PRELIMINARY METHODOLOGY FOR ACHIEVING F THRESHOLD AND TARGET FOR ATLANTIC MENHADEN

Introduction

At its November meeting, the Atlantic Menhaden Management Board approved a new fishing mortality threshold ($F_{15\%MSP}$ = 1.32) and target ($F_{30\%MSP}$ = 0.62). The Board requested that the Technical Committee (TC) explore methods to account for the uncertainty in the terminal year fishing mortality estimate (F_{2008}) as it relates to achieving the new fishing mortality reference points. The Board also requested that the Technical Committee explore landings scenarios to achieve 1) the new fishing mortality threshold immediately, and 2) the new fishing mortality target over a range of 1 to 5 years. Based on that charge, a projection analysis was initiated. Decisions regarding the structure and inputs for the projection analysis were discussed by the TC during a meeting on January 9, 2012. The documentation and methods below reflect those decisions. The program used to complete these projections is called “Constant landings projections 17 Jan 12.r”.

Methods

Data inputs and outputs from the base run of the Beaufort Assessment Model (BAM) were used as the basis for all of the projections within this document. The starting conditions of the projection analysis include initial numbers-at-age, which were the estimated numbers-at-age, N_a, for the start of 2009 (i.e., end of 2008) from the BAM plus variability. The variability in the initial numbers-at-age was incorporated based on estimated variability within the BAM during 1990 to 2007. The years 1990 to 2007 were used for consistency with other data sources (see discussion below).

Recruitment was projected without an underlying stock-recruitment function and was based on the median recruitment observed (R_{med}=13.22) from the BAM. Variability was incorporated into recruitment as a nonparametric bootstrap based on the annual deviations from the median in the base run of the BAM during the specified time period (1990 to 2007), which reflects variability in the more recent years. The final year of the BAM (2008) was not used, because recruitment tends to be poorly estimated in the terminal year. With variability included, the median recruitment was approximately 8.5 billion age-0 fish, which reflects the lower recruitment observed in the final years of the BAM data set (1990 to 2007) as estimated by the juvenile abundance index from the state surveys.

The median age varying natural mortality and weight vectors from 1990-2007 were projected into the future. Selectivity was constant across time for the base run of the BAM model and was thus constant in the projections. Selectivity was the weighted average selectivity from the bait and reduction fisheries.

Landings levels were input for each year of the simulation and the fishing mortality rate, F, was solved for within the model. Each projection incorporated the observed reduction landings for 2009, 2010, and 2011 of 143.754, 183.085, and 174.021 thousands of metric tons, respectively. Landings for 2012 was input as 186 thousand metric tons and was based on a preliminary landings forecast, which uses a multiple linear regression model that relies on projected effort for the 2012 fishing year and historical catch and effort (Smith 1991). Observed landings for the bait fishery for 2009 and 2010 were 38.9 and 43.8 thousands of metric tons, respectively. Bait landings for 2011 and 2012 were estimated at 43.5 thousand metric tons, which was the average bait landings during 2008-2010.

Starting in 2013, management was instituted with a constant level of total landings, which was projected for 5 years. Total projected landings included 75, 100, 125, 150, 175, 200, and 225 thousand metric tons. Total landings were allocated such that 75% were allocated to the reduction fishery and 25% were allocated to the bait fishery. This allocation was based on the proportion of bait landings to the total coastwide landings of Atlantic menhaden for the most recent five years (this decision will likely be revisited as additional years of landings data become available). The allocation presented here (75:25) is for illustrative purposes only; the question of allocation between the reduction and bait fisheries is a question that managers will need to address and provide guidance to the TC.

Numbers at age after the initial year were calculated as:

$$N_{a+1,y+1} = N_{a,y} e^{-Z_{a,y}}$$

where Z is age and year specific mortality and equals natural mortality for each age for that year plus the fishing mortality rate times the selectivity at age.

Each constant landings value was simulated 2,000 times. Outputs included the median and 5th and 95th percentiles for spawning stock size (ova) over time, F over time, recruitment over time, and landings over time. Spawning stock size for each year was the number of fish in each age times the median reproductive vector from 1990-2007. The reproductive vector was the product of the proportion female, the maturity vector, and the median fecundity vector. Fecundity (mature ova) was determined by weight as described in the stock assessment document (ASMFC 2010). Landings (1000s mt) over time was a model input, as discussed above. Additional outputs included the probability of *F* being less than the specified target of 0.620 and less than the specified threshold of 1.324 over time given the constant landings input.

Results

As expected, the higher the landings, the lower the probability of *F* being less than the threshold and target (Table 1; Figures 1-5). However, the range in *F* was fairly broad for a given level of constant landings (Figures 6-19). In some cases, the *F* could not be estimated or was estimated at an extremely high value, sometimes even hitting the bound of 25. The high values of *F* demonstrate the inability of the model to account for such high landings during the period of 2009 to 2012 (when observed and forecasted landing are being used; for example in Figures 7, 9, 11, 13, 15, 17, and 19). One explanation for why the observed landings could not be achieved may be because predicted recruitments were lower than actual recruitments. Variability in recruitment was a major driving factor for these projections meaning that recruitment was one of the most uncertain components of the projections and that recruitment uncertainty carried through all of the results.

Future directions

In order to address uncertainty in the numbers-at-age for the terminal year and the terminal value of *F*, the TC would like to explore using the Monte Carlo/bootstrap runs (MCB) as the set of initial conditions for each of the projection runs. This method would account for uncertainty in the base run of the model (as specified in the assessment document). The intention is to produce code to use the individual MCB runs as starting points for the projection runs; however, sufficient time was not available to do so with the short turnaround time of the current charge.

Another potential method that would be useful for setting annual landings specifications would be to use the relationship between the observed JAI and estimated numbers at age-0 from BAM. That relationship along with the observed JAI value for another year (in this case, the JAI value from 2009) would be used to project recruitment forward one year. This method was explored as an option for this analysis, but it exaggerated the observed results of not being able to fit landings due to very large values of F as seen above. The projected recruitment using this method was low, and when uncertainty was included, the results produced unrealistic values of F, which were incapable of producing the observed landings. However, this method has the advantage of incorporating new information on recruitment into projections between assessment years, and the TC would like to further explore it as a potential option.

Important notes to managers

Before the Amendment can be finalized, the Atlantic Menhaden Board needs to determine the acceptable level of risk for a given year in order to determine what level of landings would be appropriate to reduce overfishing. In addition, the Atlantic Menhaden Board needs to decide how landings will be allocated between the reduction and bait fisheries, a decision that has impacts on the selectivity and estimated F for a given constant landings value.

All results from this analysis are conditional on the assumptions made about management/implementation uncertainty. Management uncertainty was assumed to be zero because no information is available for the Atlantic menhaden fishery on this type of uncertainty. If the assumption of zero uncertainty is violated, there will be effects on the projection results.

The projections included many sources of uncertainty, and there are plans to incorporate more sources of uncertainty (see Future directions above); however, these projections did not include structural uncertainty. Therefore, results are conditional on the functional forms and assumptions made regarding population dynamics, selectivity, recruitment, etc. One major assumption that is highly uncertain is the projection of recruitment based on deviations from the median using the most recent years. If recruitment is affected by environmental or ecological conditions, stock trajectories may be affected. Additionally, if allocations between the two fisheries are different in the future, then the weighted selectivity vector will also be different, which will affect projection results.

Literature cited

Atlantic States Marine Fisheries Commission (ASMFC). 2010. Atlantic menhaden stock assessment and review panel reports. ASMFC stock assessment report no. 10-02, 325 p.

Smith, J. W. 1991. The Atlantic and gulf menhaden purse seine fisheries: origins, harvesting technologies, biostatistical monitoring, recent trends in fisheries statistics, and forecasting. Marine Fisheries Review 53: 28-41.

Table 1. The probability of the fishing mortality rate (F) being less than the threshold and target over time for given constant landings scenarios.

Years	Landings (1000s metric tons)	P(F<threshold)	P(F<target)
2009	75	0.002	0
2009	100	0.002	0
2009	125	0.002	0
2009	150	0.002	0
2009	175	0.002	0
2009	200	0.002	0
2009	225	0.002	0
2010	75	0	0
2010	100	0	0
2010	125	0	0
2010	150	0	0
2010	175	0	0
2010	200	0	0
2010	225	0	0
2011	75	0.0015	0
2011	100	0.0015	0
2011	125	0.0015	0
2011	150	0.0015	0
2011	175	0.0015	0
2011	200	0.0015	0
2011	225	0.0015	0
2012	75	0.0085	0
2012	100	0.0085	0
2012	125	0.0085	0
2012	150	0.0085	0
2012	175	0.0085	0
2012	200	0.0085	0
2012	225	0.0085	0
2013	75	0.5575	0.2105
2013	100	0.401	0.085
2013	125	0.277	0.023
2013	150	0.17	0.0075
2013	175	0.1015	0.001
2013	200	0.0525	0
2013	225	0.0245	0
2014	75	0.8895	0.6165
2014	100	0.741	0.3505
2014	125	0.547	0.1465

2014	150	0.3685	0.0495
2014	175	0.219	0.0115
2014	200	0.108	0
2014	225	0.0465	0
2015	75	0.9955	0.9065
2015	100	0.9325	0.66
2015	125	0.7825	0.376
2015	150	0.556	0.1415
2015	175	0.347	0.035
2015	200	0.1705	0.003
2015	225	0.0685	0
2016	75	0.999	0.99
2016	100	0.9895	0.878
2016	125	0.9065	0.5885
2016	150	0.728	0.268
2016	175	0.465	0.0725
2016	200	0.224	0.0075
2016	225	0.079	0
2017	75	1	0.9985
2017	100	0.998	0.9625
2017	125	0.9645	0.7645
2017	150	0.836	0.4
2017	175	0.561	0.114
2017	200	0.279	0.017
2017	225	0.0945	5.00E-04

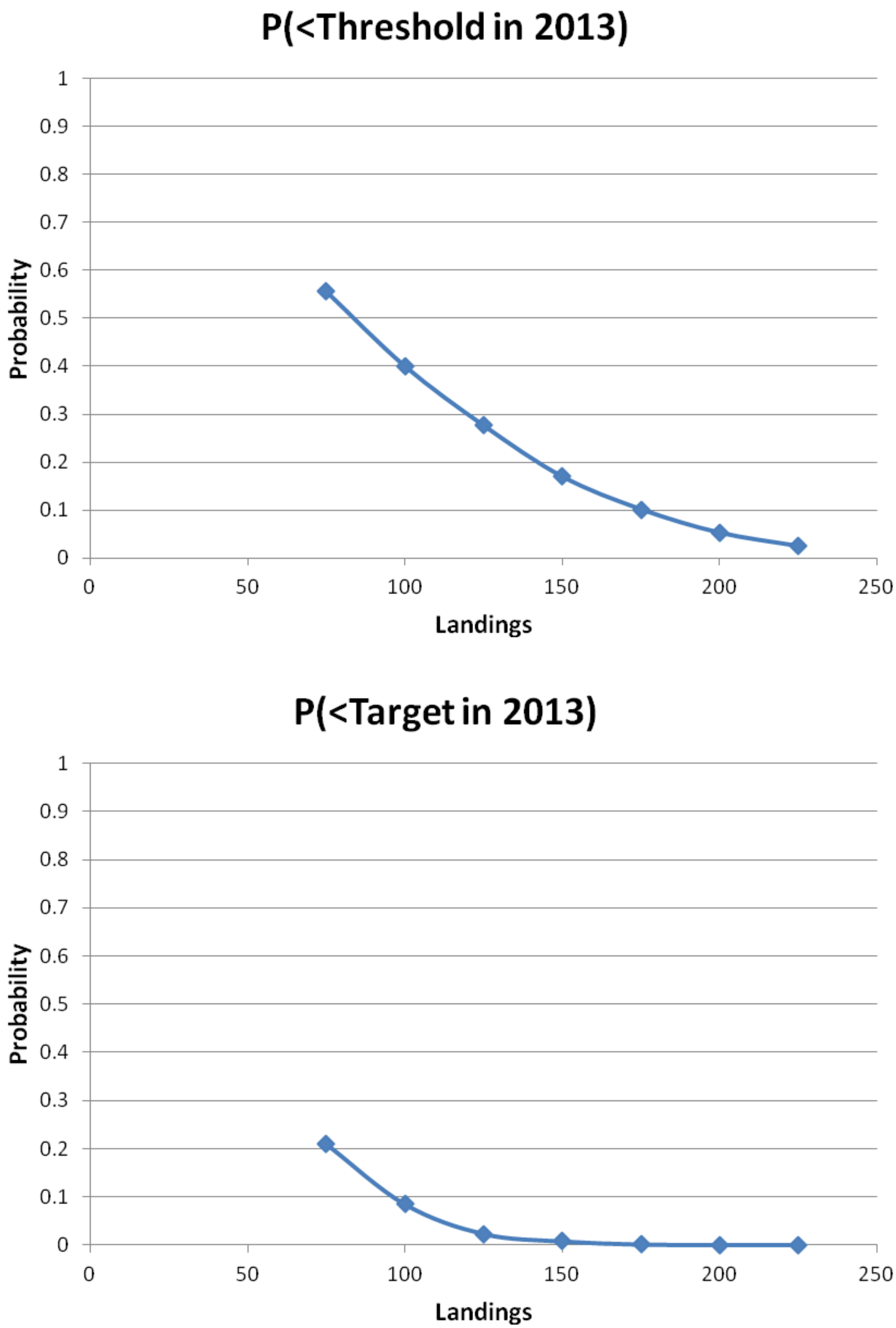


Figure 1. Probability of the fishing mortality rate being less than the threshold (upper panel) and target (lower panel) across a series of constant landings values for the year 2013.

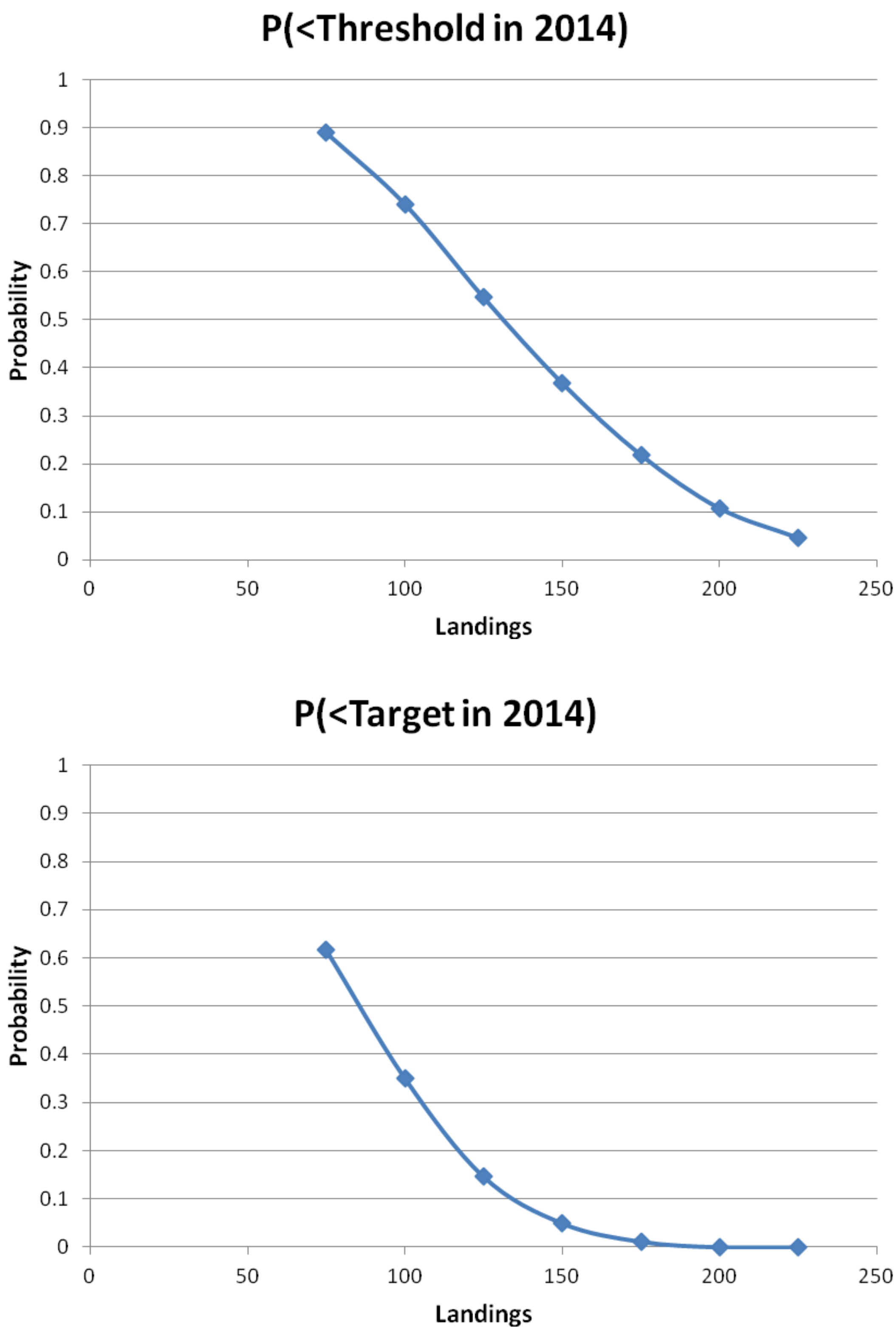
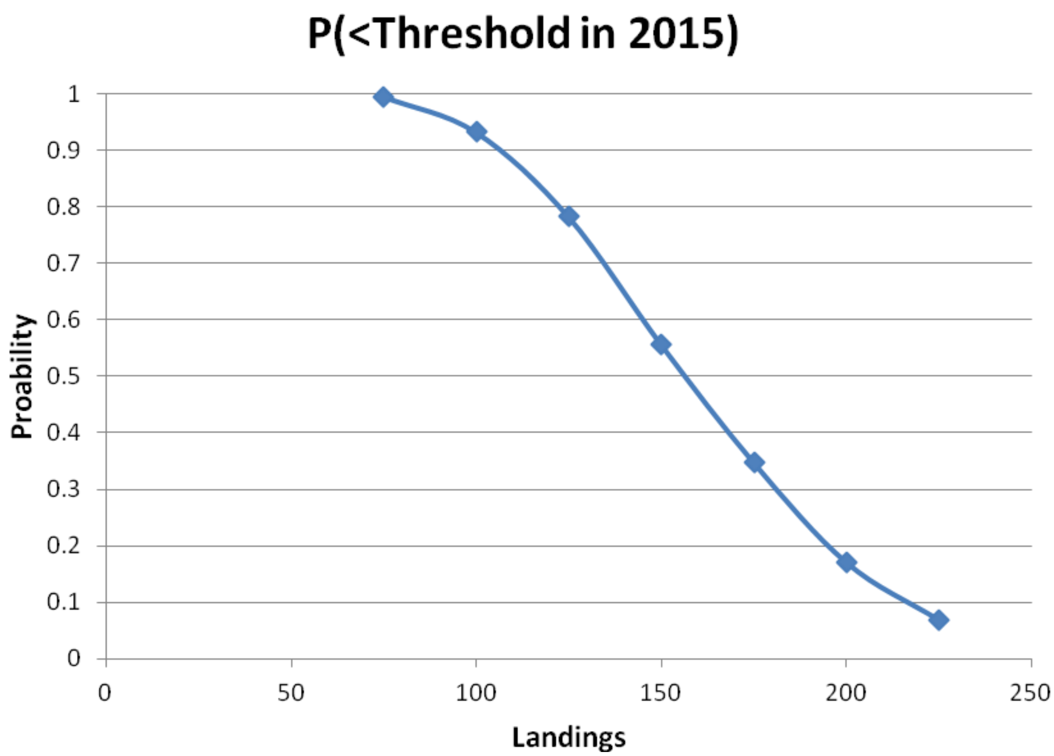


Figure 2. Probability of the fishing mortality rate being less than the threshold (upper panel) and target (lower panel) across a series of constant landings values for the year 2014.



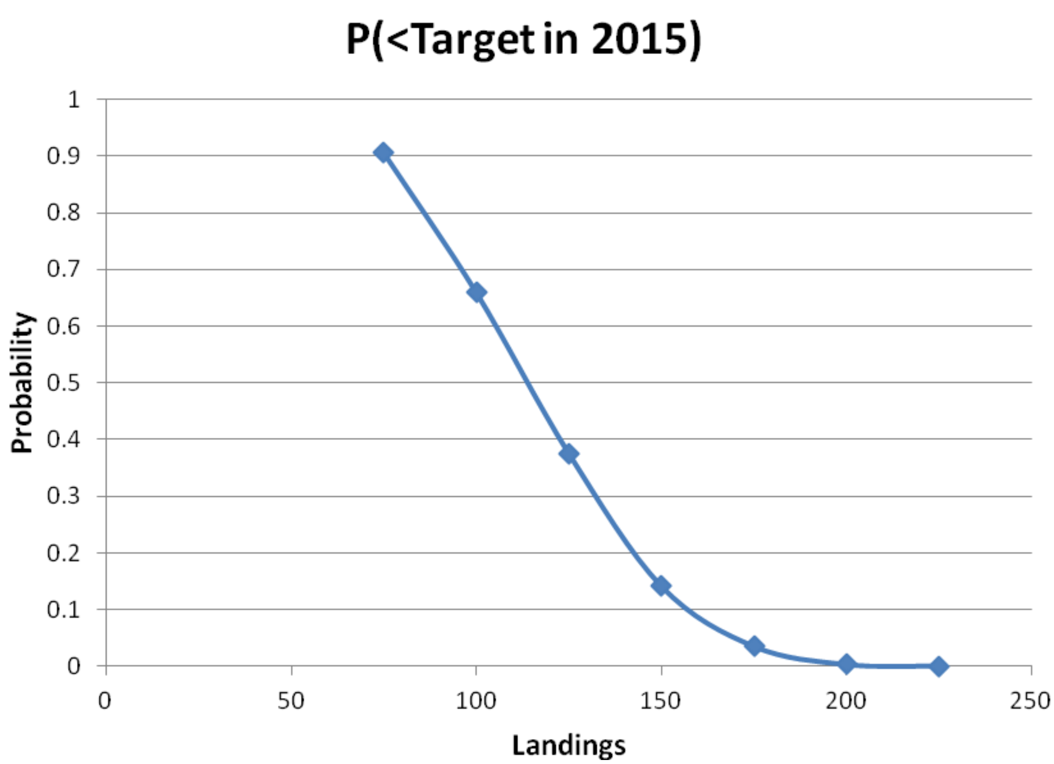
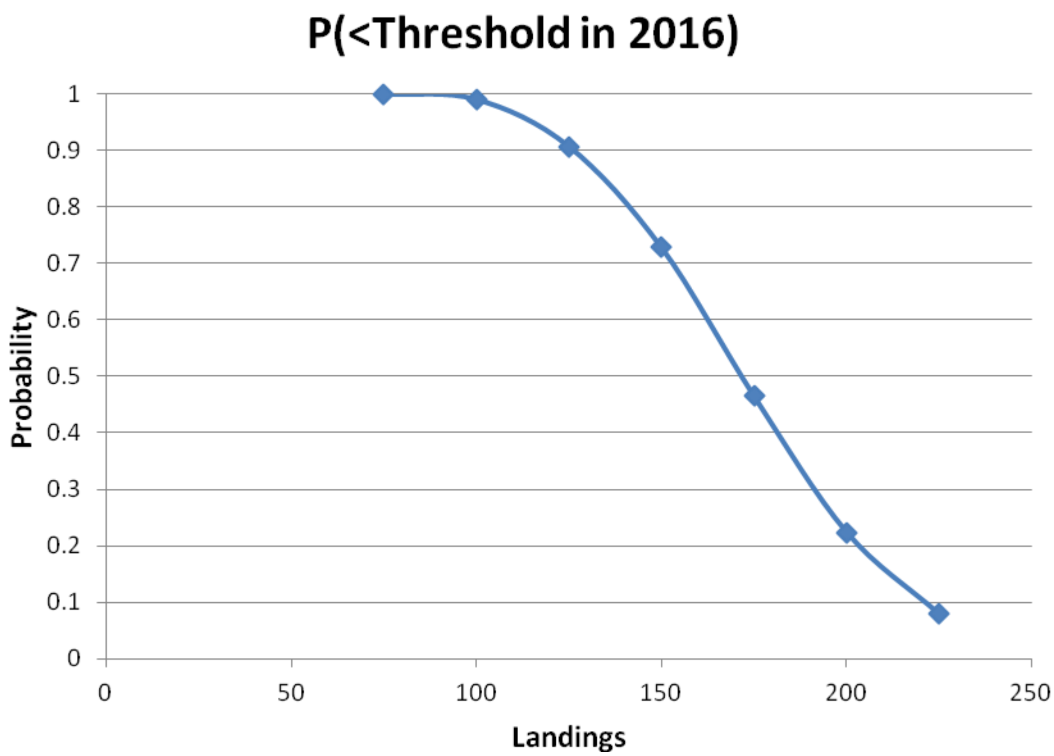


Figure 3. Probability of the fishing mortality rate being less than the threshold (upper panel) and target (lower panel) across a series of constant landings values for the year 2015.



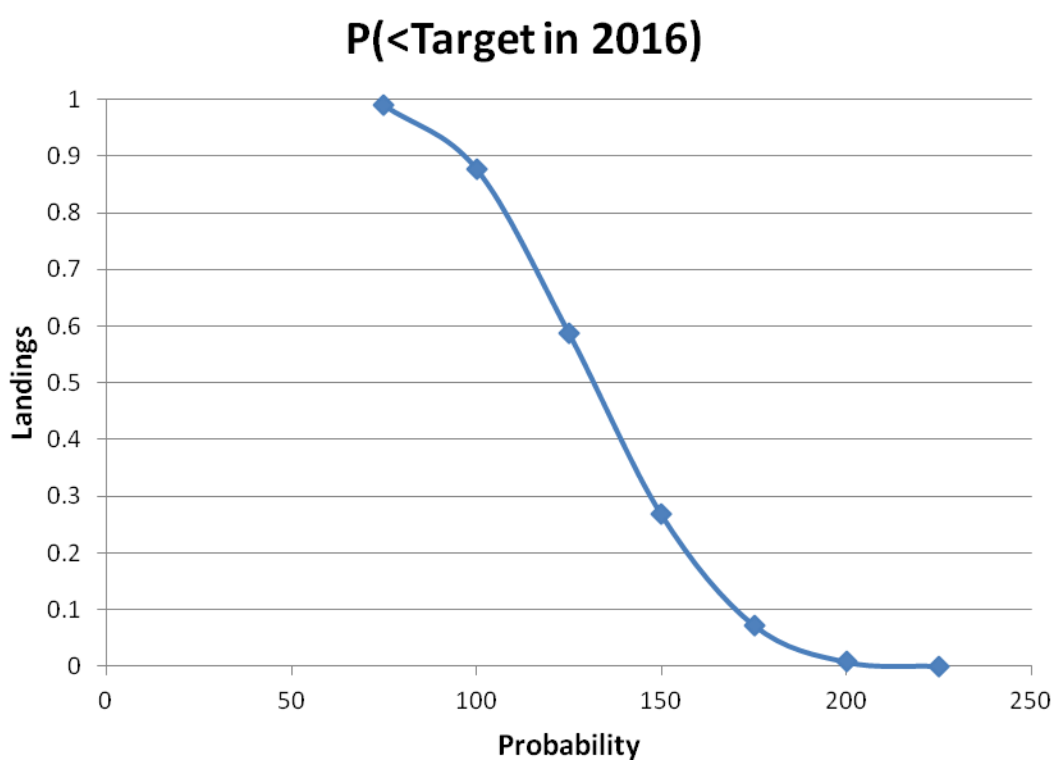


Figure 4. Probability of the fishing mortality rate being less than the threshold (upper panel) and target (lower panel) across a series of constant landings values for the year 2016.

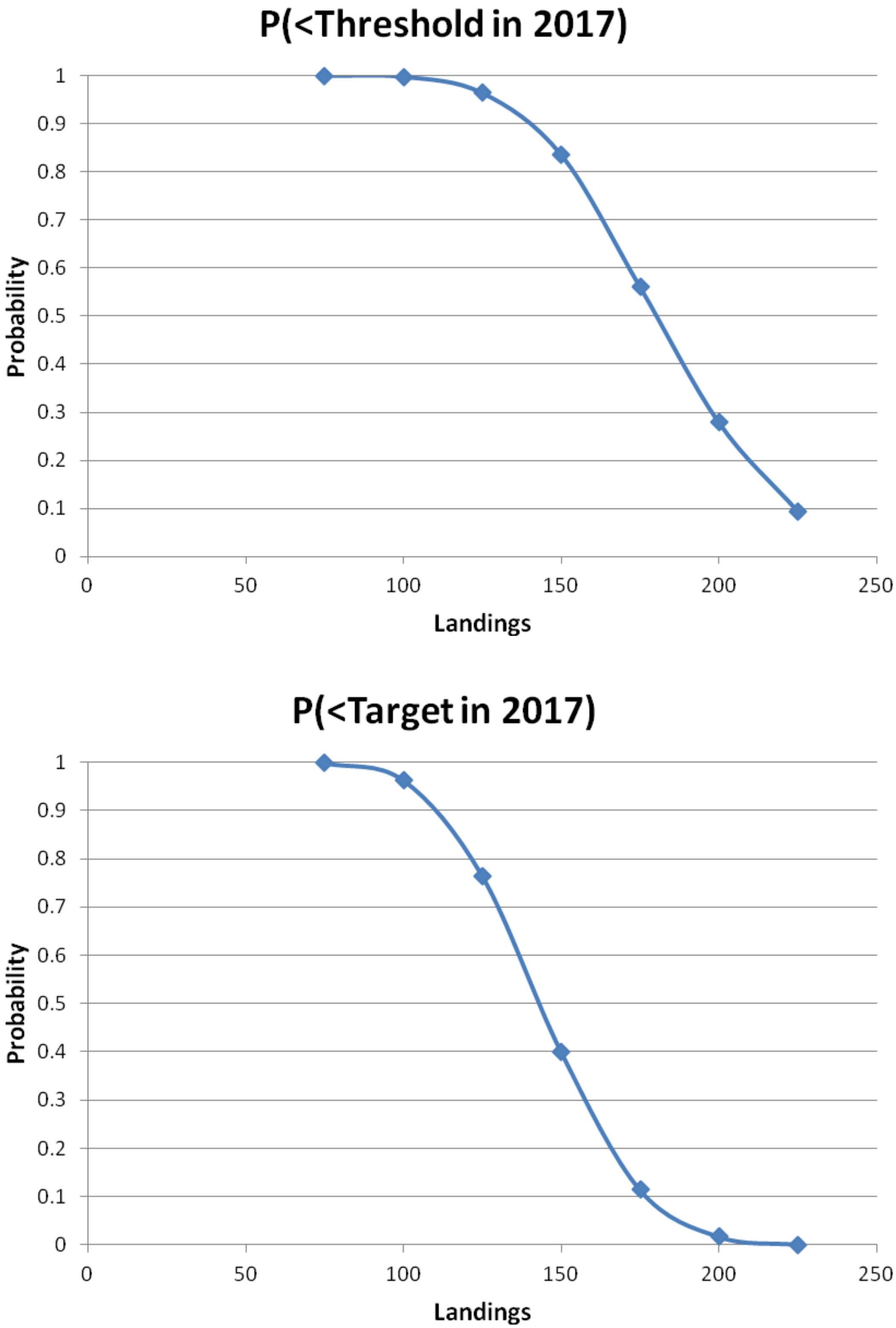


Figure 5. Probability of the fishing mortality rate being less than the threshold (upper panel) and target (lower panel) across a series of constant landings values for the year 2017.

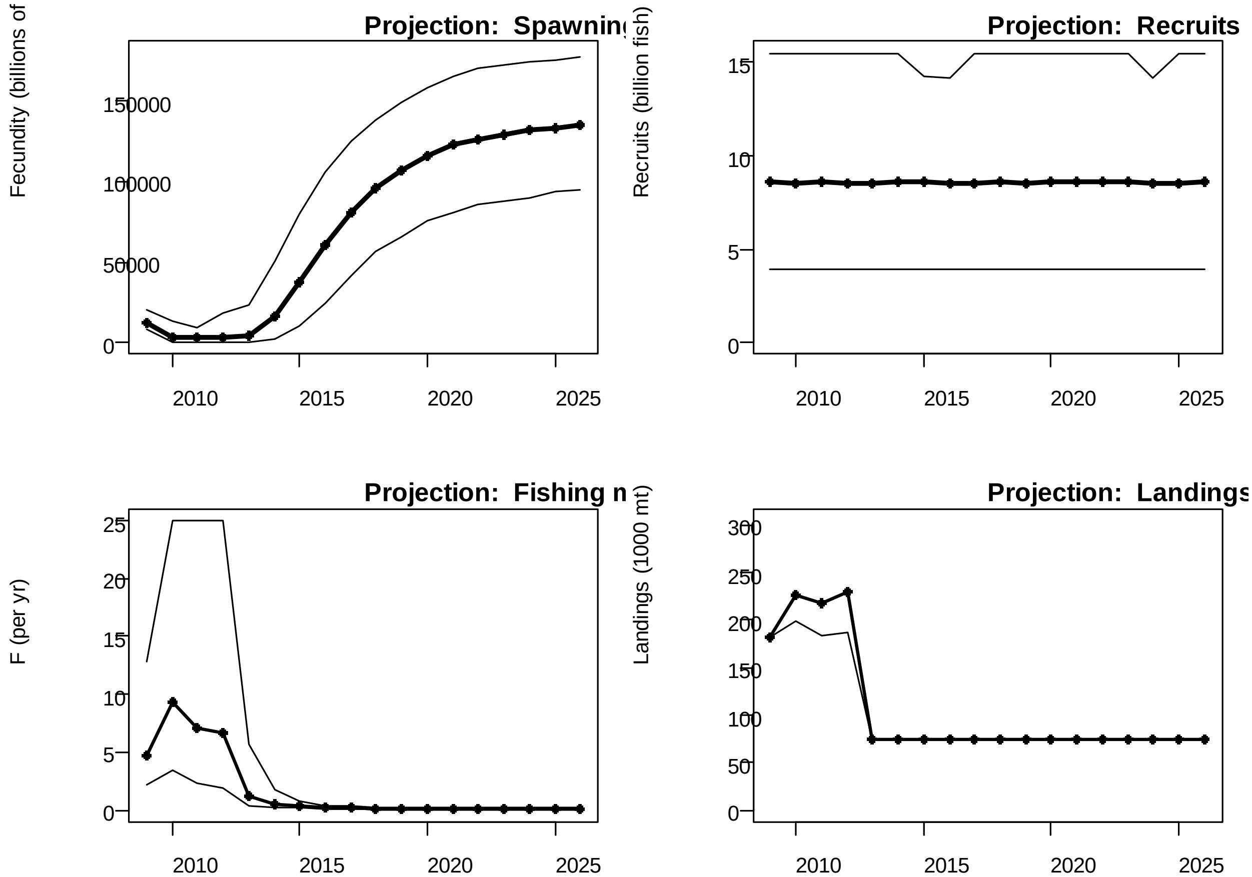


Figure 6. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 75,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

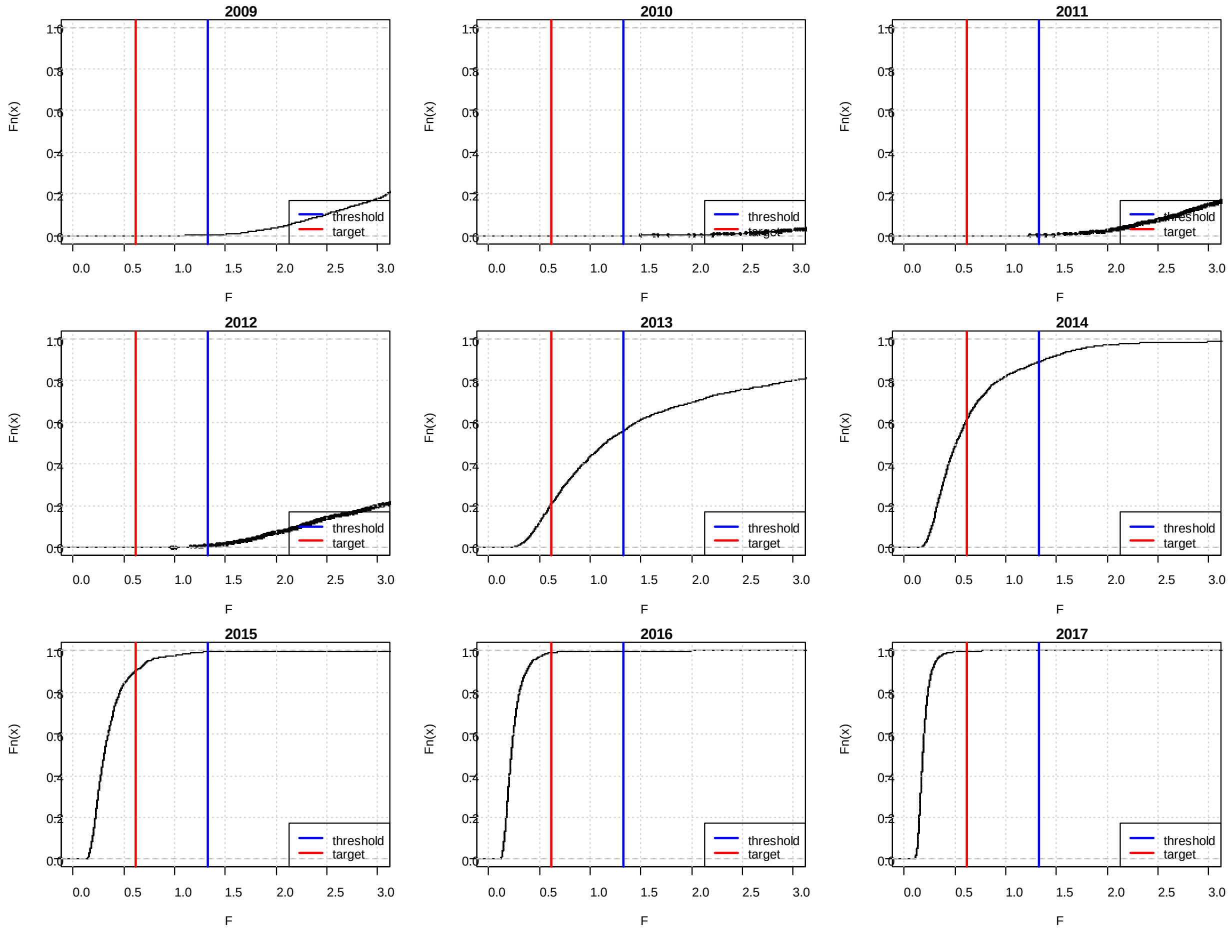


Figure 7. Cumulative distribution of fishing mortality rates for 2009 to 2017 based on constant landings of 75,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

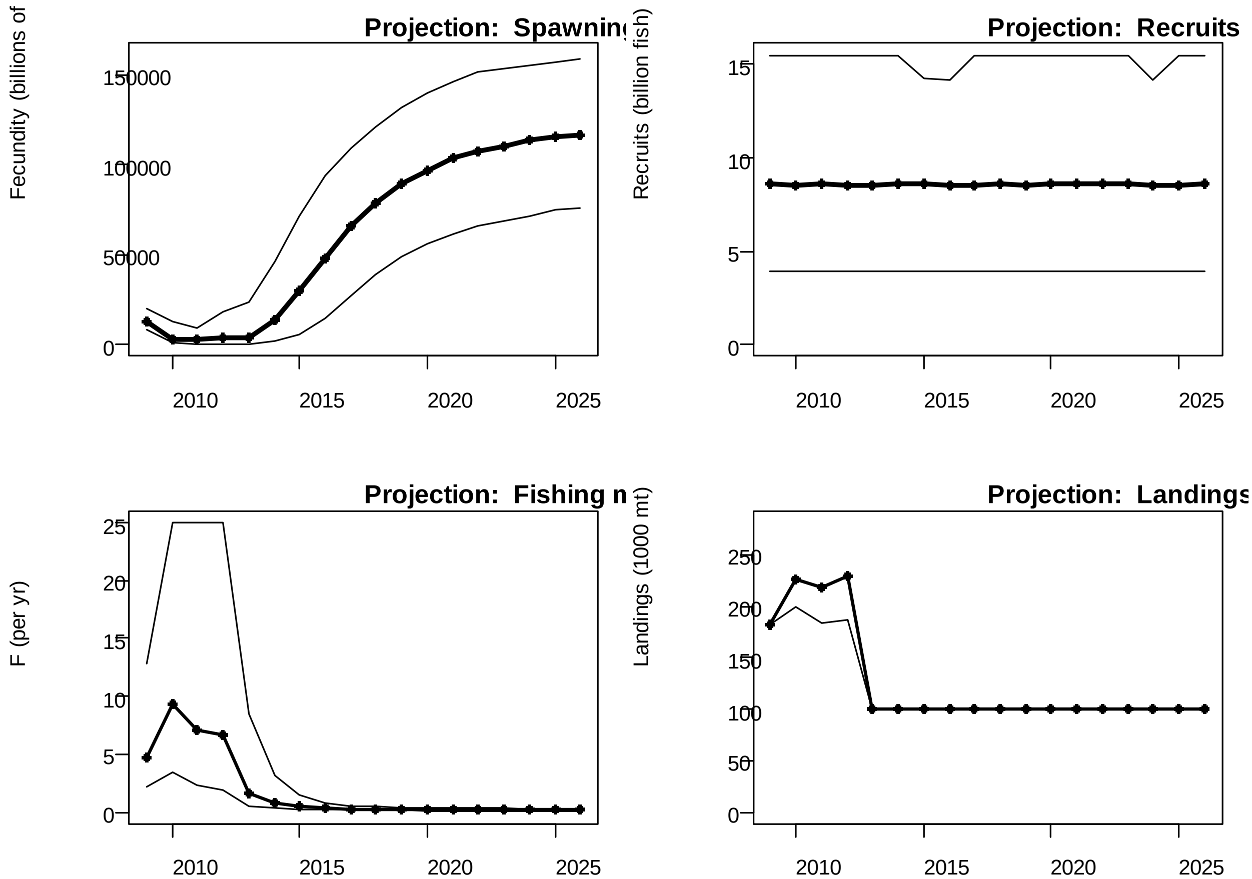


Figure 8. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 100,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

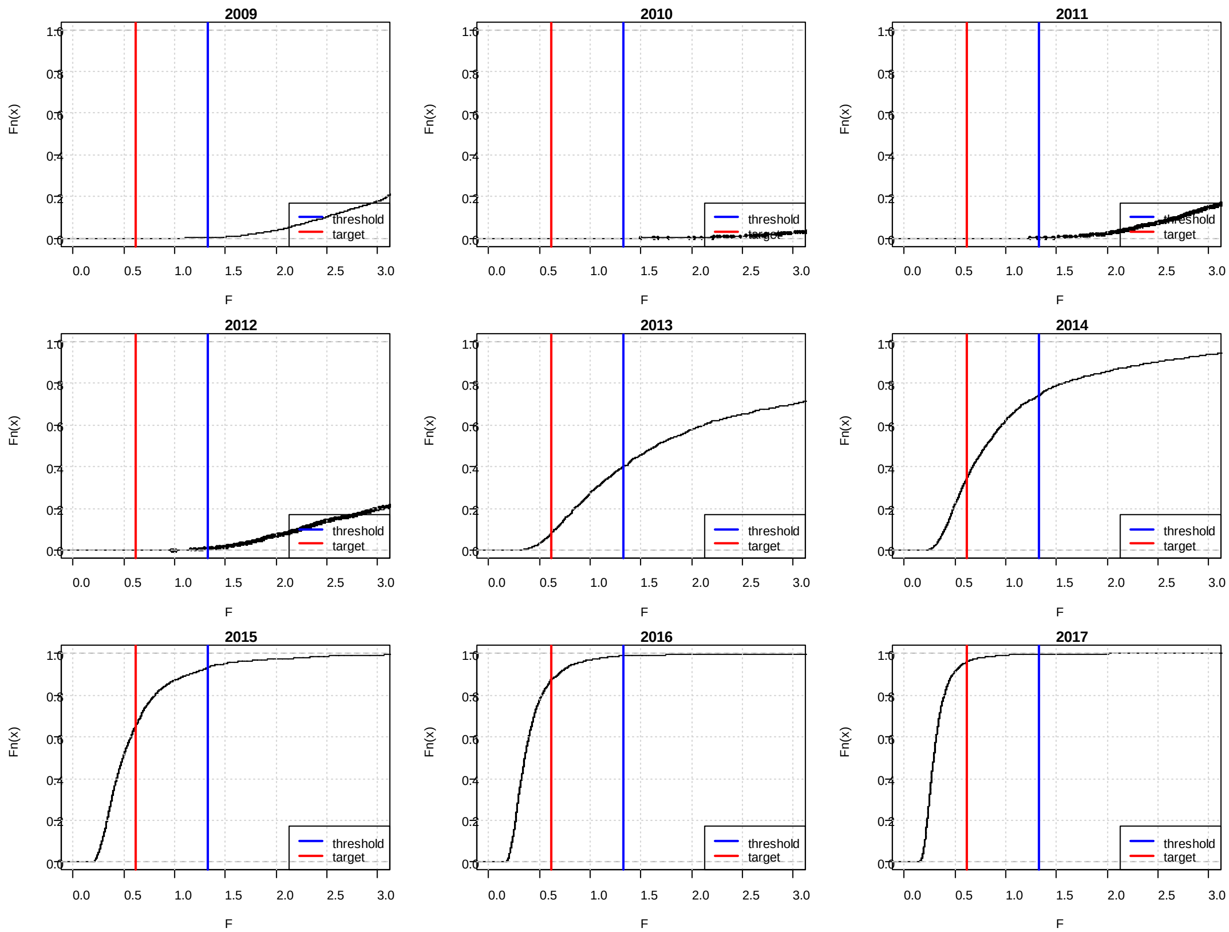


Figure 9. Cumulative distribution of fishing mortality rates for 2009 to 2017 based on constant landings of 100,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

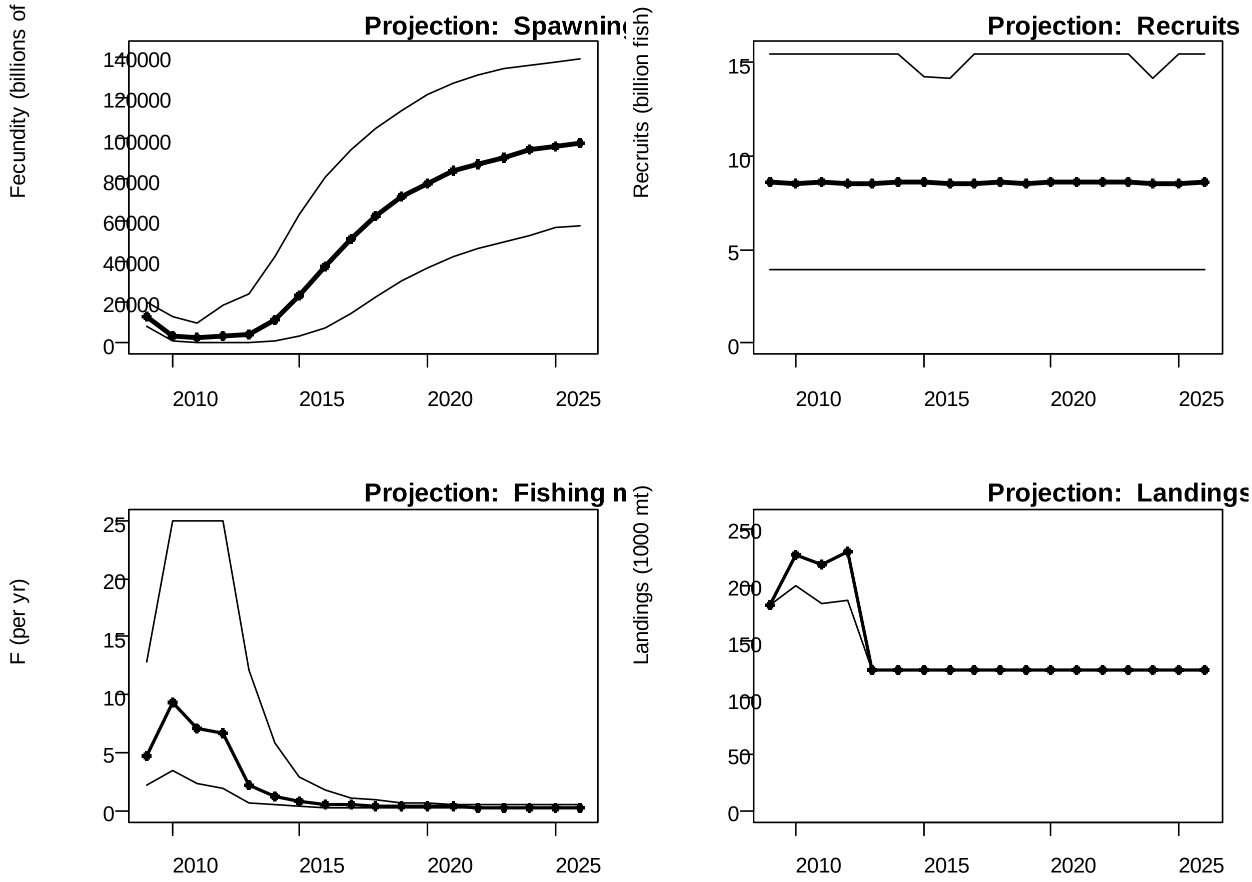


Figure 10. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 125,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

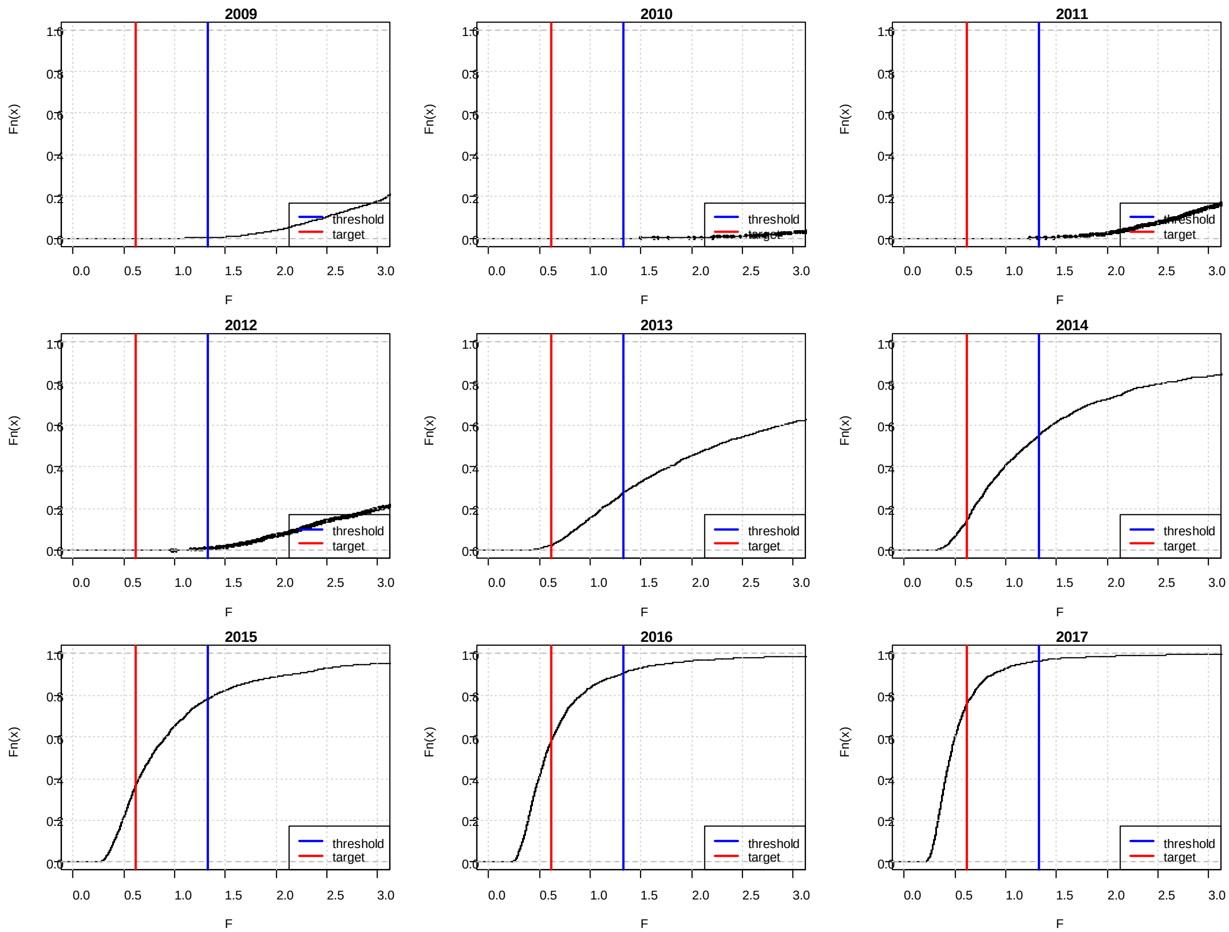


Figure 11. Cumulative distribution of fishing mortality rates for 2009 to 2017 based on constant landings of 125,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

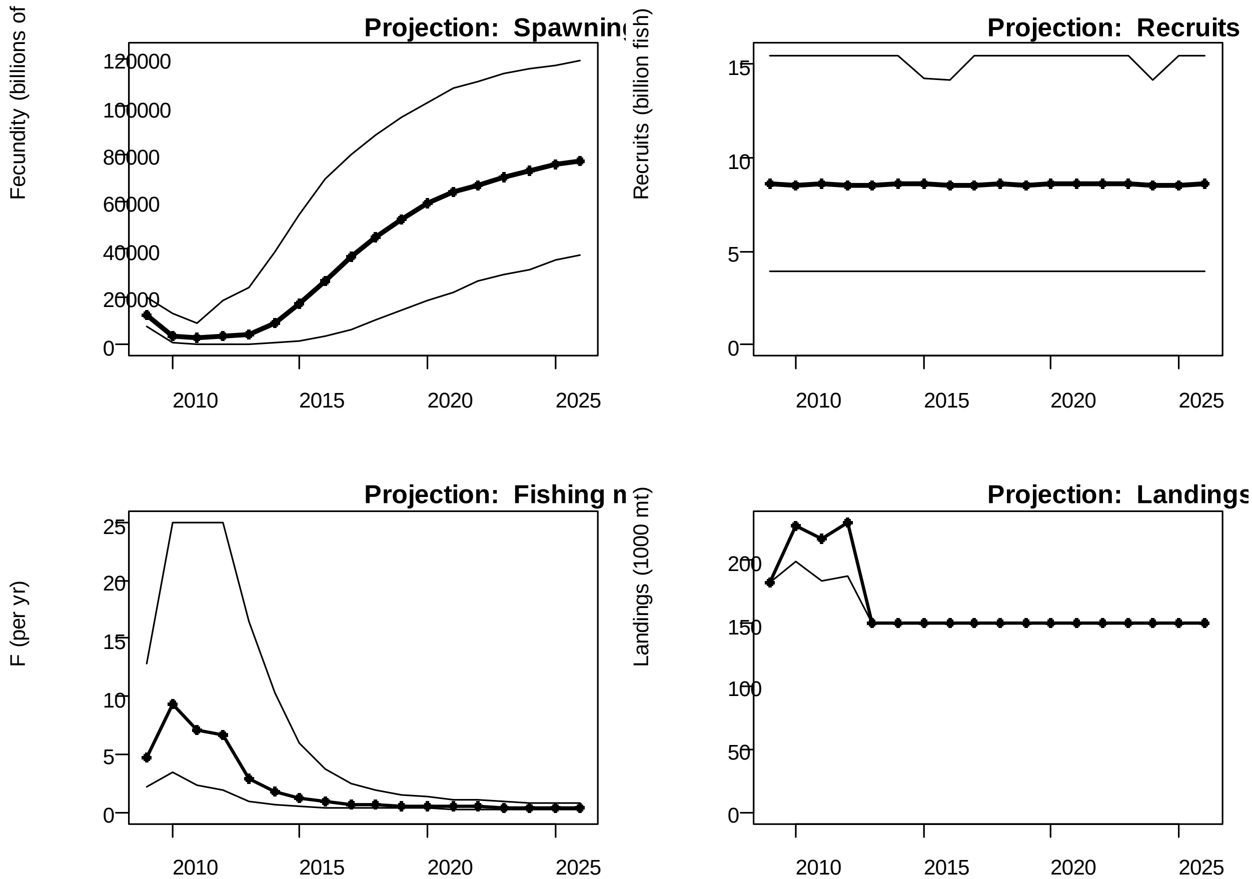


Figure 12. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 150,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

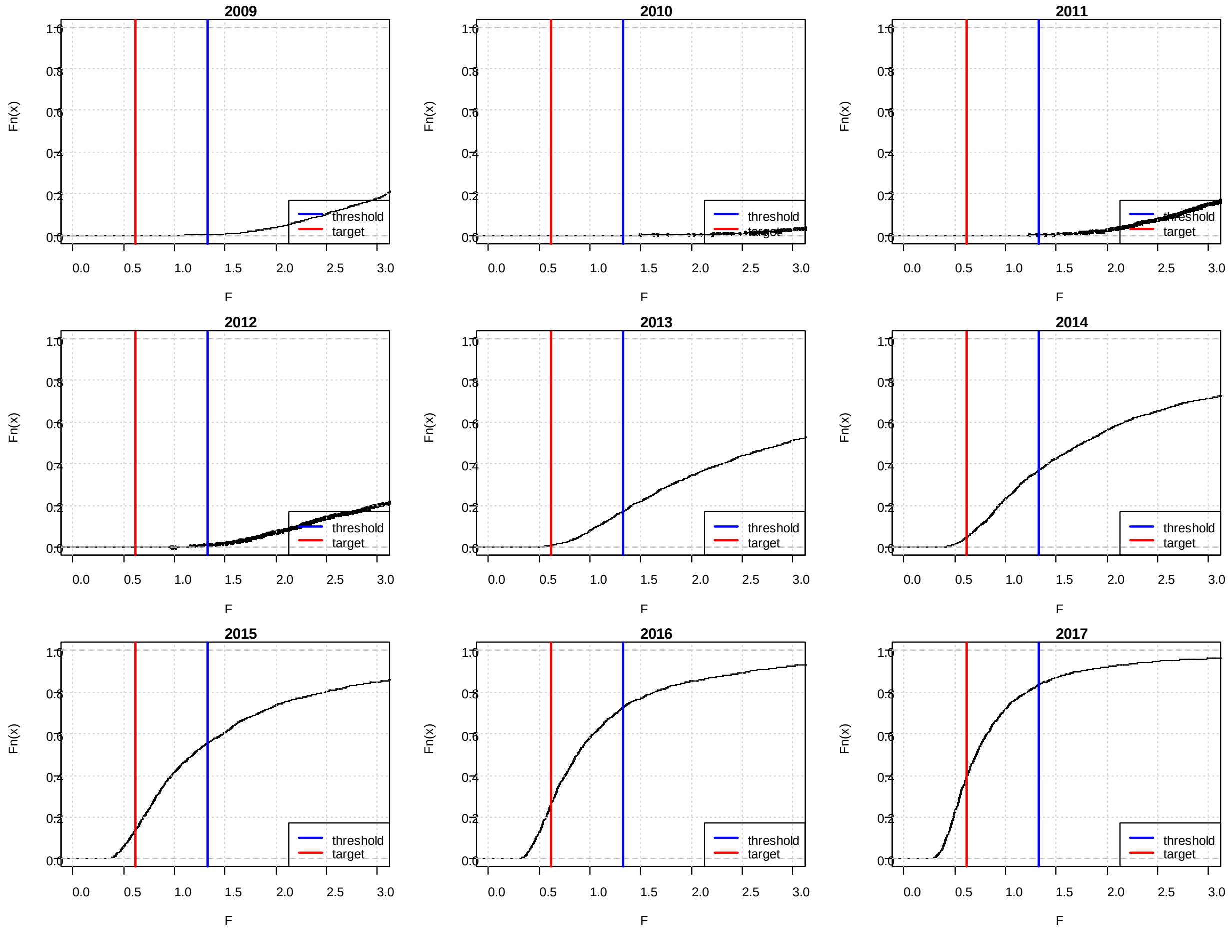


Figure 13. Cumulative distribution of fishing mortality rates for 2009 to 2017 based on constant landings of 150,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

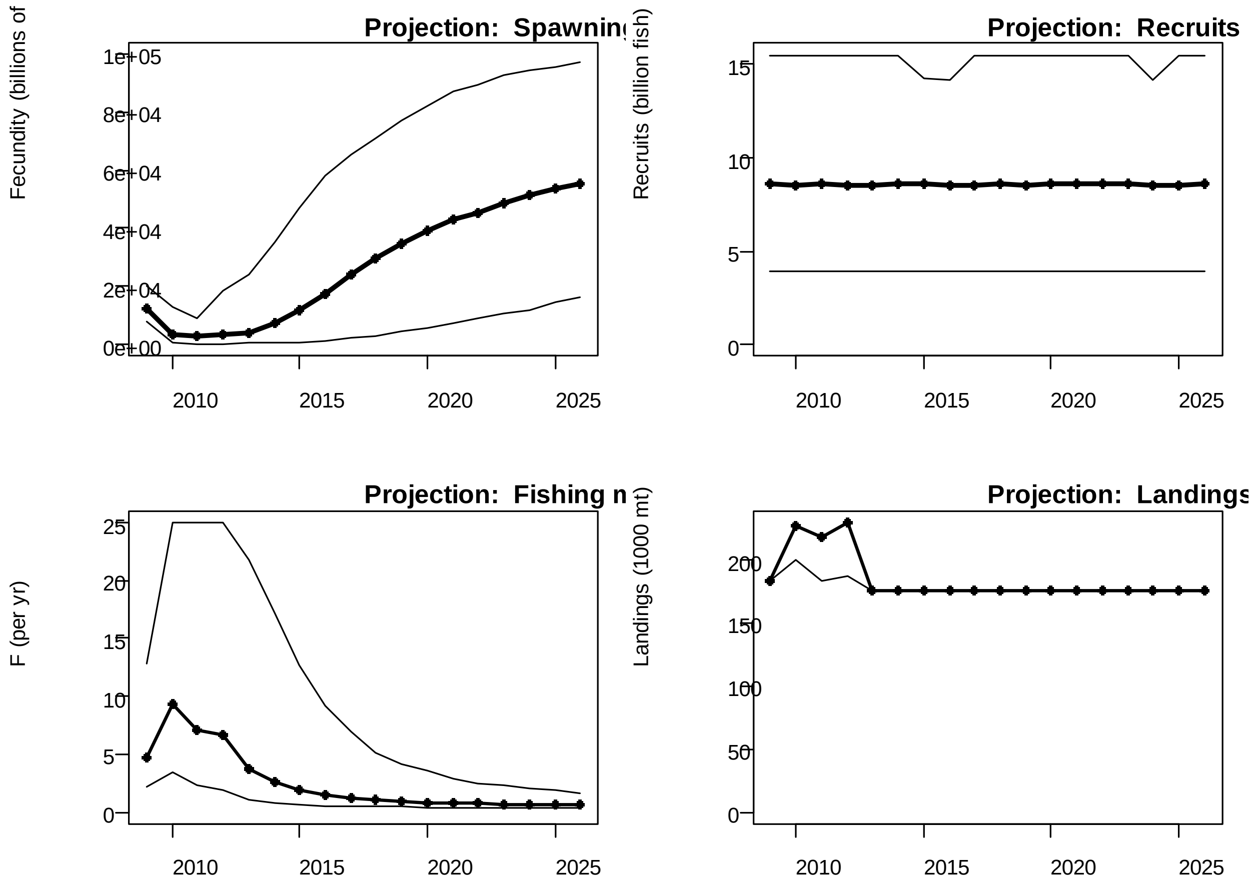


Figure 14. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 175,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

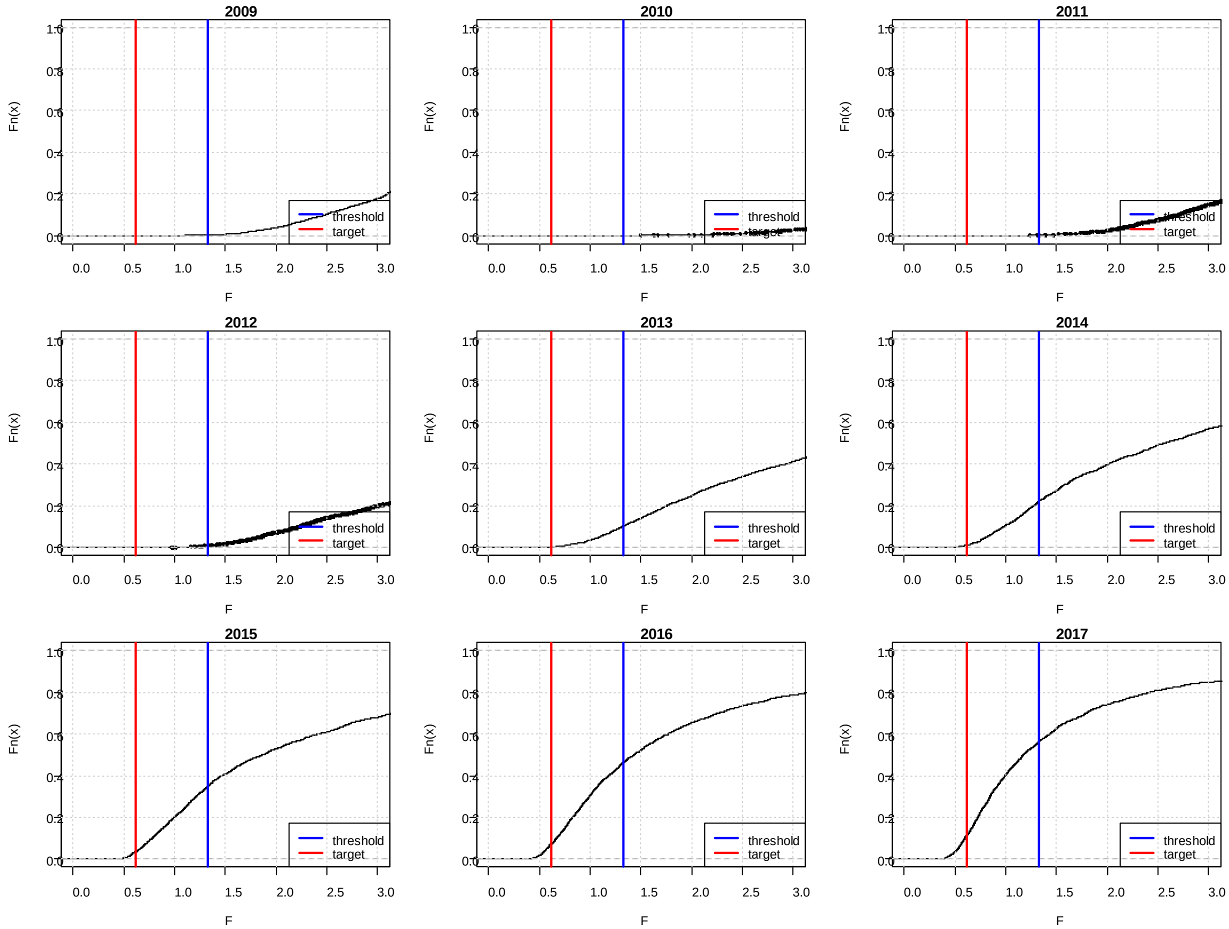


Figure 15. Cumulative distribution of fishing mortality rates for 2009 to 2017 based on constant landings of 175,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified F in that year.

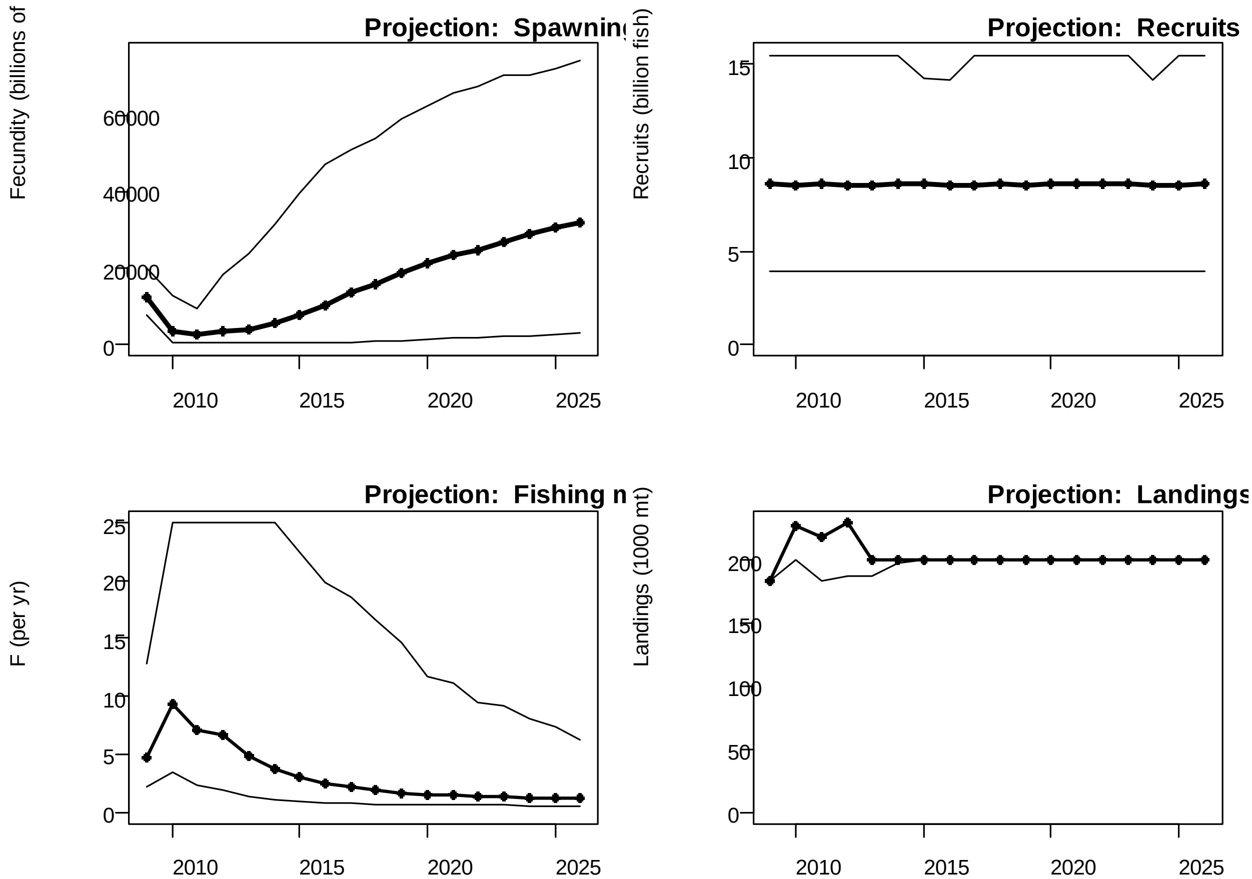


Figure 16. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 200,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

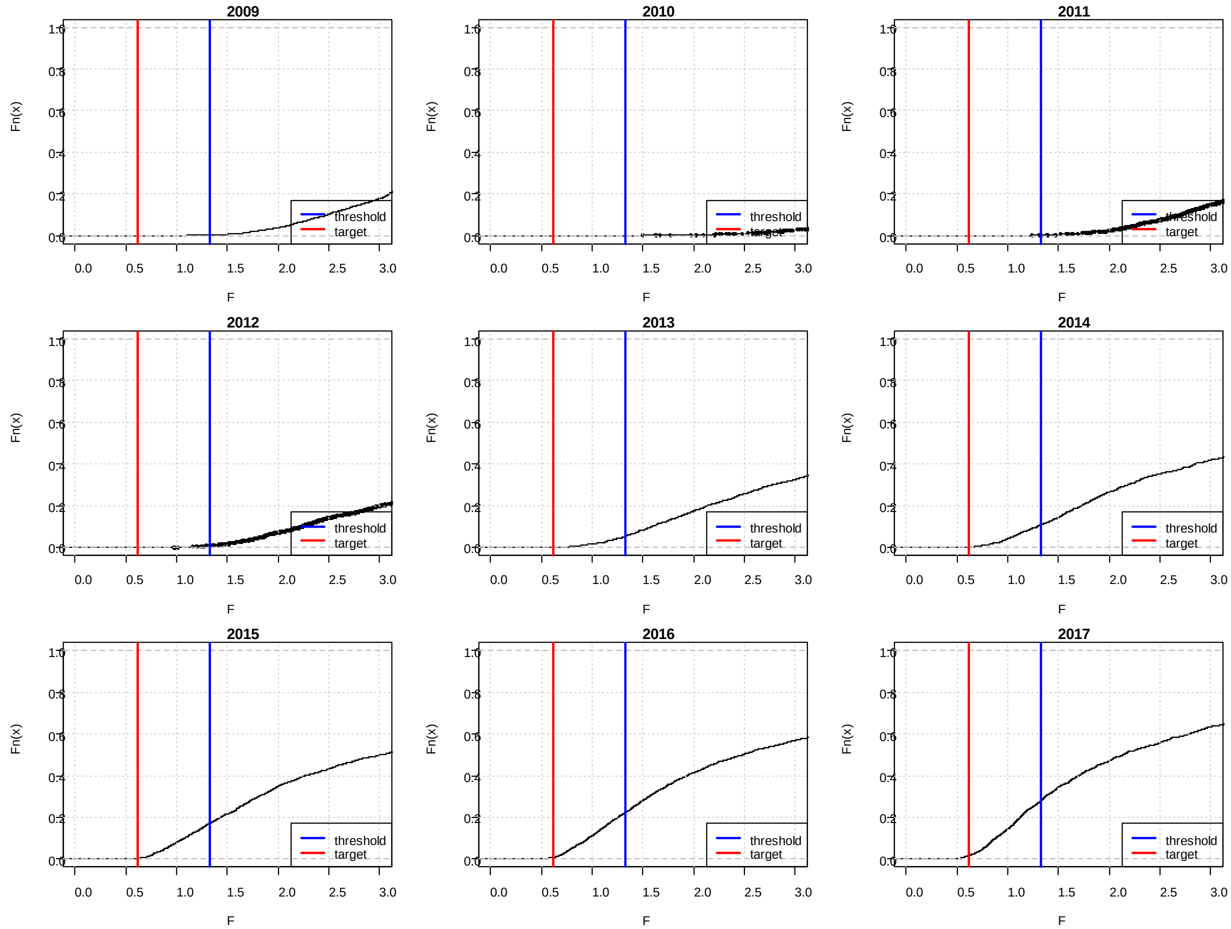


Figure 17. Cumulative distribution of fishing mortality rates for 2009 to 2017 based on constant landings of 200,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

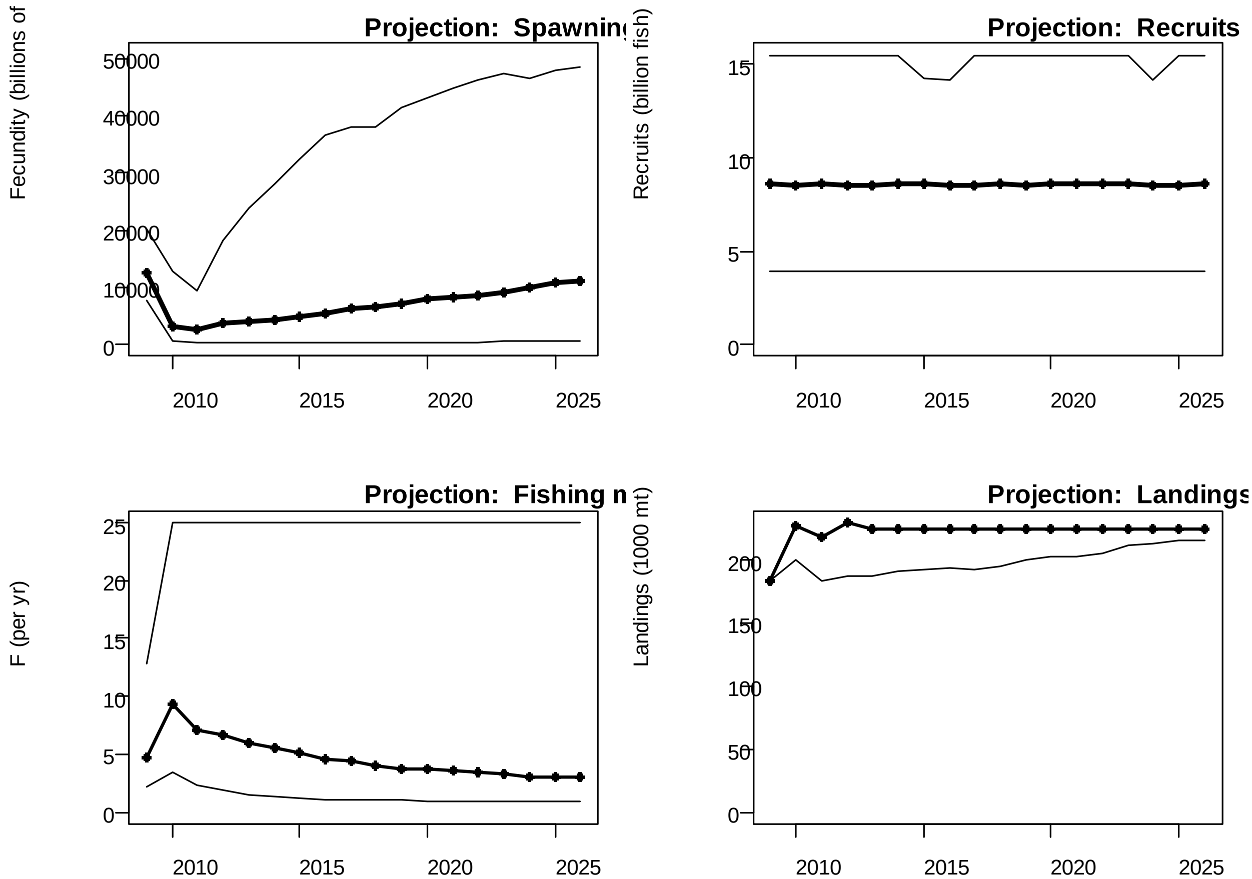


Figure 18. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 225,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

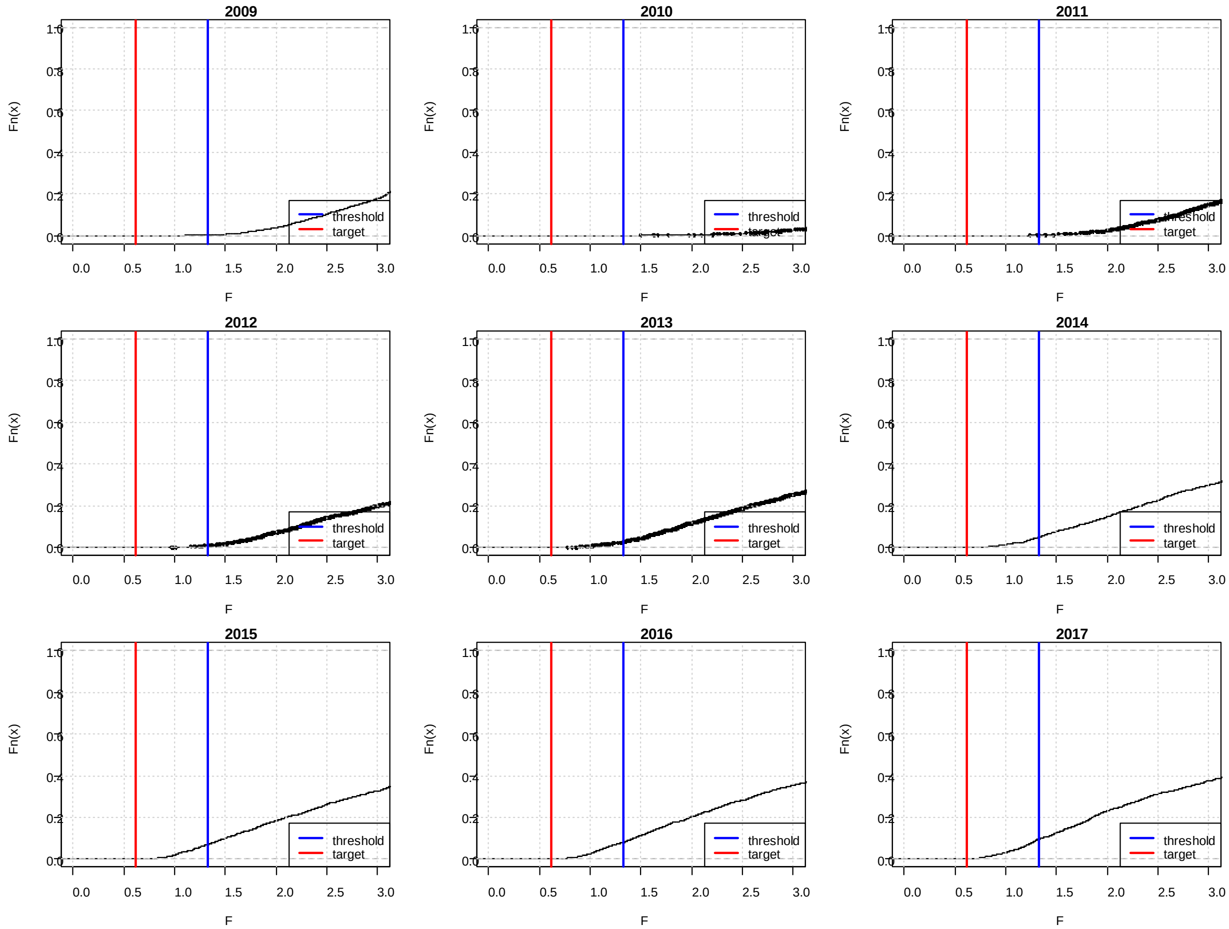


Figure 19. Cumulative distribution of fishing mortality rates for 2009 to 2017 based on constant landings of 225,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.