5	5	7	10	17	0.46	0.68	1.14	629	190	150	62
105	6	10	4	14	6	3	3	5	9	8	17	0.39	0.64	1.03	882	221	236	89
106	6	9	3	13	6	3	4	4	9	8	17	0.37	0.66	1.03	917	201	235	82
107	6	9	4	13	7	1	5	4	8	9	17	0.35	0.65	1.00	688	248	223	89
108	6	11	3	13	6	4	4	3	10	7	17	0.35	0.63	0.98	937	222	244	106
109	6	12	4	13	6	4	4	3	10	7	17	0.30	0.58	0.88	1,059	294	290	133
110	4	5	1	16	1	8	8	1	9	9	18	0.71	0.78	1.49	129	-7	-6	4
111	6	5	2	15	8	2	4	4	10	8	18	0.63	0.76	1.40	-39	9	5	0
112	6	7	2	16	5	5	3	5	10	8	18	0.63	0.73	1.36	152	24	28	24
113	6	8	2	15	5	5	3	5	10	8	18	0.59	0.72	1.30	281	48	62	38
114	6	8	3	16	5	4	3	6	9	9	18	0.57	0.70	1.27	392	86	81	40
115	4	7	3	15	6	2	5	5	8	10	18	0.55	0.71	1.25	322	126	71	41
116	4	6	2	13	7	2	7	2	9	9	18	0.50	0.74	1.23	182	76	63	35
117	6	8	3	15	5	4	3	6	9	9	18	0.53	0.70	1.23	543	105	119	44
118	6	7	2	13	7	2	5	4	9	9	18	0.46	0.72	1.18	599	102	148	42
119	6	8	4	15	5	3	3	7	8	10	18	0.49	0.69	1.18	631	149	145	49
120	6	8	3	14	6	3	4	5	9	9	18	0.46	0.69	1.15	684	146	174	53

Table B.1: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
121	6	8	3	13	7	2	5	4	9	9	18	0.40	0.68	1.08	597	180	181	65
122	6	9	4	14	7	2	4	5	9	9	18	0.40	0.66	1.06	785	209	217	75
123	4	9	4	14	7	1	5	5	8	10	18	0.41	0.65	1.06	717	256	190	85
124	6	11	4	14	6	4	3	5	10	8	18	0.38	0.62	1.01	879	230	239	100
125	4	9	4	13	7	1	7	3	8	10	18	0.35	0.64	0.99	646	264	196	100
126	6	12	4	14	6	5	3	4	11	7	18	0.38	0.61	0.99	871	239	240	112
127	6	10	4	13	7	3	4	4	10	8	18	0.31	0.62	0.93	986	271	273	107
128	6	6	3	16	6	3	4	6	9	10	19	0.60	0.74	1.34	151	60	41	14
129	6	6	3	15	7	2	4	6	9	10	19	0.58	0.74	1.31	109	70	48	16
130	4	6	2	14	7	2	6	4	9	10	19	0.55	0.74	1.29	179	80	46	26
131	6	9	2	15	5	6	4	4	11	8	19	0.58	0.70	1.28	273	58	65	50
132	6	9	2	14	6	5	4	4	11	8	19	0.51	0.69	1.21	497	92	124	58
133	4	7	3	14	7	2	6	4	9	10	19	0.49	0.71	1.20	310	130	85	47
134	4	8	4	15	6	2	5	6	8	11	19	0.50	0.68	1.18	506	189	115	58
135	6	9	2	13	7	4	4	4	11	8	19	0.45	0.68	1.13	655	124	164	67
136	6	10	3	14	6	5	3	5	11	8	19	0.44	0.66	1.09	770	169	196	80
137	4	8	3	13	7	2	7	3	9	10	19	0.40	0.68	1.08	530	191	151	74
138	6	8	4	13	7	1	7	4	8	11	19	0.39	0.67	1.05	420	222	171	74
139	6	12	3	13	7	5	4	3	12	7	19	0.35	0.61	0.96	933	231	246	117
140	6	5	2	14	8	2	6	4	10	10	20	0.59	0.76	1.35	-64	29	17	4
141	6	8	2	16	5	6	4	5	11	9	20	0.62	0.72	1.34	144	33	31	36
142	4	6	3	15	7	3	6	4	10	10	20	0.58	0.73	1.31	24	57	18	28
143	6	7	4	16	6	3	4	7	9	11	20	0.56	0.71	1.26	311	112	78	30
144	4	7	4	16	7	2	5	6	9	11	20	0.56	0.70	1.26	247	134	54	41
145	4	7	4	15	7	3	6	4	10	10	20	0.54	0.71	1.25	176	115	56	46
146	6	6	2	13	7	2	7	4	9	11	20	0.49	0.73	1.23	204	78	83	26
147	6	8	4	16	5	4	4	7	9	11	20	0.53	0.69	1.22	494	127	106	44
148	6	9	3	15	5	5	4	6	10	10	20	0.52	0.68	1.20	534	115	121	56
149	6	7	3	14	7	2	5	6	9	11	20	0.49	0.71	1.20	311	123	113	38
150	6	7	4	14	7	1	6	6	8	12	20	0.49	0.70	1.19	152	156	97	43

Table B.1: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
151	6	10	2	14	6	6	4	4	12	8	20	0.51	0.68	1.18	491	102	127	69
152	6	9	4	15	5	4	4	7	9	11	20	0.48	0.67	1.16	641	158	151	60
153	6	7	3	13	7	1	7	5	8	12	20	0.44	0.70	1.14	284	150	119	48
154	6	8	4	14	7	2	5	6	9	11	20	0.45	0.68	1.13	407	184	153	57
155	4	8	4	14	7	2	6	5	9	11	20	0.45	0.68	1.12	423	188	125	66
156	6	7	4	13	7	1	7	5	8	12	20	0.42	0.69	1.11	59	177	97	55
157	6	10	2	13	7	5	5	3	12	8	20	0.44	0.67	1.10	651	137	167	80
158	6	11	3	14	6	6	4	4	12	8	20	0.43	0.64	1.07	763	180	198	93
159	6	12	3	14	6	6	4	4	12	8	20	0.42	0.62	1.04	755	190	200	105
160	4	5	2	16	8	2	8	3	10	11	21	0.66	0.76	1.42	-66	19	-20	8
161	6	7	1	13	8	5	5	3	13	8	21	0.59	0.74	1.33	-31	1	16	28
162	6	6	4	16	7	2	5	7	9	12	21	0.60	0.73	1.32	28	89	31	16
163	6	9	2	16	5	7	4	5	12	9	21	0.61	0.70	1.31	136	42	34	47
164	6	10	2	16	6	7	4	4	13	8	21	0.60	0.69	1.29	127	52	37	59
165	6	6	3	14	8	2	6	5	10	11	21	0.54	0.73	1.27	-5	92	50	23
166	6	10	2	15	6	7	4	4	13	8	21	0.57	0.68	1.25	266	69	68	63
167	6	9	3	16	5	6	4	6	11	10	21	0.56	0.69	1.24	382	95	83	53
168	6	7	4	15	7	2	5	7	9	12	21	0.53	0.70	1.24	237	127	87	33
169	6	11	2	15	6	7	4	4	13	8	21	0.56	0.67	1.23	258	78	71	75
170	6	10	4	15	6	5	4	6	11	10	21	0.48	0.66	1.13	631	167	153	72
171	6	11	2	13	7	6	5	3	13	8	21	0.43	0.65	1.08	647	148	171	94
172	4	5	3	16	8	3	8	3	11	11	22	0.64	0.75	1.40	-191	9	-33	14
173	4	5	2	15	8	3	8	3	11	11	22	0.63	0.76	1.39	-110	13	-18	10
174	4	6	4	16	8	3	6	5	11	11	22	0.60	0.73	1.32	-18	63	8	28
175	4	6	4	15	8	4	6	4	12	10	22	0.58	0.73	1.31	-35	51	13	32
176	4	5	2	13	8	4	7	3	12	10	22	0.53	0.75	1.28	-96	13	9	20
177	6	5	2	13	8	2	7	5	10	12	22	0.52	0.75	1.27	-172	43	15	11
178	4	5	1	13	7	5	7	3	12	10	22	0.52	0.74	1.26	87	3	14	26
179	6	11	2	16	7	7	4	4	14	8	22	0.59	0.67	1.26	118	63	40	72
180	4	6	3	14	7	4	7	4	11	11	22	0.53	0.72	1.25	37	63	33	34

Table B.1: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
181	6	12	2	15	7	7	4	4	14	8	22	0.55	0.65	1.20	250	88	74	86
182	6	9	4	16	6	5	4	7	11	11	22	0.53	0.67	1.20	483	136	108	56
183	4	6	3	13	7	5	7	3	12	10	22	0.47	0.72	1.19	3	49	44	42
184	6	6	3	13	8	2	7	5	10	12	22	0.47	0.72	1.19	-61	112	54	33
185	6	10	3	15	6	6	4	6	12	10	22	0.51	0.67	1.18	525	124	124	68
186	6	11	2	14	7	7	4	4	14	8	22	0.50	0.66	1.16	486	112	130	81
187	6	11	3	15	6	7	4	5	13	9	22	0.50	0.65	1.16	516	133	126	80
188	6	12	2	14	7	7	4	4	14	8	22	0.49	0.65	1.14	480	122	133	93
189	6	12	3	15	6	7	4	5	13	9	22	0.50	0.64	1.13	506	142	128	91
190	4	7	3	13	7	4	7	4	11	11	22	0.43	0.70	1.13	252	116	97	57
191	4	7	4	13	7	5	7	3	12	10	22	0.42	0.69	1.11	165	102	90	62
192	6	11	4	15	6	6	4	6	12	10	22	0.47	0.64	1.11	621	176	154	84
193	6	12	2	13	7	7	5	3	14	8	22	0.42	0.63	1.05	643	159	174	106
194	4	8	4	13	7	4	7	4	11	11	22	0.38	0.66	1.05	359	170	137	81
195	6	5	1	13	8	8	5	2	16	7	23	0.61	0.77	1.38	-29	-21	8	4
196	4	5	2	14	8	3	8	4	11	12	23	0.58	0.75	1.33	-118	16	-8	14
197	6	10	1	14	8	7	5	3	15	8	23	0.62	0.70	1.32	-153	12	1	58
198	6	8	1	13	8	6	6	3	14	9	23	0.58	0.72	1.31	-32	12	20	40
199	6	6	4	15	8	2	6	7	10	13	23	0.58	0.73	1.30	-89	95	26	18
200	6	11	1	14	8	7	5	3	15	8	23	0.61	0.68	1.29	-156	24	6	71
201	6	6	4	14	8	2	7	6	10	13	23	0.52	0.72	1.24	-161	117	36	28
202	6	12	2	16	7	7	5	4	14	9	23	0.58	0.65	1.23	110	73	44	84
203	6	10	3	16	6	7	4	6	13	10	23	0.55	0.67	1.22	372	105	86	64
204	6	11	3	16	6	7	4	6	13	10	23	0.54	0.66	1.19	361	114	88	76
205	6	10	4	16	6	6	4	7	12	11	23	0.52	0.66	1.18	473	144	110	67
206	4	7	4	14	7	4	7	5	11	12	23	0.48	0.69	1.17	160	115	74	52
207	6	6	4	13	8	2	7	6	10	13	23	0.45	0.71	1.16	-233	119	35	37
208	6	5	3	16	8	2	8	6	10	14	24	0.64	0.76	1.40	-194	31	-15	1
209	6	5	3	15	8	2	8	6	10	14	24	0.61	0.75	1.37	-248	37	-14	3
210	6	6	1	13	8	8	5	3	16	8	24	0.60	0.76	1.36	-30	-10	12	16

Table B.1: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
211	6	5	3	14	8	2	8	6	10	14	24	0.56	0.75	1.31	-390	49	-23	8
212	6	5	4	14	8	2	8	6	10	14	24	0.55	0.74	1.29	-426	57	-22	11
213	6	9	1	13	8	7	6	3	15	9	24	0.57	0.71	1.28	-34	24	25	53
214	6	12	1	14	8	7	6	3	15	9	24	0.59	0.66	1.26	-159	35	10	84
215	6	10	1	13	8	7	6	3	15	9	24	0.57	0.69	1.26	-35	35	29	66
216	4	6	4	14	8	5	7	4	13	11	24	0.52	0.72	1.24	-80	48	20	39
217	6	5	3	13	8	3	8	5	11	13	24	0.50	0.74	1.24	-360	54	-8	17
218	6	11	1	13	8	7	6	3	15	9	24	0.56	0.67	1.23	-37	46	33	78
219	6	12	1	13	8	7	6	3	15	9	24	0.55	0.66	1.21	-39	57	37	89
220	6	12	3	16	7	7	5	5	14	10	24	0.53	0.64	1.17	351	123	91	87
221	6	11	4	16	6	7	4	7	13	11	24	0.51	0.64	1.15	462	153	112	79
222	6	12	4	15	7	7	4	6	14	10	24	0.46	0.62	1.08	609	186	157	98
223	6	5	4	16	8	2	8	7	10	15	25	0.64	0.75	1.38	-344	51	-33	3
224	6	5	4	15	8	2	8	7	10	15	25	0.61	0.74	1.36	-430	51	-38	5
225	6	12	4	16	7	7	5	6	14	11	25	0.50	0.63	1.13	450	161	114	90
226	6	6	1	16	8	8	8	2	16	10	26	0.72	0.77	1.48	-420	-59	-73	8
227	6	5	1	14	8	8	8	2	16	10	26	0.66	0.78	1.44	-140	-40	-19	0
228	4	5	3	15	8	8	8	2	16	10	26	0.63	0.76	1.38	-269	-4	-34	17
229	6	9	1	14	8	7	8	3	15	11	26	0.62	0.71	1.34	-150	2	-3	47
230	6	11	1	15	8	7	8	3	15	11	26	0.65	0.69	1.34	-333	1	-33	66
231	6	12	1	16	8	7	8	3	15	11	26	0.66	0.68	1.34	-448	1	-49	76
232	6	12	1	15	8	7	8	3	15	11	26	0.64	0.67	1.31	-338	11	-29	78
233	6	5	4	13	8	4	8	6	12	14	26	0.49	0.73	1.21	-540	41	-24	22
234	4	6	4	13	8	7	7	4	15	11	26	0.45	0.71	1.16	-146	35	35	47
235	6	7	1	16	8	8	8	3	16	11	27	0.71	0.75	1.46	-424	-48	-69	20
236	6	6	1	15	8	8	8	3	16	11	27	0.69	0.76	1.46	-312	-49	-52	9
237	6	8	1	16	8	8	8	3	16	11	27	0.70	0.74	1.43	-429	-38	-65	32
238	6	7	1	15	8	8	8	3	16	11	27	0.68	0.75	1.43	-316	-39	-49	21
239	6	6	1	14	8	8	8	3	16	11	27	0.65	0.76	1.41	-142	-29	-15	12
240	6	9	1	16	8	8	8	3	16	11	27	0.69	0.72	1.41	-434	-28	-61	43

Table B.1: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
241	6	8	1	15	8	8	8	3	16	11	27	0.68	0.73	1.41	-320	-29	-45	32
242	6	7	1	14	8	8	8	3	16	11	27	0.64	0.74	1.39	-145	-19	-11	24
243	6	10	1	16	8	8	8	3	16	11	27	0.68	0.71	1.38	-438	-19	-57	54
244	6	9	1	15	8	8	8	3	16	11	27	0.67	0.72	1.38	-324	-19	-41	44
245	6	8	1	14	8	8	8	3	16	11	27	0.63	0.73	1.36	-147	-8	-7	35
246	6	10	1	15	8	8	8	3	16	11	27	0.66	0.70	1.36	-329	-9	-37	55
247	6	11	1	16	8	8	8	3	16	11	27	0.67	0.69	1.36	-443	-9	-53	65
248	4	5	4	15	8	8	8	3	16	11	27	0.61	0.75	1.35	-356	-10	-37	20
249	4	5	4	16	8	8	8	4	16	12	28	0.63	0.75	1.38	-332	-2	-44	18
250	4	5	3	14	8	8	8	4	16	12	28	0.56	0.74	1.30	-322	-7	-28	21
251	4	5	4	14	8	8	8	4	16	12	28	0.55	0.74	1.29	-344	-7	-26	23
252	4	5	3	13	8	8	8	4	16	12	28	0.49	0.73	1.23	-269	-5	-4	26
253	4	5	4	13	8	8	8	5	16	13	29	0.49	0.73	1.22	-347	-15	-11	26
254	6	5	1	16	8	8	8	8	16	16	32	0.73	0.78	1.51	-416	-69	-77	-4
255	6	5	1	15	8	8	8	8	16	16	32	0.70	0.78	1.48	-308	-60	-56	-2
256	6	5	2	16	8	8	8	8	16	16	32	0.65	0.77	1.42	0	0	0	0

Table B.2: Ranking Policies Based on Total RSS = East RSS + West RSS and Sum S/S_0 (descending)

	Policies				Rating							S/So			Change in Surplus			
Rank	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
1	4	5	1	15	1	1	1	1	2	2	4	0.69	0.78	1.47	268	4	22	6
2	4	6	1	14	1	1	1	1	2	2	4	0.64	0.76	1.40	450	35	68	20
3	4	6	1	13	1	1	1	1	2	2	4	0.60	0.76	1.36	608	58	107	25
4	4	9	2	13	1	1	1	1	2	2	4	0.41	0.68	1.09	1,322	210	268	82
5	4	10	3	14	1	1	1	3	2	4	6	0.38	0.64	1.03	1,384	258	284	96
6	4	11	3	13	1	1	1	1	2	2	4	0.30	0.61	0.91	1,610	320	350	128
7	4	6	1	15	1	2	1	1	3	2	5	0.68	0.76	1.45	261	14	25	17
8	4	5	1	14	2	1	1	1	3	2	5	0.66	0.78	1.44	256	20	36	7
9	4	7	1	14	1	2	1	1	3	2	5	0.63	0.75	1.38	444	46	71	32
10	4	7	1	13	2	1	1	1	3	2	5	0.59	0.74	1.34	605	68	110	37
11	4	7	2	16	1	2	1	4	3	5	8	0.59	0.73	1.32	744	98	107	34
12	4	7	2	15	2	1	2	4	3	6	9	0.57	0.73	1.29	667	107	112	35
13	4	8	2	15	1	2	1	3	3	4	7	0.54	0.71	1.25	976	128	158	51
14	4	8	2	14	2	1	1	3	3	4	7	0.50	0.70	1.20	944	155	183	56
15	4	9	2	14	1	2	1	3	3	4	7	0.47	0.69	1.16	1,200	173	224	70
16	4	9	3	15	1	2	2	5	3	7	10	0.47	0.67	1.14	1,109	200	202	70
17	4	10	4	16	1	2	2	6	3	8	11	0.46	0.64	1.10	1,149	235	200	82
18	4	10	2	13	1	2	1	1	3	2	5	0.40	0.66	1.06	1,404	223	284	96
19	4	10	4	15	1	2	2	5	3	7	10	0.41	0.64	1.05	1,268	260	242	90
20	4	11	3	14	1	2	1	3	3	4	7	0.37	0.63	1.00	1,445	269	295	108
21	4	12	3	13	1	2	1	1	3	2	5	0.29	0.59	0.88	1,658	332	359	141
22	4	12	4	13	2	1	1	1	3	2	5	0.24	0.57	0.81	1,638	390	381	152
23	4	6	1	16	1	3	8	1	4	9	13	0.70	0.77	1.47	121	3	-2	16
24	4	7	1	15	1	3	1	1	4	2	6	0.67	0.75	1.42	254	24	28	29
25	4	8	1	13	2	2	1	1	4	2	6	0.58	0.73	1.31	601	79	114	49
26	4	8	2	16	1	3	1	4	4	5	9	0.57	0.71	1.28	808	109	120	46
27	4	9	2	15	1	3	1	3	4	4	8	0.53	0.69	1.22	964	137	161	63
28	4	8	3	16	2	2	2	6	4	8	12	0.53	0.69	1.22	815	163	139	52
29	4	8	3	15	3	1	3	5	4	8	12	0.51	0.69	1.20	761	173	145	55
30	4	9	3	16	1	3	2	5	4	7	11	0.50	0.67	1.17	1,066	180	175	66

Table B.2: Continued

	Policies				Rating							S/So			Change in Surplus			
Rank	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
31	4	10	2	14	1	3	1	3	4	4	8	0.47	0.67	1.14	1,191	183	226	82
32	4	10	3	15	1	3	1	4	4	5	9	0.45	0.66	1.11	1,231	212	222	83
33	4	11	2	13	1	3	1	1	4	2	6	0.39	0.64	1.03	1,397	233	286	108
34	4	11	4	15	1	3	2	5	4	7	11	0.41	0.62	1.02	1,309	270	250	102
35	4	12	2	13	1	3	1	1	4	2	6	0.38	0.63	1.01	1,390	243	288	120
36	4	12	3	14	1	3	1	2	4	3	7	0.37	0.61	0.98	1,457	278	300	119
37	4	11	4	14	2	2	1	4	4	5	9	0.33	0.60	0.93	1,414	322	315	118
38	4	12	4	14	2	2	1	3	4	4	8	0.32	0.58	0.90	1,502	336	331	133
39	4	6	2	16	3	2	2	4	5	6	11	0.62	0.74	1.37	333	69	47	20
40	4	8	1	14	2	3	1	1	5	2	7	0.63	0.73	1.36	439	56	75	43
41	4	6	2	15	4	1	3	4	5	7	12	0.60	0.74	1.34	289	72	49	22
42	4	9	2	16	1	4	1	4	5	5	10	0.56	0.69	1.26	795	120	122	59
43	4	7	2	14	4	1	3	3	5	6	11	0.53	0.72	1.25	620	128	124	41
44	4	8	4	16	4	1	4	6	5	10	15	0.52	0.68	1.20	603	189	117	54
45	4	10	2	15	1	4	1	3	5	4	9	0.52	0.67	1.20	953	147	163	75
46	4	10	3	16	1	4	2	5	5	7	12	0.49	0.66	1.15	1,051	189	176	77
47	4	8	2	13	4	1	3	2	5	5	10	0.44	0.70	1.14	920	181	200	64
48	4	9	4	16	3	2	3	6	5	9	14	0.48	0.66	1.14	945	219	172	68
49	4	9	4	15	4	1	3	6	5	9	14	0.46	0.66	1.12	886	232	182	72
50	4	11	2	14	1	4	1	2	5	3	8	0.46	0.65	1.11	1,181	193	229	94
51	4	9	3	14	4	1	3	4	5	7	12	0.42	0.66	1.09	987	230	216	78
52	4	11	3	15	1	4	2	4	5	6	11	0.44	0.64	1.08	1,216	222	223	96
53	4	10	4	14	4	1	3	4	5	7	12	0.37	0.63	1.00	1,093	298	262	100
54	4	10	3	13	4	1	2	2	5	4	9	0.33	0.64	0.97	1,239	293	291	107
55	4	7	1	16	2	4	1	1	6	2	8	0.69	0.75	1.44	114	13	2	28
56	4	8	1	15	2	4	1	1	6	2	8	0.66	0.73	1.40	247	34	32	40
57	4	9	1	14	2	4	1	1	6	2	8	0.62	0.72	1.33	434	66	78	55
58	4	9	1	13	2	4	1	1	6	2	8	0.57	0.71	1.29	597	91	118	62
59	4	7	3	16	4	2	4	5	6	9	15	0.56	0.71	1.28	444	128	79	37
60	4	10	2	16	1	5	2	4	6	6	12	0.56	0.68	1.23	782	129	125	71

Table B.2: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
61	4	11	2	15	1	5	1	3	6	4	10	0.52	0.66	1.18	941	156	165	86
62	4	11	3	16	2	4	2	5	6	7	13	0.48	0.64	1.13	1,036	198	177	89
63	4	12	2	14	1	5	1	2	6	3	9	0.45	0.63	1.08	1,170	204	231	108
64	4	11	4	16	2	4	3	6	6	9	15	0.45	0.62	1.07	1,131	244	201	96
65	4	12	3	15	1	5	2	4	6	6	12	0.44	0.62	1.06	1,201	231	224	109
66	4	12	4	15	2	4	2	4	6	6	12	0.40	0.60	1.00	1,299	278	252	114
67	4	11	4	13	5	1	3	2	6	5	11	0.28	0.59	0.87	1,285	362	322	136
68	4	8	1	16	2	5	2	2	7	4	11	0.68	0.73	1.42	106	23	5	39
69	4	9	1	15	2	5	1	2	7	3	10	0.65	0.72	1.37	240	44	35	52
70	6	6	2	15	4	3	3	4	7	7	14	0.60	0.75	1.35	295	29	56	14
71	6	7	3	16	4	3	3	6	7	9	16	0.57	0.72	1.29	402	76	78	28
72	4	8	3	14	6	1	5	5	7	10	17	0.46	0.68	1.14	629	190	150	62
73	4	12	3	16	2	5	3	4	7	7	14	0.48	0.63	1.10	1,019	207	179	102
74	4	12	4	16	2	5	3	5	7	8	15	0.44	0.61	1.05	1,114	252	202	108
75	6	6	2	16	4	4	3	4	8	7	15	0.63	0.75	1.38	159	14	25	13
76	4	6	3	16	6	2	5	4	8	9	17	0.61	0.74	1.34	83	69	15	24
77	4	10	1	14	3	5	1	1	8	2	10	0.61	0.70	1.31	428	76	82	66
78	6	7	3	15	5	3	3	6	8	9	17	0.54	0.72	1.26	494	95	107	32
79	4	10	1	13	3	5	1	1	8	2	10	0.56	0.69	1.26	593	102	122	74
80	4	7	3	15	6	2	5	5	8	10	18	0.55	0.71	1.25	322	126	71	41
81	6	7	2	14	5	3	3	4	8	7	15	0.53	0.72	1.25	507	72	117	33
82	4	11	2	16	2	6	2	4	8	6	14	0.55	0.66	1.21	769	138	127	83
83	6	7	4	14	7	1	6	6	8	12	20	0.49	0.70	1.19	152	156	97	43
84	4	7	2	13	7	1	5	3	8	8	16	0.47	0.71	1.18	528	142	129	49
85	4	8	4	15	6	2	5	6	8	11	19	0.50	0.68	1.18	506	189	115	58
86	6	8	4	15	5	3	3	7	8	10	18	0.49	0.69	1.18	631	149	145	49
87	4	12	2	15	2	6	2	3	8	5	13	0.51	0.64	1.15	929	165	167	98
88	6	7	3	13	7	1	7	5	8	12	20	0.44	0.70	1.14	284	150	119	48
89	6	9	3	14	5	3	3	5	8	8	16	0.44	0.68	1.12	777	158	193	66
90	6	7	4	13	7	1	7	5	8	12	20	0.42	0.69	1.11	59	177	97	55

Table B.2: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
91	4	9	4	14	7	1	5	5	8	10	18	0.41	0.65	1.06	717	256	190	85
92	6	8	4	13	7	1	7	4	8	11	19	0.39	0.67	1.05	420	222	171	74
93	4	9	3	13	7	1	5	2	8	7	15	0.36	0.65	1.02	868	255	221	92
94	6	9	4	13	7	1	5	4	8	9	17	0.35	0.65	1.00	688	248	223	89
95	4	9	4	13	7	1	7	3	8	10	18	0.35	0.64	0.99	646	264	196	100
96	4	10	4	13	7	1	5	2	8	7	15	0.31	0.61	0.93	920	319	253	119
97	4	5	1	16	1	8	8	1	9	9	18	0.71	0.78	1.49	129	-7	-6	4
98	4	9	1	16	3	6	2	2	9	4	13	0.68	0.72	1.39	98	33	9	50
99	4	10	1	15	3	6	2	2	9	4	13	0.65	0.70	1.35	233	53	39	63
100	6	6	3	16	6	3	4	6	9	10	19	0.60	0.74	1.34	151	60	41	14
101	6	7	2	15	5	4	3	5	9	8	17	0.59	0.73	1.33	288	38	59	26
102	6	6	4	16	7	2	5	7	9	12	21	0.60	0.73	1.32	28	89	31	16
103	6	6	3	15	7	2	4	6	9	10	19	0.58	0.74	1.31	109	70	48	16
104	6	6	2	14	7	2	4	4	9	8	17	0.56	0.74	1.30	234	53	73	18
105	4	6	2	14	7	2	6	4	9	10	19	0.55	0.74	1.29	179	80	46	26
106	4	11	1	14	3	6	2	1	9	3	12	0.60	0.68	1.28	421	88	86	80
107	6	8	3	16	5	4	3	6	9	9	18	0.57	0.70	1.27	392	86	81	40
108	6	7	4	16	6	3	4	7	9	11	20	0.56	0.71	1.26	311	112	78	30
109	4	7	4	16	7	2	5	6	9	11	20	0.56	0.70	1.26	247	134	54	41
110	6	7	4	15	7	2	5	7	9	12	21	0.53	0.70	1.24	237	127	87	33
111	4	6	2	13	7	2	7	2	9	9	18	0.50	0.74	1.23	182	76	63	35
112	4	11	1	13	3	6	2	1	9	3	12	0.56	0.68	1.23	590	113	126	86
113	6	8	2	14	5	4	3	4	9	7	16	0.52	0.71	1.23	502	82	120	46
114	6	8	3	15	5	4	3	6	9	9	18	0.53	0.70	1.23	543	105	119	44
115	6	6	2	13	7	2	7	4	9	11	20	0.49	0.73	1.23	204	78	83	26
116	6	8	4	16	5	4	4	7	9	11	20	0.53	0.69	1.22	494	127	106	44
117	6	7	3	14	7	2	5	6	9	11	20	0.49	0.71	1.20	311	123	113	38
118	4	7	3	14	7	2	6	4	9	10	19	0.49	0.71	1.20	310	130	85	47
119	4	12	2	16	2	7	2	3	9	5	14	0.54	0.65	1.18	756	147	129	94
120	6	7	2	13	7	2	5	4	9	9	18	0.46	0.72	1.18	599	102	148	42

Table B.2: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
121	6	9	4	15	5	4	4	7	9	11	20	0.48	0.67	1.16	641	158	151	60
122	6	8	2	13	6	3	4	4	9	8	17	0.45	0.70	1.15	658	114	161	54
123	6	8	3	14	6	3	4	5	9	9	18	0.46	0.69	1.15	684	146	174	53
124	6	8	4	14	7	2	5	6	9	11	20	0.45	0.68	1.13	407	184	153	57
125	4	8	4	14	7	2	6	5	9	11	20	0.45	0.68	1.12	423	188	125	66
126	6	8	3	13	7	2	5	4	9	9	18	0.40	0.68	1.08	597	180	181	65
127	4	8	3	13	7	2	7	3	9	10	19	0.40	0.68	1.08	530	191	151	74
128	6	9	4	14	7	2	4	5	9	9	18	0.40	0.66	1.06	785	209	217	75
129	6	10	4	14	6	3	3	5	9	8	17	0.39	0.64	1.03	882	221	236	89
130	6	9	3	13	6	3	4	4	9	8	17	0.37	0.66	1.03	917	201	235	82
131	6	10	3	13	6	3	4	3	9	7	16	0.36	0.64	1.00	942	212	242	94
132	6	11	4	13	6	3	4	3	9	7	16	0.31	0.60	0.91	1,039	283	284	121
133	4	5	2	16	8	2	8	3	10	11	21	0.66	0.76	1.42	-66	19	-20	8
134	6	5	3	16	8	2	8	6	10	14	24	0.64	0.76	1.40	-194	31	-15	1
135	6	5	2	15	8	2	4	4	10	8	18	0.63	0.76	1.40	-39	9	5	0
136	6	5	4	16	8	2	8	7	10	15	25	0.64	0.75	1.38	-344	51	-33	3
137	4	10	1	16	3	7	2	2	10	4	14	0.67	0.70	1.37	90	42	12	61
138	6	5	3	15	8	2	8	6	10	14	24	0.61	0.75	1.37	-248	37	-14	3
139	6	7	2	16	5	5	3	5	10	8	18	0.63	0.73	1.36	152	24	28	24
140	6	5	4	15	8	2	8	7	10	15	25	0.61	0.74	1.36	-430	51	-38	5
141	6	5	2	14	8	2	6	4	10	10	20	0.59	0.76	1.35	-64	29	17	4
142	4	11	1	15	3	7	2	1	10	3	13	0.64	0.69	1.32	225	63	42	74
143	4	6	3	15	7	3	6	4	10	10	20	0.58	0.73	1.31	24	57	18	28
144	6	5	3	14	8	2	8	6	10	14	24	0.56	0.75	1.31	-390	49	-23	8
145	6	8	2	15	5	5	3	5	10	8	18	0.59	0.72	1.30	281	48	62	38
146	6	6	4	15	8	2	6	7	10	13	23	0.58	0.73	1.30	-89	95	26	18
147	6	5	4	14	8	2	8	6	10	14	24	0.55	0.74	1.29	-426	57	-22	11
148	6	6	3	14	8	2	6	5	10	11	21	0.54	0.73	1.27	-5	92	50	23
149	6	5	2	13	8	2	7	5	10	12	22	0.52	0.75	1.27	-172	43	15	11
150	4	7	4	15	7	3	6	4	10	10	20	0.54	0.71	1.25	176	115	56	46

Table B.2: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
151	6	6	4	14	8	2	7	6	10	13	23	0.52	0.72	1.24	-161	117	36	28
152	4	12	1	13	4	6	2	1	10	3	13	0.55	0.66	1.21	586	123	129	98
153	6	9	3	15	5	5	4	6	10	10	20	0.52	0.68	1.20	534	115	121	56
154	6	6	3	13	8	2	7	5	10	12	22	0.47	0.72	1.19	-61	112	54	33
155	6	6	4	13	8	2	7	6	10	13	23	0.45	0.71	1.16	-233	119	35	37
156	6	11	4	14	6	4	3	5	10	8	18	0.38	0.62	1.01	879	230	239	100
157	6	11	3	13	6	4	4	3	10	7	17	0.35	0.63	0.98	937	222	244	106
158	6	10	4	13	7	3	4	4	10	8	18	0.31	0.62	0.93	986	271	273	107
159	6	12	4	13	6	4	4	3	10	7	17	0.30	0.58	0.88	1,059	294	290	133
160	4	5	3	16	8	3	8	3	11	11	22	0.64	0.75	1.40	-191	9	-33	14
161	4	5	2	15	8	3	8	3	11	11	22	0.63	0.76	1.39	-110	13	-18	10
162	4	11	1	16	4	7	2	2	11	4	15	0.66	0.69	1.35	82	52	15	73
163	6	8	2	16	5	6	4	5	11	9	20	0.62	0.72	1.34	144	33	31	36
164	4	5	2	14	8	3	8	4	11	12	23	0.58	0.75	1.33	-118	16	-8	14
165	4	6	4	16	8	3	6	5	11	11	22	0.60	0.73	1.32	-18	63	8	28
166	4	12	1	16	4	7	3	2	11	5	16	0.65	0.67	1.32	73	61	19	84
167	4	12	1	15	4	7	2	1	11	3	14	0.63	0.67	1.30	216	74	46	87
168	6	9	2	15	5	6	4	4	11	8	19	0.58	0.70	1.28	273	58	65	50
169	4	12	1	14	4	7	2	1	11	3	14	0.59	0.67	1.25	415	98	89	92
170	4	6	3	14	7	4	7	4	11	11	22	0.53	0.72	1.25	37	63	33	34
171	6	9	3	16	5	6	4	6	11	10	21	0.56	0.69	1.24	382	95	83	53
172	6	5	3	13	8	3	8	5	11	13	24	0.50	0.74	1.24	-360	54	-8	17
173	6	9	2	14	6	5	4	4	11	8	19	0.51	0.69	1.21	497	92	124	58
174	6	9	4	16	6	5	4	7	11	11	22	0.53	0.67	1.20	483	136	108	56
175	4	7	4	14	7	4	7	5	11	12	23	0.48	0.69	1.17	160	115	74	52
176	6	10	4	15	6	5	4	6	11	10	21	0.48	0.66	1.13	631	167	153	72
177	6	9	2	13	7	4	4	4	11	8	19	0.45	0.68	1.13	655	124	164	67
178	4	7	3	13	7	4	7	4	11	11	22	0.43	0.70	1.13	252	116	97	57
179	6	10	3	14	6	5	3	5	11	8	19	0.44	0.66	1.09	770	169	196	80
180	4	8	4	13	7	4	7	4	11	11	22	0.38	0.66	1.05	359	170	137	81

Table B.2: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
181	6	12	4	14	6	5	3	4	11	7	18	0.38	0.61	0.99	871	239	240	112
182	6	9	2	16	5	7	4	5	12	9	21	0.61	0.70	1.31	136	42	34	47
183	4	6	4	15	8	4	6	4	12	10	22	0.58	0.73	1.31	-35	51	13	32
184	4	5	2	13	8	4	7	3	12	10	22	0.53	0.75	1.28	-96	13	9	20
185	4	5	1	13	7	5	7	3	12	10	22	0.52	0.74	1.26	87	3	14	26
186	6	5	4	13	8	4	8	6	12	14	26	0.49	0.73	1.21	-540	41	-24	22
187	4	6	3	13	7	5	7	3	12	10	22	0.47	0.72	1.19	3	49	44	42
188	6	10	2	14	6	6	4	4	12	8	20	0.51	0.68	1.18	491	102	127	69
189	6	10	3	15	6	6	4	6	12	10	22	0.51	0.67	1.18	525	124	124	68
190	6	10	4	16	6	6	4	7	12	11	23	0.52	0.66	1.18	473	144	110	67
191	4	7	4	13	7	5	7	3	12	10	22	0.42	0.69	1.11	165	102	90	62
192	6	11	4	15	6	6	4	6	12	10	22	0.47	0.64	1.11	621	176	154	84
193	6	10	2	13	7	5	5	3	12	8	20	0.44	0.67	1.10	651	137	167	80
194	6	11	3	14	6	6	4	4	12	8	20	0.43	0.64	1.07	763	180	198	93
195	6	12	3	14	6	6	4	4	12	8	20	0.42	0.62	1.04	755	190	200	105
196	6	12	3	13	7	5	4	3	12	7	19	0.35	0.61	0.96	933	231	246	117
197	6	7	1	13	8	5	5	3	13	8	21	0.59	0.74	1.33	-31	1	16	28
198	6	10	2	16	6	7	4	4	13	8	21	0.60	0.69	1.29	127	52	37	59
199	6	10	2	15	6	7	4	4	13	8	21	0.57	0.68	1.25	266	69	68	63
200	4	6	4	14	8	5	7	4	13	11	24	0.52	0.72	1.24	-80	48	20	39
201	6	11	2	15	6	7	4	4	13	8	21	0.56	0.67	1.23	258	78	71	75
202	6	10	3	16	6	7	4	6	13	10	23	0.55	0.67	1.22	372	105	86	64
203	6	11	3	16	6	7	4	6	13	10	23	0.54	0.66	1.19	361	114	88	76
204	6	11	3	15	6	7	4	5	13	9	22	0.50	0.65	1.16	516	133	126	80
205	6	11	4	16	6	7	4	7	13	11	24	0.51	0.64	1.15	462	153	112	79
206	6	12	3	15	6	7	4	5	13	9	22	0.50	0.64	1.13	506	142	128	91
207	6	11	2	13	7	6	5	3	13	8	21	0.43	0.65	1.08	647	148	171	94
208	6	8	1	13	8	6	6	3	14	9	23	0.58	0.72	1.31	-32	12	20	40
209	6	11	2	16	7	7	4	4	14	8	22	0.59	0.67	1.26	118	63	40	72
210	6	12	2	16	7	7	5	4	14	9	23	0.58	0.65	1.23	110	73	44	84

Table B.2: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
211	6	12	2	15	7	7	4	4	14	8	22	0.55	0.65	1.20	250	88	74	86
212	6	12	3	16	7	7	5	5	14	10	24	0.53	0.64	1.17	351	123	91	87
213	6	11	2	14	7	7	4	4	14	8	22	0.50	0.66	1.16	486	112	130	81
214	6	12	2	14	7	7	4	4	14	8	22	0.49	0.65	1.14	480	122	133	93
215	6	12	4	16	7	7	5	6	14	11	25	0.50	0.63	1.13	450	161	114	90
216	6	12	4	15	7	7	4	6	14	10	24	0.46	0.62	1.08	609	186	157	98
217	6	12	2	13	7	7	5	3	14	8	22	0.42	0.63	1.05	643	159	174	106
218	6	9	1	14	8	7	8	3	15	11	26	0.62	0.71	1.34	-150	2	-3	47
219	6	11	1	15	8	7	8	3	15	11	26	0.65	0.69	1.34	-333	1	-33	66
220	6	12	1	16	8	7	8	3	15	11	26	0.66	0.68	1.34	-448	1	-49	76
221	6	10	1	14	8	7	5	3	15	8	23	0.62	0.70	1.32	-153	12	1	58
222	6	12	1	15	8	7	8	3	15	11	26	0.64	0.67	1.31	-338	11	-29	78
223	6	11	1	14	8	7	5	3	15	8	23	0.61	0.68	1.29	-156	24	6	71
224	6	9	1	13	8	7	6	3	15	9	24	0.57	0.71	1.28	-34	24	25	53
225	6	12	1	14	8	7	6	3	15	9	24	0.59	0.66	1.26	-159	35	10	84
226	6	10	1	13	8	7	6	3	15	9	24	0.57	0.69	1.26	-35	35	29	66
227	6	11	1	13	8	7	6	3	15	9	24	0.56	0.67	1.23	-37	46	33	78
228	6	12	1	13	8	7	6	3	15	9	24	0.55	0.66	1.21	-39	57	37	89
229	4	6	4	13	8	7	7	4	15	11	26	0.45	0.71	1.16	-146	35	35	47
230	6	5	1	16	8	8	8	8	16	16	32	0.73	0.78	1.51	-416	-69	-77	-4
231	6	6	1	16	8	8	8	2	16	10	26	0.72	0.77	1.48	-420	-59	-73	8
232	6	5	1	15	8	8	8	8	16	16	32	0.70	0.78	1.48	-308	-60	-56	-2
233	6	7	1	16	8	8	8	3	16	11	27	0.71	0.75	1.46	-424	-48	-69	20
234	6	6	1	15	8	8	8	3	16	11	27	0.69	0.76	1.46	-312	-49	-52	9
235	6	5	1	14	8	8	8	2	16	10	26	0.66	0.78	1.44	-140	-40	-19	0
236	6	8	1	16	8	8	8	3	16	11	27	0.70	0.74	1.43	-429	-38	-65	32
237	6	7	1	15	8	8	8	3	16	11	27	0.68	0.75	1.43	-316	-39	-49	21
238	6	5	2	16	8	8	8	8	16	16	32	0.65	0.77	1.42	0	0	0	0
239	6	6	1	14	8	8	8	3	16	11	27	0.65	0.76	1.41	-142	-29	-15	12
240	6	9	1	16	8	8	8	3	16	11	27	0.69	0.72	1.41	-434	-28	-61	43

Table B.2: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
241	6	8	1	15	8	8	8	3	16	11	27	0.68	0.73	1.41	-320	-29	-45	32
242	6	7	1	14	8	8	8	3	16	11	27	0.64	0.74	1.39	-145	-19	-11	24
243	6	10	1	16	8	8	8	3	16	11	27	0.68	0.71	1.38	-438	-19	-57	54
244	6	9	1	15	8	8	8	3	16	11	27	0.67	0.72	1.38	-324	-19	-41	44
245	4	5	3	15	8	8	8	2	16	10	26	0.63	0.76	1.38	-269	-4	-34	17
246	4	5	4	16	8	8	8	4	16	12	28	0.63	0.75	1.38	-332	-2	-44	18
247	6	5	1	13	8	8	5	2	16	7	23	0.61	0.77	1.38	-29	-21	8	4
248	6	8	1	14	8	8	8	3	16	11	27	0.63	0.73	1.36	-147	-8	-7	35
249	6	10	1	15	8	8	8	3	16	11	27	0.66	0.70	1.36	-329	-9	-37	55
250	6	11	1	16	8	8	8	3	16	11	27	0.67	0.69	1.36	-443	-9	-53	65
251	6	6	1	13	8	8	5	3	16	8	24	0.60	0.76	1.36	-30	-10	12	16
252	4	5	4	15	8	8	8	3	16	11	27	0.61	0.75	1.35	-356	-10	-37	20
253	4	5	3	14	8	8	8	4	16	12	28	0.56	0.74	1.30	-322	-7	-28	21
254	4	5	4	14	8	8	8	4	16	12	28	0.55	0.74	1.29	-344	-7	-26	23
255	4	5	3	13	8	8	8	4	16	12	28	0.49	0.73	1.23	-269	-5	-4	26
256	4	5	4	13	8	8	8	5	16	13	29	0.49	0.73	1.22	-347	-15	-11	26

Table B.3: Ranking Policies Based on Total TS = East TS + West TS) and Sum S/S_0 (descending)

	Policies				Rating							S/So			Change in Surplus			
Rank	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
1	4	5	1	15	1	1	1	1	2	2	4	0.69	0.78	1.47	268	4	22	6
2	4	6	1	15	1	2	1	1	3	2	5	0.68	0.76	1.45	261	14	25	17
3	4	7	1	16	2	4	1	1	6	2	8	0.69	0.75	1.44	114	13	2	28
4	4	5	1	14	2	1	1	1	3	2	5	0.66	0.78	1.44	256	20	36	7
5	4	7	1	15	1	3	1	1	4	2	6	0.67	0.75	1.42	254	24	28	29
6	4	6	1	14	1	1	1	1	2	2	4	0.64	0.76	1.40	450	35	68	20
7	4	8	1	15	2	4	1	1	6	2	8	0.66	0.73	1.40	247	34	32	40
8	4	7	1	14	1	2	1	1	3	2	5	0.63	0.75	1.38	444	46	71	32
9	4	6	1	13	1	1	1	1	2	2	4	0.60	0.76	1.36	608	58	107	25
10	4	8	1	14	2	3	1	1	5	2	7	0.63	0.73	1.36	439	56	75	43
11	4	7	1	13	2	1	1	1	3	2	5	0.59	0.74	1.34	605	68	110	37
12	4	9	1	14	2	4	1	1	6	2	8	0.62	0.72	1.33	434	66	78	55
13	4	8	1	13	2	2	1	1	4	2	6	0.58	0.73	1.31	601	79	114	49
14	4	10	1	14	3	5	1	1	8	2	10	0.61	0.70	1.31	428	76	82	66
15	4	9	1	13	2	4	1	1	6	2	8	0.57	0.71	1.29	597	91	118	62
16	4	10	1	13	3	5	1	1	8	2	10	0.56	0.69	1.26	593	102	122	74
17	4	9	2	13	1	1	1	1	2	2	4	0.41	0.68	1.09	1,322	210	268	82
18	4	10	2	13	1	2	1	1	3	2	5	0.40	0.66	1.06	1,404	223	284	96
19	4	11	2	13	1	3	1	1	4	2	6	0.39	0.64	1.03	1,397	233	286	108
20	4	12	2	13	1	3	1	1	4	2	6	0.38	0.63	1.01	1,390	243	288	120
21	4	11	3	13	1	1	1	1	2	2	4	0.30	0.61	0.91	1,610	320	350	128
22	4	12	3	13	1	2	1	1	3	2	5	0.29	0.59	0.88	1,658	332	359	141
23	4	12	4	13	2	1	1	1	3	2	5	0.24	0.57	0.81	1,638	390	381	152
24	4	9	1	15	2	5	1	2	7	3	10	0.65	0.72	1.37	240	44	35	52
25	4	11	1	15	3	7	2	1	10	3	13	0.64	0.69	1.32	225	63	42	74
26	4	12	1	15	4	7	2	1	11	3	14	0.63	0.67	1.30	216	74	46	87
27	4	11	1	14	3	6	2	1	9	3	12	0.60	0.68	1.28	421	88	86	80
28	4	12	1	14	4	7	2	1	11	3	14	0.59	0.67	1.25	415	98	89	92
29	4	11	1	13	3	6	2	1	9	3	12	0.56	0.68	1.23	590	113	126	86
30	4	12	1	13	4	6	2	1	10	3	13	0.55	0.66	1.21	586	123	129	98

Table B.3: Continued

	Policies				Rating							S/So			Change in Surplus			
Rank	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
31	4	11	2	14	1	4	1	2	5	3	8	0.46	0.65	1.11	1,181	193	229	94
32	4	12	2	14	1	5	1	2	6	3	9	0.45	0.63	1.08	1,170	204	231	108
33	4	12	3	14	1	3	1	2	4	3	7	0.37	0.61	0.98	1,457	278	300	119
34	4	8	1	16	2	5	2	2	7	4	11	0.68	0.73	1.42	106	23	5	39
35	4	9	1	16	3	6	2	2	9	4	13	0.68	0.72	1.39	98	33	9	50
36	4	10	1	16	3	7	2	2	10	4	14	0.67	0.70	1.37	90	42	12	61
37	4	10	1	15	3	6	2	2	9	4	13	0.65	0.70	1.35	233	53	39	63
38	4	11	1	16	4	7	2	2	11	4	15	0.66	0.69	1.35	82	52	15	73
39	4	8	2	15	1	2	1	3	3	4	7	0.54	0.71	1.25	976	128	158	51
40	4	9	2	15	1	3	1	3	4	4	8	0.53	0.69	1.22	964	137	161	63
41	4	8	2	14	2	1	1	3	3	4	7	0.50	0.70	1.20	944	155	183	56
42	4	10	2	15	1	4	1	3	5	4	9	0.52	0.67	1.20	953	147	163	75
43	4	11	2	15	1	5	1	3	6	4	10	0.52	0.66	1.18	941	156	165	86
44	4	9	2	14	1	2	1	3	3	4	7	0.47	0.69	1.16	1,200	173	224	70
45	4	10	2	14	1	3	1	3	4	4	8	0.47	0.67	1.14	1,191	183	226	82
46	4	10	3	14	1	1	1	3	2	4	6	0.38	0.64	1.03	1,384	258	284	96
47	4	11	3	14	1	2	1	3	3	4	7	0.37	0.63	1.00	1,445	269	295	108
48	4	10	3	13	4	1	2	2	5	4	9	0.33	0.64	0.97	1,239	293	291	107
49	4	12	4	14	2	2	1	3	4	4	8	0.32	0.58	0.90	1,502	336	331	133
50	4	12	1	16	4	7	3	2	11	5	16	0.65	0.67	1.32	73	61	19	84
51	4	7	2	16	1	2	1	4	3	5	8	0.59	0.73	1.32	744	98	107	34
52	4	8	2	16	1	3	1	4	4	5	9	0.57	0.71	1.28	808	109	120	46
53	4	9	2	16	1	4	1	4	5	5	10	0.56	0.69	1.26	795	120	122	59
54	4	12	2	16	2	7	2	3	9	5	14	0.54	0.65	1.18	756	147	129	94
55	4	12	2	15	2	6	2	3	8	5	13	0.51	0.64	1.15	929	165	167	98
56	4	8	2	13	4	1	3	2	5	5	10	0.44	0.70	1.14	920	181	200	64
57	4	10	3	15	1	3	1	4	4	5	9	0.45	0.66	1.11	1,231	212	222	83
58	4	11	4	14	2	2	1	4	4	5	9	0.33	0.60	0.93	1,414	322	315	118
59	4	11	4	13	5	1	3	2	6	5	11	0.28	0.59	0.87	1,285	362	322	136
60	4	6	2	16	3	2	2	4	5	6	11	0.62	0.74	1.37	333	69	47	20

Table B.3: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
61	4	7	2	15	2	1	2	4	3	6	9	0.57	0.73	1.29	667	107	112	35
62	4	7	2	14	4	1	3	3	5	6	11	0.53	0.72	1.25	620	128	124	41
63	4	10	2	16	1	5	2	4	6	6	12	0.56	0.68	1.23	782	129	125	71
64	4	11	2	16	2	6	2	4	8	6	14	0.55	0.66	1.21	769	138	127	83
65	4	11	3	15	1	4	2	4	5	6	11	0.44	0.64	1.08	1,216	222	223	96
66	4	12	3	15	1	5	2	4	6	6	12	0.44	0.62	1.06	1,201	231	224	109
67	4	12	4	15	2	4	2	4	6	6	12	0.40	0.60	1.00	1,299	278	252	114
68	6	6	2	16	4	4	3	4	8	7	15	0.63	0.75	1.38	159	14	25	13
69	6	5	1	13	8	8	5	2	16	7	23	0.61	0.77	1.38	-29	-21	8	4
70	6	6	2	15	4	3	3	4	7	7	14	0.60	0.75	1.35	295	29	56	14
71	4	6	2	15	4	1	3	4	5	7	12	0.60	0.74	1.34	289	72	49	22
72	6	7	2	14	5	3	3	4	8	7	15	0.53	0.72	1.25	507	72	117	33
73	6	8	2	14	5	4	3	4	9	7	16	0.52	0.71	1.23	502	82	120	46
74	4	9	3	16	1	3	2	5	4	7	11	0.50	0.67	1.17	1,066	180	175	66
75	4	10	3	16	1	4	2	5	5	7	12	0.49	0.66	1.15	1,051	189	176	77
76	4	9	3	15	1	2	2	5	3	7	10	0.47	0.67	1.14	1,109	200	202	70
77	4	11	3	16	2	4	2	5	6	7	13	0.48	0.64	1.13	1,036	198	177	89
78	4	12	3	16	2	5	3	4	7	7	14	0.48	0.63	1.10	1,019	207	179	102
79	4	9	3	14	4	1	3	4	5	7	12	0.42	0.66	1.09	987	230	216	78
80	4	10	4	15	1	2	2	5	3	7	10	0.41	0.64	1.05	1,268	260	242	90
81	4	11	4	15	1	3	2	5	4	7	11	0.41	0.62	1.02	1,309	270	250	102
82	4	9	3	13	7	1	5	2	8	7	15	0.36	0.65	1.02	868	255	221	92
83	6	10	3	13	6	3	4	3	9	7	16	0.36	0.64	1.00	942	212	242	94
84	4	10	4	14	4	1	3	4	5	7	12	0.37	0.63	1.00	1,093	298	262	100
85	6	12	4	14	6	5	3	4	11	7	18	0.38	0.61	0.99	871	239	240	112
86	6	11	3	13	6	4	4	3	10	7	17	0.35	0.63	0.98	937	222	244	106
87	6	12	3	13	7	5	4	3	12	7	19	0.35	0.61	0.96	933	231	246	117
88	4	10	4	13	7	1	5	2	8	7	15	0.31	0.61	0.93	920	319	253	119
89	6	11	4	13	6	3	4	3	9	7	16	0.31	0.60	0.91	1,039	283	284	121
90	6	12	4	13	6	4	4	3	10	7	17	0.30	0.58	0.88	1,059	294	290	133

Table B.3: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
91	6	5	2	15	8	2	4	4	10	8	18	0.63	0.76	1.40	-39	9	5	0
92	6	7	2	16	5	5	3	5	10	8	18	0.63	0.73	1.36	152	24	28	24
93	6	6	1	13	8	8	5	3	16	8	24	0.60	0.76	1.36	-30	-10	12	16
94	6	7	1	13	8	5	5	3	13	8	21	0.59	0.74	1.33	-31	1	16	28
95	6	7	2	15	5	4	3	5	9	8	17	0.59	0.73	1.33	288	38	59	26
96	6	10	1	14	8	7	5	3	15	8	23	0.62	0.70	1.32	-153	12	1	58
97	6	8	2	15	5	5	3	5	10	8	18	0.59	0.72	1.30	281	48	62	38
98	6	6	2	14	7	2	4	4	9	8	17	0.56	0.74	1.30	234	53	73	18
99	6	10	2	16	6	7	4	4	13	8	21	0.60	0.69	1.29	127	52	37	59
100	6	11	1	14	8	7	5	3	15	8	23	0.61	0.68	1.29	-156	24	6	71
101	6	9	2	15	5	6	4	4	11	8	19	0.58	0.70	1.28	273	58	65	50
102	6	11	2	16	7	7	4	4	14	8	22	0.59	0.67	1.26	118	63	40	72
103	6	10	2	15	6	7	4	4	13	8	21	0.57	0.68	1.25	266	69	68	63
104	6	11	2	15	6	7	4	4	13	8	21	0.56	0.67	1.23	258	78	71	75
105	4	8	3	16	2	2	2	6	4	8	12	0.53	0.69	1.22	815	163	139	52
106	6	9	2	14	6	5	4	4	11	8	19	0.51	0.69	1.21	497	92	124	58
107	6	12	2	15	7	7	4	4	14	8	22	0.55	0.65	1.20	250	88	74	86
108	4	8	3	15	3	1	3	5	4	8	12	0.51	0.69	1.20	761	173	145	55
109	6	10	2	14	6	6	4	4	12	8	20	0.51	0.68	1.18	491	102	127	69
110	4	7	2	13	7	1	5	3	8	8	16	0.47	0.71	1.18	528	142	129	49
111	6	11	2	14	7	7	4	4	14	8	22	0.50	0.66	1.16	486	112	130	81
112	6	8	2	13	6	3	4	4	9	8	17	0.45	0.70	1.15	658	114	161	54
113	6	12	2	14	7	7	4	4	14	8	22	0.49	0.65	1.14	480	122	133	93
114	6	9	2	13	7	4	4	4	11	8	19	0.45	0.68	1.13	655	124	164	67
115	6	9	3	14	5	3	3	5	8	8	16	0.44	0.68	1.12	777	158	193	66
116	6	10	2	13	7	5	5	3	12	8	20	0.44	0.67	1.10	651	137	167	80
117	4	10	4	16	1	2	2	6	3	8	11	0.46	0.64	1.10	1,149	235	200	82
118	6	10	3	14	6	5	3	5	11	8	19	0.44	0.66	1.09	770	169	196	80
119	6	11	2	13	7	6	5	3	13	8	21	0.43	0.65	1.08	647	148	171	94
120	6	11	3	14	6	6	4	4	12	8	20	0.43	0.64	1.07	763	180	198	93

Table B.3: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
121	6	12	2	13	7	7	5	3	14	8	22	0.42	0.63	1.05	643	159	174	106
122	4	12	4	16	2	5	3	5	7	8	15	0.44	0.61	1.05	1,114	252	202	108
123	6	12	3	14	6	6	4	4	12	8	20	0.42	0.62	1.04	755	190	200	105
124	6	10	4	14	6	3	3	5	9	8	17	0.39	0.64	1.03	882	221	236	89
125	6	9	3	13	6	3	4	4	9	8	17	0.37	0.66	1.03	917	201	235	82
126	6	11	4	14	6	4	3	5	10	8	18	0.38	0.62	1.01	879	230	239	100
127	6	10	4	13	7	3	4	4	10	8	18	0.31	0.62	0.93	986	271	273	107
128	4	5	1	16	1	8	8	1	9	9	18	0.71	0.78	1.49	129	-7	-6	4
129	4	6	1	16	1	3	8	1	4	9	13	0.70	0.77	1.47	121	3	-2	16
130	4	6	3	16	6	2	5	4	8	9	17	0.61	0.74	1.34	83	69	15	24
131	6	8	2	16	5	6	4	5	11	9	20	0.62	0.72	1.34	144	33	31	36
132	6	9	2	16	5	7	4	5	12	9	21	0.61	0.70	1.31	136	42	34	47
133	6	8	1	13	8	6	6	3	14	9	23	0.58	0.72	1.31	-32	12	20	40
134	6	7	3	16	4	3	3	6	7	9	16	0.57	0.72	1.29	402	76	78	28
135	6	9	1	13	8	7	6	3	15	9	24	0.57	0.71	1.28	-34	24	25	53
136	4	7	3	16	4	2	4	5	6	9	15	0.56	0.71	1.28	444	128	79	37
137	6	8	3	16	5	4	3	6	9	9	18	0.57	0.70	1.27	392	86	81	40
138	6	12	1	14	8	7	6	3	15	9	24	0.59	0.66	1.26	-159	35	10	84
139	6	7	3	15	5	3	3	6	8	9	17	0.54	0.72	1.26	494	95	107	32
140	6	10	1	13	8	7	6	3	15	9	24	0.57	0.69	1.26	-35	35	29	66
141	6	12	2	16	7	7	5	4	14	9	23	0.58	0.65	1.23	110	73	44	84
142	4	6	2	13	7	2	7	2	9	9	18	0.50	0.74	1.23	182	76	63	35
143	6	11	1	13	8	7	6	3	15	9	24	0.56	0.67	1.23	-37	46	33	78
144	6	8	3	15	5	4	3	6	9	9	18	0.53	0.70	1.23	543	105	119	44
145	6	12	1	13	8	7	6	3	15	9	24	0.55	0.66	1.21	-39	57	37	89
146	6	7	2	13	7	2	5	4	9	9	18	0.46	0.72	1.18	599	102	148	42
147	6	11	3	15	6	7	4	5	13	9	22	0.50	0.65	1.16	516	133	126	80
148	6	8	3	14	6	3	4	5	9	9	18	0.46	0.69	1.15	684	146	174	53
149	4	9	4	16	3	2	3	6	5	9	14	0.48	0.66	1.14	945	219	172	68
150	6	12	3	15	6	7	4	5	13	9	22	0.50	0.64	1.13	506	142	128	91

Table B.3: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
151	4	9	4	15	4	1	3	6	5	9	14	0.46	0.66	1.12	886	232	182	72
152	6	8	3	13	7	2	5	4	9	9	18	0.40	0.68	1.08	597	180	181	65
153	4	11	4	16	2	4	3	6	6	9	15	0.45	0.62	1.07	1,131	244	201	96
154	6	9	4	14	7	2	4	5	9	9	18	0.40	0.66	1.06	785	209	217	75
155	6	9	4	13	7	1	5	4	8	9	17	0.35	0.65	1.00	688	248	223	89
156	6	6	1	16	8	8	8	2	16	10	26	0.72	0.77	1.48	-420	-59	-73	8
157	6	5	1	14	8	8	8	2	16	10	26	0.66	0.78	1.44	-140	-40	-19	0
158	4	5	3	15	8	8	8	2	16	10	26	0.63	0.76	1.38	-269	-4	-34	17
159	6	5	2	14	8	2	6	4	10	10	20	0.59	0.76	1.35	-64	29	17	4
160	6	6	3	16	6	3	4	6	9	10	19	0.60	0.74	1.34	151	60	41	14
161	6	6	3	15	7	2	4	6	9	10	19	0.58	0.74	1.31	109	70	48	16
162	4	6	3	15	7	3	6	4	10	10	20	0.58	0.73	1.31	24	57	18	28
163	4	6	4	15	8	4	6	4	12	10	22	0.58	0.73	1.31	-35	51	13	32
164	4	6	2	14	7	2	6	4	9	10	19	0.55	0.74	1.29	179	80	46	26
165	4	5	2	13	8	4	7	3	12	10	22	0.53	0.75	1.28	-96	13	9	20
166	4	5	1	13	7	5	7	3	12	10	22	0.52	0.74	1.26	87	3	14	26
167	4	7	3	15	6	2	5	5	8	10	18	0.55	0.71	1.25	322	126	71	41
168	4	7	4	15	7	3	6	4	10	10	20	0.54	0.71	1.25	176	115	56	46
169	6	9	3	16	5	6	4	6	11	10	21	0.56	0.69	1.24	382	95	83	53
170	6	10	3	16	6	7	4	6	13	10	23	0.55	0.67	1.22	372	105	86	64
171	4	8	4	16	4	1	4	6	5	10	15	0.52	0.68	1.20	603	189	117	54
172	6	9	3	15	5	5	4	6	10	10	20	0.52	0.68	1.20	534	115	121	56
173	4	7	3	14	7	2	6	4	9	10	19	0.49	0.71	1.20	310	130	85	47
174	6	11	3	16	6	7	4	6	13	10	23	0.54	0.66	1.19	361	114	88	76
175	4	6	3	13	7	5	7	3	12	10	22	0.47	0.72	1.19	3	49	44	42
176	6	8	4	15	5	3	3	7	8	10	18	0.49	0.69	1.18	631	149	145	49
177	6	10	3	15	6	6	4	6	12	10	22	0.51	0.67	1.18	525	124	124	68
178	6	12	3	16	7	7	5	5	14	10	24	0.53	0.64	1.17	351	123	91	87
179	4	8	3	14	6	1	5	5	7	10	17	0.46	0.68	1.14	629	190	150	62
180	6	10	4	15	6	5	4	6	11	10	21	0.48	0.66	1.13	631	167	153	72

Table B.3: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
181	4	7	4	13	7	5	7	3	12	10	22	0.42	0.69	1.11	165	102	90	62
182	6	11	4	15	6	6	4	6	12	10	22	0.47	0.64	1.11	621	176	154	84
183	6	12	4	15	7	7	4	6	14	10	24	0.46	0.62	1.08	609	186	157	98
184	4	8	3	13	7	2	7	3	9	10	19	0.40	0.68	1.08	530	191	151	74
185	4	9	4	14	7	1	5	5	8	10	18	0.41	0.65	1.06	717	256	190	85
186	4	9	4	13	7	1	7	3	8	10	18	0.35	0.64	0.99	646	264	196	100
187	6	7	1	16	8	8	8	3	16	11	27	0.71	0.75	1.46	-424	-48	-69	20
188	6	6	1	15	8	8	8	3	16	11	27	0.69	0.76	1.46	-312	-49	-52	9
189	6	8	1	16	8	8	8	3	16	11	27	0.70	0.74	1.43	-429	-38	-65	32
190	6	7	1	15	8	8	8	3	16	11	27	0.68	0.75	1.43	-316	-39	-49	21
191	4	5	2	16	8	2	8	3	10	11	21	0.66	0.76	1.42	-66	19	-20	8
192	6	6	1	14	8	8	8	3	16	11	27	0.65	0.76	1.41	-142	-29	-15	12
193	6	9	1	16	8	8	8	3	16	11	27	0.69	0.72	1.41	-434	-28	-61	43
194	6	8	1	15	8	8	8	3	16	11	27	0.68	0.73	1.41	-320	-29	-45	32
195	4	5	3	16	8	3	8	3	11	11	22	0.64	0.75	1.40	-191	9	-33	14
196	4	5	2	15	8	3	8	3	11	11	22	0.63	0.76	1.39	-110	13	-18	10
197	6	7	1	14	8	8	8	3	16	11	27	0.64	0.74	1.39	-145	-19	-11	24
198	6	10	1	16	8	8	8	3	16	11	27	0.68	0.71	1.38	-438	-19	-57	54
199	6	9	1	15	8	8	8	3	16	11	27	0.67	0.72	1.38	-324	-19	-41	44
200	6	8	1	14	8	8	8	3	16	11	27	0.63	0.73	1.36	-147	-8	-7	35
201	6	10	1	15	8	8	8	3	16	11	27	0.66	0.70	1.36	-329	-9	-37	55
202	6	11	1	16	8	8	8	3	16	11	27	0.67	0.69	1.36	-443	-9	-53	65
203	4	5	4	15	8	8	8	3	16	11	27	0.61	0.75	1.35	-356	-10	-37	20
204	6	9	1	14	8	7	8	3	15	11	26	0.62	0.71	1.34	-150	2	-3	47
205	6	11	1	15	8	7	8	3	15	11	26	0.65	0.69	1.34	-333	1	-33	66
206	6	12	1	16	8	7	8	3	15	11	26	0.66	0.68	1.34	-448	1	-49	76
207	4	6	4	16	8	3	6	5	11	11	22	0.60	0.73	1.32	-18	63	8	28
208	6	12	1	15	8	7	8	3	15	11	26	0.64	0.67	1.31	-338	11	-29	78
209	6	6	3	14	8	2	6	5	10	11	21	0.54	0.73	1.27	-5	92	50	23
210	6	7	4	16	6	3	4	7	9	11	20	0.56	0.71	1.26	311	112	78	30

Table B.3: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
211	4	7	4	16	7	2	5	6	9	11	20	0.56	0.70	1.26	247	134	54	41
212	4	6	3	14	7	4	7	4	11	11	22	0.53	0.72	1.25	37	63	33	34
213	4	6	4	14	8	5	7	4	13	11	24	0.52	0.72	1.24	-80	48	20	39
214	6	6	2	13	7	2	7	4	9	11	20	0.49	0.73	1.23	204	78	83	26
215	6	8	4	16	5	4	4	7	9	11	20	0.53	0.69	1.22	494	127	106	44
216	6	7	3	14	7	2	5	6	9	11	20	0.49	0.71	1.20	311	123	113	38
217	6	9	4	16	6	5	4	7	11	11	22	0.53	0.67	1.20	483	136	108	56
218	4	8	4	15	6	2	5	6	8	11	19	0.50	0.68	1.18	506	189	115	58
219	6	10	4	16	6	6	4	7	12	11	23	0.52	0.66	1.18	473	144	110	67
220	4	6	4	13	8	7	7	4	15	11	26	0.45	0.71	1.16	-146	35	35	47
221	6	9	4	15	5	4	4	7	9	11	20	0.48	0.67	1.16	641	158	151	60
222	6	11	4	16	6	7	4	7	13	11	24	0.51	0.64	1.15	462	153	112	79
223	6	12	4	16	7	7	5	6	14	11	25	0.50	0.63	1.13	450	161	114	90
224	4	7	3	13	7	4	7	4	11	11	22	0.43	0.70	1.13	252	116	97	57
225	6	8	4	14	7	2	5	6	9	11	20	0.45	0.68	1.13	407	184	153	57
226	4	8	4	14	7	2	6	5	9	11	20	0.45	0.68	1.12	423	188	125	66
227	6	8	4	13	7	1	7	4	8	11	19	0.39	0.67	1.05	420	222	171	74
228	4	8	4	13	7	4	7	4	11	11	22	0.38	0.66	1.05	359	170	137	81
229	4	5	4	16	8	8	8	4	16	12	28	0.63	0.75	1.38	-332	-2	-44	18
230	4	5	2	14	8	3	8	4	11	12	23	0.58	0.75	1.33	-118	16	-8	14
231	6	6	4	16	7	2	5	7	9	12	21	0.60	0.73	1.32	28	89	31	16
232	4	5	3	14	8	8	8	4	16	12	28	0.56	0.74	1.30	-322	-7	-28	21
233	4	5	4	14	8	8	8	4	16	12	28	0.55	0.74	1.29	-344	-7	-26	23
234	6	5	2	13	8	2	7	5	10	12	22	0.52	0.75	1.27	-172	43	15	11
235	6	7	4	15	7	2	5	7	9	12	21	0.53	0.70	1.24	237	127	87	33
236	4	5	3	13	8	8	8	4	16	12	28	0.49	0.73	1.23	-269	-5	-4	26
237	6	7	4	14	7	1	6	6	8	12	20	0.49	0.70	1.19	152	156	97	43
238	6	6	3	13	8	2	7	5	10	12	22	0.47	0.72	1.19	-61	112	54	33
239	4	7	4	14	7	4	7	5	11	12	23	0.48	0.69	1.17	160	115	74	52
240	6	7	3	13	7	1	7	5	8	12	20	0.44	0.70	1.14	284	150	119	48

Table B.3: Continued

	Policies				Ranking							S/So			Change in Surplus			
No.	Month Open	TAC	Bag Limit	Min. Size Limit	East RSS	West RSS	East TS	West TS	Total RSS	Total TS	Total	East S/So	West S/So	Sum S/So	East RS	West RS	East TS	West TS
241	6	7	4	13	7	1	7	5	8	12	20	0.42	0.69	1.11	59	177	97	55
242	6	6	4	15	8	2	6	7	10	13	23	0.58	0.73	1.30	-89	95	26	18
243	6	6	4	14	8	2	7	6	10	13	23	0.52	0.72	1.24	-161	117	36	28
244	6	5	3	13	8	3	8	5	11	13	24	0.50	0.74	1.24	-360	54	-8	17
245	4	5	4	13	8	8	8	5	16	13	29	0.49	0.73	1.22	-347	-15	-11	26
246	6	6	4	13	8	2	7	6	10	13	23	0.45	0.71	1.16	-233	119	35	37
247	6	5	3	16	8	2	8	6	10	14	24	0.64	0.76	1.40	-194	31	-15	1
248	6	5	3	15	8	2	8	6	10	14	24	0.61	0.75	1.37	-248	37	-14	3
249	6	5	3	14	8	2	8	6	10	14	24	0.56	0.75	1.31	-390	49	-23	8
250	6	5	4	14	8	2	8	6	10	14	24	0.55	0.74	1.29	-426	57	-22	11
251	6	5	4	13	8	4	8	6	12	14	26	0.49	0.73	1.21	-540	41	-24	22
252	6	5	4	16	8	2	8	7	10	15	25	0.64	0.75	1.38	-344	51	-33	3
253	6	5	4	15	8	2	8	7	10	15	25	0.61	0.74	1.36	-430	51	-38	5
254	6	5	1	16	8	8	8	8	16	16	32	0.73	0.78	1.51	-416	-69	-77	-4
255	6	5	1	15	8	8	8	8	16	16	32	0.70	0.78	1.48	-308	-60	-56	-2
256	6	5	2	16	8	8	8	8	16	16	32	0.65	0.77	1.42	0	0	0	0

Appendix C: Estimation Results of Hedonic Wage Function

Dependent Variable: HR_WAGE
Method: Least Squares
Included observations: 1663

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.634138	4.656740	0.136176	0.8917
AGE	0.779103	0.203294	3.832390	0.0001
AGE2	-0.007057	0.002479	-2.846805	0.0045
WHITE	1.654453	1.504920	1.099363	0.2718
MALE	4.111645	1.324988	3.103157	0.0019
DWAGE	-11.63140	0.800576	-14.52878	0.0000

R-squared	0.159936	Mean dependent var	18.19456
Adjusted R-squared	0.157401	S.D. dependent var	17.23988
S.E. of regression	15.82504	Akaike info criterion	8.364665
Sum squared resid	414965.4	Schwarz criterion	8.384207
Log likelihood	-6949.219	F-statistic	63.09376
Durbin-Watson stat	0.089204	Prob(F-statistic)	0.000000

Note: HR_WAGE=hourly wage.

AGE=respondents' age.

AGE2=Age squared.

WHITE=an ethnical dummy variable if white=1, otherwise=0.

MALE= A gender dummy variable if Male=1, otherwise=0

Dwage is a dummy variable if hourly wage = 1 , salary/2000=0.

The estimator of Dwage is highly significant and negative.