1.0 ENVIRONMENTAL IMPACTS OF ALTERNATIVES

The impacts of the alternatives under consideration are evaluated herein relative to the valued ecosystem components (VECs) described in the Affected Environment (Section 5.0) and to each other. This action evaluates the potential impacts using the criteria in Table 1.

Table 1. General definitions for impacts and qualifiers relative to resource condition (i.e., baseline).

<table>
<tr><th rowspan="2">VEC</th><th rowspan="2">Resource Condition</th><th colspan="3">Impact of Action</th></tr>
<tr><th>Positive (+)</th><th>Negative (-)</th><th>No Impact (0)</th></tr>
<tr><td>Target and Non-target Species</td><td>Overfished status defined by the MSA</td><td>Alternatives that would maintain or are projected to result in a stock status above an overfished condition*</td><td>Alternatives that would maintain or are projected to result in a stock status below an overfished condition*</td><td>Alternatives that do not impact stock / populations</td></tr>
<tr><td>ESA-listed Protected Species (endangered or threatened)</td><td>Populations at risk of extinction (endangered) or endangerment (threatened)</td><td>Alternatives that contain specific measures to ensure no interactions with protected species (e.g., no take)</td><td>Alternatives that result in interactions/take of listed resources, including actions that reduce interactions</td><td>Alternatives that do not impact ESA listed species</td></tr>
<tr><td>MMPA Protected Species (not also ESA listed)</td><td>Stock health may vary but populations remain impacted</td><td>Alternatives that will maintain takes below PBR and approaching the Zero Mortality Rate Goal</td><td>Alternatives that result in interactions with/take of marine mammal species that could result in takes above PBR</td><td>Alternatives that do not impact MMPA Protected Species</td></tr>
<tr><td>Physical Environment / Habitat / EFH</td><td>Many habitats degraded from historical effort (see condition of the resources table for details)</td><td>Alternatives that improve the quality or quantity of habitat</td><td>Alternatives that degrade the quality, quantity or increase disturbance of habitat</td><td>Alternatives that do not impact habitat quality</td></tr>
<tr><td>Human Communities (Socioeconomic)</td><td>Highly variable but generally stable in recent years (see condition of the resources table for details)</td><td>Alternatives that increase revenue and social well-being of fishermen and/or communities</td><td>Alternatives that decrease revenue and social well-being of fishermen and/or communities</td><td>Alternatives that do not impact revenue and social well-being of fishermen and/or communities</td></tr>
<tr><th colspan="5">Impact Qualifiers</th></tr>
<tr><td rowspan="6">A range of impact qualifiers is used to indicate any existing uncertainty</td><td colspan="2">Negligible</td><td colspan="2">To such a small degree to be indistinguishable from no impact</td></tr>
<tr><td colspan="2">Slight (sl) as in slight positive or slight negative</td><td colspan="2">To a lesser degree / minor</td></tr>
<tr><td colspan="2">Moderately (M) positive or negative</td><td colspan="2">To an average degree (i.e., more than “slight”, but not “high”)</td></tr>
<tr><td colspan="2">High (H), as in high positive or high negative</td><td colspan="2">To a substantial degree (not significant unless stated)</td></tr>
<tr><td colspan="2">Significant (in the case of an EIS)</td><td colspan="2">Affecting the resource condition to a great degree, see 40 CFR 1508.27.</td></tr>
<tr><td colspan="2">Likely</td><td colspan="2">Some degree of uncertainty associated with the impact</td></tr>
<tr><td colspan="5">*Actions that will substantially increase or decrease stock size, but do not change a stock status may have different impacts depending on the particular action and stock. Meaningful differences between alternatives may be illustrated by using another resource attribute aside from the MSA status, but this must be justified within the impact analysis.</td></tr>
</table>

1.1 Impacts on Target Species (Atlantic herring)

1.1.1 Methods

The potential impacts of the rebuilding plan alternatives under consideration on the Atlantic herring resource are primarily assessed using biological projections prepared by the Herring Plan Development Team. The methods used in the last herring assessment were applied here as well using the base Age Structured Assessment Model (ASAP model; NEFSC 2020).

However, the projections of spawning stock biomass using the assumption that recruitment is "average" [1] may be overly optimistic in the near-term because recent estimates have been well below average (figure ??? in AE). Therefore, additional sensitivity projections were completed to evaluate the risks associated with recruitment assumptions.

The second set of projections assume herring recruitment is "autocorrelated". When using autocorrelated recruitment (AR, sometimes referred to as autoregressive), annual recruitment values depend on recruitment from the previous year and some random noise or variation in recruitment. The degree of autocorrelation was estimated via linear regression between sequential recruitments, and the regression was found to be significant. The detailed methods and formulas used for these AR projections are included in Appendix ???.

The short-term consequence of AR recruitment is that the projected recruitments in the near term will be more like the current state. For example, recruitment is currently low and so the projected recruitments will remain relatively low until the random noise aspect of the process produces improved recruitment. In the long-term, the AR process still reverts to a similar average level of recruitment as the "average recruitment" assumption, but it does so more slowly (Figure 1). In this case, the AR recruitment levels are lower than the average recruitment series because the AR process produces higher highs and lower lows; therefore, the average will be different than just random recruitments. An AR process will not always have a lower average than the random, "average" approach, it just happens to in this case. Furthermore, the AR process is modeled on the log scale and so back transforming the actual recruitments produces a distribution that is non-normal and skewed, which causes differences between the AR and "average" approach (recruitments under the "average" approach would be normally distributed). The main difference between these assumptions is in the first few years, as illustrated in Figure 1.

The 5% and 95% confidence intervals for median recruitment estimated are presented in Table 2. Projection results for recruitment are reported as medians, not averages. Note the confidence intervals around the median for the AR projections are wider than the average recruitment projections because the AR process allows for greater variability than average recruitment. The degree of correlation in the AR process and the amount of random noise were defined using the full time series of estimated herring recruitments. It was discussed that this approach is likely superior to defining an ad-hoc "below average" recruitment series, or truncated number of years to define recruitment (i.e. most recent 5 or 10 years).

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[1] The 2020 management track assessment calculated recruitment the same way it was handled in projections prepared in the 2018 benchmark assessment. Recruitment in each year of the projections was drawn from the empirical cumulative distribution of the estimated recruitments from 1965-2017. The estimates of recruitment from 2018-2019 were excluded because they were imprecisely estimated with CVs equal to 58% and 210%, respectively. In drawing recruitments from the empirical distribution, a uniform random value is drawn between 0-1 each year, and the recruitment associated with that probability from the cumulative distribution is applied. Thus, any recruitment between the minimum and maximum in the estimated time series has an equal probability of selection each year.

Figure 1 - Median Atlantic herring recruitment values (numbers of fish) for the "average" (in bold) versus autocorrelated (AR) recruitment (dashed line) used in projections (2020-2032).

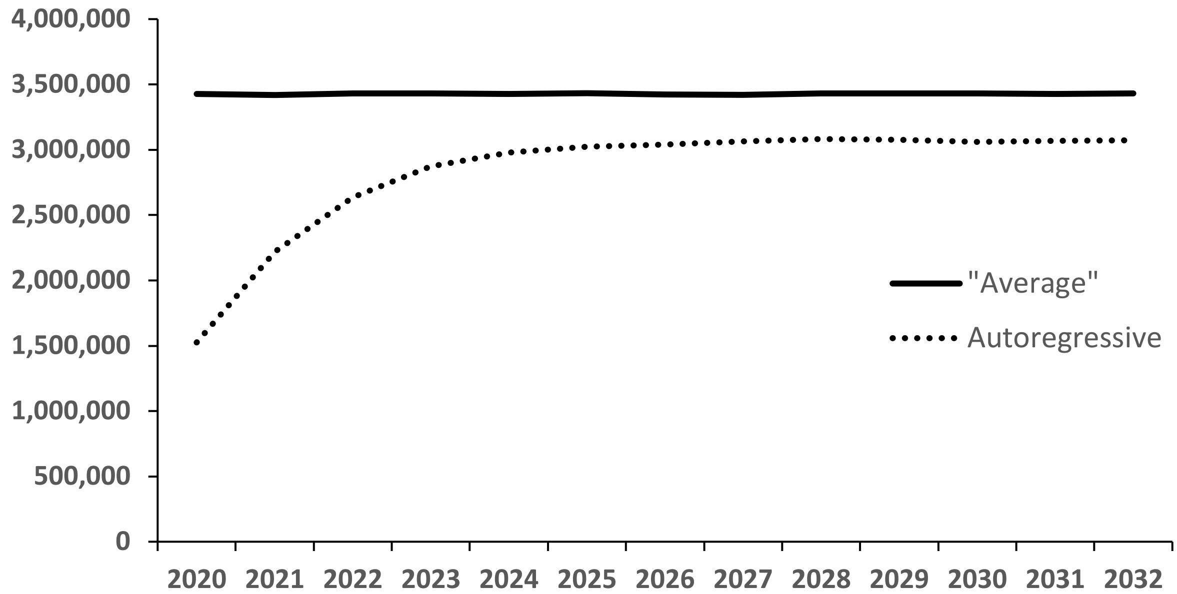


Table 2 – Confidence intervals for the "average" and "autocorrelated" recruitment estimates.

	"Average"			Autocorrelated		
	5% CI	**Median**	**95% CI**	**5% CI**	**Median**	**95% CI**
2020	913,731	3,426,684	10,155,950	409,357	1,525,166	5,706,166
2021	922,668	3,420,659	10,085,660	525,945	2,221,235	9,467,169
2022	924,183	3,430,797	10,144,480	610,415	2,636,857	11,630,340
2023	909,784	3,429,611	10,121,820	647,364	2,871,534	12,642,840
2024	920,629	3,426,485	10,131,220	675,641	2,978,760	13,140,140
2025	911,010	3,432,964	10,129,350	684,505	3,024,599	13,370,900
2026	912,660	3,423,533	10,132,990	687,635	3,039,450	13,476,070
2027	919,130	3,420,290	10,136,130	691,318	3,066,175	13,480,390
2028	915,434	3,432,648	10,134,300	691,176	3,082,158	13,615,480
2029	914,410	3,432,566	10,126,580	696,582	3,074,937	13,566,900
2030	917,414	3,432,263	10,115,880	699,493	3,059,563	13,632,900
2031	909,597	3,425,736	10,131,430	694,163	3,069,602	13,498,890
2032	928,317	3,432,679	10,131,170	688,754	3,070,659	13,567,230

An additional way to evaluate risk would be to develop additional projections that assume the original ABCs projected under one assumption of recruitment are caught, but later the other assumption of recruitment is realized. For example, if ABCs are calculated assuming average recruitment, but recruitment ends up being more like AR recruitment (lower than average in the near term), than harvesting the original ABC will require higher fishing mortality rates. In this example, realized biomass would be lower than under original projections and if ABC remained the same, fishing mortality would increase higher than projections to attain the original ABC (AVG in AR). In addition, the same approach could be applied in the reverse, realized biomass could be higher than assumed if recruitment ends up being closer to average levels compared to the recent lower levels. In this reverse case, if the same ABC is harvested based on AR projections but biomass is higher than projected, then lower fishing mortality rates would occur, and biomass would rebuild faster than the original AR projections estimate (AR in AVG).

The Herring PDT prepared two additional sets of sensitivity runs to analyze these two cases and help evaluate what could happen if the allocated catch is harvested (the full ABC in this case), but biomass is either higher or lower than anticipated.

For these projections, fishing years 2020 – 2022 are considered bridge years. The fishery specifications in place are assumed to remain in place and the full ABC harvested in each year. Year 1 of this rebuilding plan is FY2022 because that is the year this rebuilding plan is expected to be implemented. However, this action is expected to be effective mid-year; therefore, the specifications already set for FY2022 will remain in place and are the same across all projections. Also, once the stock is estimated to rebuild the projections assume the ABC control rule adopted in Amendment 8 will be used in all the remaining years.

1.1.1.1 Projection results

For each alternative (ABC CR and 7year constant) four projections have been developed. The first run is the primary projection that informs the details of the rebuilding plan alternative, and the remaining three runs were prepared as sensitivity analyses to help evaluate the risk and uncertainty associated with future herring recruitment.

1. Assuming future recruitment will be equal to the long-term average (AVG) (median recruitment over the entire time series (1965-2017), excluding the last two years (2018 and 2019), which are very uncertain)
2. Assuming future recruitment will be autocorrelated (AR) and more similar to recent values (annual recruitment depends on recruitment values from the previous year and some variation)
3. Assuming AVG recruitment, when in truth it is AR (AVG in AR)
4. Assuming AR recruitment, when in truth it is AVG (AR in AVG).

Table 3 summarizes the projection results for Alternative 2 (ABC CR). Table 4 includes three separate sensitivity projections for Alternative 2 (ABC CR). Similarly, Table 5 summarizes the projection results for Alternative 3 (7yr constant) and Table 6 includes three separate sensitivity projections for Alternative 3 using different recruitment assumptions. "Prebuild" represents the fraction of stochastic realizations for each year, or the probability that projected annual biomass is at or above $SSB_{MSY\ proxy}$, compared to "Poverfished", which represents the probability that the projected annual biomass is at or above the overfished threshold (1/2 $SSB_{MSY\ proxy}$). "P overfishing" represents the probability that projected fishing mortality is at or above the overfishing threshold ($F_{MSY\ proxy}$, currently estimated at 0.54). Finally, "Pclosure" represents the probability projected biomass may fall below 10% of $SSB_{MSY\ proxy}$, under the current ABC control rule if biomass falls below 10% of $SSB_{MSY\ proxy}$ ABC is set to zero, or the fishery is closed, no allocation to the fishery.

Several key attributes have been summarized across rebuilding plan alternatives assuming average recruitment (Table 7). In addition, summary figures have been developed to help compare the results of Alternative 2 and Alternative 3 (Figure 2 - Figure 7). Finally, two summary figures are included that compare the results for Alternative 2 and 3 as well as the sensitivity runs completed to help assess risk; Figure 8 is a bar graph comparing the performance of two metrics at once across all runs (Pclosure and #Years to rebuild), and Figure 9 is a radar graph comparing the tradeoffs between rebuilding and short-term ABC across all runs.

Table 3 – Projection results for Alternative 2 (ABC CR), assuming "average" recruitment.
Note: the year with shading indicates the year the stock is projected to rebuild.

	Reb Year	Mobile Fleet F	SSB	P (overfishing)	P (overfished)	OFL	ABC	SSB/ SSBmsy	P (rebuild)	P (closure)
2020	*	0.243	56375	0.002	0.999	–	–	0.210	0.000	0.005
2021	*	0.119	48760	0.000	0.918	23424	9483	0.181	0.017	0.066
2022	1*	0.088	45876	0.000	0.893	26283	8722	0.171	0.031	0.115
2023	2	0.077	130736	0.000	0.521	44660	11036	0.486	0.097	0.001
2024	3	0.419	206057	0.290	0.174	69575	56070	0.766	0.274	0.000
2025	4	0.434	250790	0.323	0.060	85649	70950	0.932	0.428	0.000
2026	5	0.434	274581	0.321	0.024	97048	80407	1.021	0.525	0.000
2027	6	0.434	284774	0.321	0.014	105158	87217	1.059	0.569	0.000
2028	7	0.434	289764	0.322	0.010	108837	90302	1.077	0.594	0.000
2029	8	0.434	291899	0.321	0.009	110165	91422	1.085	0.603	0.000
2030	9	0.434	293070	0.321	0.008	110776	91942	1.089	0.605	0.000
2031	10	0.434	293119	0.321	0.008	110964	92089	1.090	0.609	0.000
2032	11	0.434	293798	0.322	0.008	111186	92298	1.092	0.610	0.000

** Projections assume the ABCs already allocated under the current specification package for FY2020-2022 will remain in place (Framework 8). Year 1 of this rebuilding plan is FY2022 because that is the year this action is expected to be implemented, but the specifications in place will remain until FY2023 and beyond.*

Table 4 – Sensitivity runs for Alternative 2 (ABC CR) under different recruitment scenarios: (a) autocorrelated recruitment; (b) assuming ABC from average recruitment, but AR recruitment realized; (c) assuming ABC from AR recruitment, but AVG recruitment realized.
Note: the year with shading indicates the year the stock is projected to rebuild, if there is no shading in the table the stock is not expected to rebuild by 2032 under the assumed conditions.

(a) Autocorrelated Recruitment

	Reb Year	Mobile Fleet F	SSB	P (overfishing)	P (overfished)	OFL	ABC	SSB/ SSBmsy	P (rebuild)	P (closure)
2020	*	0.243	56376	0.002	0.999	–	–	0.210	0.000	0.005
2021	*	0.119	48572	0.000	0.918	23348	9483	0.181	0.017	0.067
2022	1*	0.101	44799	0.000	0.890	23339	8722	0.167	0.031	0.157
2023	2	0.072	79407	0.000	0.778	31932	8832	0.295	0.046	0.028
2024	3	0.212	133074	0.071	0.506	47277	22655	0.495	0.138	0.004
2025	4	0.429	174436	0.370	0.338	63871	52662	0.648	0.248	0.001
2026	5	0.434	208073	0.381	0.242	75371	62615	0.774	0.343	0.000
2027	6	0.434	233899	0.388	0.186	85900	71311	0.870	0.412	0.000
2028	7	0.434	251533	0.391	0.151	93962	78019	0.935	0.456	0.000
2029	8	0.434	263024	0.391	0.132	99541	82609	0.978	0.486	0.000
2030	9	0.434	270142	0.390	0.121	103191	85690	1.004	0.503	0.000
2031	10	0.434	275483	0.388	0.114	105627	87708	1.024	0.516	0.000
2032	11	0.434	278533	0.387	0.110	107025	88868	1.035	0.522	0.000

(b) ABC from average recruitment, but AR recruitment realized

	Reb Year	Mobile Fleet F	SSB	P (overfishing)	P (overfished)	OFL	ABC	SSB/ SSBmsy	P (rebuild)	P (closure)
2020	*	0.243	56376	0.002	0.999	–	–	0.210	0.000	0.000
2021	*	0.119	48571	0.000	0.918	23350	9483	0.181	0.017	0.015
2022	1*	0.101	44781	0.000	0.890	23376	8722	0.166	0.031	0.059
2023	2	0.112	77932	0.002	0.778	31931	11036	0.290	0.048	0.004
2024	3	0.673	109547	0.618	0.594	46880	56070	0.407	0.133	0.005
2025	4	0.716	134955	0.625	0.499	55818	70950	0.502	0.235	0.004
2026	5	0.700	158981	0.603	0.447	64141	80407	0.591	0.314	0.002
2027	6	0.669	179306	0.577	0.419	72024	87217	0.667	0.365	0.001
2028	7	0.627	196910	0.551	0.397	78697	90302	0.732	0.399	0.001
2029	8	0.581	213571	0.523	0.379	84631	91422	0.794	0.428	0.000
2030	9	0.542	230032	0.500	0.364	90315	91942	0.855	0.450	0.000
2031	10	0.509	243510	0.479	0.349	95279	92089	0.905	0.469	0.000
2032	11	0.487	254394	0.466	0.338	99132	92298	0.946	0.482	0.000

(c) ABC from AR recruitment, but average recruitment realized

	Reb Year	Mobile Fleet F	SSB	P (overfishing)	P (overfished)	OFL	ABC	SSB/ SSBmsy	P (rebuild)	P (closure)
2020	*	0.243	56377	0.002	0.999	–	–	0.210	0.000	0.000
2021	*	0.119	48761	0.000	0.918	23418	9483	0.181	0.017	0.014
2022	1*	0.088	45819	0.000	0.888	26269	8722	0.170	0.031	0.053
2023	2	0.049	132146	0.000	0.513	44763	8832	0.491	0.113	0.000
2024	3	0.136	232552	0.002	0.146	70398	22655	0.865	0.385	0.000
2025	4	0.272	297541	0.063	0.063	94830	52662	1.106	0.587	0.000
2026	5	0.278	334501	0.071	0.042	110971	62615	1.243	0.681	0.000
2027	6	0.284	351461	0.082	0.037	123597	71311	1.307	0.721	0.000
2028	7	0.296	359372	0.100	0.038	130175	78019	1.336	0.734	0.000
2029	8	0.311	358987	0.122	0.041	132065	82609	1.335	0.729	0.000
2030	9	0.326	355426	0.143	0.045	131738	85690	1.321	0.720	0.000
2031	10	0.338	349522	0.165	0.052	130472	87708	1.299	0.705	0.000
2032	11	0.349	344071	0.185	0.057	128831	88868	1.279	0.692	0.000

** Projections assume the ABCs already allocated under the current specification package for FY2020-2022 will remain in place (Framework 8). Year 1 of this rebuilding plan is FY2022 because that is the year this action is expected to be implemented, but the specifications in place will remain until FY2023 and beyond.*

Table 5 – Projection results for Alternative 3(7-year constant F), assuming average recruitment.
Note: the year with shading indicates the year the stock is projected to rebuild.

	Reb Year	Mobile Fleet F	SSB	P (overfishing)	P (overfished)	OFL	ABC	SSB/ SSBmsy	P (rebuild)	P (closure)
2020	*	0.243	56375	0.002	0.999	–	–	0.21	0	0.005
2021	*	0.119	48760	0	0.918	23424	9483	0.181	0.017	0.066
2022	1*	0.088	45802	0	0.888	26283	8722	0.17	0.031	0.132
2023	2	0.483	112408	0.408	0.634	44736	40766	0.418	0.059	0.009
2024	3	0.483	180082	0.411	0.264	62261	56521	0.669	0.188	0.000
2025	4	0.483	226293	0.406	0.099	78329	71015	0.841	0.328	0.000
2026	5	0.483	252676	0.401	0.043	90163	81753	0.939	0.427	0.000
2027	6	0.483	264874	0.397	0.025	98447	89318	0.985	0.481	0.000
2028	7	0.483	270826	0.397	0.019	102568	93093	1.007	0.508	0.000
2029	8	0.434	284642	0.346	0.09	106849	88646	1.058	0.55	0.000
2030	9	0.434	289141	0.341	0.041	108776	90275	1.075	0.574	0.000
2031	10	0.434	290883	0.336	0.018	109781	91092	1.081	0.594	0.000
2032	11	0.434	292429	0.333	0.011	110370	91608	1.087	0.603	0.000

** Projections assume the ABCs already allocated under the current specification package for FY2020-2022 will remain in place (Framework 8). Year 1 of this rebuilding plan is FY2022 because that is the year this action is expected to be implemented, but the specifications in place will remain until FY2023 and beyond.*

Table 6 – Sensitivity runs for Alternative 3 (7-year constant F) under different recruitment scenarios: (a) autocorrelated recruitment; (b) assuming ABC from average recruitment, but AR recruitment realized; (c) assuming ABC from AR recruitment, but AVG recruitment realized.
Note: the year with shading indicates the year the stock is projected to rebuild, if there is no shading in the table the stock is not expected to rebuild by 2032 under the assumed conditions.

(a) Autocorrelated Recruitment

	Reb Year	Mobile Fleet F	SSB	P (overfishing)	P (overfished)	OFL	ABC	SSB/ SSBmsy	P (rebuild)	P (closure)
2020	*	0.243	56376	0.002	0.999	–	–	0.21	0	0.005
2021	*	0.119	48572	0	0.918	23348	9483	0.181	0.017	0.067
2022	1*	0.101	44799	0	0.89	23339	8722	0.167	0.031	0.157
2023	2	0.358	69911	0.234	0.825	31932	23508	0.26	0.031	0.100
2024	3	0.358	114824	0.283	0.597	43325	31231	0.427	0.096	0.071
2025	4	0.358	163260	0.295	0.38	57823	41169	0.607	0.221	0.061
2026	5	0.358	208910	0.3	0.243	72546	51328	0.777	0.347	0.058
2027	6	0.358	245113	0.309	0.167	86432	61029	0.911	0.442	0.061
2028	7	0.358	270372	0.314	0.124	97575	68815	1.005	0.503	0.064
2029	8	0.434	286091	0.403	0.204	109588	90936	1.064	0.53	0.030
2030	9	0.434	286383	0.405	0.158	110974	92107	1.065	0.536	0.005
2031	10	0.434	285655	0.405	0.126	110966	92115	1.062	0.538	0.001
2032	11	0.434	283861	0.401	0.111	110337	91604	1.055	0.536	0.000

(b) ABC from average recruitment, but AR recruitment realized

	Reb Year	Mobile Fleet F	SSB	P (overfishing)	P (overfished)	OFL	ABC	SSB/ SSBmsy	P (rebuild)	P (closure)
2020	*	0.243	56376	0.002	0.999	–	–	0.210	0.000	0.000
2021	*	0.119	48571	0.000	0.918	23350	9483	0.181	0.017	0.015
2022	1*	0.101	44781	0.000	0.890	23376	8722	0.166	0.031	0.059
2023	2	0.749	58667	0.681	0.829	31931	40766	0.218	0.039	0.054
2024	3	0.842	85667	0.696	0.671	39400	56521	0.318	0.109	0.028
2025	4	0.845	112618	0.676	0.558	48867	71015	0.419	0.207	0.013
2026	5	0.809	138147	0.646	0.492	57859	81753	0.514	0.286	0.006
2027	6	0.766	159484	0.618	0.456	65966	89318	0.593	0.340	0.003
2028	7	0.711	177652	0.589	0.430	72989	93093	0.660	0.376	0.002
2029	8	0.657	194485	0.561	0.409	79026	94642	0.723	0.405	0.001
2030	9	0.611	211266	0.536	0.391	84731	95359	0.785	0.428	0.000
2031	10	0.570	225169	0.516	0.376	89750	95583	0.837	0.447	0.000
2032	11	0.545	236123	0.501	0.362	93614	95820	0.878	0.460	0.000

(c) ABC from AR recruitment, but average recruitment realized

	Reb Year	Mobile Fleet F	SSB	P (overfishing)	P (overfished)	OFL	ABC	SSB/ SSBmsy	P (rebuild)	P (closure)
2020	*	0.243	56377	0.002	0.999	–	–	0.210	0.000	0.000
2021	*	0.119	48761	0.000	0.918	23418	9483	0.181	0.017	0.014
2022	1*	0.088	45819	0.000	0.888	26269	8722	0.170	0.031	0.053
2023	2	0.238	122894	0.043	0.563	44763	23508	0.457	0.100	0.000
2024	3	0.217	213788	0.037	0.205	66774	31231	0.795	0.332	0.000
2025	4	0.218	287239	0.034	0.079	89240	41169	1.068	0.555	0.000
2026	5	0.226	336675	0.034	0.040	108579	51328	1.252	0.687	0.000
2027	6	0.235	363729	0.039	0.028	124494	61029	1.352	0.751	0.000
2028	7	0.248	378433	0.048	0.024	134064	68815	1.407	0.779	0.000
2029	8	0.330	369971	0.135	0.032	138175	90936	1.375	0.756	0.000
2030	9	0.345	357927	0.163	0.043	134772	92107	1.331	0.726	0.000
2031	10	0.356	346834	0.188	0.054	131129	92115	1.289	0.699	0.000
2032	11	0.364	338942	0.208	0.062	128010	91604	1.260	0.679	0.000

** Projections assume the ABCs already allocated under the current specification package for FY2020-2022 will remain in place (Framework 8). Year 1 of this rebuilding plan is FY2022 because that is the year this action is expected to be implemented, but the specifications in place will remain until FY2023 and beyond.*

Table 7 summarizes the projection results for both rebuilding plan alternatives assuming "average" recruitment. The first few years maintain the specifications already in place and assume the full ABC is harvested each year. The main difference between these alternatives is the different fishing mortality allowed under these plans in FY2023, rows below the dark line in the table below.

Table 7 – Summary of projection results for several metrics comparing Rebuilding Plan Alternatives 2 and 3 through 2028.

		Alt. 2 (A8 ABC CR)					Alt. 3 (7yr constant)				
Year	Rebuild Year	F	P (overfishing)	P (overfished)	ABC	P (rebuild)	F	P (overfishing)	P (overfished)	ABC	P (rebuild)
2020	*Bridge*	*0.24*	*0.002*	*0.999*	*0*	*0*	*0.24*	*0.002*	*0.999*	*0*	*0*
2021	*Bridge*	*0.12*	*0*	*0.918*	*9,483*	*0.017*	*0.12*	*0*	*0.918*	*9,483*	*0.017*
2022	*1 (Bridge)*	*0.09*	*0*	*0.893*	*8,722*	*0.031*	*0.09*	*0*	*0.888*	*8,722*	*0.031*
2023	2	0.08	0	0.521	11,036	0.097	0.48	0.408	0.634	40,766	0.059
2024	3	0.42	0.29	0.174	56,070	0.274	0.48	0.411	0.264	56,521	0.188
2025	4	0.43	0.323	0.06	70,950	0.428	0.48	0.406	0.099	71,015	0.328
2026	5	0.43	0.321	0.024	80,407	0.525	0.48	0.401	0.043	81,753	0.427
2027	6	0.43	0.321	0.014	87,217	0.569	0.48	0.397	0.025	89,318	0.481
2028	7	0.43	0.322	0.01	90,302	0.594	0.48	0.397	0.019	93,093	0.508

Figure 2 – Projections of Prebuild for Alternative 2 (ABC CR) assuming average recruitment (gray solid line) and AR recruitment (gray dotted line) compared to Alternative 3 (F7 or 7yr constant) assuming average recruitment (black solid line) and AR recruitment (black dotted line).

Note: Alt 2 reaches Prebuild of 0.5 in year 5 (2026) and alt 3 reaches Prebuild of 0.5 in year 7 (2028).

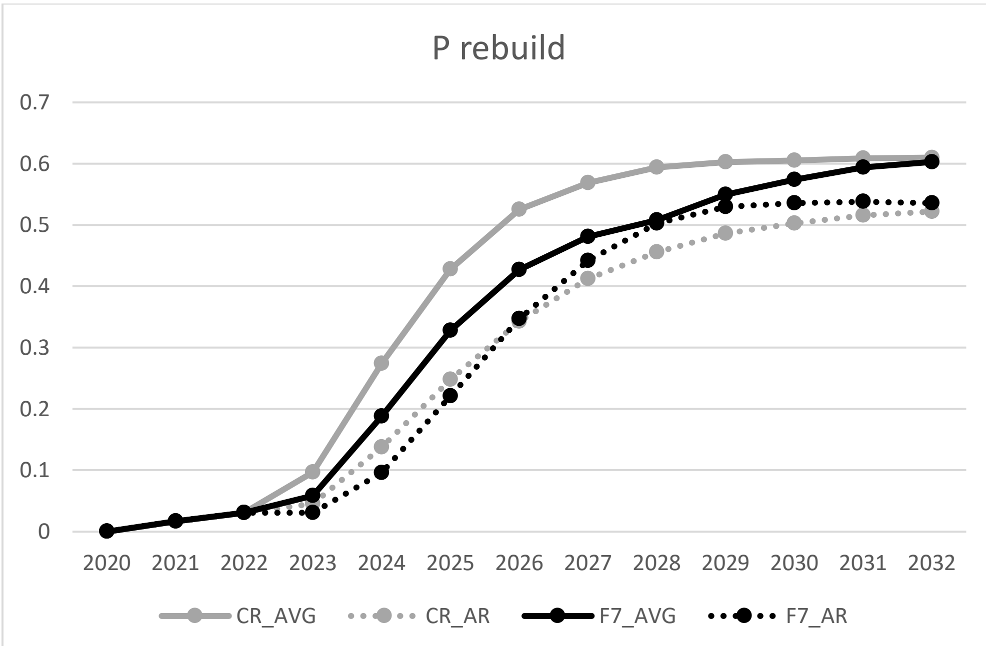


Figure 3 – Projections of Poverfished for Alternative 2 (ABC CR) assuming average recruitment (gray solid line) and AR recruitment (gray dotted line) compared to Alternative 3 (F7 or 7yr constant) assuming average recruitment (black solid line) and AR recruitment (black dotted line).

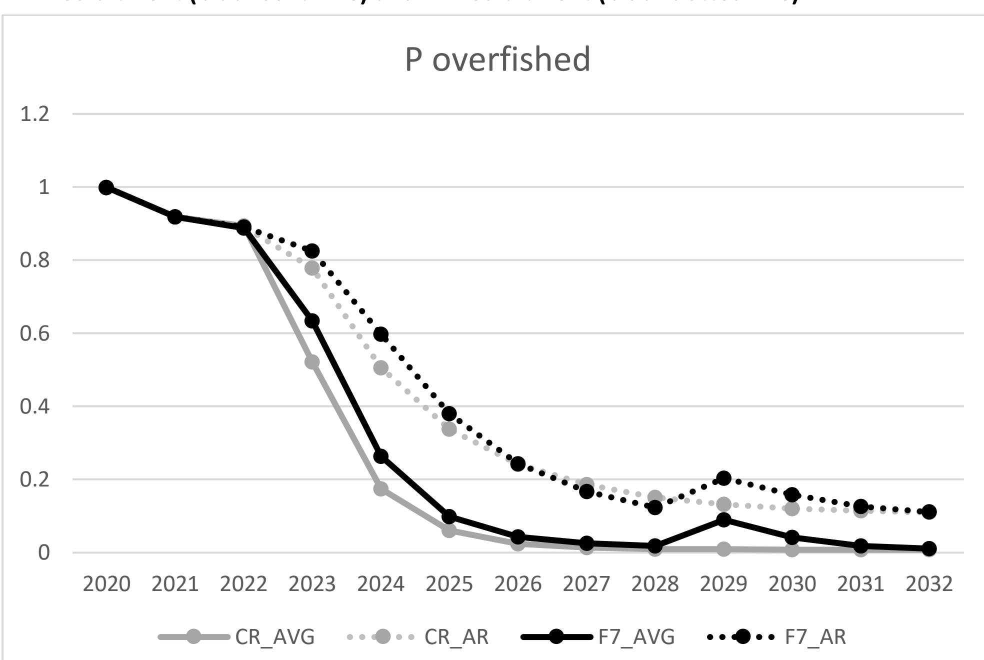


Figure 4 – Projections of Poverfishing for Alternative 2 (ABC CR) assuming average recruitment (gray solid line) and AR recruitment (gray dotted line) compared to Alternative 3 (F7 or 7yr constant) assuming average recruitment (black solid line) and AR recruitment (black dotted line).

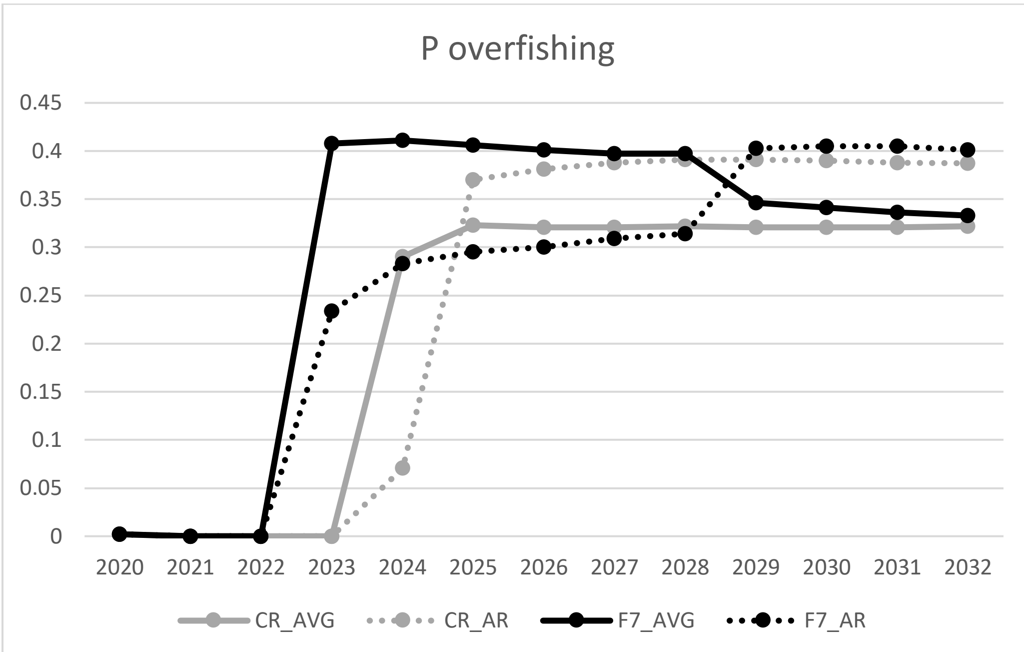


Figure 5 – Projected fishing mortality (F) for Alternative 2 (ABC CR) assuming average recruitment (gray solid line) and AR recruitment (gray dotted line) compared to Alternative 3 (F7 or 7yr constant) assuming average recruitment (black solid line) and AR recruitment (black dotted line).

Note: After the stock is projected to rebuild, F is set to $F_{msy\ proxy}$ (F=0.43) for both alternatives.

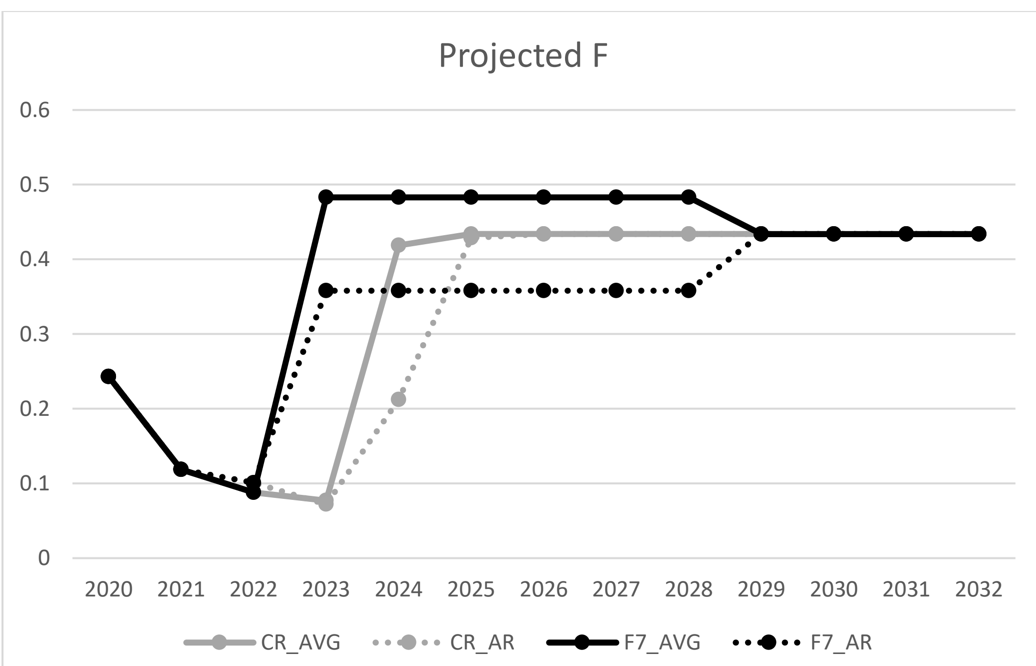


Figure 6 – Projected ABC for Alternative 2 (ABC CR) assuming average recruitment (gray solid line) and AR recruitment (gray dotted line) compared to Alternative 3 (F7 or 7yr constant) assuming average recruitment (black solid line) and AR recruitment (black dotted line).

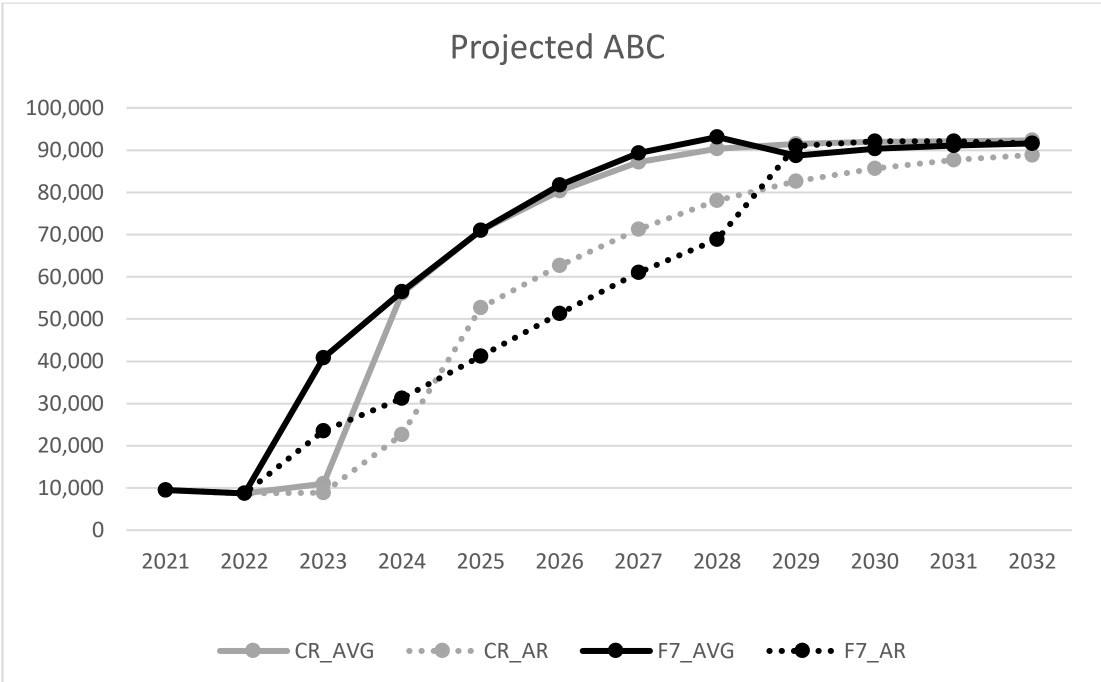


Figure 7 – Projected spawning stock biomass (SSB) for Alternative 2 (ABC CR) assuming average recruitment (gray solid line) and AR recruitment (gray dotted line) compared to Alternative 3 (F7 or 7yr constant) assuming average recruitment (black solid line) and AR recruitment (black dotted line).

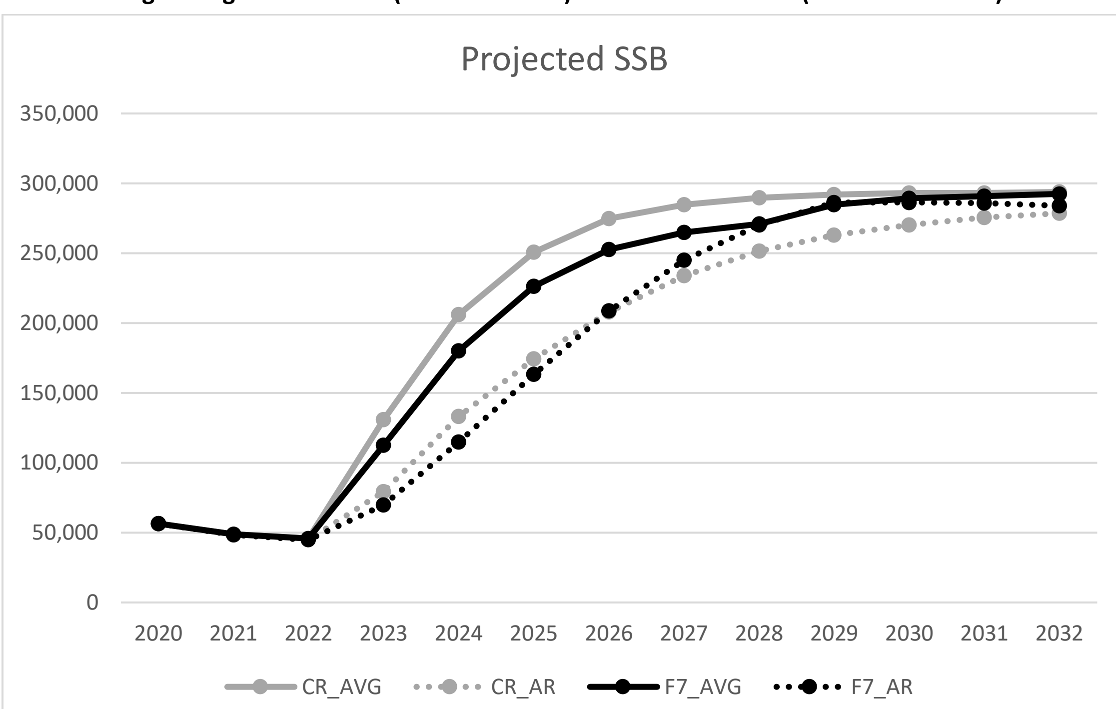


Figure 8 below compares probability of a fishery closure (ABC=0) at least once during the next 10 years, and number of years it takes the stock to rebuild. Darker bars are results for scenarios that would implement a rebuilding plan based on average recruitment (AVG), and lighter bars represent the results for the sensitivity runs using other recruitment assumptions. Higher bars indicate “poor” performance and results closer to zero (shorter bars) suggest more desirable performance. This figure summarizes the two primary risks embedded in these options: 1) a constant fishing mortality rate results in a higher probability of a closure, especially if recruitment is lower (AR), and 2) if management assumes recruitment will be average and it is not (AVG in AR runs) the fishery will take much longer to rebuild.

Figure 8 – Bar chart comparing performance of rebuilding plan alternatives (ABC CR and 7Y constant) for probability of a fishery closure (top bars) and number of years it takes the resource to rebuild (bottom bars)
Note: The dark bars represent the results for each alternative, and the lighter bars show the results for the sensitivity runs for each alternative under different assumptions about recruitment (AR, AVG in AR and AR in AVG).

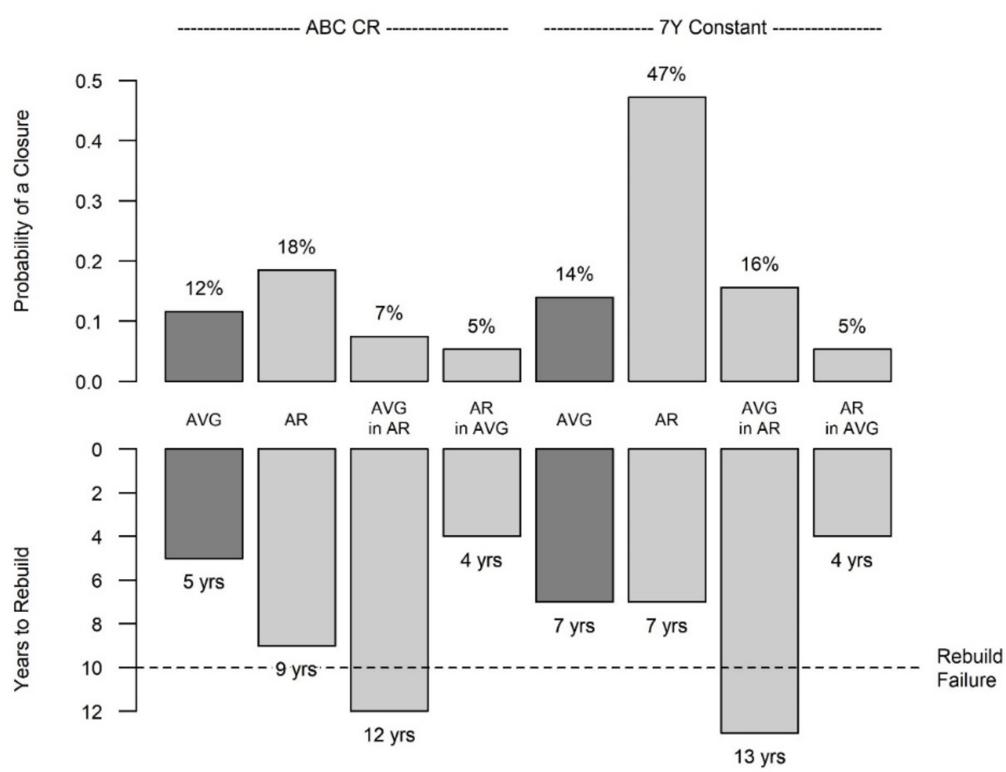
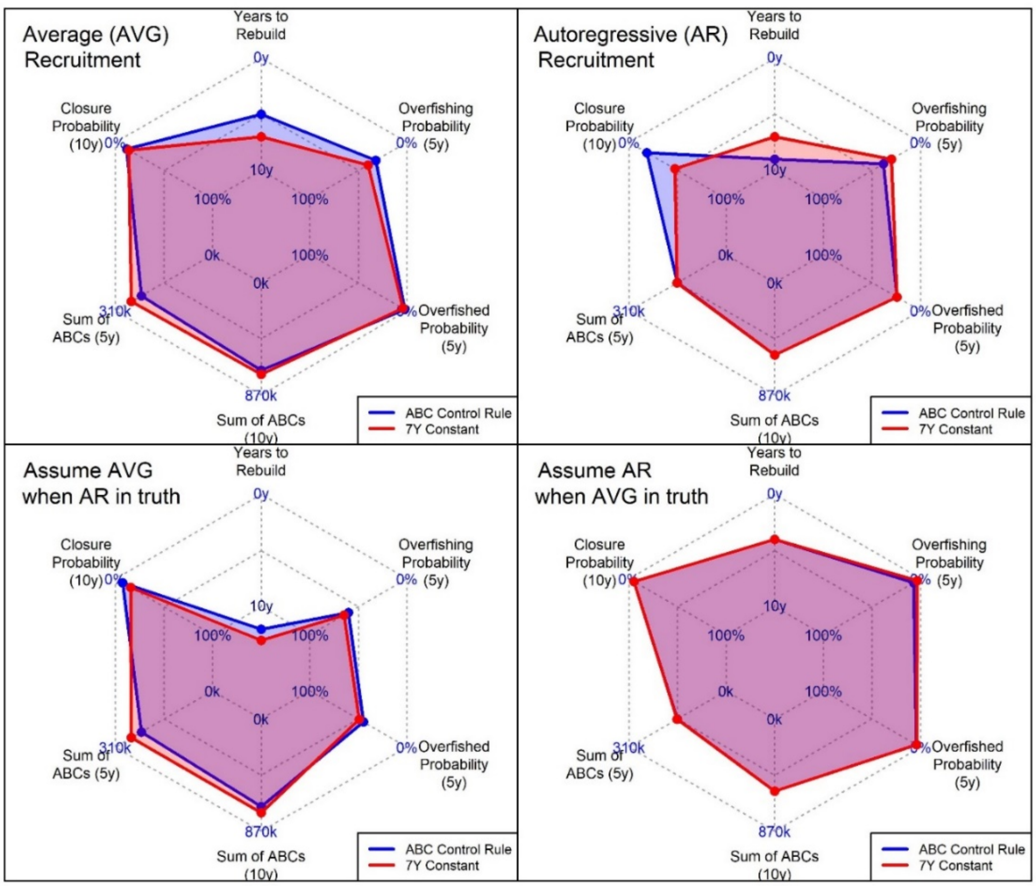


Figure 9 presents the tradeoffs between rebuilding and short-term ABC by displaying results for several metrics at once for both alternatives (ABC CR in blue and 7yr constant in red). For these figures the farther out the results are from the center indicates “good” performance and results closer to the center are less desirable. In summary, these plots show that allocating higher ABCs in the near term has higher risks of a fishery closure (ABC=0), especially under AR recruitment. The fishery may rebuild faster under the ABC CR, but the sum of ABCs over the next five years is slightly lower for the ABC CR (Alt. 2) compared to 7yr constant (Alt. 3). The radar plots also show that both options have similar total catch over the next 10 years as well as Poverfished.

Pclosure in Figure 9 represents the probability of the fishery closing *at least* once during the next ten years under each rebuilding plan alternative.[2] This metric shows the risk of a fishery closure (ABC=0) over the next ten years. For example, if there were a 10% chance of closure each year, the fishery would likely close at least once over the next ten years.

Figure 9 – Radar plot comparing two rebuilding alternatives (ABC CR in blue and 7yr constant in red) across several metrics (number of years for resource to rebuild, Poverfished in Year5, Poverfishing in Year5, sum of ABCs over the next 10 years, probability of fishery closure ABC=0)



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[2] The formula used to calculate Pclosure over the next ten years is: $pClosure_{y1:y10} = 1 - \prod_y(1 - pClosure_y)$

1.1.2 Action 1 – Rebuilding Plan

1.1.2.1 Rebuilding Plan Alternative 1 (No Action)

Under this alternative, the Council would not recommend implementing a rebuilding plan for Atlantic herring. The Council would continue to set fishery specifications every two years, with default measures for year 3, but there would not be a formal rebuilding plan in place that defines how fishing mortality should be set to achieve rebuilding goals. Because Atlantic herring has recently been declared overfished, the Magnuson Stevens Act (MSA) requires that a rebuilding plan be implemented to help ensure the measures in place support rebuilding of the resource. Therefore, if a rebuilding plan is not adopted through this action there could be slightly negative impacts on the Atlantic herring resource if fishery specifications do not support rebuilding. An? intent of implementing a rebuilding plan is to help track progress. The MSA requires the Secretary of Commerce review rebuilding plans to ensure that adequate progress toward ending overfishing and rebuilding affected fish stocks is being made. Not having a rebuilding plan in place could make it more difficult to track progress.

Because the Council has approved an ABC control rule in the Atlantic herring plan that is the same rule used in Rebuilding Plan Alternative 2, it is likely the same rebuilding F would be used to set future specifications. The projection results for the rebuilding F used in Alternative 2 are expected to have moderately positive impacts on the resources. Therefore, this alternative is expected to have slight negative impacts if there is no rebuilding plan to track progress, and moderate positive benefits if the rebuilding F from the ABC control rule is used and supports rebuilding.

1.1.2.2 Rebuilding Plan Alternative 2 (ABC control rule)

Under this alternative, a rebuilding plan would be established. The policy for setting fishing mortality targets for the rebuilding plan would be consistent with the ABC control rule approved in Amendment 8, which is a biomass-based control rule. $F_{rebuild}$ would vary based on the annual estimate of biomass; the projections prepared for this action suggest that $F_{rebuild}$ would vary between 0.08 and 0.43 (15% - 80% of F_{MSY}).

The Council recommended the ABC control rule in Amendment 8 because it met specific criteria identified by the Council including low variability in yield, low probability of overfished, low probability of closing the herring fishery, and catch at relatively high proportion of MSY. In summary, the control rule was selected because it explicitly accounts for the role of herring as forage in the ecosystem by limiting fishing mortality at 80% of F_{MSY} and accounts for uncertainty by limiting the maximum allowable fishing mortality rate at 80%. This control rule is expected to help stabilize the fishery in the long term. For these reasons, this alternative is expected to have moderately positive impacts on the Atlantic herring resource. Because this rebuilding strategy reduces fishing mortality when biomass is low, it is expected to support rebuilding more quickly than a constant fishing mortality strategy that applies the same fishing pressure regardless of biomass. While implementation of a rebuilding plan is expected to inherently have positive impacts on the resource, there is still uncertainty and potential error in the projections, somewhat captured in the sensitivity analyses described above (Section 1.1.1.1). Rebuilding will take time and it could take herring longer to reach higher biomass levels and revert the stock status from overfished.

This alternative is expected to have slight positive impacts on the resource compared to Alternative 1 (No Action) because it would establish an official rebuilding plan. The fishing mortality targets the Council recommends under Alternative 1 (no rebuilding plan) may in fact be similar or the same as Alternative 2 if the Council maintains use of the ABC CR in future actions. Therefore, the positive impacts on the resource may ultimately be similar between these two alternatives. However, having a formal rebuilding plan in place is required by MSA when a stock is declared overfished, and it should provide slight positive benefits to the resource by providing a mechanism for the Secretary to ensure that adequate progress toward ending overfishing and rebuilding affected fish stocks is being made.

This alternative is expected to have moderately positive impacts on the resource compared to Alternative 3 (7year constant). In general, if recruitment returns to average levels, the impacts of these alternatives would not be not very different. Alternative 3 allows higher fishing mortality in the short term, but as biomass increases, the fishing mortality allowed under both strategies is relatively similar (0.43 under Alternative 2 and 0.48 under Alternative 3). Poverfishing and Poverfished are lower for Alternative 2 in the first few years of the rebuilding period, and Prebuild and Projected SSB are higher for Alternative 2 compared to Alternative 3 (See Table 7, Figure 2, Figure 3, Figure 4, and Figure 7). These results suggest moderately positive impacts on the resource from Alternative 2 compared to Alternative 3.

However, if recruitment does not improve Alternative 3 (7yr constant) has higher risks of closing the fishery; ABC is set to zero if biomass falls below 10% SSB_{MSY} under the current ABC CR. P closure over the next ten years for Alternative 2 increases from 12% assuming average recruitment to 18% assuming AR recruitment, compared to Alternative 3 that changes from 14% under average recruitment to 47% under AR recruitment. This suggests that the risk of biomass falling to very low levels under a constant F strategy of 0.48 is greater than a rebuilding strategy that reduces F when biomass is at lower levels (Figure 8).

In addition, there is fairly strong evidence that several herring populations are subject to Allee effects; the productivity (per-capita recruitment) of the populations becomes reduced at low stock size. Several papers suggest that a goal of management should be to avoid very low stock sizes to help maintain overall productivity of the resource[3]. If the Atlantic herring spawning stock remains low for several years, there is a risk that recruitment will worsen and cause further depletion, an outcome not included in the current projections and sensitivity runs.

By design, the Amendment 8 biomass-based control rule uses a relatively risk-averse fishing mortality rate when stock size is low and increases fishing mortality up to 80% of F_{MSY} when biomass is relatively high (>50% $SSB_{MSY\ proxy}$). A biomass-based control rule is intended to be robust to all resource conditions (high or low recruitment). Therefore, even if herring recruitment does not return to levels used in the projections, if biomass remains low in future years, the fishing mortality levels allowed under the Amendment 8 biomass-based control rule would also remain low until biomass increases.

When considering the impacts of a rebuilding plan for Atlantic herring, it is also important to consider species that rely on herring for forage. Because herring is an important prey species in the region, ecosystem considerations should be taken into account when selecting a rebuilding plan. Taking all of these issues into account, moderately positive impacts are expected from Alternative 2 compared to Alternative 3.

It is important to note for both alternatives (ABC CR and 7year constant), when ABC is defined assuming average recruitment, but AR recruitment is realized (AVG in AR runs), the stock will not rebuild within ten years (See Table 4 and Table 6). It is important to recognize that even if fishing mortality is kept very low, the stock may not rebuild as scheduled unless recruitment improves.

[3] (Frank & Brickman 2000; Pera¨la¨ & Kuparinen 2017; Saha et al. 2013; Sau et al. 2020).

1.1.2.3 Rebuilding Plan Alternative 3 (7year constant)

Under this alternative, a rebuilding plan would be established. The fishing mortality target of the rebuilding plan would be constant, $F_{rebuild}$ would be set at F=0.48, about 89% of F_{MSY} during the rebuilding timeframe.

This alternative is expected to have slight positive to slight negative impacts on the resource compared to Alternative 1 (No Action). There may be slight positive impacts because it would establish an official rebuilding plan compared to not have a rebuilding plan under Alternative 1. However, in the absence of a rebuilding plan, the Council may continue to recommend fishing mortality targets consistent with the ABC CR in place, which are lower than the $F_{rebuild}$ under this alternative. Therefore, if that is the case there may be slight negative impacts on the resource if it takes longer to rebuild under this alternative compared to applying the ABC control rule in place. On its own, the alternative is expected to have slight positive impacts on the resource because it is expected to help rebuild the resource in a relatively timely way (in 7 years assuming average recruitment). This is less than ten years, but if recruitment is below average, it may take longer.

This alternative is expected to have moderately negative impacts on the resource compared to Alternative 2 (ABC CR). In general, if recruitment returns to average levels, these alternatives are not very different. This alternative allows higher fishing mortality in the short term, but as biomass increases the fishing mortality allowed under both strategies is relatively similar (0.43 under Alternative 2 and 0.48 under Alternative 3). Poverfishing and Poverfished are higher for this alternative under the first few years of the rebuilding period, and Prebuild and Projected SSB are lower compared to Alternative 2 (See Table 7, Figure 2, Figure 3, Figure 4, and Figure 7). These results suggest slightly negative impacts on the resource from Alternative 3 compared to Alternative 2.

However, if recruitment does not improve Alternative 3 (7yr constant) has higher risks of closing the fishery. The risk of biomass falling to lower levels and closing the fishery are higher under Alternative 3; therefore, moderately negative impacts are expected on the resource compared to Alternative 2, especially if recruitment does not improve (Figure 8). The projections with lower estimates of recruitment (AR) are where these alternatives differ the most. Alternative 2 may be more robust to uncertainty compared to Alternative 3 because Pclosure is lower for Alternative 2 compared to Alternative 3 in the runs with AR recruitment (Figure 8). Similarly, the number of years it could take for herring to rebuild if recruitment is lower than average is longer for Alternative 3 compared to Alternative 2.

Figure 9 summarizes the tradeoffs between rebuilding and short-term ABCs for Alternative 2 compared to Alternative 3. For the most part the results are very similar. It is expected to take longer to rebuild the resource under Alternative 3 compared to Alternative 2 assuming average recruitment, 7 years compared to 5 years. Similarly, the probability of overfishing is slightly higher for Alternative 3 compared to Alternative 2 under the first 5 years of the rebuilding plan. Therefore, there may be moderately negative impacts on the resource under Alternative 3 compared to Alternative 2, but in the longer term these rebuilding plan alternatives are expected to have more similar impacts. Both are expected to rebuild the resource under ten years, provided recruitment improves.

1.1.3 Action 2 – Adjust Herring Accountability Measures (AMs)

1.1.3.1 Overage AM Alternative 1 (No Action)

Under this alternative, there would be no changes to the proactive, in-season or reactive AMs in place to minimize overages of Atlantic herring catch limits. These include in-season reduced possession limits that limit the directed herring fishery as well as reactive pound for pound AMs to address any overages. These measures are expected to have moderately positive impacts on the resource by preventing overfishing and keeping the fishery accountable for any overages above catch limits. These measures have been in place since ???? and to date there have been relatively limited cases when sub-ACLs have been exceeded in one management area or another, and the total ACL has never been exceeded (Figures ???).

1.1.3.2 Overage AM Alternative 2

Under this alternative catch from a management area that exceeds the sub-ACL by less than 10% of the sub-ACL is not deducted from the ACL and respective sub-ACL in a subsequent year unless total catch also exceeds the total ACL. This alternative is expected to have slight negative impact on the resource if one area is consistently fished above target levels. However, this alternative only allows an up to 10% overage in a particular area and herring stocks are known to mix during the year; therefore, any potential slight negative impacts are limited. Because this alternative maintains that the total ACL cannot be exceeded there are minimal risks in terms of overfishing overall; therefore, more neutral impacts are expected. Thus, compared to Alternative 1, No Action, there could be slight negative impacts since No Action prevents overages in all herring management areas.

Compared to Alternative 3, this alternative may have slight positive impacts on the resource because overages are limited to 10% per management area, compared to unlimited overages per sub-ACL, so long as the total ACL is not exceeded.

1.1.3.3 Overage AM Alternative 3

Under this alternative catch from a management area that exceeds the sub-ACL would be deducted from the ACL and respective sub-ACL in a subsequent year, only if total catch also exceeded the total ACL. Catch can exceed a sub-ACL by any amount so long as the total ACL is not exceeded.

This alternative is expected to have moderate negative to no impacts on the resource There may be moderate negative impacts on a sub-component of the stock if one area is consistently fished above target levels. However, because this alternative maintains that the total ACL cannot be exceeded there are minimal risks in terms of overfishing the resource overall; therefore, there may be no impacts on the overall stock, but moderately negative impacts on portions of the stock. Compared to Alternative 1, No Action, there could be moderate negative impacts since No Action prevents overages in all herring management areas.

Compared to Alternative 2, this alternative may have slight negative impacts on the resource because this alternative does not have overage limits per area. The four herring management areas have different allocations per area: Area 1A – 28.9%, Area 1B – 4.3%, Area 2 – 27.8% and Area 3 – 39%). Therefore, without overage limits there is a greater risk that one sub-area could be fished higher than another. This measure would still help prevent overfishing overall because the total ACL cannot be exceeded. However, there may be a greater risk of overfishing one stock component under this alternative compared to Alternative 2 and Alternative 1.

1.2 IMPACTS ON NON-TARGET SPECIES (BYCATCH)

Non-target species refers to species other than Atlantic herring which are caught/landed by federally permitted vessels while fishing for herring. Most catch by herring vessels on directed trips is Atlantic herring, with extremely low percentages of bycatch (discards). Atlantic mackerel is targeted in combination with Atlantic herring during part of the year in the southern New England and Mid-Atlantic areas and is therefore not considered a non-target species. The primary non-target species in the directed Atlantic herring fishery are groundfish (particularly haddock) and the river herring/shad (RH/S) species.

There are accountability measures in place for both haddock and river herring/shad if area and gear specific catch cap is exceeded. Dogfish, squid, butterfish and Atlantic mackerel are also common species encountered in the directed Atlantic herring fishery. However, in some cases (especially Atlantic mackerel), while herring is often the target species, mackerel is also landed, and some trips are quite mixed in terms of mackerel and herring landings. Therefore, Atlantic mackerel is not considered a non-target species since there can be substantial landings of that species for various segments of the fishery during certain seasons and in certain areas, Section 5.2 has more information about non-target species in the herring fishery.

1.2.1 Methods

Different gear types and seasonal fishing activity have different potential impacts on non-target species. This section focuses on the biological impacts on species caught incidentally in the herring fishery; these analyses are largely qualitative and based on whether alternatives under consideration are expected to shift effort to areas that may have increased interactions or change gear types that can have differential impacts on bycatch rates. River herring and haddock are the two primary species caught as bycatch in the Atlantic herring fishery. The potential impacts on non-target species or bycatch are primarily qualitative. In general, if more fishing time is expected as a result of an action, there could be potential negative impacts on non-target species or bycatch, particularly if fishing effort is expected to shift to an area or season with higher bycatch rates.

1.2.2 Action 1 – Rebuilding Plan

This action would establish a rebuilding program for Atlantic herring. Under Alternative 1 (No Action), the Council would not recommend implementing a rebuilding plan. While future specifications for the fishery will be set outside a rebuilding plan, they will use the Council's existing ABC control rule, implemented via Amendment 8. This control rule adjusts the fishing mortality rate and thus the ACL depending on estimated herring biomass relative to MSY, with lower F at lower biomass values. Under Alternatives 2 and 3, a rebuilding plan would be established. The fishing mortality target for the Alternative 2 rebuilding plan would be consistent with the ABC control rule approved in Amendment 8. Because Alternatives 1 and 2 use the same ABC control rule, fishing mortality rates and the associated ACLs will be the same for Alternatives 1 and 2. ACLs and fishing effort should increase over time under these alternatives as the stock rebuilds. Under Alternative 3, the fishing mortality target for the rebuilding plan, $F_{rebuild}$, would be set at a constant value F=0.48, about 89% of F_{MSY}. While F will be held constant under Alternative 3, the resulting ABC and ACL is expected to increase over time as biomass increases.

It is important to note that rebuilding trajectories are often uncertain, and depend on factors beyond fishing mortality, including recruitment rates, which are discussed in detail in the target species impacts section. Thus, even though the rebuilding plans specify fishing mortality rates, it is difficult to predict how biomass, annual catch limits, and thus fishing activity will change over time for each alternative. For the purpose of estimating impacts on non-target species, it is assumed that differences in ACLs will translate to differences in fishing effort. In this fishery, ACLs and effort are likely to track closely, given that quota utilization is high, especially under lower biomass values.

The expected trajectories of F, biomass, and catch limits is different under Alternative 3 as compared to Alternatives 1 and 2, with higher catches and effort in the short term under Alternative 3. However total ABC across the entire ten-year rebuilding period is very similar, whether the A8 control rule or a constant $F_{rebuild}$ approach is selected. Therefore, impacts on non-target species are expected to be similar across the three alternatives considering the entire rebuilding period in aggregate. While similar aggregate impacts are expected to be similar across alternatives, lower catch limits and fishing effort in a given year will be associated with potentially lower impacts on non-target species, but the differences are small.

Overall, despite possible variations in fishing effort between these options, and because this action maintains the use of catch caps for both haddock and river herring/shad to control impacts on bycatch, these alternatives are expected to have negligible impacts relative to one another on non-target species.

1.2.3 Action 2 – Adjust Herring Accountability Measures (AMs)

These alternatives could adjust the reactive AMs used in the herring fishery to account for overages. All alternatives would maintain the current pro-active AMs. Alternative 1 (No Action) would also maintain the current reactive AM, which requires a pound for pound reduction in future ACLs if there are overages in any of the four herring management areas. Alternatives 2 and 3 change when pound for pound payback would be required. Under Alternative 2, if a sub-ACL is exceeded by less than 10%, and the overall ACL is not exceeded, then the overage is not deducted from future allocations. Under Alternative 3, if the sub-ACL is exceeded by any amount, but the overall ACL is not exceeded, then the overage is not deducted from future allocations. Under other conditions, overages are deducted.

In general, reactive AMs do not have a large effect on the amount of effort in the fishery over time. The in-season measures serve to reduce fishing effort as the catch limits are approached, such that quota overages are generally small relative to overall effort. In addition, the nature of reactive AMs means that harvest occurs in one year, but then effort is reduced in subsequent years, meaning that while effort may be temporally redistributed, the amount of fishing activity over several years will be similar, whether AMs were implemented or not. Alternatives 2 and 3, which include some scenarios where payback is not required, could lead to a slight net increase in effort relative to Alternative 1, but the total ACL cannot be exceeded under any of the alternatives. Therefore, any potential increase in effort is still within the total ACL level considered. Despite possible variations in fishing effort between these options, and because this action maintains the use of catch caps for both haddock and river herring/shad to control impacts on bycatch, these alternatives are expected to have negligible impacts relative to one another on non-target species.

1.3 Impacts on Protected Species

Protected species are those afforded protections under the Endangered Species Act (ESA; species listed as threatened or endangered under the ESA) and/or the Marine Mammal Protection Act (MMPA). Section 5.3 lists protected species that occur in the affected environment of the Atlantic herring FMP and have the potential to be impacted by the fishery, specifically via interactions with fishing gear predominantly used in the Atlantic herring fishery (i.e. midwater trawl and purse seine gear) and/or via removal of forage (i.e., Atlantic herring).

As provided in section 5.3, ESA listed species and designated critical habitat are not expected to be impacted, via interactions with fishing gear, by the herring fishery. Specifically, as provided in Section 5.3, NMFS determined that the Atlantic Herring FMP is extremely unlikely to interact with ESA listed species of marine mammals, sea turtles, or fish, and will not destroy or adversely modify designated critical habitat (NMFS 2010; see section 5.3). However, as the forage base of ESA listed species of fin and sei whales includes small schooling fish, such as Atlantic herring, the operation of the Atlantic herring fishery has the potential to impact these species by affecting a component of their forage base (see Section 5.3). By definition, all ESA-listed species are in poor condition and therefore, any action that has the potential to adversely impact forage can negatively impact that species' recovery.

As provided in Section 5.3, MMPA (non-ESA listed) protected species of large whales (e.g., humpback and minke whales), species of small cetaceans, and pinnipeds have the potential to be impacted by the Atlantic herring fishery, via foraging and/or interactions with fishing gear predominantly used in the fishery (i.e., purse seine and mid-water trawls). To evaluate the impacts of gear interactions on MMPA (non-ESA listed) protected species of large whales (i.e., humpback whales), species of small cetaceans, and pinnipeds, it is important to note that the predominant gear types used in the herring fishery are purse seines and midwater trawls, and that most landings is by the midwater trawl fishery, but most activity in terms of trips and permits is to purse seine vessels (see Section 5.5.1). As some MMPA protected species forage on Atlantic herring (See Table 42), the potential foraging impacts to these marine mammal species will also be evaluated.

In addition, evaluating the impacts of each alternative on MMPA protected species takes into account the species or stocks (resource) condition (see section 5.3 and Table 42). Specifically, the evaluation of impacts takes into consideration whether the MMPA protected species is in good condition (i.e., marine mammal stocks whose PBR level have not been exceeded) or in poor condition (i.e., marine mammal stocks that have exceeded or are near exceeding their PBR level). For marine mammal stocks that have their PBR level reached or exceeded, some level of negative impacts would be expected from alternatives that result in the potential for interactions between fisheries and those stocks. For species that are at more sustainable levels (i.e., PBR levels have not been exceeded), alternatives not expected to change fishing behavior or effort may have some level of positive impacts by maintaining takes below the PBR level and approaching the zero mortality rate goal (Table 42).

With respect to this action, there will not be major changes in the amount or areas that herring vessels fish from most of the alternatives under consideration. The alternatives under consideration that may impact herring fishing patterns directly are identified, and potential impacts are described. Discussions regarding potential interactions with protected species (i.e., non ESA-listed marine mammal species) as well as impacts on prey availability are largely qualitative. The alternatives under consideration are evaluated below in terms of whether they are expected to greatly change the availability of herring as prey, as well as whether they will change fishing effort in time and space, such that, relative to current operating conditions, interaction risks to protected species identified in Section 5.3 change.

1.3.1 Action 1 – Rebuilding Plan

This action would establish a rebuilding program for Atlantic herring. Under Alternative 1 (No Action), the Council would not recommend implementing a rebuilding plan. While future specifications for the fishery will be set outside a rebuilding plan, they will use the Council’s existing ABC control rule, implemented via Amendment 8. This control rule adjusts the fishing mortality rate and thus the ACL depending on estimated herring biomass relative to MSY, with lower F at lower biomass values. Under Alternatives 2 and 3, a rebuilding plan would be established. The fishing mortality target for the Alternative 2 rebuilding plan would be consistent with the ABC control rule approved in Amendment 8. Because Alternatives 1 and 2 use the same ABC control rule, fishing mortality rates and the associated ACLs will be the same for Alternatives 1 and 2. ACLs and fishing effort should increase over time under these alternatives as the stock rebuilds. Under Alternative 3, the fishing mortality target for the rebuilding plan, $F_{rebuild}$, would be set at a constant value F=0.48, about 89% of F_{MSY}. While F will be held constant under Alternative 3, the resulting ABC and ACL is expected to increase over time as biomass increases.

As provided in Section 5.3, interactions between ESA-listed species and gear used in the Atlantic herring fishery have never been observed or documented. However, MMPA (non-ESA listed) protected species of marine mammals, specifically minke and humpback whales, as well as species of small cetaceans and pinnipeds, have the potential to interact with fishing gear used in the herring fishery. Interaction risks with protected species are strongly associated with the amount of gear in the water, gear soak or tow time, as well as the area of overlap, either in space or time, of the gear and a protected species (with risk of an interaction increasing with increases in of any or all of these factors). None of the rebuilding plan alternatives are expected to result in elevated effort (e.g., longer tow times, more trawl gear placed in the water and towed); therefore, increased interaction risks with MMPA (non-ESA listed) protected species of marine mammals are not expected. Given this information, under Alternative 1 and Alternative 2, depending on resource condition (strategic versus non-strategic stocks; see Table 20), impacts to MMPA (non-ESA listed) protected species of marine mammals are expected to be slight negative (strategic stocks) to slight positive (non-strategic stocks).

Under Alternative 3, given that effort is expected to increase marginally in the first few years, interaction risks have the potential to slightly increase compared to fishing levels projected under Alternative 1/2. While this may provide some additional risk to MMPA (non-ESA listed) protected species, depending on resource condition (strategic versus non-strategic stocks; see Table 20), impacts to MMPA (non-ESA listed) protected species of marine mammals are still expected to be slight negative (strategic stocks) to moderately positive (non-strategic stocks). In regard to ESA-listed species, impacts, as it relates to interaction risks, are expected to be negligible. Relative to Alternatives 1 and 2, Alternative 3 is expected to result in slight negative impacts to protected species (ESA-listed and/or MMPA protected).

Regarding foraging, under all three rebuilding plan alternatives, herring will continue to be removed from the ecosystem at their present rate. Therefore, impacts to protected species (ESA-listed and/or MMPA protected) are expected to remain negligible (i.e., for those protected species of marine mammals that don't forage on herring) to slight negative impacts (i.e., for protected species that do forage on herring). Under Alternative 3, a slight increase in fishery removals would potentially provide less herring in the ecosystem compared to more status quo levels under Alternatives 1 and 2. As a result, there may be somewhat less forage available for protected species of marine mammals (ESA-listed and/or MMPA protected) that prey on herring (see section 5.3 PR affected Environment). Given this, the foraging impacts to ESA-listed and/or MMPA protected species from Alternative 3 are expected to be negligible (i.e., for protected species that don't forage on herring) to slight negative (i.e., for protected species that do forage on herring).

1.3.2 Action 2 – Adjust Herring Accountability Measures (AMs)

These alternatives could adjust the AMs used in the herring fishery. All alternatives would maintain the current pro-active AMs. Alternative 1 (No Action) would also maintain the current reactive AM, which requires a pound for pound reduction in future ACLs if there are overages in any of the four herring management areas. Alternatives 2 and 3 change when pound for pound payback would be required. Under Alternative 2, if a sub-ACL is exceeded by less than 10%, and the overall ACL is not exceeded, then the overage is not deducted from future allocations. Under Alternative 3, if the sub-ACL is exceeded by any amount, but the overall ACL is not exceeded, then the overage is not deducted from future allocations. Under other conditions, overages are deducted.

In general, reactive AMs do not have a large effect on the amount of effort in the fishery over time. The in-season measures serve to reduce fishing effort as the catch limits are approached, such that quota overages are generally small relative to overall effort. In addition, the nature of reactive AMs means that harvest occurs in one year, but then effort is reduced in subsequent years, meaning that while effort may be temporally redistributed, the amount of fishing activity will be similar, whether AMs were implemented or not. Alternatives 2 and 3, which include some scenarios where payback is not required, could lead to a slight net increase in effort relative to Alternative 1.

Overall, despite possible spatial variations in fishing effort if sub-ACLs are exceeded (under Alternative 2 or 3), changes in total fishing effort are not expected to greatly differ from current operating conditions in the fishery. Interaction risks with protected species are strongly associated with the amount of gear in the water, gear soak or tow time, as well as the area of overlap, either in space or time, of the gear and a protected species (with risk of an interaction increasing with increases in of any or all of these factors). Since none of the alternatives allow fishing to exceed above the total ACL, increased interaction risks with protected species are not expected. Given this information, and the information provided in section 5.3 and Table 42, as it relates to interactions, the impacts of all three rebuilding plan alternatives is expected to result in slight negative to slight positive impacts to MMPA (non-ESA listed) protected species of marine mammals, and negligible impacts to ESA listed species.

In terms of foraging impacts, none of the alternatives have the potential to result in herring catch to exceed the total ACL. Therefore, none of the alternatives will result in the fishery removing herring at levels that go above and beyond current conditions, large changes in the forage availability for those protected species of marine mammals that prey upon Atlantic herring is not expected. Based on this, the impacts of Alternative 1, 2, or 3 on protected species (ESA-listed and MMPA protected), in terms of forage, are expected to be similar to those provided in section 6.3.1 (i.e., ESA listed and/or MMPA protected species: slight negative to slight positive). However, as Alternative 2 would limit overages at 10% of a sub-ACL compared to no limit under Alternative 3, there may be slightly more herring left in a particular herring management area. But the total removal fishery wide would still be limited to the total ACL under all three alternatives. Given this, Alternative 1 or 2 may afford negligible to slightly more positive impacts to ESA-listed and MMPA protected species compared to Alternative 3 if sub-ACLs help limit herring removals within a herring management area where ESA-listed and/or MMPA species forage on herring.

1.4 Impacts on Physical Environment and Essential Fish Habitat

Since 1996, the MSA has included a requirement to evaluate the potential adverse effects of fisheries, including the Atlantic herring fishery, on the essential fish habitat (EFH) of Atlantic herring and other species. A general description of the physical environment and EFH is in the Affected Environment (Section 6.4). The EFH regulations specify that measures to minimize impacts should be enacted when adverse effects that are "more than minimal" and "not temporary in nature" are anticipated.

The magnitude of adverse effects resulting from fishing operations is generally related to (1) the location of fishing effort, because habitat vulnerability is spatially heterogeneous, and (2) the amount of fishing effort, specifically the amount of seabed area swept or bottom time. To the extent that adoption of a management alternative would shift fishing to more vulnerable habitats, and/or increase seabed area swept, adoption would be expected to cause an increase in habitat impacts as compared to no action. If adoption of an alternative is expected to reduce seabed area swept or cause fishing effort to shift away from more vulnerable into less vulnerable habitats, a decrease in habitat impacts would be expected. The magnitude of an increase or decrease in adverse effects relates to the proportion of total fishing effort affected by an alternative.

Bearing in mind that both the direction and magnitude of changes are difficult to predict, because changes in fishing behavior in response to management actions can be difficult to predict, potential shifts in adverse effects are described for each alternative under consideration. However, changes in the magnitude of fishing effort resulting from individual measures should be viewed in the context of the overall impacts that the herring fishery is estimated to have on seabed habitats. Specifically, previous analyses (described below) have concluded that adverse effect to EFH that result from operation of the herring fishery do not exceed the more than minimal or temporary thresholds.

An assessment of the potential effects of the directed Atlantic herring commercial fishery on EFH for Atlantic herring and other federally managed species in the Northeastern U.S. was conducted as part of an EIS that evaluated impacts of the Atlantic herring fishery on EFH (NMFS 2005). This analysis was included in Appendix VI, Volume II of the FEIS for Amendment 1 to the Atlantic Herring FMP. It found that midwater trawls and purse seines do occasionally contact the seafloor and may adversely impact benthic habitats used by federally managed species, including EFH for Atlantic herring eggs. However, after reviewing all the available information, the conclusion was reached that if the quality of EFH is reduced due to this contact, the impacts are minimal and/or temporary and, pursuant to MSA, do not need to be minimized, i.e., that there was no need to take specific action at that time to minimize the adverse effects of the herring fishery on benthic EFH. This conclusion also applied to pelagic EFH for Atlantic herring larvae, juveniles, and adults, and to pelagic EFH for any other federally managed species in the region.

Atlantic herring vessels primarily use purse seines, single midwater trawls or midwater pair trawls, and bottom trawls to direct on herring, with the MWT fleet harvesting most landings since 2008. Bottom trawls are the only gear in this fishery that has adverse impacts on EFH, and those vessels only represented about 4% of total herring landings between 2017 and 2019 and are primarily concentrated in SNE/Area 2 (see Table 27 in Framework 8). There are also smaller scale operations that land herring with bottom trawls under a Category C permit, mostly in the GOM.

1.4.1 Methods

As noted above, fishery effects on EFH are related to the amount and location of fishing activity and the gear types employed. In general herring fishery impacts on EFH are estimated to be minimal. A qualitative approach is used to estimate the potential impacts on the physical environment and EFH across the range of alternatives considered in this action. In general, if more fishing time is expected, there could be potential negative impacts on physical habitats relative to other alternatives considered. For some herring actions, shifts in the types of gear used.

1.4.2 Action 1 – Rebuilding Plan

This action would establish a rebuilding program for Atlantic herring. Under Alternative 1 (No Action), the Council would not recommend implementing a rebuilding plan. While future specifications for the fishery will be set outside a rebuilding plan, they will use the Council's existing ABC control rule, implemented via Amendment 8. This control rule adjusts the fishing mortality rate and thus the ACL depending on estimated herring biomass relative to MSY, with lower F at lower biomass values. Under Alternatives 2 and 3, a rebuilding plan would be established. The fishing mortality target for the Alternative 2 rebuilding plan would be consistent with the ABC control rule approved in Amendment 8. Because Alternatives 1 and 2 use the same ABC control rule, fishing mortality rates and the associated ACLs will be the same for Alternatives 1 and 2. ACLs and fishing effort should increase over time under these alternatives as the stock rebuilds. Under Alternative 3, the fishing mortality target for the rebuilding plan, $F_{rebuild}$, would be set at a constant value F=0.48, about 89% of F_{MSY}. While F will be held constant under Alternative 3, the resulting ABC and ACL is expected to increase over time as biomass increases.

It is important to note that rebuilding trajectories are often uncertain, and depend on factors beyond fishing mortality, including recruitment rates, which are discussed in detail in the target species impacts section. Thus, even though the rebuilding plans specify fishing mortality rates, it is difficult to predict how biomass, annual catch limits, and thus fishing activity will change over time for each alternative. For the purpose of estimating habitat impacts, it is assumed that differences in ACLs will translate to differences in fishing effort. In this fishery, ACLs and effort are likely to track closely, given that quota utilization is high, especially under lower biomass values.

The expected trajectories of F, biomass, and catch limits is different under Alternative 3 as compared to Alternatives 1 and 2, with higher catches and effort in the short term under Alternative 3. However total ABC across the entire ten-year rebuilding period is very similar, whether the A8 control rule or a constant $F_{rebuild}$ approach is selected. Therefore, habitat impacts are expected to be similar across the three alternatives considering the entire rebuilding period in aggregate. While similar aggregate impacts are expected to be similar across alternatives, lower catch limits and fishing effort in a given year will be associated with lower habitat impacts.

Overall, despite possible variations in fishing effort between these options, given the minimal and temporary nature of adverse effects on EFH in the Atlantic herring fishery, these alternatives are expected to have negligible impacts relative to one another on the physical environment and EFH.

1.4.3 Action 2 – Adjust Herring Accountability Measures (AMs)

These alternatives could adjust the AMs used in the herring fishery. All alternatives would maintain the current pro-active AMs. Alternative 1 (No Action) would also maintain the current reactive AM, which requires a pound for pound reduction in future ACLs if there are overages in any of the four herring management areas. Alternatives 2 and 3 change when pound for pound payback would be required. Under Alternative 2, if a sub-ACL is exceeded by less than 10%, and the overall ACL is not exceeded, then the overage is not deducted from future allocations. Under Alternative 3, if the sub-ACL is exceeded by any amount, but the overall ACL is not exceeded, then the overage is not deducted from future allocations. Under other conditions, overages are deducted.

In general, reactive AMs do not have a large effect on the amount of effort in the fishery over time. The in-season measures serve to reduce fishing effort as the catch limits are approached, such that quota overages are generally small relative to overall effort. In addition, the nature of reactive AMs means that harvest occurs in one year, but then effort is reduced in subsequent years, meaning that while effort may be temporally redistributed, the amount of fishing activity will be similar, whether AMs were implemented or not. Alternatives 2 and 3, which include some scenarios where payback is not required, could lead to a slight net increase in effort relative to Alternative 1.

Overall, despite possible variations in fishing effort between these options, given the minimal and temporary nature of adverse effects on EFH in the Atlantic herring fishery, these alternatives are expected to have negligible impacts relative to one another on the physical environment and EFH.

1.5 IMPACTS ON HUMAN COMMUNITIES

The analysis of impacts on human communities characterizes the magnitude and extent of the economic and social impacts likely to result from the alternatives considered, individually and in relation to each other. Management regulations influence the direction and magnitude of economic and social change, but attribution is difficult, because communities are constantly evolving in response to many external factors (e.g., market conditions, technology, alternate uses of waterfront) that contribute to community vulnerability and adaptability to changing regulations.

1.5.1 Methods

Economic impacts. The economic effects of regulations can be categorized by changes in costs (including transactions costs such as search, information, bargaining, and enforcement costs) or revenues (by changing market prices or by changing the quantities supplied). These economic effects may be felt by the directly regulated entities as well as related industries. For the herring fishery, this would include participants in the mackerel and lobster fisheries.

Social impacts. The social effects of regulations relate to changes factors such as demographics, employment fishery dependence, safety, attitudes towards management, equity, cultural values, and the well-being of persons, families, and fishing communities (e.g., Burdge 1998; NMFS 2007).

It is important to consider impacts on the following: the fishing fleet (vessels grouped by fishery, primary gear type, and/or size); vessel owners and employees (captains and crew); dealers and processors;

consumers; community cooperatives; fishing industry associations; cultural components of the community; and fishing families. While some management measures may have a short-term negative impact on some communities, this should be weighed against potential long-term benefits to all communities which can be derived from a sustainable fishery. Amendment 8 further describes approaches to the analysis of impacts on human communities.

General impacts of an Atlantic herring rebuilding plan on human communities

Human communities would be impacted by an Atlantic herring rebuilding plan as it sets harvest levels for the fishery. A rebuilding plan is likely to have long-term economic and social benefits to the fishery by helping to prevent overfishing and optimize yield on a continuous basis. In the long term, ensuring continued, sustainable harvest of fishery resources benefits all fisheries and their communities. However, if catch limits need to be lowered to achieve rebuilding, increasing the ABC (and associated catch limits) would likely have positive short-term impacts on fishing communities. Likewise, lowering allowable harvests could result in short-term revenue reductions, which may, in turn, have negative impacts on employment and the size of the herring fishery within fishing communities. Additionally, declines in fishing earnings may decrease job satisfaction among fishermen (e.g., Pollnac & Poggie 2008; Pollnac et al. 2015), which may reduce the well-being of fishermen, their families, and their communities (e.g., Pollnac, et al. 2015; Smith & Clay 2010).

The specific communities that may be impacted by this action are identified in Section ??? (in Affected Environment). This includes eight primary (e.g., Gloucester, Portland, New Bedford, Rockland) and 16 secondary ports in the Atlantic herring fishery. The communities more involved in the Atlantic herring fishery are likely to experience more direct impacts of this action, though indirect impacts may be experienced across all the identified communities. As this action largely affects stock-wide harvest levels, impacts would likely occur across the communities that participate in the Atlantic herring and other potentially affected fisheries, proportional to their degree of participation in the fisheries.

1.5.2 Action 1 – Rebuilding Plan

The rebuilding plans are projected to produce flow of gross revenues in each year out to ten years in the future. The timing of these is benefits likely to vary across the different rebuilding plans. Because a benefit that occurs sooner is more valuable than a benefit far in the future, it is necessary to discount projected revenues. The Office of Management and Budget mandates that, in such cases, the analysis must discount revenues by 7% and 3% (OMB Circular A-4).Thus, the general approach used in this analysis is to describe the discounted projected revenues under the different rebuilding alternatives and recruitment assumptions. To do this:

1. Landings are assumed to be equal to the projected ABCs described in Section 6.1.[4]
2. Predict prices corresponding to that level of landings using the results of a simple price model.
3. Multiply price by landings to construct revenue.
4. Discount by 7% or 3% per year.
5. Sum up the discounted yearly revenue.

Prices

Annual herring landings and price data from 2003-2020 were used to estimate a relationship between prices and landings. Prices are normalized to 2019 real US dollars using the GDP implicitprice deflator. Prices per metric ton and landings are expressed in thousands of metric tons. The first column of Table 8 contains the model of prices that is used to predict future prices[5]. The landings coefficient implies that, on average, an increase in landings of 1,000 mt will reduce prices by $5.89 per metric ton. Ordinary least squares and a pair of log-transformed models are also estimated as robustness check. The log-landings coefficient from the IV model is an elasticity and implies that an increase in landings of 1% will reduce prices by 0.44%.

Based on the econometric model of prices, predicted prices and revenues are calculated according to:

$$\text{Predicted Price} = 815 - 5.893 * \text{landings} \tag{1}$$

$$\text{Predicted Revenue} = (815 - 5.893 * \text{landings}) * \text{landings} \tag{2}$$

The methods used to model prices are slightly different that those used in Deroba *et al* (2019), in which an autoregressive distributed lag model was used. The authors found that an increase in landings of 1,000 mt will reduce prices by $1.19 per metric ton;alternatively, an increase in landings of 1% will reduce prices by 0.395%. Note that the elasticity[6] estimates in Deroba *et al* (2019) are comparable to elasticities in Table 8.

In Amendment 8, an elasticity of -0.50 was assumed. By coincidence, this assumption turned out to be fairly close to both the estimates in Deroba *et al* (2019) and the elasticities in this analysis (columns 3 or 4 of Table 8).

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[4] Due to the uncertainty buffer, the actual annual catch limit is always less than the ABC. Therefore, the analysis produces revenues that are likely higher than actual.

[5] A least-squares regression will produce biased estimates if prices and quantities are simultaneously determined. An Instrumental Variables (IV) estimator, in which another (instrumental) variable that is correlated with quantities, but not determined simultaneously with prices, can overcome this problem. Landings from the previous year is used as an instrument.

[6] Elasticity here is how price changes in response to changes in landings.

Table 8. Regression results of IV model (shaded) and sensitivity analyses

	IV	Sensitivity Analyses		
		OLS	Log-Log IV	Log-Log
Landings (000 mt)	-5.893*** (0.628)	-5.356*** (0.500)		
Log landings			-0.442*** (0.0706)	-0.465*** (0.0695)
Constant	815.0*** (46.92)	774.6*** (38.79)	7.734*** (0.294)	7.813*** (0.292)
Observations	17	18	17	18
R^2	0.861	0.878	0.751	0.737
Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.001$, *** $p < 0.001$				

The predicted revenue is quadratic relative to landings (Figure 10). According to this model of prices, the maximum revenue is about \$28M, which occurs at landings of about 69,000 mt. Increasing landings beyond this point will decrease gross revenues.

Figure 10. Relationship between landings and predicted revenue

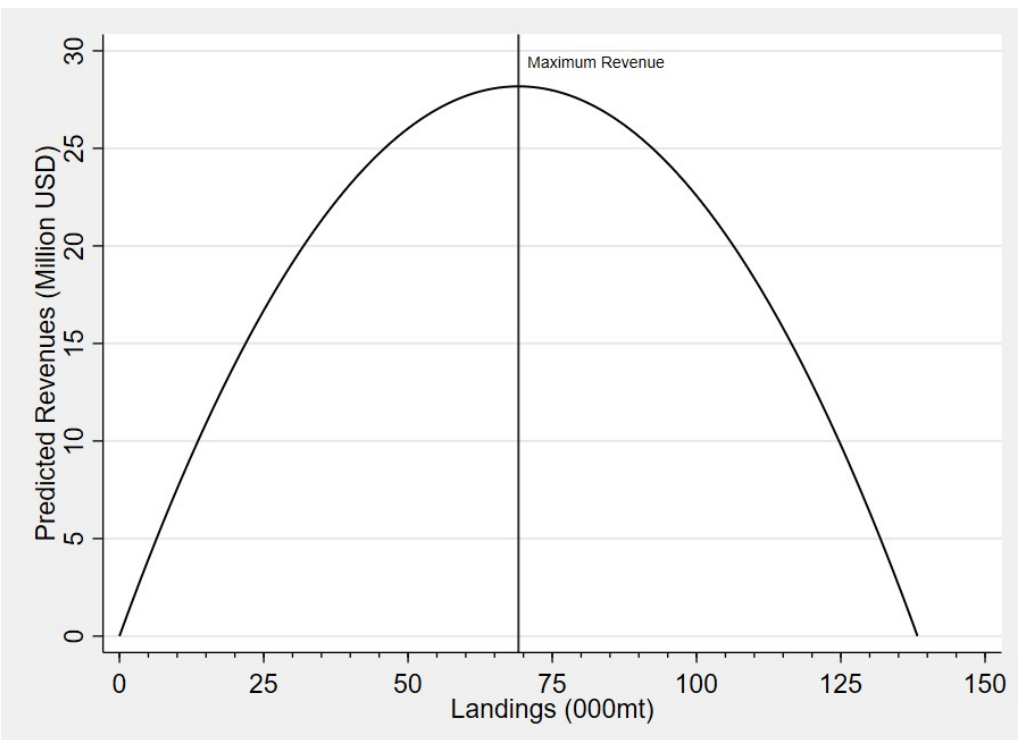
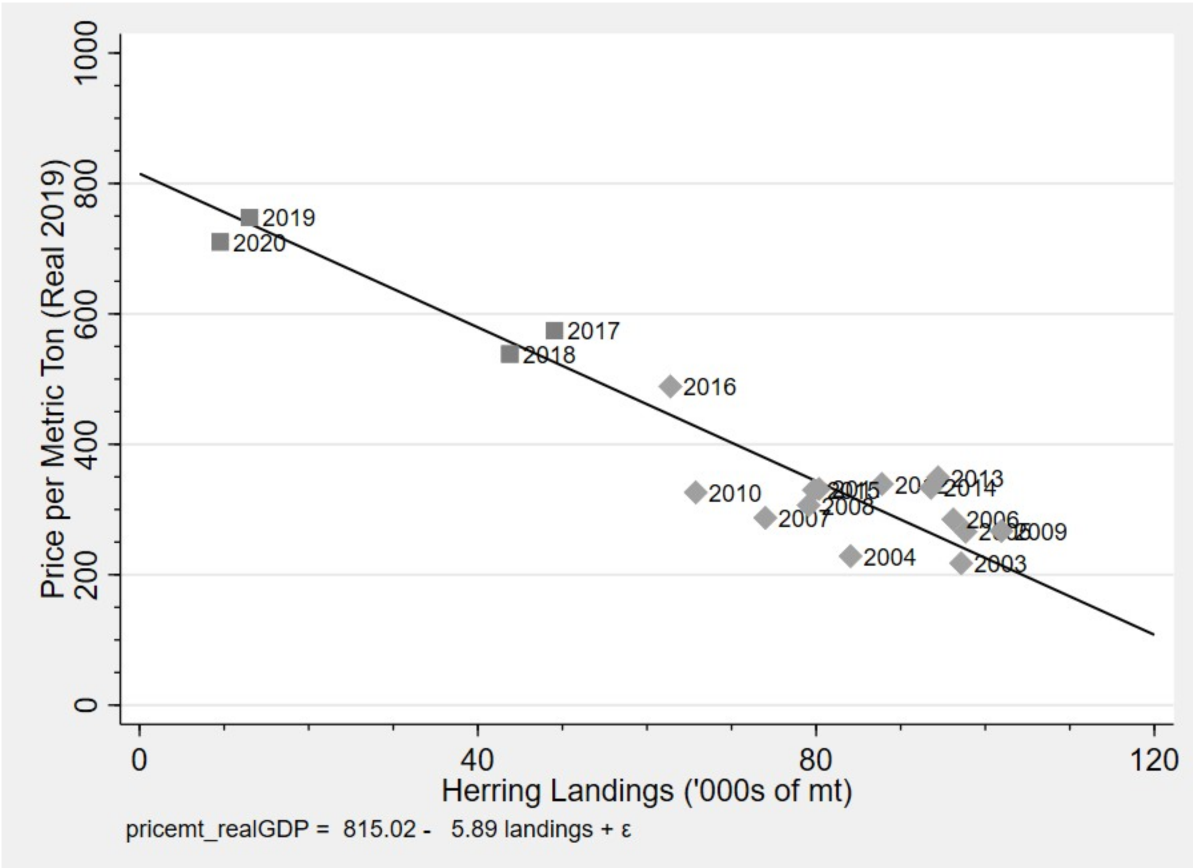


Figure 11 is a scatterplot of real herring prices and landings from 2003-2020, in 1000s of metric tons. A line representing equation 1, which is derived from the first columns of Table 8, is added. Data available after the Amendment 8 analysis are marked with triangles.

Figure 11. Annual herring prices and landings



Results Overview

Table 9 and Table 10 give the discounted gross revenue for Alternative 2 (ABC Control Rule) and Alternative 3 (Constant F). Under baseline recruitment and discounting (upper left cell of both tables), discounted gross revenues are about $16M less for Alternative 2 relative to Alternative 3. Changing the discount rate to 7% reduces the difference to approximately $13M (bottom left cells).

Under autocorrelated recruitment, discounted gross revenues are about $5M less under Alternative 2 relative to Alternative 3. Changing the discount rate to 7%, the difference between the two is still about $5M.

The ABC CR AR in AVG sensitivity analysis uses the same ABCs as derived from the ABC CR AR, so revenues in columns 2 and 3 of Table 9 are the same. The ABC CR AVG in AR sensitivity analysis uses the same ABCs as derived from the ABC CR, so revenues in columns1 and 4 of 2 are the same. The same is true for Table 10.

Table 9. Projected discounted revenues ($M USD) over the 2021-2032 time period using 3% and 7% discount rates for Alternative 2 ABC control rule (shaded) and sensitivity analyses

Discounted Revenue	ABC CR	Sensitivity Analyses		
		ABC CR AR	ABC CR AR in AVG	ABC CR AVG in AR
3%	$213.68	207.87	212.61	213.68
7%	$170.26	163.93	169.32	170.26

Table 10. Projected discounted revenues ($M USD) over the 2021-2032 time period using 3% and 7% discount rates for Alternative 3 Constant F (shaded) and sensitivity analyses

Discounted Revenue	Constant F	Sensitivity Analyses		
		Constant F AR	Constant F AR in AVG	Constant F AVG in AR
3%	228.06	212.61	212.61	223.89
7%	183.49	169.32	169.32	180.57

1.5.2.1 Rebuilding Plan Alternative 1 (No Action)

Under this alternative, the Council would not recommend implementing a rebuilding plan for Atlantic herring.

The impacts of Alternative 1 on human communities would likely be indirect and slight negative. The Council would likely continue to use the ABC control rule set through Amendment 8, but there would be no formal rebuilding plan in place. If fishery specifications do not support rebuilding, there could be continued negative impacts on the herring resource and the industry could not benefit from a rebuilt stock. Since a rebuilding plan is a MSA requirement, due to the overfished status of herring, Alternative 1 may result in distrust in the management process if stakeholders feel that managers are not meeting rebuilding requirements.

A realistic projection of ABCs under Alterative 1 is difficult; it would require projecting how fisheries managers would set ABC without a rebuilding plan. As described in Section 4.1.1, This analysis assumes that the Council would continue to use the ABC control rule to set fishery specifications two years at a time, producing the same set of ABCs as Alternative 2.

Alternative 1 is expected to result in discounted gross revenues of $213.68 M over 2021-2032 (Table 9). Sensitivity analysis regarding the type of recruitment in Figure 13 shows the time series trajectory of (non-discounted) revenues corresponding to the ABC CR. This provides some insight into the yearly projected fishing revenues. The first year in which the Rebuilding F starts (2022) is marked with a vertical dashed line. In all four plots, revenue decreases towards the end of the rebuilding period. This occurs because the ABCs are above the 69,000 mt critical point described in Section 1.5.2. Table 11 summarizes average revenue, by year, for Alternatives 1 and 2 along with the sensitivity analysis.

Alternative 1 would continue the period of substantially reduced catch limits implemented in 2019. The social and economic impacts on herring fishery-related businesses and communities would likely continue to be negative, as the period of reduced revenue would continue. With no change in the ABC from what was already implemented, there would be a degree of constancy and predictability for fishing industry operations and a steady supply to the market. It is possible that the size and demographic characteristics of the fishery-related workforce would remain unchanged, as would the dependence on and participation in the fishery – relative to the conditions currently expected.

Figure 12. Projected revenue at mean ABCs for the four ABC Control Rule Scenarios

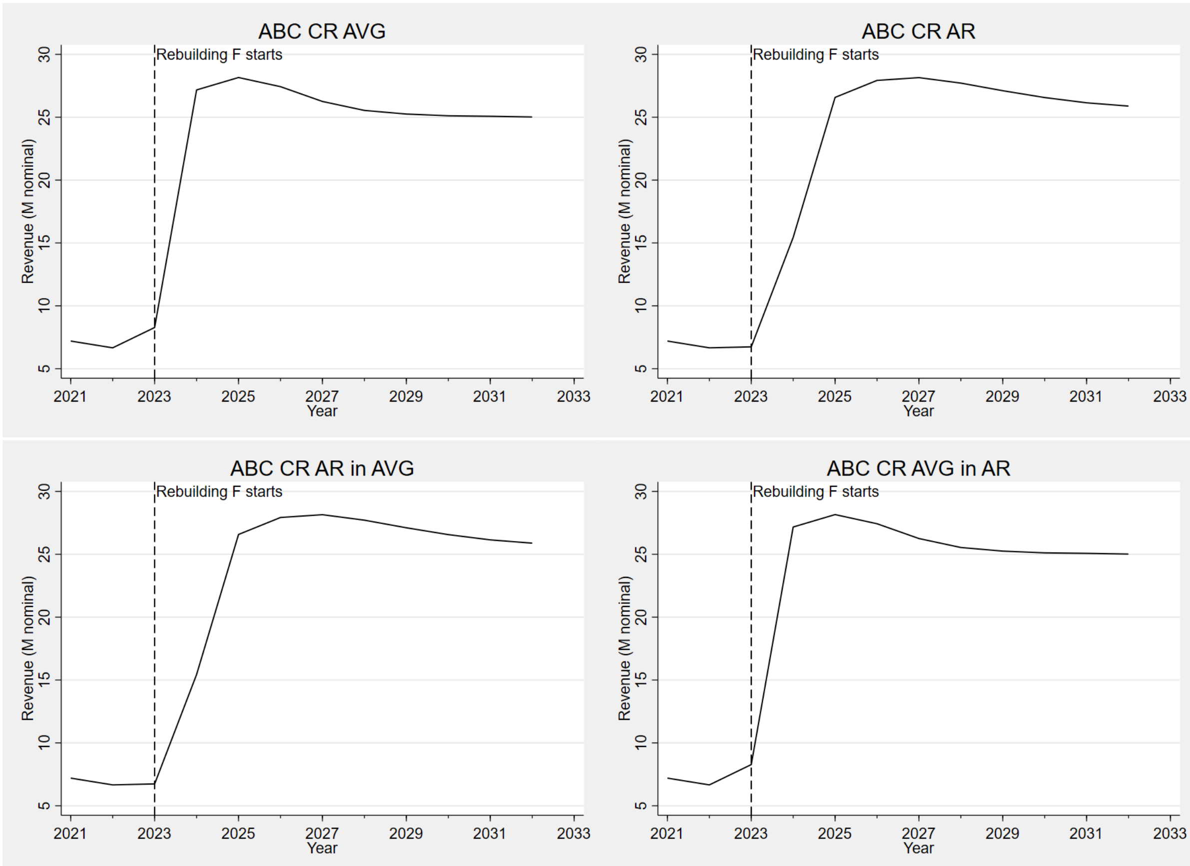


Table 11. Projected annual revenue ($M USD) for Alternatives 1 and 2 under different assumptions

	ABC CR AVG	ABC CR AR	ABC CR AR in AVG	ABC CR AVG in AR
2021	7.20	7.20	7.20	7.20
2022	6.66	6.66	6.66	6.66
2023	8.28	6.74	6.74	8.28
2024	27.17	15.44	15.44	27.17
2025	28.16	26.58	26.58	28.16
2026	27.43	27.93	27.93	27.43
2027	26.25	28.15	28.15	26.25
2028	25.54	27.71	27.71	25.54
2029	25.25	27.11	27.11	25.25
2030	25.12	26.56	26.56	25.12
2031	25.08	26.15	26.15	25.08
2032	25.02	25.89	25.89	25.02

1.5.2.2 Rebuilding Plan Alternative 2 (ABC control rule)

Under this alternative, a rebuilding plan would be established. The fishing mortality target for the rebuilding plan would be consistent with the ABC control rule approved in Amendment 8.

The impacts of Alternative 2 on human communities would likely be indirect and slight negative but slight positive relative to Alternative 1. The Council would continue to use the ABC control rule set through Amendment 8, and it would become the formal rebuilding plan.

However, having a formal rebuilding plan in place is required by MSA when a stock is declared overfished, and it should provide slight positive benefits to the resource by providing a mechanism for the Secretary to ensure that adequate progress toward ending overfishing and rebuilding affected fish stocks is being made. Alternative 2 may result in more trust in the management process if stakeholders feel that managers are meeting rebuilding requirements. Having a rebuilding plan may better ensure that fishery specifications support rebuilding; there could be more positive impacts on the herring resource, and the industry could benefit from a rebuilt stock.

As with Alternative 1, Alternative 2 is likely to result in discounted gross revenues of about $213.68 M over 2021-2032 (Table 10). In all four plots, revenue decreases towards the end of the rebuilding period. This occurs because the ABC are above the 69,000 mt critical point described in Section 6.5.1.1. Table 11 summarizes average revenue, by year, for Alternatives 1 and 2 along with the sensitivity analysis.

Alternative 2 would continue the period of substantially reduced catch limits implemented in 2019. The social and economic impacts on herring fishery-related businesses and communities would likely continue to be negative, as the period of reduced revenue would continue. However, the probability of a fishery closure is low ($p_{closure}$ = 0.000 after 2023, Table 3). With no change in the ABC from what was already implemented, there would be a degree of constancy and predictability for fishing industry operations and a steady supply to the market. It is possible that the size and demographic characteristics of the fishery-related workforce would remain unchanged, as would the dependence on and participation in the fishery – relative to the conditions currently expected.

1.5.2.3 Rebuilding Plan Alternative 3 (7year constant)

Under this alternative, a rebuilding plan would be established. The fishing mortality target of the rebuilding plan would be constant, $F_{rebuild}$ would be set at F=0.48, about 89% of F_{MSY}.

The impacts of Alternative 3 on human communities would likely be indirect and slight negative but slight positive relative to Alternatives 1 and 2. Having a formal rebuilding plan in place is required by MSA when a stock is declared overfished. Alternative 3 may result in more trust in the management process relative to No Action if stakeholders feel that managers are meeting rebuilding requirements. Having a rebuilding plan may better ensure that fishery specifications support rebuilding; there could be more positive impacts on the herring resource, and the industry could benefit from a rebuilt stock. As the $F_{rebuild}$ under Alternative 3 is higher than under the ABC CR in place (under Alternatives 1 and 2), there may be more positive impacts to the herring fishery as catch limits would be set higher, at least in the near term. However, the overfishing probability is slightly higher under Alternative 3, and it could take longer to rebuild relative to applying the ABC control rule (Figure 3), so any long-term gains to the fishery of this approach may be tempered if rebuilding is hindered.

Alternative 3 is likely to result in discounted gross revenues of about $228M over 2020-2032; this is $15M higher than under Alternatives 1 and 2. The timing of revenues under Alternative 3 is different than Alternatives 1 and 2; ABC, and therefore revenues, are higher earlier in the rebuilding plan. In particular, gross revenues in 2023 are projected to be $23M, which is about $15M higher than gross revenues under Alternatives 1 and 2 in the same year.

Figure 15 shows the time series trajectory of (non-discounted) revenues corresponding to the 7-year constant F rebuilding plan. This provides some insight into the yearly projected fishing revenues and uncertainty about those projections. The first year the rebuilding plan (2022) is marked with a vertical dashed line. In all four plots, revenue decreases towards the end of the rebuilding period. This occurs because the ABC are above the 69,000 mt critical point described in Section 6.5.1.1. Table 12 summarizes average revenue, by year, for Alternative 3 along with the sensitivity analysis.

As with Alternative 2, Alternative 3 would continue the period of substantially reduced catch limits implemented in 2019 (though slightly higher than under Alternative 2). The social and economic impacts on herring fishery-related businesses and communities would likely continue to be negative, as the period of reduced revenue would continue. The probability of a fishery closure is low, slightly higher than under Alternative 2 in the early years of rebuilding, but $p_{closure}$ is 0.000 after 2023 (Table 5) like Alternative 2. With little change in the ABC from what may be implemented under No Action or Alternative 2, there would be a degree of constancy and predictability for fishing industry operations and a steady supply to the market. It is possible that the size and demographic characteristics of the fishery-related workforce would remain unchanged, as would the dependence on and participation in the fishery – relative to the conditions currently expected.

Figure 13. Projected revenue at mean ABCs for the constant catch scenarios

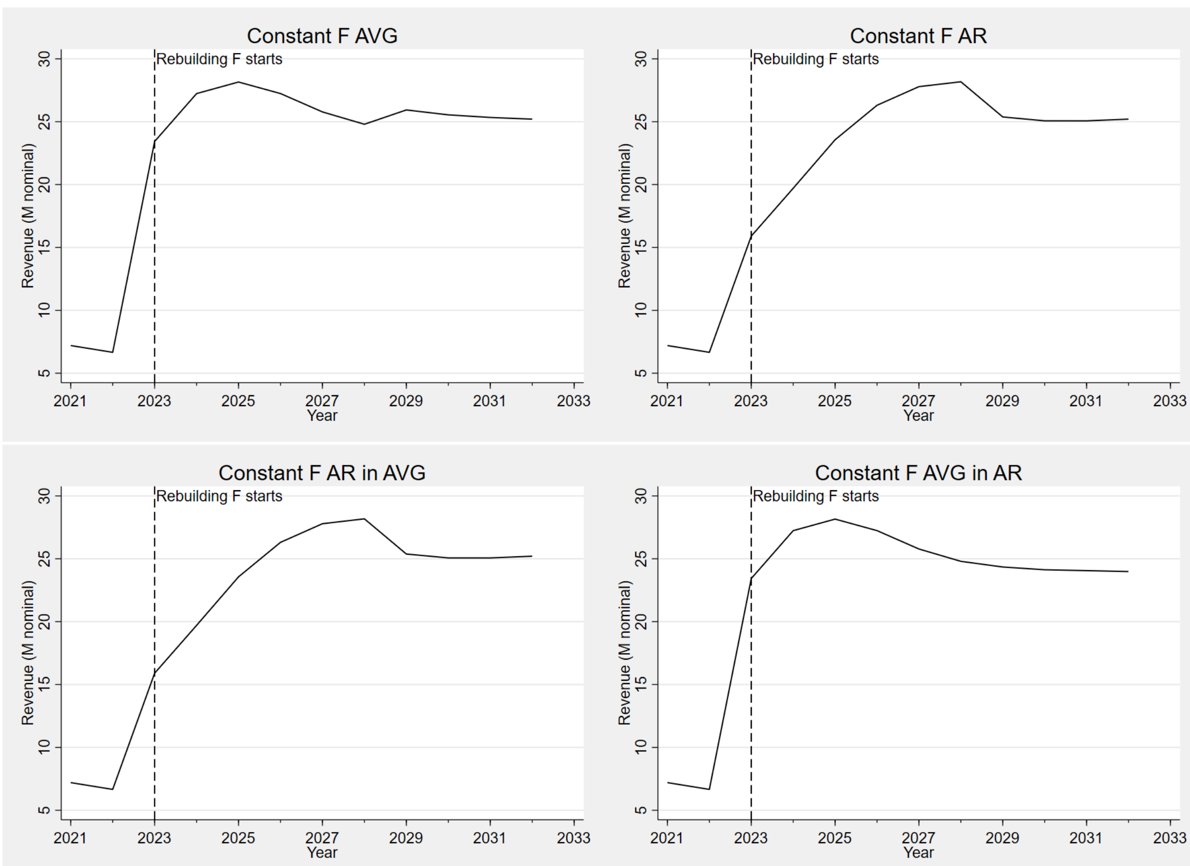


Table 12. Projected annual revenue ($M USD) for Alternative 3 under different assumptions

	Constant F AVG	Constant F AR	Constant F AR in AVG	Constant F AVG in AR
2021	7.20	7.20	7.20	7.20
2022	6.66	6.66	6.66	6.66
2023	23.43	15.90	15.90	23.43
2024	27.24	19.71	19.71	27.24
2025	28.16	23.56	23.56	28.16
2026	27.24	26.31	26.31	27.24
2027	25.78	27.79	27.79	25.78
2028	24.80	28.18	28.18	24.80
2029	25.94	25.38	25.38	24.35
2030	25.55	25.07	25.07	24.13
2031	25.34	25.07	25.07	24.06
2032	25.20	25.21	25.21	23.98

1.5.3 Action 2 – Adjust Herring Accountability Measures (AMs)

Since 2009, there have been 11 overages of a sub-ACL, although only three have occurred in the last five years (Table 13). Improvements to the quota monitoring system over time are making overages less likely. In these years, the total ACL was never exceeded. Current low sub-ACLs for all areas (relative to the fleet's daily ability to catch herring) make in-season quota management that is designed to achieve, but not exceed a sub-ACL, logistically difficult and more difficult to predict which, if any, sub-ACLs might be exceeded.

Table 13. Sub-ACL overages since 2009

Year	Area	sub-ACL (mt)	Catch (mt)	Overage (%)
2009	1A	43,650	44,088	1%
2010	1A	26,546	28,424	7%
	1B	4,362	6,001	38%
2011	1A	29,251	30,676	5%
2012	1B	2,723	4,307	58%
	2	22,146	22,482	2%
	3	38,146	39,471	3%
2014	1B	2,878	4,399	53%
2016	1B	2,844	3,657	29%
2019	2	4,061	4,758	17%
2020	1B	483	831	72%

The general approach to examining the economic impacts of these alternatives is to compute the change in revenues that would have been caused by the overage deductions over the last five years. In 2020, herring prices were about $710/mt (real 2019 USD); this is used to compute revenue. For the three overages that occurred from 2016-2020, the total overages were 1,858 mt.

Under the *status quo,* the 1,858 mt of overages are deducted from a future catch limit. Therefore, the overages reduce fishery revenue by $1.3M. Because overages do not occur every year, annual foregone revenues of about $264,000 per year are expected. This is the baseline against which the alternatives are measured against. Note that future losses described in theses alternatives would be somewhat offset by any gain in the year of an overages, a value that is assumed to be equivalent across the alternatives, so not quantified further here.

1.5.3.1 Overage AM Alternative 1 (No Action)

Under this alternative, there would be no changes to the proactive (in-season) or reactive AMs in place to minimize overages of Atlantic herring catch limits. These include in-season reduced possession limits that limit the directed herring fishery as well as reactive pound for pound AMs to address any overages. This action is not considering modifications to the in-season proactive AMs; therefore, the focus of these analyses is on the reactive, pound for pound payback AM to address overages.

The social and economic impacts of Alternative 1 on herring fishery-related businesses and communities would likely be neutral. Alternative 1 is the status quo. Therefore, the expected annual foregone revenues are $264,000 per year. The change relative to the *status quo* is zero.

In the short term, the impacts of the No Action reactive AM would likely be neutral to slight negative. The reactive AMs (for sub-ACL or ACL overages) are enforced in the year after the final catch is tallied, typically resulting in a one-year delay of consequences, given the timing of the fishery. Participants in the fishery during a year in which a sub-ACL/the ACLs is exceeded will benefit from those higher levels of catch. When the AM is implemented in a future year, active participants will experience a reduction in potential herring landings and therefore may suffer negative impacts. However, impacts would be nullified over the three-year process for vessels fishing in all years. The delay could cause an economic consequence for any fishery participants who are new or were not fishing during the year of the overage, resulting in slight negative impacts on the attitudes and beliefs among these participants if management is perceived to be unfair. However, due to the limited access nature of the fishery, the number of potential new participants is small. Because Alternative 1 would reduce a future ACL even if the ACL was not exceeded, the fishery is prevented from achieving optimum yield on a continual basis, resulting in negative impacts to the fishery.

In the long term, impacts would be slight positive. The AMs are designed to keep harvests within catch limits, which will help secure the long-term sustainability of the resources and the fishery and other user groups that depend on herring. Ensuring continued, sustainable harvest of fishery resources benefits all fisheries and their communities.

1.5.3.2 Overage AM Alternative 2

Under this alternative, catch from a management area that exceeds its sub-ACL by less than 10% would not be deducted from the ACL and respective sub-ACL in a subsequent year unless total catch also exceeds the total ACL.

The social and economic impacts of Alternative 2 on herring fishery-related businesses and communities would likely be slight positive and more positive than No Action. If Alternative 2 had been in place over 2016-2020, the three overages would have resulted in reduction of 1,120 mt to future catch limits. This would have reduced fishery revenue by $0.8M or $160,000 per year. Therefore, under Alternative 2, the foregone revenue is $160,000 per year. Relative to the *status quo*, about $104,000 in additional revenue per year to accrue to the fishery under Alternative 2 relative to Alternative 1.

The short-term impacts of Alternative 2 would likely be slight positive and more positive than No Action. The fishery could exceed a sub-ACL in a herring management area (by <10%) without having a reduction in potential herring landings in a future year (unless the ACL was exceeded). This flexibility could be particularly used in Area 1B where sub-ACLs are often quite small relative to the capacity of vessels to catch herring. Positive impacts that are likely to accrue to those users of areas that have gone over the ACLs. If a sub-ACL overage is <10%, there would not be economic consequences for any fishery participants who are new or were not fishing during the year of the overage, so management could be perceived to be fairer relative to No Action. Because Alternative 2 would not automatically reduce a future ACL unless the ACL was exceeded, optimum yield would more likely be achieved on a continual basis relative to No Action, resulting in more positive impacts to the fishery. Catch monitoring and in-season closures to the directed fishery would still be in place; this should limit the magnitude of any sub-ACL overages.

In the long term, impacts would likely be slight positive but slightly less positive than No Action. The AMs are designed to keep harvests within overall catch limits, which will help secure the long-term sustainability of the resources and the fishery and other user groups that depend on herring. This alternative could allow one sub-area to be fished harder than the target catch limit for that sub-component; however, the potential for causing negative harm to any sub-component of the herring resource is small since overages are limited to 10%. Ensuring continued, sustainable harvest of fishery resources benefits all fisheries and their communities.

1.5.3.3 Overage AM Alternative 3

Under this alternative, catch from a management area that exceeds its sub-ACL would be deducted from the ACL and respective sub-ACL in a subsequent year, only if total catch also exceeded the total ACL. Catch can exceed a sub-ACL by any amount so long as the total ACL is not exceeded.

The social and economic impacts of Alternative 3 on herring-related fisheries and communities would likely be slight positive and more positive than No Action and Alternative 2.

If Alternative 3 had been in place over 2016-2020, the three overages would have resulted in no reductions to future catch limits. Therefore, under Alternative 3, the foregone revenue is $0 per year. Relative to the status quo, about $264,000 in additional revenue per year, is likely to accrue to the fishery under Alternative 3. Note that catch monitoring and in-season closures to the directed fishery would still be in place; this limits the magnitude of any overages of sub-ACLs.

The short-term impacts would likely be slight positive and more positive than No Action and Alternative 2. The fishery could exceed a sub-ACL in a herring management area (by any amount) without having a reduction in potential herring landings in a future year (unless the ACL was exceeded). This could be particularly used in Area 1B where sub-ACLs are often quite small relative to the capacity of vessels to catch herring. As with Alternative 2, positive impacts that are likely to accrue to users of areas that have gone over the ACLs. No matter the sub-ACL overage, there would not be economic consequences for any fishery participants who are new or were not fishing during the year of the overage, so management could be perceived to be fairer relative to No Action and Alternative 2. Because Alternative 3 would not automatically reduce a future ACL unless the ACL was exceeded (like Alternative 2), optimum yield would more likely be achieved on a continual basis relative to No Action, resulting in more positive impacts to the fishery.

While catch monitoring and in-season closures to the directed fishery would still be in place should limit the magnitude of any sub-ACL overages, Alternative 3 provides less incentive for the fishery to prevent sub-ACL overages than Alternative 2 (or No Action). Thus, there may be higher risk of negative distributional impacts within the fishery if fishing in an area is less restrained early in the year, leading to an area or fishery-wide closure earlier in the year, precluding fishing by other participants that tend to fish later or in other areas. For example, small-mesh bottom trawl vessels tend to fish in Area 2 late in the year. An early closure from fishing by other vessels may preclude their access to the area. Under low total quotas, these risks may be higher than under larger quotas. Thus, the more positive impacts to the fishery of Alternative 3 than Alternative 2 are tempered by the higher risk of negative distributional impacts.

In the long term, impacts would likely be less certain and potentially slight negative relative to No Action and Alternative 2. The AMs are designed to keep harvests within overall catch limits, which will help secure the long-term sustainability of the resources and the fishery and other user groups that depend on herring. However, there is greater potential for causing negative harm to a sub-component of the herring resource relative to the other alternatives if the sub-ACL in a management area is consistently exceeded by a substantial amount. Doing so may jeopardize the continued, sustainable harvest of fishery resources and benefits accrued to fisheries and their communities.

1.6 CUMULATIVE EFFECTS ANALYSIS

To be completed after the final preferred alternatives are selected.

2.0 REFERENCES

Burdge RJ. (1998). *A Conceptual Approach to Social Impact Assessment*. Revised ed. Madison, WI: Social Ecology Press. 284 p.

Carr HA & Milliken HO. (1998). Conservation engineering: options to minimize fishing's impacts to the sea floor. In: *Effects of Fishing Gear on the Sea Floor of New England*. Boston, MA: MIT Sea Grant. p. 100-103.

Deroba JJ, Gaichas SK, Lee M-Y, Feeney RG, Boelke DV & Irwin BJ. (2019). The dream and the reality: meeting decision-making time frames while incorporating ecosystem and economic models into management strategy evaluation. *Canadian Journal of Fisheries and Aquatic Sciences. 76*(7): 1112-1133.

EDF. Environmental Defense Fund Catch Share Design Center: Environmental Defense Fund; http://catchshares.edf.org.

Field J. (2003). *Social Capital*. London and New York: Routledge p.

Frank K & Brickman D. (2000). Allee effects and compensatory population dynamics within a stock complex. *Canadian Journal of Fisheries and Aquatic Sciences. 57*: 513-517.

Lovgren, J. et al. vs. Locke, G. et al. (2012). United States Court of Appeals for the First Circuit. 11-1952.

McCay BJ. (2003). Sea Changes in Marine Fisheries Policy: Contributions from Anthropology. Paper presented at: Proceedings of the Third World Fisheries Congress: Feeding the World with Fish in the Next Millennium – The Balance Between Production and Environment, Beijing, 2000.

NEFMC. (2018). Framework Adjustment 57 to the Northeast Multispecies Fishery Management Plan. Newburyport, MA: New England Fishery Management Council in consultation with the National Marine Fisheries Service. 381 p.

NEFSC. (2020). Atlantic Herring 2020 Assessment Update Report. Woods Hole, MA: U.S. Department of Commerce. 9 p. https://www.fisheries.noaa.gov/event/peer-review-june-2020-management-track-assessments.

NMFS. (2007). Guidelines for the Assessment of the Social Impact of Fishery Management Actions. In: NOAA/NMFS Council Operational Guidelines - Fishery Management Process. Silver Spring, MD: National Oceanic and Atmospheric Administration. NMFSI 01-111-02. 39 p.

Pera¨la¨ T & Kuparinen A. (2017). Detection of Allee effects in marine fishes: analytical biases generated by data availability and model selection. *Proceedings of the Royal Society B,. 284*: 20171284.

Pollnac RB & Poggie JJ. (2008). Happiness, well-being and psychocultural adaptation to the stresses associated with marine fishing. *Human Ecology Review. 15*(2): 194-200.

Pollnac RB, Seara T & Colburn LL. (2015). Aspects of Fishery Management, Job Satisfaction, and Well-Being among Commercial Fishermen in the Northeast Region of the United States. *Society and Natural Resources. 28*(1): 75-92.

Saha B, Bhowmick AR, Chattopadhyay J & Bhattacharya S. (2013). On the evidence of an Allee effect in herring populations and consequences for population survival: A model-based study. *Ecological Modelling. 250*: 72-80.

Sau A, Saha B & Bhattacharya S. (2020). An extended stochastic Allee model with harvesting and the risk of extinction of the herring population. *Journal of Theoretical Biology. 503*: 110375.

Sherman K, Jaworski NA & Smayda TJ eds. (1996). *The Northeastern Shelf Ecosystem - Assessment, Sustainability, and Management*. Cambridge, MA: Blackwell Science. 564 p.

Smith CL & Clay PM. (2010). Measuring subjective and objective well-being: analyses from five marine commercial fisheries. *Human Organization. 62*(2): 158-168.

From PDT memo:

Goodyear, C.P. 1995. Red snapper in U.S. waters of the Gulf of Mexico. NMFS/SEFSC Contribution MIA-95/96-05.

Munch SB, Giron-Nava A, Sugihara G. (2018). *Nonlinear dynamics and noise in fisheries recruitment: A global meta-analysis*. Fish Fish. 1–10. https://doi.org/10.1111/faf.12304

Northeast Fisheries Science Center (NEFSC). 2018. 65th Northeast Regional Stock Assessment Workshop (65th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 18-11; 659 p. Available from: http://www.nefsc.noaa.gov/publications/

Thomspon et al. 1998. Technical Guidance On the Use of Precautionary Approaches to Implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS–F/SPO–31.