Cable-CDFW Model Sensitivity Analyses

Asymptotic Vulnerability Sensitivity Analysis

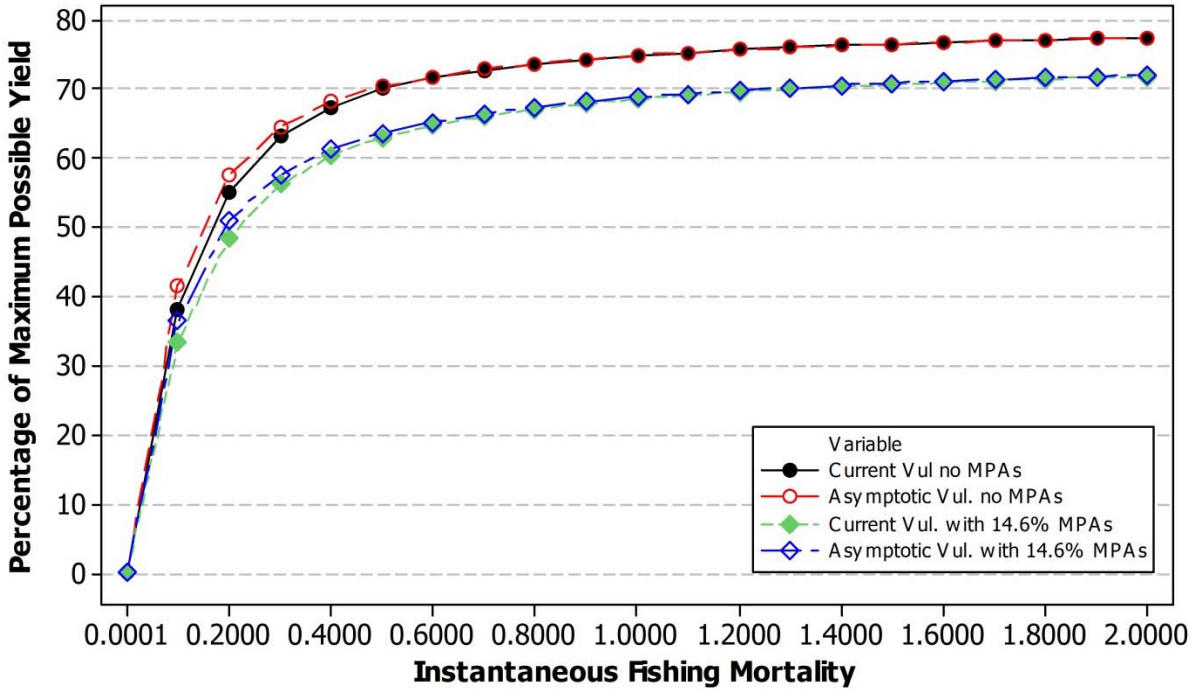
Summary

The original or "current" vulnerability equation in the Cable model produced a curve increasing lobster vulnerability to traps from their initial size to slightly larger than legal size, then decreased vulnerability after a size of 110 mm CL to simulate large lobsters having difficulty entering traps. This analysis compares outputs under that scenario to outputs using the same vulnerability for small lobsters and full or asymptotic vulnerability for larger lobster. Therefore large lobsters have no difficulty entering traps.

Using an asymptotic vulnerability rather than a vulnerability that is dampened at large sizes has little impact on model output. There is a slight difference in the yield and average weight outputs at intermediate fishing mortality but no difference at low and high fishing mortality. This is reasonable because at low fishing mortality, gear selectivity is unimportant and natural mortality dominates. At high fishing mortality, few to no lobsters reach the large sizes that would be impacted by this change in the vulnerability curve. These differences in output are small enough that they don't translate to SPR which appears equal under these two scenarios.

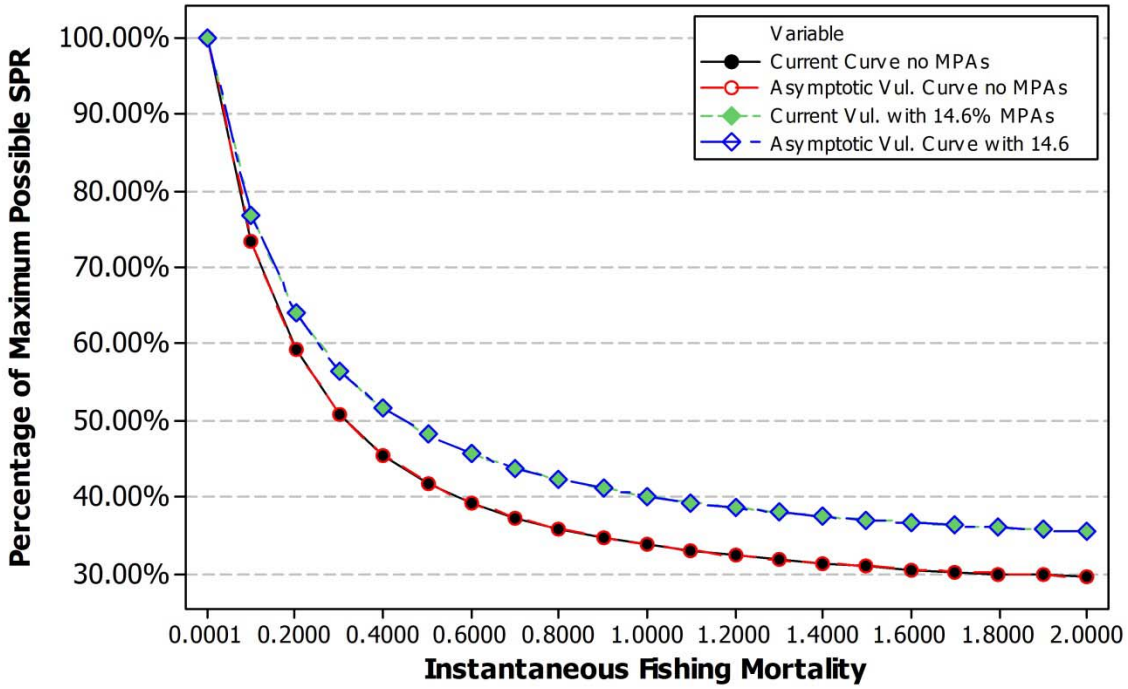
Yield (Percent of Maximum Possible)

Instantaneous Fishing Mortality	Current Curve no MPAs	Asymptotic Vul. Curve no MPAs	Difference (Asymptotic no MPA-Current no MPA)	Current Vul. with 14.6% MPAs	Asymptotic Vul. Curve with 14.6% MPAs	Difference (Asymptotic 14.6% MPA-Current 14.6% MPA)
0.0001	0.1	0.1	0.01	0.0	0.1	0.01
0.10	38.1	41.6	3.43	33.4	36.5	3.08
0.20	55.0	57.5	2.51	48.6	51.0	2.39
0.30	63.2	64.6	1.41	56.2	57.7	1.50
0.40	67.5	68.2	0.72	60.5	61.4	0.92
0.50	70.1	70.4	0.35	63.1	63.7	0.61
0.60	71.7	71.9	0.17	64.9	65.3	0.44
0.70	72.9	73.0	0.08	66.2	66.5	0.36
0.80	73.7	73.8	0.04	67.2	67.5	0.31
0.90	74.4	74.4	0.02	68.0	68.2	0.28
1.00	74.9	75.0	0.01	68.6	68.9	0.26
1.10	75.4	75.4	0.00	69.2	69.4	0.24
1.20	75.8	75.8	0.00	69.7	69.9	0.23
1.30	76.1	76.1	0.00	70.1	70.3	0.22
1.40	76.4	76.4	0.00	70.4	70.7	0.21
1.50	76.6	76.6	0.00	70.8	71.0	0.20
1.60	76.9	76.9	0.00	71.1	71.2	0.19
1.70	77.0	77.0	0.00	71.3	71.5	0.18
1.80	77.2	77.2	0.00	71.5	71.7	0.17
1.90	77.4	77.4	0.00	71.8	71.9	0.17
2.00	77.5	77.5	0.00	71.9	72.1	0.16



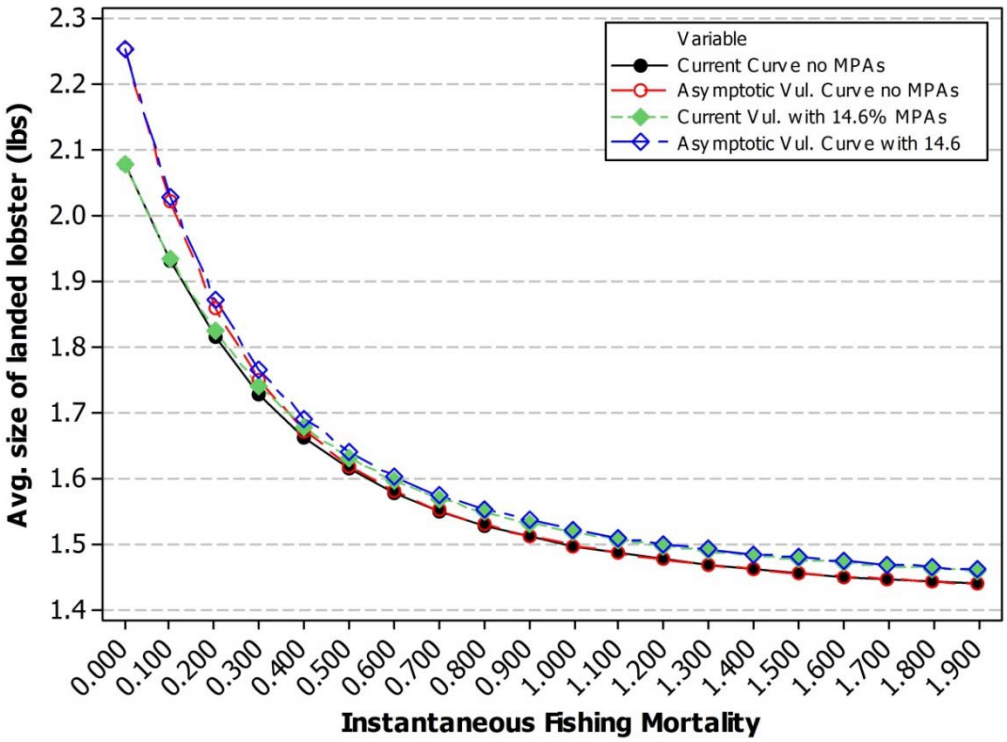
SPR

Instantaneous Fishing Mortality	Current Curve no MPAs	Asymptotic Vul. Curve no MPAs	Difference (Asymptotic no MPA-Current no	Current Vul. with 14.6% MPAs	Asymptotic Vul. Curve with 14.6% MPAs	Difference (Asymptotic 14.6% MPA-Current 14.6%
0.0001	100%	100%	0%	100%	100%	0%
0.10	73.4%	73.4%	0%	76.8%	76.8%	0%
0.20	59.2%	59.2%	0%	64.1%	64.1%	0%
0.30	50.8%	50.8%	0%	56.5%	56.5%	0%
0.40	45.5%	45.5%	0%	51.6%	51.6%	0%
0.50	41.9%	41.9%	0%	48.2%	48.2%	0%
0.60	39.3%	39.3%	0%	45.7%	45.7%	0%
0.70	37.4%	37.4%	0%	43.8%	43.8%	0%
0.80	35.9%	35.9%	0%	42.3%	42.3%	0%
0.90	34.7%	34.7%	0%	41.1%	41.1%	0%
1.00	33.8%	33.8%	0%	40.2%	40.2%	0%
1.10	33.0%	33.0%	0%	39.3%	39.3%	0%
1.20	32.4%	32.4%	0%	38.6%	38.6%	0%
1.30	31.8%	31.8%	0%	38.0%	38.0%	0%
1.40	31.4%	31.4%	0%	37.5%	37.5%	0%
1.50	31.0%	31.0%	0%	37.1%	37.1%	0%
1.60	30.6%	30.6%	0%	36.7%	36.7%	0%
1.70	30.3%	30.3%	0%	36.3%	36.3%	0%
1.80	30.1%	30.1%	0%	36.0%	36.0%	0%
1.90	29.8%	29.8%	0%	35.7%	35.7%	0%
2.00	29.6%	29.6%	0%	35.5%	35.5%	0%



Average Weight (lbs)

Instantaneous Fishing Mortality	Current Curve no MPAs	Asymptotic Vul. Curve no MPAs	Difference (Asymptotic no MPA-Current no MPA)	Current Vul. with 14.6% MPAs	Asymptotic Vul. Curve with 14.6% MPAs	Difference (Asymptotic 14.6% MPA-Current 14.6% MPA)
0.000	2.078	2.252	0.174	2.078	2.252	0.174
0.100	1.931	2.023	0.092	1.935	2.029	0.094
0.200	1.815	1.860	0.045	1.823	1.872	0.049
0.300	1.728	1.749	0.021	1.740	1.765	0.026
0.400	1.663	1.673	0.009	1.678	1.692	0.014
0.500	1.615	1.619	0.004	1.631	1.640	0.009
0.600	1.579	1.580	0.002	1.596	1.603	0.006
0.700	1.551	1.551	0.001	1.570	1.575	0.005
0.800	1.529	1.529	0.000	1.549	1.553	0.004
0.900	1.512	1.512	0.000	1.532	1.536	0.004
1.000	1.498	1.498	0.000	1.518	1.522	0.004
1.100	1.486	1.486	0.000	1.507	1.510	0.003
1.200	1.477	1.477	0.000	1.498	1.501	0.003
1.300	1.468	1.468	0.000	1.489	1.492	0.003
1.400	1.462	1.462	0.000	1.483	1.485	0.003
1.500	1.456	1.456	0.000	1.477	1.479	0.003
1.600	1.450	1.450	0.000	1.471	1.474	0.002
1.700	1.446	1.446	0.000	1.467	1.469	0.002
1.800	1.442	1.442	0.000	1.463	1.465	0.002
1.900	1.439	1.439	0.000	1.459	1.461	0.002



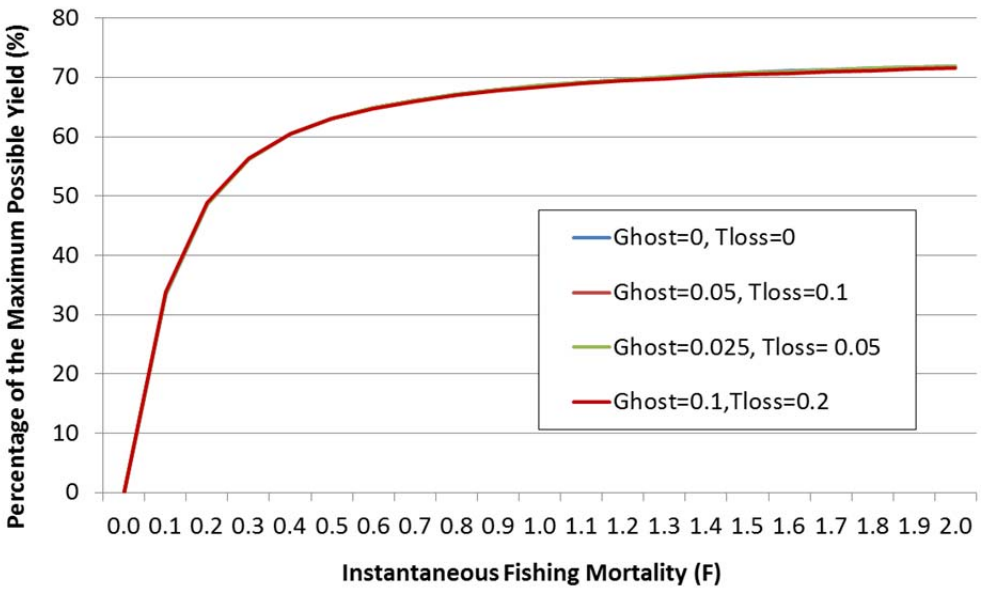
Ghost Fishing Sensitivity Analysis

Summary

This analysis compared key model outputs under scenarios with no ghost fishing, the level of ghost fishing used by Dr. Parrish in his Cable 6.0 model version, and double and half that level. Ghost fishing's impact on these outputs was negligible.

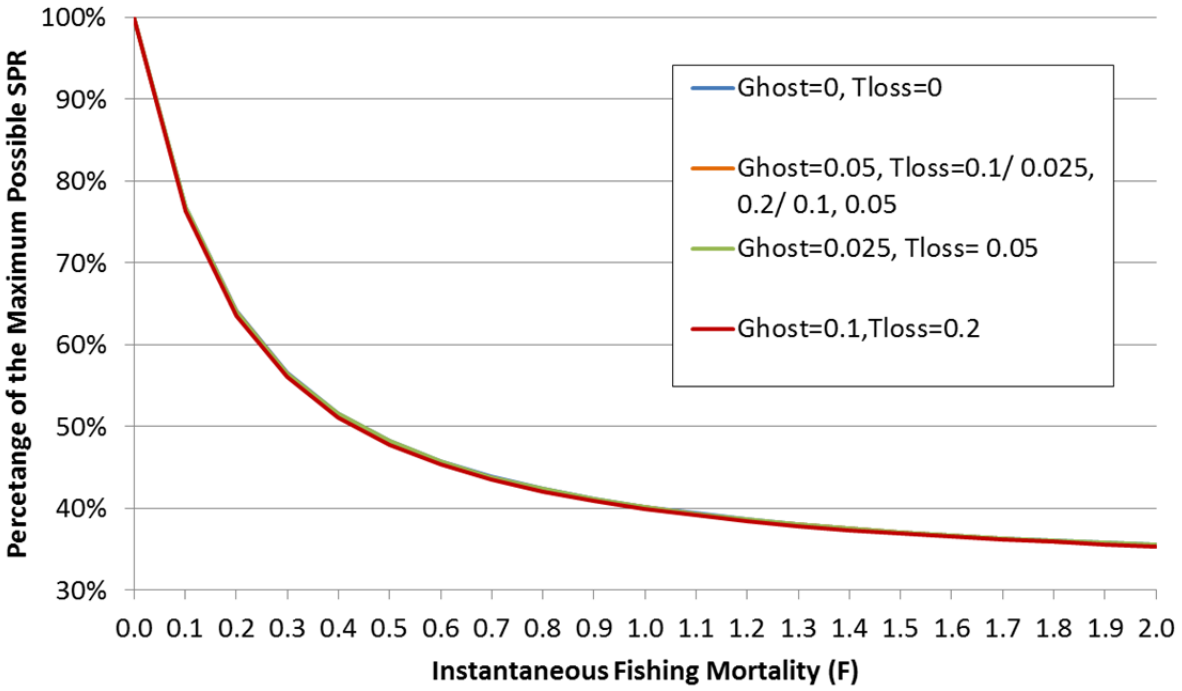
Yield (Percent of Maximum Possible)

Instantaneous Fishing Mortality	Default Ghost=0, Tloss=0	Cable 6.0 Ghost=0.05, Tloss=0.1	Difference (Default - Cable 6.0)	Half Ghost=0.025, Tloss= 0.05	Difference (Default - Half)	Double Ghost=0.1,Tloss=0.2	Difference (Default - Double)
0.0001	0.05	0.05	0.00	0.05	0.00	0.05	0.00
0.10	33.43	33.52	-0.09	33.46	-0.03	33.86	-0.43
0.20	48.62	48.68	-0.05	48.64	-0.02	48.93	-0.31
0.30	56.24	56.24	0.00	56.25	-0.01	56.38	-0.14
0.40	60.48	60.45	0.03	60.48	0.00	60.49	-0.01
0.50	63.10	63.04	0.05	63.09	0.00	63.03	0.07
0.60	64.87	64.80	0.07	64.86	0.01	64.75	0.12
0.70	66.17	66.09	0.08	66.16	0.01	66.00	0.16
0.80	67.16	67.08	0.09	67.15	0.01	66.97	0.19
0.90	67.97	67.87	0.10	67.95	0.01	67.75	0.22
1.00	68.63	68.53	0.10	68.61	0.02	68.39	0.24
1.10	69.19	69.08	0.11	69.17	0.02	68.93	0.26
1.20	69.67	69.56	0.11	69.65	0.02	69.39	0.27
1.30	70.08	69.97	0.12	70.06	0.02	69.79	0.29
1.40	70.45	70.33	0.12	70.43	0.02	70.14	0.31
1.50	70.77	70.64	0.13	70.75	0.02	70.44	0.33
1.60	71.06	70.93	0.13	71.03	0.02	70.71	0.35
1.70	71.31	71.18	0.14	71.29	0.02	70.95	0.37
1.80	71.54	71.40	0.14	71.52	0.02	71.16	0.38
1.90	71.75	71.61	0.15	71.73	0.03	71.35	0.40
2.00	71.94	71.79	0.15	71.92	0.03	71.52	0.42



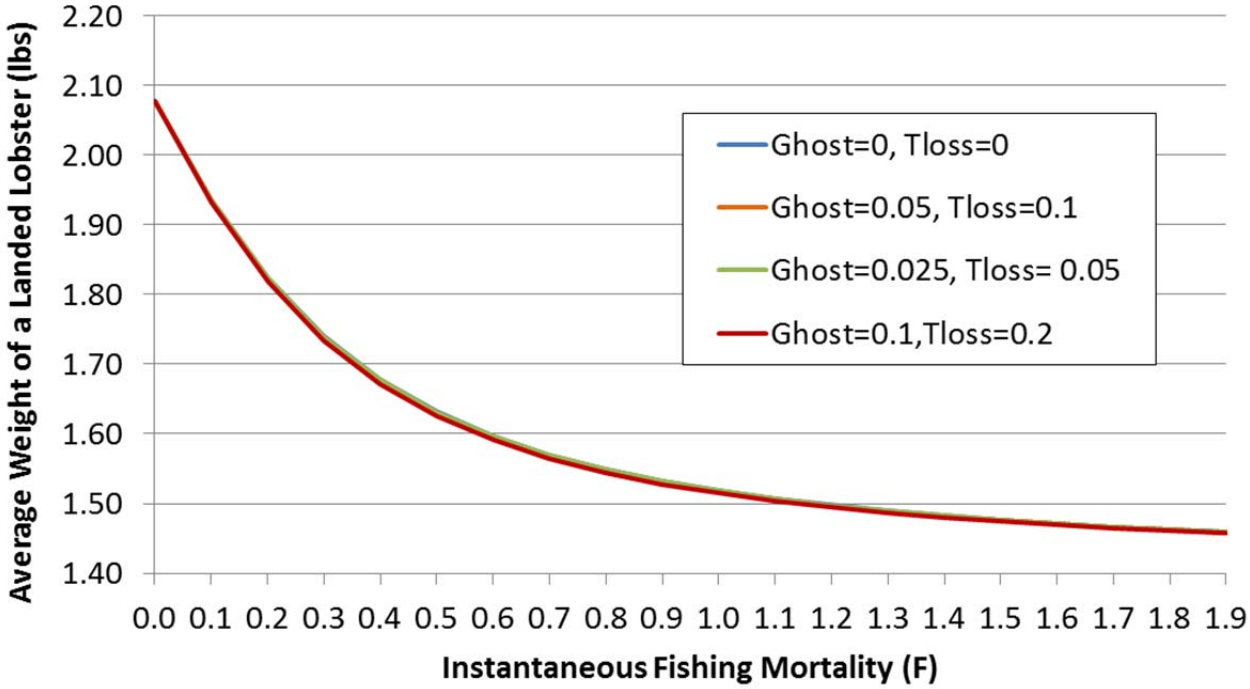
SPR

Instantaneous Fishing Mortality	Default Ghost=0, Tloss=0	Cable 6.0 Ghost=0.05, Tloss=0.1	Difference (Default - Cable 6.0)	Half Ghost=0.025, Tloss= 0.05	Difference (Default - Half)	Double Ghost=0.1,Tloss=0.2	Difference (Default - Double)
0.0001	99.97%	99.97%	0.00%	99.97%	0.00%	99.97%	0.00%
0.10	76.76%	76.63%	0.13%	76.73%	0.03%	76.27%	0.49%
0.20	64.08%	63.94%	0.15%	64.05%	0.04%	63.53%	0.56%
0.30	56.50%	56.36%	0.14%	56.47%	0.03%	55.98%	0.52%
0.40	51.59%	51.47%	0.13%	51.56%	0.03%	51.13%	0.47%
0.50	48.19%	48.08%	0.11%	48.17%	0.03%	47.78%	0.41%
0.60	45.71%	45.61%	0.10%	45.69%	0.02%	45.34%	0.37%
0.70	43.82%	43.73%	0.09%	43.80%	0.02%	43.49%	0.33%
0.80	42.34%	42.25%	0.08%	42.32%	0.02%	42.03%	0.30%
0.90	41.14%	41.06%	0.08%	41.12%	0.02%	40.86%	0.28%
1.00	40.16%	40.08%	0.07%	40.14%	0.02%	39.90%	0.26%
1.10	39.33%	39.27%	0.07%	39.32%	0.02%	39.10%	0.24%
1.20	38.64%	38.57%	0.06%	38.62%	0.01%	38.42%	0.22%
1.30	38.04%	37.98%	0.06%	38.03%	0.01%	37.83%	0.21%
1.40	37.52%	37.47%	0.05%	37.51%	0.01%	37.33%	0.19%
1.50	37.07%	37.02%	0.05%	37.06%	0.01%	36.89%	0.18%
1.60	36.68%	36.63%	0.05%	36.67%	0.01%	36.51%	0.17%
1.70	36.33%	36.28%	0.05%	36.32%	0.01%	36.17%	0.16%
1.80	36.02%	35.97%	0.04%	36.01%	0.01%	35.86%	0.15%
1.90	35.74%	35.70%	0.04%	35.73%	0.01%	35.60%	0.14%
2.00	35.49%	35.45%	0.04%	35.48%	0.01%	35.35%	0.13%



Average Weight (lbs)

Instantaneous Fishing Mortality	Default Ghost=0, Tloss=0	Cable 6.0 Ghost=0.05, Tloss=0.1	Difference (Default - Cable 6.0)	Half Ghost=0.025, Tloss= 0.05	Difference (Default - Half)	Double Ghost=0.1,Tloss=0.2	Difference (Default - Double)
0.0001	2.078	2.078	0.000	2.078	0.000	2.078	0.000
0.10	1.935	1.934	0.001	1.935	0.000	1.931	0.004
0.20	1.823	1.822	0.002	1.823	0.000	1.818	0.006
0.30	1.740	1.738	0.002	1.739	0.000	1.733	0.006
0.40	1.678	1.676	0.002	1.677	0.000	1.671	0.006
0.50	1.631	1.630	0.002	1.631	0.000	1.625	0.006
0.60	1.596	1.595	0.001	1.596	0.000	1.591	0.005
0.70	1.570	1.568	0.001	1.569	0.000	1.565	0.005
0.80	1.549	1.547	0.001	1.548	0.000	1.544	0.004
0.90	1.532	1.531	0.001	1.532	0.000	1.528	0.004
1.00	1.518	1.517	0.001	1.518	0.000	1.515	0.004
1.10	1.507	1.506	0.001	1.507	0.000	1.504	0.003
1.20	1.498	1.497	0.001	1.497	0.000	1.494	0.003
1.30	1.489	1.489	0.001	1.489	0.000	1.487	0.003
1.40	1.483	1.482	0.001	1.482	0.000	1.480	0.003
1.50	1.477	1.476	0.001	1.476	0.000	1.474	0.002
1.60	1.471	1.471	0.001	1.471	0.000	1.469	0.002
1.70	1.467	1.466	0.001	1.467	0.000	1.465	0.002
1.80	1.463	1.462	0.001	1.463	0.000	1.461	0.002
1.90	1.459	1.459	0.001	1.459	0.000	1.457	0.002



MPA Parameter Sensitivity Analysis

Summary

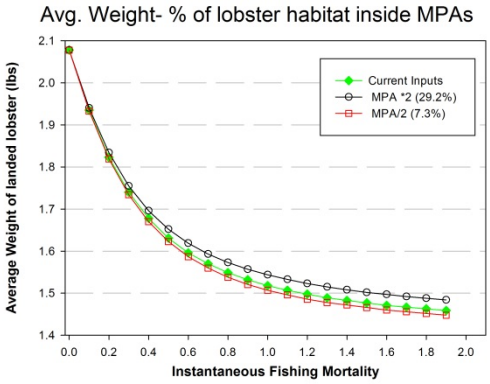
This analysis compares the primary model outputs with varied parameter settings that are relevant to MPAs. Parameters were the percentage of lobster habitat protected by MPAs (MPA), the rate of migration out of MPAs to fished habitat (Migout), the percent of F applied to MPA edge habitat simulating risk to fishing due to nightly foraging movements (Fin), and the average width of MPAs (MPAmi). Each of these parameters was left at current or default values, doubled and reduced by half.

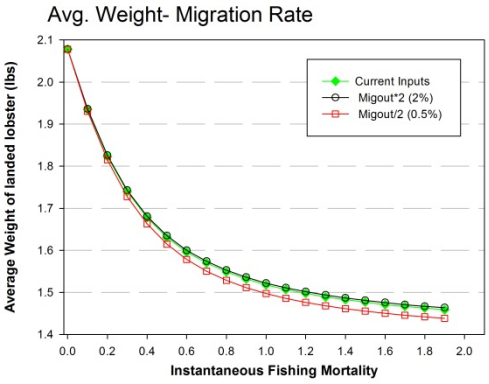
The parameter with the largest effect on yield and SPR was MPA. Higher MPA leads to lower yield and higher SPR, as expected. Higher Migout leads to higher yield but has a negligible effect on SPR. A larger Fin also increases yield and decreases SPR by a small amount. Both of these results are consistent with our expectations. Finally, increasing MPAmi slightly increases yield and decreases SPR. The reason for this is unclear.

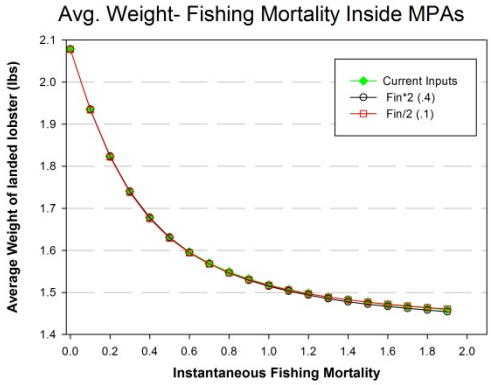
Interestingly, MPA has little impact on the average weight of lobsters in the landings. A larger MPA coverage leads to very slightly larger lobsters in the catch. The direction of this impact matches expectations because MPAs allow for survival of lobsters to a larger size and some of these are landed due to spill-over. Fin has a negligible impact on average weight. However, the results are opposite of our expectations. We expect that a higher rate of fishing in MPAs where lobsters are larger would increase the average weight in landings but we find the opposite. This small difference may be a result of the knife edge selection problem. A similar result with the average width of MPAs may also be a result of knife edge selection. Migout has the largest impact on average weight with less migration out of MPAs resulting in a lower weight in the catch. This meets our expectation.

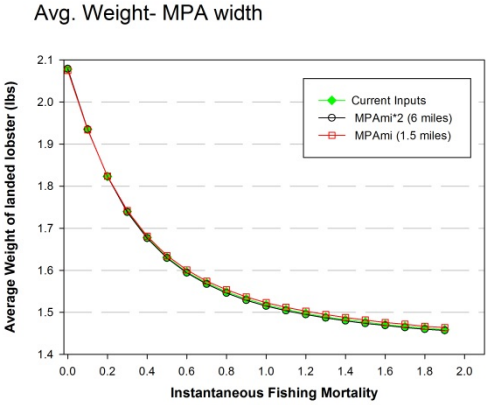
Yield (Percent of Maximum Possible)

		current MPA= 14.6%		current Migout=1%		current Fin=.2		current MPAmi=3	
Instantaneous Fishing Mortality	Current Inputs	MPA *2 (29.2%)	MPA/2 (7.3%)	Migout *2 (2%)	Migout/2 (.5%)	Fin*2 (.4)	Fin/2 (.1)	MPAmi*2 (6 miles)	MPAmi/2 (1.5 miles)
0.0001	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0
0.10	33.4	28.7	35.8	33.5	33.3	34.1	33.1	33.9	32.5
0.20	48.6	42.2	51.8	48.8	48.5	49.6	48.0	49.2	47.4
0.30	56.2	49.3	59.7	56.6	56.0	57.4	55.4	56.8	55.0
0.40	60.5	53.4	64.0	60.9	60.2	61.7	59.5	61.0	59.3
0.50	63.1	56.1	66.6	63.5	62.8	64.3	62.0	63.6	62.0
0.60	64.9	58.0	68.3	65.3	64.5	66.1	63.7	65.3	63.8
0.70	66.2	59.5	69.5	66.6	65.8	67.4	65.0	66.6	65.2
0.80	67.2	60.6	70.4	67.7	66.8	68.3	65.9	67.6	66.2
0.90	68.0	61.5	71.2	68.5	67.6	69.1	66.7	68.3	67.1
1.00	68.6	62.3	71.8	69.2	68.3	69.7	67.4	69.0	67.8
1.10	69.2	63.0	72.3	69.7	68.8	70.2	67.9	69.5	68.4
1.20	69.7	63.6	72.7	70.2	69.3	70.7	68.4	70.0	68.9
1.30	70.1	64.1	73.1	70.6	69.7	71.0	68.8	70.4	69.3
1.40	70.4	64.5	73.4	71.0	70.0	71.4	69.2	70.7	69.7
1.50	70.8	64.9	73.7	71.4	70.3	71.6	69.5	71.0	70.1
1.60	71.1	65.3	74.0	71.7	70.6	71.9	69.9	71.3	70.4
1.70	71.3	65.6	74.2	71.9	70.9	72.1	70.1	71.6	70.7
1.80	71.5	65.9	74.4	72.2	71.1	72.3	70.4	71.8	70.9
1.90	71.8	66.1	74.6	72.4	71.3	72.5	70.6	72.0	71.1
2.00	71.9	66.4	74.7	72.6	71.5	72.7	70.8	72.2	71.3



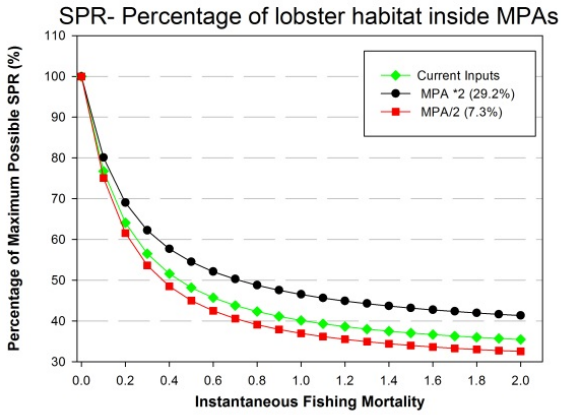


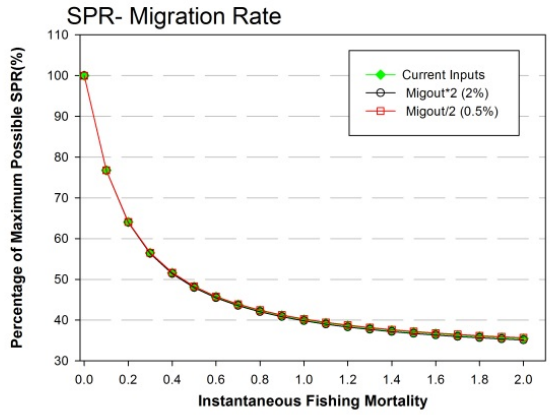


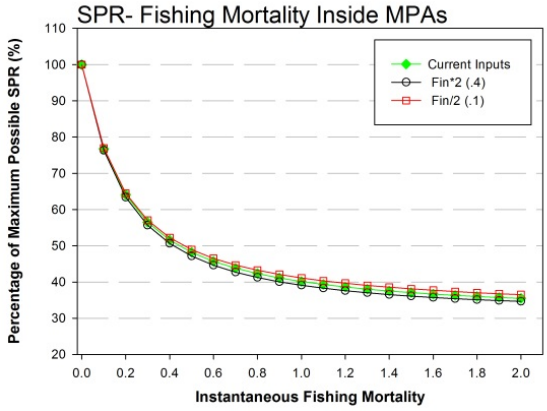


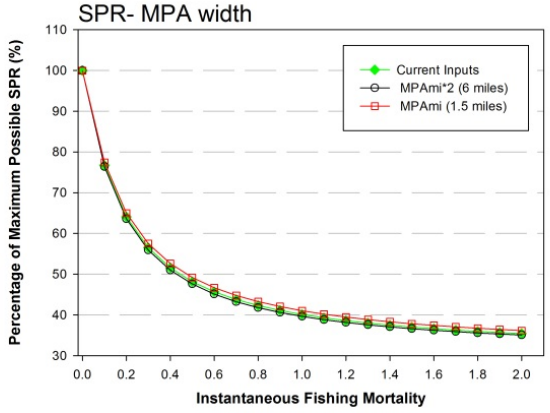
SPR

		current MPA= 14.6%		current Migout=1%		current Fin=.2		current MPAmi=3	
Instantaneous Fishing Mortality	Current Inputs	MPA *2 (29.2%)	MPA/2 (7.3%)	Migout *2 (2%)	Migout/2 (.5%)	Fin*2 (.4)	Fin/2 (.1)	MPAmi*2 (6 miles)	MPAmi/2 (1.5 miles)
0.0001	100%	100%	100%	100%	100%	100%	100%	100%	100%
0.10	76.8%	80.1%	75.1%	76.7%	76.8%	76.3%	77.0%	76.4%	77.4%
0.20	64.1%	69.0%	61.6%	64.0%	64.1%	63.4%	64.5%	63.6%	65.0%
0.30	56.5%	62.2%	53.7%	56.4%	56.6%	55.6%	57.0%	56.0%	57.5%
0.40	51.6%	57.7%	48.5%	51.4%	51.7%	50.6%	52.2%	51.0%	52.7%
0.50	48.2%	54.5%	45.0%	48.0%	48.3%	47.2%	48.9%	47.6%	49.2%
0.60	45.7%	52.1%	42.5%	45.5%	45.8%	44.6%	46.5%	45.2%	46.7%
0.70	43.8%	50.3%	40.6%	43.6%	43.9%	42.7%	44.7%	43.3%	44.8%
0.80	42.3%	48.8%	39.1%	42.1%	42.5%	41.2%	43.3%	41.8%	43.3%
0.90	41.1%	47.5%	37.9%	40.9%	41.3%	40.1%	42.1%	40.6%	42.1%
1.00	40.2%	46.5%	37.0%	39.9%	40.3%	39.1%	41.1%	39.7%	41.1%
1.10	39.3%	45.7%	36.2%	39.0%	39.5%	38.3%	40.3%	38.9%	40.2%
1.20	38.6%	44.9%	35.5%	38.3%	38.8%	37.6%	39.7%	38.2%	39.5%
1.30	38.0%	44.3%	34.9%	37.7%	38.2%	37.0%	39.1%	37.6%	38.9%
1.40	37.5%	43.7%	34.4%	37.2%	37.7%	36.5%	38.6%	37.1%	38.3%
1.50	37.1%	43.2%	34.0%	36.7%	37.2%	36.1%	38.1%	36.7%	37.9%
1.60	36.7%	42.7%	33.6%	36.3%	36.9%	35.7%	37.7%	36.3%	37.5%
1.70	36.3%	42.3%	33.3%	36.0%	36.5%	35.4%	37.4%	35.9%	37.1%
1.80	36.0%	42.0%	33.0%	35.7%	36.2%	35.1%	37.1%	35.6%	36.8%
1.90	35.7%	41.7%	32.8%	35.4%	35.9%	34.9%	36.8%	35.4%	36.5%
2.00	35.5%	41.4%	32.6%	35.1%	35.7%	34.6%	36.5%	35.1%	36.2%



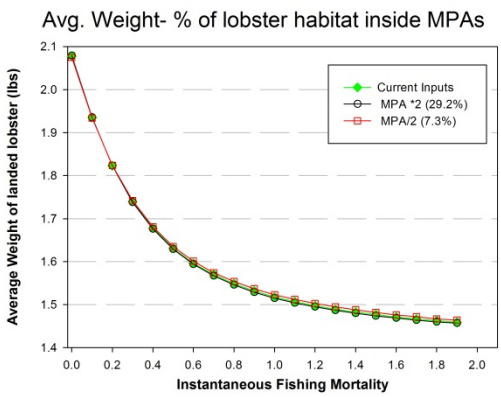


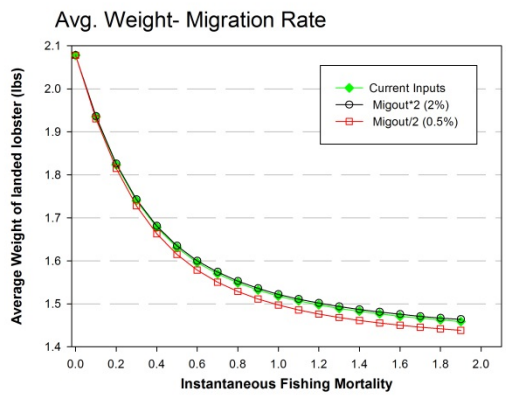


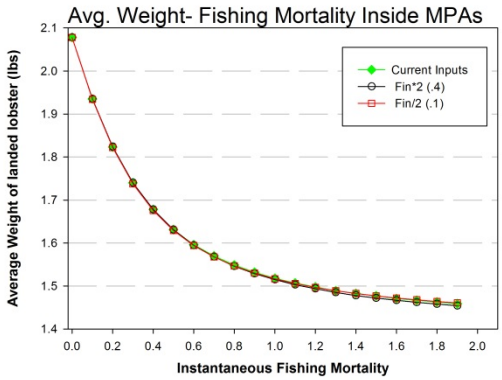


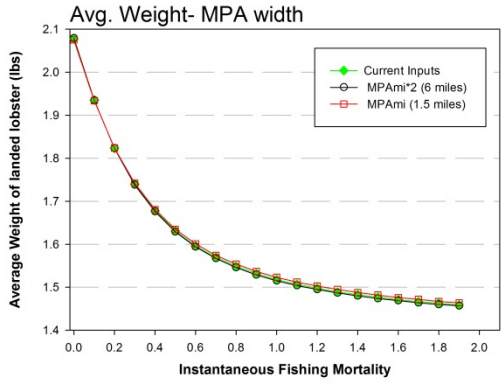
Average Weight (lbs)

		current MPA= 14.6%		current Migout=1%		current Fin=.2		current MPAmi=3	
Instantaneous Fishing Mortality	Current Inputs	MPA *2 (29.2%)	MPA/2 (7.3%)	Migout *2 (2%)	Migout/2 (.5%)	Fin*2 (.4)	Fin/2 (.1)	MPAmi*2 (6 miles)	MPAmi/2 (1.5 miles)
0.0001	2.078	2.078	2.078	2.078	2.078	2.078	2.078	2.079	2.075
0.10	1.935	1.940	1.933	1.936	1.934	1.935	1.934	1.935	1.934
0.20	1.823	1.834	1.819	1.826	1.822	1.824	1.822	1.823	1.824
0.30	1.740	1.755	1.734	1.743	1.738	1.740	1.738	1.738	1.742
0.40	1.678	1.696	1.670	1.681	1.675	1.678	1.675	1.676	1.681
0.50	1.631	1.652	1.623	1.635	1.629	1.631	1.629	1.629	1.635
0.60	1.596	1.619	1.587	1.600	1.594	1.595	1.594	1.594	1.601
0.70	1.570	1.593	1.560	1.574	1.567	1.568	1.567	1.567	1.574
0.80	1.549	1.573	1.538	1.553	1.546	1.546	1.547	1.546	1.554
0.90	1.532	1.557	1.521	1.536	1.529	1.529	1.530	1.529	1.537
1.00	1.518	1.544	1.507	1.522	1.516	1.515	1.517	1.515	1.523
1.10	1.507	1.533	1.496	1.511	1.504	1.503	1.506	1.504	1.512
1.20	1.498	1.523	1.486	1.502	1.495	1.494	1.497	1.495	1.503
1.30	1.489	1.515	1.478	1.494	1.487	1.485	1.489	1.487	1.495
1.40	1.483	1.508	1.472	1.487	1.480	1.478	1.483	1.480	1.488
1.50	1.477	1.502	1.466	1.481	1.474	1.472	1.477	1.474	1.482
1.60	1.471	1.497	1.460	1.476	1.469	1.467	1.472	1.469	1.476
1.70	1.467	1.492	1.456	1.471	1.464	1.462	1.468	1.464	1.472
1.80	1.463	1.488	1.452	1.467	1.460	1.458	1.464	1.460	1.467
1.90	1.459	1.484	1.448	1.464	1.456	1.454	1.461	1.457	1.464









Natural Mortality Sensitivity Analysis

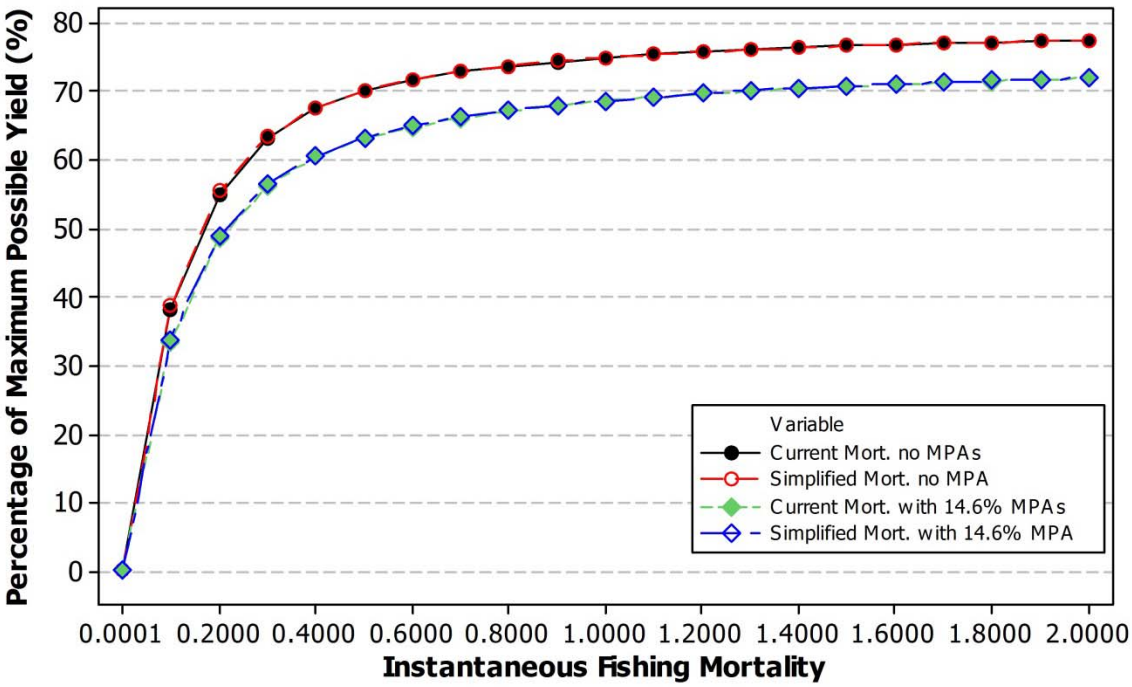
Summary

In the original natural mortality function coded by Dr. Parrish, natural mortality decreases as lobsters grow bigger. However, past the carapace length of 110 mm, natural mortality increases again, simulating senility. This last part of the natural mortality function was removed for the "simplified mortality curve," and lobsters simply suffer less and less natural mortality as they age.

This change in the natural mortality equation has very little impact on model output. Yield is slightly higher and SPR is slightly lower with the simplified natural mortality. This is reasonable because a slight increase in survival of large lobsters would increase yield. Harvest of these large lobsters then removes the production of their eggs and decreases SPR. These differences are slight because very few lobsters reach this age/size where the change in the natural mortality equation applies.

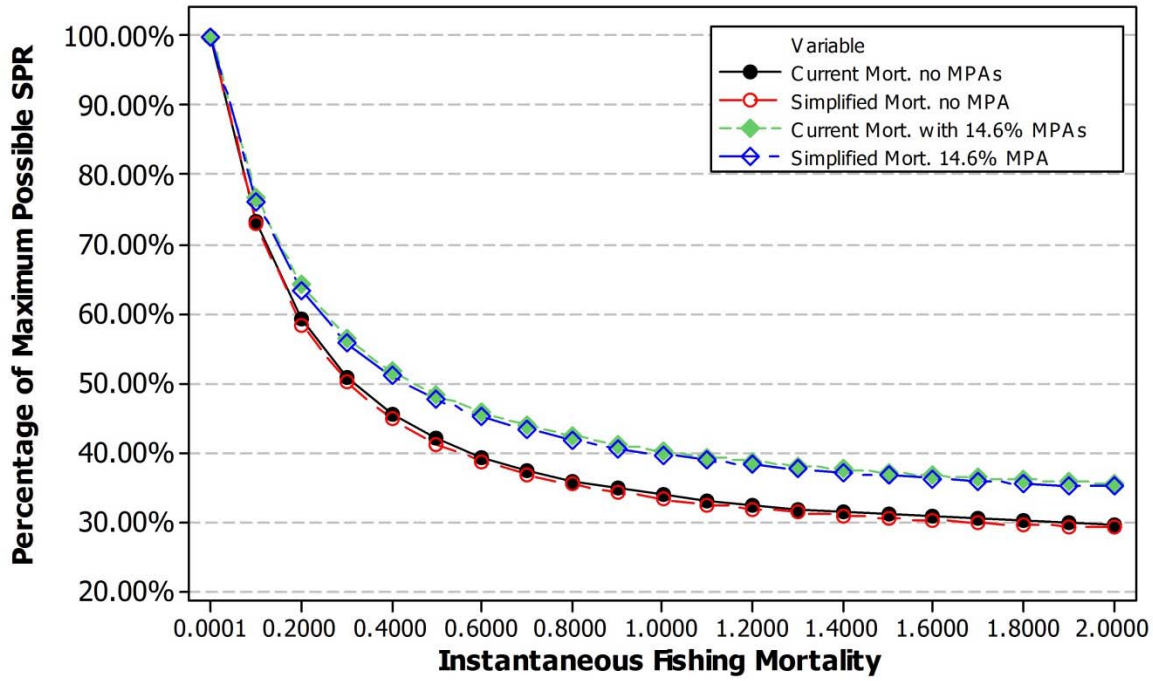
Yield (Percent of Maximum Possible)

Instantaneous Fishing Mortality	Current Mortality Curve no MPAs	Simplified Mortality Curve no MPAs	Difference (Simplifed no MPA-Current no MPA)	Current Mortality Curve with 14.6% MPAs	Simplified Mortality Curve with 14.6% MPAs	Difference (Simplified 14.6% MPA-Current 14.6% MPA)
0.0001	0.1	0.1	0.001	0.0	0.1	0.001
0.10	38.1	38.6	0.492	33.4	33.9	0.441
0.20	55.0	55.4	0.399	48.6	49.0	0.379
0.30	63.2	63.4	0.250	56.2	56.5	0.261
0.40	67.5	67.7	0.143	60.5	60.7	0.174
0.50	70.1	70.1	0.078	63.1	63.2	0.121
0.60	71.7	71.8	0.042	64.9	65.0	0.090
0.70	72.9	72.9	0.022	66.2	66.2	0.073
0.80	73.7	73.7	0.012	67.2	67.2	0.063
0.90	74.4	74.4	0.006	68.0	68.0	0.057
1.00	74.9	74.9	0.003	68.6	68.7	0.053
1.10	75.4	75.4	0.002	69.2	69.2	0.051
1.20	75.8	75.8	0.001	69.7	69.7	0.049
1.30	76.1	76.1	0.000	70.1	70.1	0.047
1.40	76.4	76.4	0.000	70.4	70.5	0.046
1.50	76.6	76.6	0.000	70.8	70.8	0.045
1.60	76.9	76.9	0.000	71.1	71.1	0.044
1.70	77.0	77.0	0.000	71.3	71.4	0.043
1.80	77.2	77.2	0.000	71.5	71.6	0.042
1.90	77.4	77.4	0.000	71.8	71.8	0.041
2.00	77.5	77.5	0.000	71.9	72.0	0.041



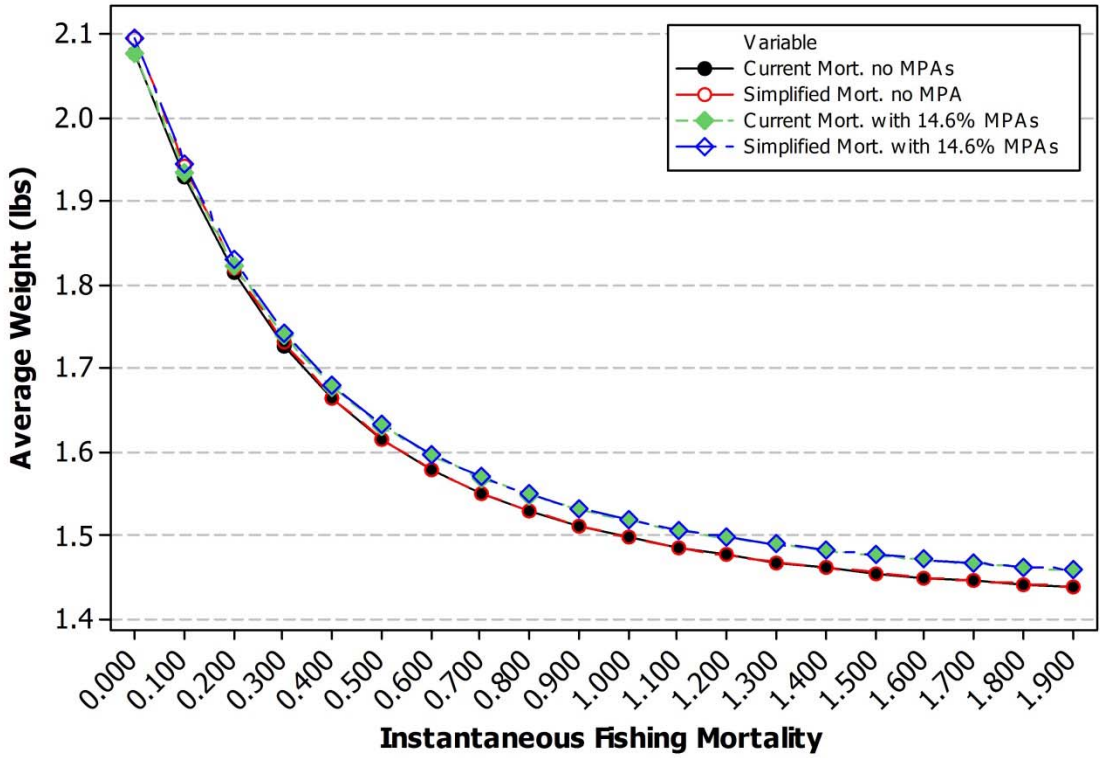
SPR

Instantaneous Fishing Mortality	Current Mortality Curve no MPAs	Simplified Mortality Curve no MPAs	Difference (Simplifed no MPA-Current no MPA)	Current Mortality Curve with 14.6% MPAs	Simplified Mortality Curve with 14.6% MPAs	Difference (Simplified 14.6% MPA-Current 14.6% MPA)
0.0001	100%	100%	0.000	100%	100%	0.000
0.10	73.4%	72.8%	-0.006	76.8%	76.2%	-0.005
0.20	59.2%	58.4%	-0.007	64.1%	63.4%	-0.007
0.30	50.8%	50.1%	-0.007	56.5%	55.8%	-0.007
0.40	45.5%	44.8%	-0.007	51.6%	50.9%	-0.007
0.50	41.9%	41.2%	-0.007	48.2%	47.6%	-0.006
0.60	39.3%	38.7%	-0.006	45.7%	45.1%	-0.006
0.70	37.4%	36.8%	-0.006	43.8%	43.2%	-0.006
0.80	35.9%	35.3%	-0.006	42.3%	41.8%	-0.006
0.90	34.7%	34.2%	-0.006	41.1%	40.6%	-0.005
1.00	33.8%	33.2%	-0.006	40.2%	39.6%	-0.005
1.10	33.0%	32.5%	-0.005	39.3%	38.8%	-0.005
1.20	32.4%	31.8%	-0.005	38.6%	38.1%	-0.005
1.30	31.8%	31.3%	-0.005	38.0%	37.5%	-0.005
1.40	31.4%	30.8%	-0.005	37.5%	37.0%	-0.005
1.50	31.0%	30.5%	-0.005	37.1%	36.6%	-0.005
1.60	30.6%	30.1%	-0.005	36.7%	36.2%	-0.005
1.70	30.3%	29.8%	-0.005	36.3%	35.8%	-0.005
1.80	30.1%	29.6%	-0.005	36.0%	35.5%	-0.005
1.90	29.8%	29.3%	-0.005	35.7%	35.3%	-0.005
2.00	29.6%	29.1%	-0.005	35.5%	35.0%	-0.005



Average Weight (lbs)

Instantaneous Fishing Mortality	Current Mortality Curve no MPAs	Simplified Mortality Curve no MPAs	Difference (Simplifed no MPA-Current no MPA)	Current Mortality Curve with 14.6% MPAs	Simplified Mortality Curve with 14.6% MPAs	Difference (Simplified 14.6% MPA-Current 14.6% MPA)
0.000	2.078	2.095	0.017	2.078	2.095	0.017
0.100	1.931	1.941	0.011	1.935	1.946	0.011
0.200	1.815	1.822	0.006	1.823	1.830	0.007
0.300	1.728	1.732	0.003	1.740	1.744	0.004
0.400	1.663	1.665	0.002	1.678	1.680	0.003
0.500	1.615	1.616	0.001	1.631	1.633	0.002
0.600	1.579	1.579	0.001	1.596	1.598	0.001
0.700	1.551	1.551	0.000	1.570	1.571	0.001
0.800	1.529	1.529	0.000	1.549	1.549	0.001
0.900	1.512	1.512	0.000	1.532	1.533	0.001
1.000	1.498	1.498	0.000	1.518	1.519	0.001
1.100	1.486	1.486	0.000	1.507	1.508	0.001
1.200	1.477	1.477	0.000	1.498	1.498	0.001
1.300	1.468	1.468	0.000	1.489	1.490	0.001
1.400	1.462	1.462	0.000	1.483	1.483	0.001
1.500	1.456	1.456	0.000	1.477	1.477	0.001
1.600	1.450	1.450	0.000	1.471	1.472	0.001
1.700	1.446	1.446	0.000	1.467	1.467	0.001
1.800	1.442	1.442	0.000	1.463	1.463	0.001
1.900	1.439	1.439	0.000	1.459	1.460	0.001



Constant Natural Mortality Sensitivity Analysis

Summary

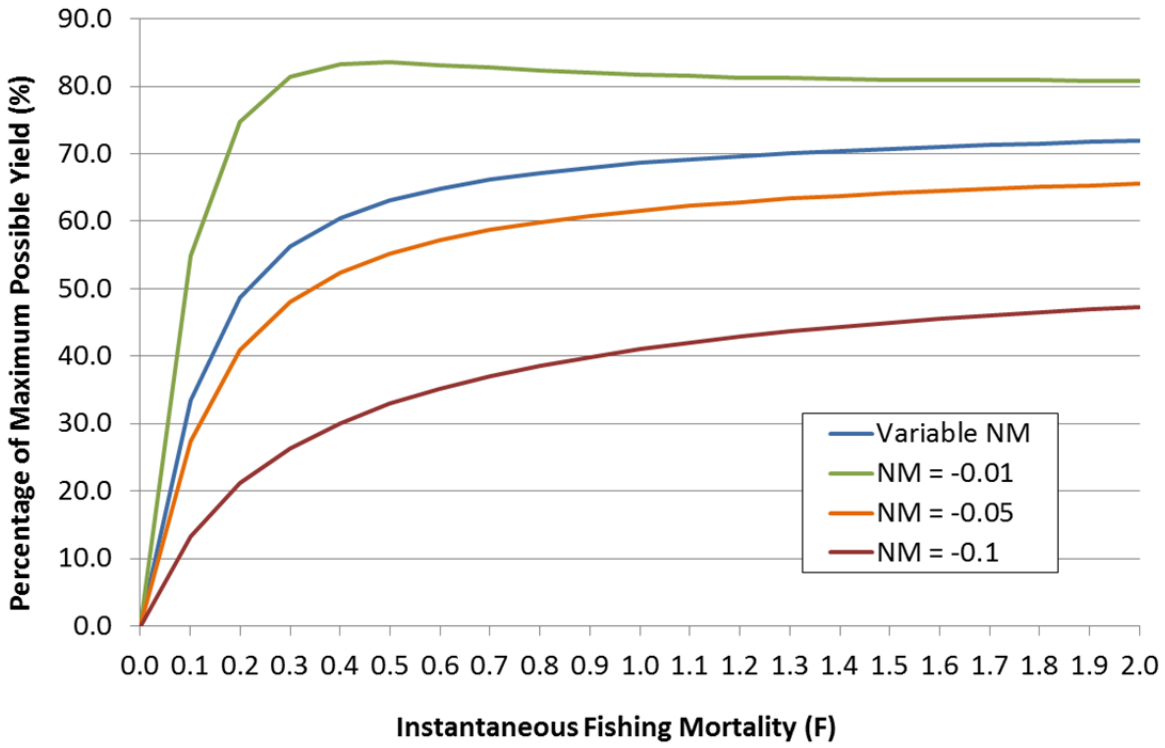
In the original function coded by Dr. Parrish, natural mortality decreases as lobsters grow over most of their life span but increases again slightly at large sizes, simulating senility. This analysis compares model outputs using this current or default natural mortality curve and three values of constant natural mortality over all lobster sizes.

Yield is lower when natural mortality is higher as expected. Average weight is also lower when natural mortality is higher. This is reasonable because few lobsters reach larger/heavier sizes before succumbing to natural mortality. However, SPR is higher when natural mortality is higher. This result was unexpected. We then examined egg production and it decreases with increasing natural mortality as expected. Examining the model calculations for the number and catch of lobsters under different mortality scenarios helps to clarify the SPR result. With high natural mortality, proportionally more of the total egg production happens when lobsters are young because few of them live to be old. Therefore fishing has relatively little effect on this type of population because the majority of reproduction occurs before lobsters reach the fishery. SPR is high in this scenario and the total egg production in both the fished and unfished numerator and denominator values are very low (see Model Calculations section below). This might lead managers to conclude the stock is healthy because the fishery is having little impact, when in fact the stock is very unproductive because it is suffering from high natural mortality.

However, as long as natural mortality is calculated consistently between the threshold and current scenarios used in the FMP, and not to a fixed numerical value, the impact of natural mortality on SPR may not present a management problem (see SPR or Different Scenarios.xls).

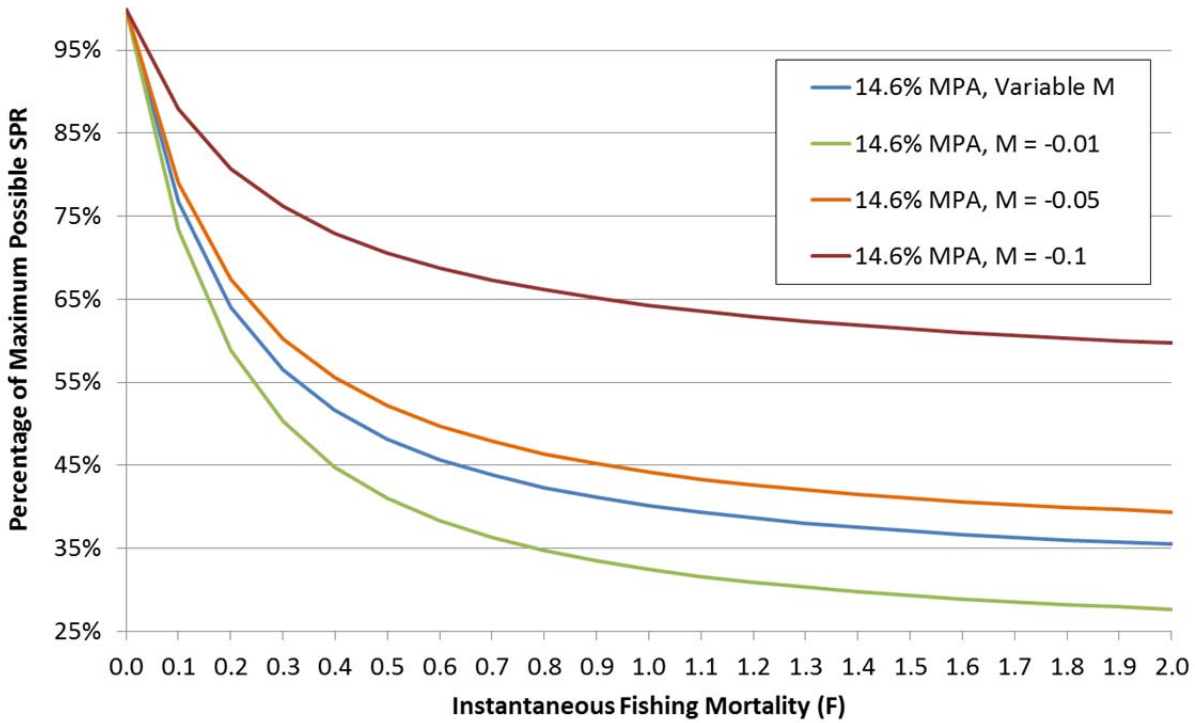
Yield (Percent of Maximum Possible)

Instantaneous Fishing Mortality	Current Variable NM	Constant NM = -0.01	Difference (Variable - NM=-0.01)	Constant NM = -0.05	Difference (Variable - NM=-0.05)	Constant NM = -0.1	Difference (Variable - NM=-0.1)
0.0001	0.0	0.1	0.0	0.0	0.0	0.0	0.0
0.10	33.4	54.9	-21.5	27.5	6.0	13.3	20.2
0.20	48.6	74.7	-26.1	40.8	7.8	21.2	27.5
0.30	56.2	81.4	-25.2	48.1	8.2	26.4	29.9
0.40	60.5	83.3	-22.8	52.4	8.1	30.1	30.4
0.50	63.1	83.5	-20.4	55.2	7.9	32.9	30.2
0.60	64.9	83.2	-18.3	57.2	7.7	35.2	29.7
0.70	66.2	82.7	-16.6	58.7	7.5	37.0	29.1
0.80	67.2	82.3	-15.2	59.9	7.3	38.6	28.6
0.90	68.0	82.0	-14.0	60.8	7.1	39.9	28.1
1.00	68.6	81.7	-13.1	61.6	7.0	41.0	27.6
1.10	69.2	81.5	-12.3	62.3	6.9	42.0	27.2
1.20	69.7	81.3	-11.6	62.8	6.8	42.9	26.8
1.30	70.1	81.2	-11.1	63.3	6.8	43.6	26.5
1.40	70.4	81.1	-10.6	63.8	6.7	44.3	26.1
1.50	70.8	81.0	-10.2	64.1	6.6	44.9	25.8
1.60	71.1	80.9	-9.9	64.5	6.6	45.5	25.5
1.70	71.3	80.9	-9.6	64.8	6.5	46.0	25.3
1.80	71.5	80.9	-9.3	65.1	6.5	46.5	25.0
1.90	71.8	80.8	-9.1	65.3	6.4	46.9	24.8
2.00	71.9	80.8	-8.9	65.5	6.4	47.3	24.6



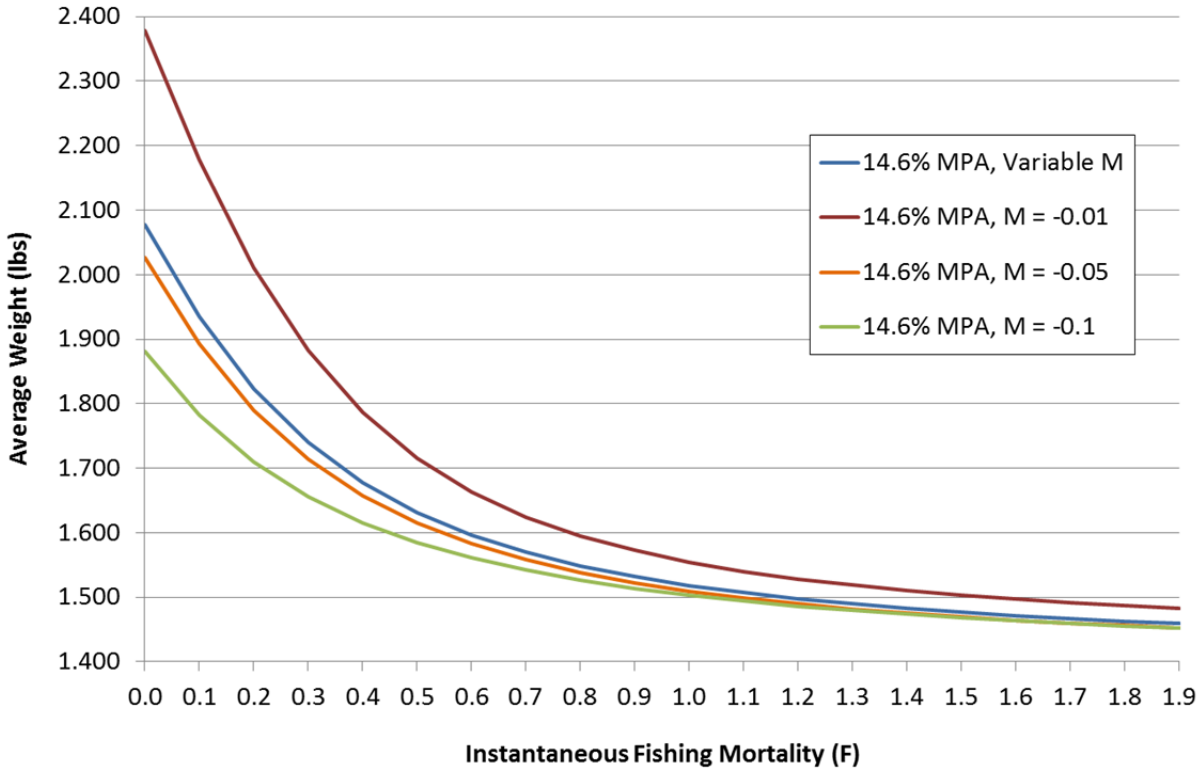
SPR

Instantaneous Fishing Mortality	Current Variable NM	Constant NM = -0.01	Difference (Variable - NM=-0.01)	Constant NM = -0.05	Difference (Variable - NM=-0.05)	Constant NM = -0.1	Difference (Variable - NM=-0.1)
0.0001	100%	100%	0%	100%	0%	100%	0%
0.10	76.8%	73.4%	3%	79.1%	-2%	87.9%	-11%
0.20	64.1%	58.9%	5%	67.4%	-3%	80.7%	-17%
0.30	56.5%	50.3%	6%	60.2%	-4%	76.1%	-20%
0.40	51.6%	44.8%	7%	55.5%	-4%	73.0%	-21%
0.50	48.2%	41.0%	7%	52.2%	-4%	70.6%	-22%
0.60	45.7%	38.3%	7%	49.8%	-4%	68.8%	-23%
0.70	43.8%	36.3%	8%	47.9%	-4%	67.3%	-24%
0.80	42.3%	34.7%	8%	46.4%	-4%	66.1%	-24%
0.90	41.1%	33.5%	8%	45.2%	-4%	65.1%	-24%
1.00	40.2%	32.5%	8%	44.2%	-4%	64.3%	-24%
1.10	39.3%	31.6%	8%	43.4%	-4%	63.6%	-24%
1.20	38.6%	30.9%	8%	42.6%	-4%	62.9%	-24%
1.30	38.0%	30.3%	8%	42.0%	-4%	62.3%	-24%
1.40	37.5%	29.8%	8%	41.5%	-4%	61.8%	-24%
1.50	37.1%	29.3%	8%	41.0%	-4%	61.4%	-24%
1.60	36.7%	28.9%	8%	40.6%	-4%	61.0%	-24%
1.70	36.3%	28.6%	8%	40.3%	-4%	60.6%	-24%
1.80	36.0%	28.2%	8%	39.9%	-4%	60.3%	-24%
1.90	35.7%	27.9%	8%	39.7%	-4%	60.0%	-24%
2.00	35.5%	27.7%	8%	39.4%	-4%	59.7%	-24%

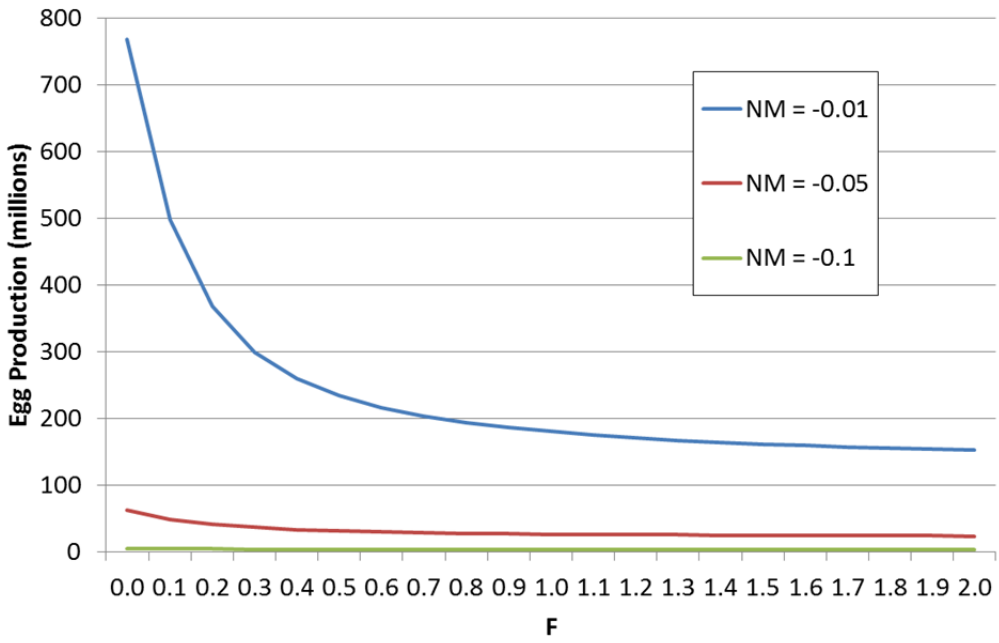


Average Weight (lbs)

Instantaneous Fishing Mortality	Current Variable NM	Constant NM = -0.01	Difference (Variable - NM=-0.01)	Constant NM = -0.05	Difference (Variable - NM=-0.05)	Constant NM = -0.1	Difference (Variable - NM=-0.1)
0.10	1.935	2.177	-0.242	1.892	0.043	1.782	0.153
0.20	1.823	2.011	-0.188	1.790	0.033	1.709	0.114
0.30	1.740	1.883	-0.143	1.714	0.026	1.655	0.084
0.40	1.678	1.786	-0.109	1.657	0.021	1.615	0.062
0.50	1.631	1.715	-0.084	1.615	0.017	1.585	0.046
0.60	1.596	1.663	-0.067	1.583	0.014	1.561	0.035
0.70	1.570	1.624	-0.055	1.558	0.012	1.542	0.028
0.80	1.549	1.595	-0.046	1.538	0.011	1.527	0.022
0.90	1.532	1.572	-0.040	1.522	0.010	1.514	0.018
1.00	1.518	1.554	-0.036	1.509	0.009	1.503	0.015
1.10	1.507	1.540	-0.033	1.499	0.008	1.494	0.013
1.20	1.498	1.528	-0.031	1.490	0.008	1.486	0.011
1.30	1.489	1.519	-0.029	1.482	0.008	1.479	0.010
1.40	1.483	1.510	-0.028	1.475	0.007	1.473	0.009
1.50	1.477	1.503	-0.027	1.469	0.007	1.468	0.009
1.60	1.471	1.497	-0.026	1.464	0.007	1.463	0.008
1.70	1.467	1.492	-0.025	1.460	0.007	1.459	0.008
1.80	1.463	1.487	-0.024	1.456	0.007	1.455	0.007
1.90	1.459	1.483	-0.024	1.452	0.007	1.452	0.007



Egg Production



Model Calculations of the Number and Catch of Males

F = 0.7, MPA = 14.6%

				SPR=28.8/62=46% Constant M=-0.05		SPR=3.4/5=72% Constant M=-0.1	
		Default M					
length	var M	Nopen	Catopen	Nopen	Catopen	Nopen	Catopen
17.2	-0.3770	427.0	0.00	427.0	0.00	427.0	0.00
25.5	-0.1600	292.9	0.00	406.2	0.00	386.4	0.00
33.9	-0.0968	249.6	0.00	386.4	0.00	349.6	0.00
39.5	-0.0780	226.5	0.00	367.5	0.00	316.3	0.00
43.1	-0.0703	209.5	0.00	349.6	0.00	286.2	0.00
45.6	-0.0661	195.3	0.00	332.5	0.00	259.0	0.00
47.6	-0.0634	182.8	0.00	316.3	0.00	234.3	0.00
49.2	-0.0614	171.6	0.01	300.9	0.03	212.0	0.02
50.6	-0.0598	161.4	0.01	286.2	0.02	191.9	0.01
51.9	-0.0586	152.0	0.00	272.3	0.00	173.6	0.00
53.1	-0.0575	143.4	0.00	259.0	0.00	157.1	0.00
54.2	-0.0566	135.4	0.05	246.4	0.10	142.1	0.05
55.2	-0.0558	127.9	0.04	234.3	0.07	128.6	0.04
56.2	-0.0551	121.0	0.00	222.9	0.00	116.4	0.00
57.2	-0.0544	114.5	0.00	212.0	0.00	105.3	0.00
58.1	-0.0538	108.4	0.14	201.7	0.25	95.3	0.12
59.0	-0.0533	102.7	0.10	191.9	0.18	86.2	0.08
59.9	-0.0528	97.4	0.00	182.5	0.00	78.0	0.00
60.7	-0.0523	92.4	0.00	173.6	0.00	70.6	0.00
61.6	-0.0519	87.7	0.32	165.1	0.60	63.9	0.23
62.4	-0.0514	83.3	0.22	157.1	0.41	57.8	0.15
63.3	-0.0510	79.1	0.00	149.4	0.00	52.3	0.00
64.1	-0.0507	75.2	0.00	142.1	0.00	47.3	0.00
64.9	-0.0503	71.4	0.70	135.2	1.33	42.8	0.41
65.7	-0.0500	67.9	0.48	128.6	0.91	38.7	0.27
66.5	-0.0497	64.6	0.00	122.3	0.00	35.1	0.00
67.4	-0.0494	61.5	0.00	116.4	0.00	31.7	0.00
68.2	-0.0491	58.5	1.50	110.7	2.84	28.7	0.72
69.0	-0.0488	55.7	1.01	105.3	1.91	26.0	0.46
69.8	-0.0485	53.1	0.00	100.2	0.00	23.5	0.00
70.6	-0.0483	50.6	0.00	95.3	0.00	21.3	0.00
71.4	-0.0480	48.2	3.01	90.6	5.65	19.2	1.17
72.2	-0.0478	45.9	1.98	86.2	3.72	17.4	0.73
73.0	-0.0476	43.8	0.00	82.0	0.00	15.7	0.00
73.8	-0.0474	41.7	0.00	78.0	0.00	14.3	0.00
74.6	-0.0472	39.8	5.36	74.2	9.97	12.9	1.69
75.4	-0.0470	38.0	3.38	70.6	6.28	11.7	1.01
76.2	-0.0468	36.2	0.00	67.1	0.00	10.6	0.00
77.1	-0.0466	34.6	0.00	63.9	0.00	9.6	0.00
77.9	-0.0464	33.0	7.83	60.8	14.39	8.6	1.99
78.7	-0.0462	31.5	4.67	57.8	8.55	7.8	1.13
79.5	-0.0461	30.1	0.00	55.0	0.00	7.1	0.00
80.3	-0.0459	28.7	0.00	52.3	0.00	6.4	0.00
81.1	-0.0458	27.4	9.12	49.7	16.49	5.8	1.87
81.9	-0.0456	26.2	5.17	47.3	9.31	5.2	1.01
82.7	-0.0455	25.0	0.00	45.0	0.00	4.7	0.00
83.7	-0.0453	23.9	0.00	42.8	0.00	4.3	0.00
84.7	-0.0451	22.9	7.46	40.7	13.25	3.9	1.24
85.7	-0.0450	14.6	2.98	25.8	5.26	2.3	0.47
86.8	-0.0448	11.0	0.00	19.5	0.00	1.7	0.00
87.9	-0.0447	10.6	0.00	18.5	0.00	1.5	0.00
89.1	-0.0445	10.1	3.50	17.6	6.09	1.4	0.46
90.3	-0.0443	6.3	1.34	10.9	2.32	0.8	0.17
91.5	-0.0442	4.7	0.00	8.1	0.00	0.6	0.00
92.8	-0.0440	4.5	0.00	7.7	0.00	0.5	0.00
94.1	-0.0439	4.3	1.52	7.3	2.58	0.5	0.16
95.5	-0.0437	2.6	0.57	4.5	0.97	0.3	0.06
96.9	-0.0436	2.0	0.00	3.3	0.00	0.2	0.00
98.4	-0.0435	1.9	0.00	3.2	0.00	0.2	0.00

SPR Values and Thresholds in Different Model Scenarios

	Threshold	Current
Default Model Setup	41%	42%
Ghost =0.025, Tloss=0.05	41%	42%
Ghost=0.1,Tloss=0.2	40%	41%
Static M=-0.1	75%	73%
Static M=-0.01	20%	23%
MPA*2**	41%	45%
MPA/2**	41%	39%
Migout*2	40%	40%
Migout/2	40%	41%
MPAmi*2	39%	36%
MPAmi/2	41%	42%

**Assumes reference period MPA coverage was still 4.5%