Evaluation of directed commercial fishery size limits in 2020

PREPARED BY: IPHC SECRETARIAT (I. STEWART, A. HICKS, & B. HUTNICZAK; 15 DECEMBER 2020)

PURPOSE

To provide the Commission with an evaluation of directed commercial fishery size limits in response to the discussion and request from AM096:

AM096 (para. 157):

> *"The Commission **NOTED** the stakeholder questions regarding the current minimum size limit applied to the directed commercial Pacific halibut fishery. In light of the newly available sex-ratio information from the directed commercial fishery, the Commission identified the need for a better understanding of the effects of the minimum size limit on available fishery yield and potential changes from previous analyses. Further, investigation of the use of a maximum size limit has also been a topic on ongoing discussion."*

AM096–Req.08 (para. 158):

> *"The Commission **REQUESTED** that the IPHC Secretariat prepare an updated discussion of the costs and benefits of removing or adjusting the current minimum size limit and/or adding a maximum size limit. This analysis would be presented during the 2020 Work Meeting and IM096."*

SUMMARY

Since 1973, the International Pacific Halibut Commission (IPHC) has restricted the directed commercial fishery for Pacific halibut (*Hippoglossus stenolepis*) with a 32 inch (81.3 cm) Minimum Size Limit (MinSL). We find that in 2020 the MinSL reduced fishery landed yield by 7% at the Spawning Potential Ratio (SPR) projected for the adopted catch limits ($F_{42\%}$; Table 1). This loss in potential yield is due to a projected 0.80 million net pounds (~363 mt) of discard as well as increased harvest of fish larger than would provide the peak yields under current estimated size-at-age and sex-ratios. If the relative price for Pacific halibut less than 32" (U32) is at least 63% of the price of current catch of fish larger than 32" (O32), then the fishery as a whole is projected to achieve equal or increased value if the MinSL is removed. Additional benefits of removing the MinSL include a projected 18% increase in fishery efficiency (landings relative to total catch), improved data on total catch through port sampling, assuming full retention of all legal catch is retained in regulation, and improved public perception of the fishery.

Introduction of a Maximum Size Limit (MaxSL; a regulation prohibiting the retention of all fish larger than a specified length) is projected to result in little net change to fishery yield based on evaluation of a 60 inch (152 cm) MaxSL in place for 2020. However, a MaxSL would create a new (and largely unobserved) source of mortality through discarding of large female Pacific halibut: approximately 0.12 million pounds (~54 mt) at the 2020 adopted mortality limits (based on a 16% discard mortality rate). This discard mortality would be approximately offset by increased yield due to a higher fraction of males in the retained catch and average size closer to the peak yields under current size-at-age. If the relative price of fish larger than 60" (O60) remains slightly lower than the average for fish less than 60" (U60), then the average fish size in the landings is projected to result in no change in aggregate fishery value. Introduction of a MaxSL would provide an increase in the proportion of the Spawning Biomass (SB) comprised of large female Pacific halibut, and increased opportunity to encounter these fish in recreational fisheries in some IPHC Regulatory Areas (e.g. IPHC Regulatory Area 2C). The change in age composition of the SB will depend on future spatial and overall patterns of stock productivity and fishery management. It is unlikely, given the data available at this time on stock-recruitment,

fecundity, and maternal effects, that a MaxSL would increase recruitment. A 60” MaxSL would reduce fishery efficiency by approximately 3%, and also reduce the data quality on fish in the total vs. landed commercial fishery catch.

The effects of removing the MinSL or implementing a MaxSL are not estimated to be uniformly distributed among Biological Regions, IPHC Regulatory Areas, or fishing grounds within Areas. In some places, there is little projected change (e.g., removing the MinSL in IPHC Regulatory Area 2C, or implementing a MaxSL in Area 2A), and in others fishery efficiency and composition of the landings would differ importantly (removing the MinSL in Regulatory Area 3B and 4A). This analysis focuses on short-term effects; long-term changes in stock and fishery distribution and productivity would be best addressed through the Management Strategy Evaluation (MSE) process.

Table 1. Evaluation summary of removal of the current minimum size limit (MinSL) and/or addition of a maximum size limit (MaxSL) of 60” (152 cm) in 2020 relative to the *status quo*.

	Management action	
Response	Remove MinSL	Add MaxSL = 60”
Fishery yield	7% increase	No change
Fishery value	Increased if U32 price >= 63% of O32 price	No change
Discard mortality	Decreased by 0.80 million pounds	Increased by 0.12 million pounds, may increase further over time
Fishery efficiency (landings/catch)	18% increase	3% decrease
Data on total fishery catch and biology	Improved	Degraded
Recreational encounters with large fish	No change	Increased
Abundance/biomass of old females	No change	Increased
Average projected recruitment	No change	No change

BACKGROUND/INTRODUCTION

The IPHC introduced the first MinSL for the directed commercial Pacific halibut fishery in 1940 (Myhre 1973). The 5 pound (2.27 kg) limit was based on “dressed” weight (gilled and gutted), and was converted to length (26”; 66 cm) in 1944 in order to facilitate easier compliance. Due to increases in size-at-age, the quantity of small fish encountered and discarded by the fishery during this time period was likely low and declining from the 1940s through the 1970s, based on contemporary reports (Myhre 1974), and historical age composition data (Stewart and Webster 2020). In 1973, the MinSL was revised to 32” (81.3 cm; Myhre 1973). Yield-Per-Recruit (YPR) analysis in the 1960s indicated that the age of entry to the fishery was near optimal under equilibrium conditions based on the landed catch from the 26” MinSL (IPHC 1960), and very large size at age in the 1970s (relative to the historical record) was not likely resulting in substantial amounts of discard mortality (fish that are captured, discarded, and subsequently die). Therefore, discard mortality was not identified as a significant concern at that time.

After an apparent peak in the late 1970s, Pacific halibut size-at-age declined through approximately 2010, and has been relatively stable since, although trends differ among Biological Regions (Stewart and Webster 2020). The largest declines in size-at-age have been observed in the Gulf of Alaska (GOA), which also represents the geographical and demographic center of the stock. During this period of changing size-at-age, there have been many analyses evaluating the effects of the MinSL on the Pacific halibut stock and fishery. Myhre (1974) found that a 32” (81.3 cm) MinSL was ‘optimal’ (with regard to fishery yield and value of fish sales) only under the lowest discard mortality rates, and that discard mortality rates above 25% would favor a 29.5” (75 cm) or lower MinSL. Clark and Parma (1995) also used equilibrium methods (YPR and Spawning Biomass Per Recruit, SBPR) to evaluate the MinSL based on sampled landings in 1990-91. Their analysis found that the 32” MinSL was near optimal, but noted that revised analysis was already underway due to observations in the early 1990s of continued decline in size-at-age (and that removing the MinSL in IPHC Regulatory Area 2B would result in no loss in YPR). Parma (1999) provided an update to previous analyses, with similar conclusions: small gains in YPR would occur under smaller MinSLs, but these were slightly offset by losses in SBPR suggesting that retaining the 32” MinSL was still optimal.

Valero and Hare (2012) used a broader suite of analyses, including female maturity-at-age, YPR, SBPR, and a migratory model to evaluate the MinSL. They found that YPR and SBPR would both decrease with greatly reduced size-limits under the assumption that the fishery selectivity would resemble that of the IPHC’s Fishery-Independent Setline Survey (FISS). Small reductions (3-12 cm) in the MinSL were found to have a slight positive effect on YPR (<=3%; partially due to increasing the proportion of males in the landings by <10%). Larger reductions in the MinSL were found to reduce both YPR and SBPR. The migratory analysis was the first to clearly identify differential effects of the MinSL among the IPHC Regulatory Areas. Their analysis was based on the Spawning Biomass Per Recruit ratio ($SBPR_{ratio}$); however, their calculation of $SBPR_{ratio}$ used long-term average conditions rather than current size-at-age and selectivity. They identified the precautionary nature of retaining the MinSL, and potential risks to spawning biomass of eliminating it.

The next MinSL analysis occurred in 2014-15 (Martell et al. 2015a; Martell et al. 2015b; presented at AM091), in response to a Commission request to evaluate reducing the MinSL from 32” to 30”. That analysis used equilibrium methods to compare Maximum Sustainable Yield (MSY; adjusting the fishing intensity to produce the largest long term-average landed catch) under alternative MinSLs. Fishery yield and efficiency was found to be increased for all reductions in the MinSL down to 26” (the smallest evaluated). However, reducing the MinSL below 30” was found to result in a slight loss in total fishery value due to the reduced price assumed for smaller fish. That study also identified fishery selectivity, discard mortality rates, and bycatch in non-directed commercial fisheries as important contributors to the optimal level of fishing intensity and overall fishery yield.

The IPHC Secretariat most recently evaluated the MinSL in 2018 (IPHC-2018-AM094-14). That analysis found that discard mortality in the directed commercial fishery was an important component of the total, leading to foregone yield, as well as reduced fishery efficiency. Specifically, that study determined that 4% more commercial fishery landings could be achieved at the same level of fishing intensity if the 32” MinSL was removed; a result that was relatively insensitive to potential shifts in fishery selectivity toward targeting of smaller fish (Stewart and Hicks 2018). However, U32 Pacific halibut comprised approximately 25% of the projected commercial landings in the absence of a MinSL. Considerable discussion of potential low prices for these smaller fish led to concern that the fishery as a whole could lose value, even at a slightly higher biological yield. That analysis found no compelling evidence that the current minimum size limit was providing protection of the spawning biomass given slow growth, late maturity, and considerable fishery mortality on juvenile female Pacific halibut, and noted that under the

Commission's interim management procedure using a constant SPR ensured that the lifetime reproductive output was maintained regardless of the demographics of the sources of mortality.

The trend among historical studies has been toward decreasing support for the current MinSL as size-at-age declined and other factors such as discard mortality and fishery efficiency have become more routinely included in annual considerations. A fully re-evaluated and reviewed stock assessment for 2019 (Stewart and Hicks 2020), as well as newly available direct estimates of the sex-ratio of the commercial landings (Stewart and Webster 2020), have led to renewed interest in the topic of size-limits, both the current MinSL and the potential utility of a MaxSL. This document provides a response to the requests from AM096, extending historical analyses with new information and providing a basis for developing short-term IPHC policy on size limits and/or structuring future investigation through the MSE process.

METHODS

This analysis is divided into four components, each utilizing differing data and methods:

1) A description of the data on discard mortality and age-structure of discards associated with the current MinSL.
2) A description of data on encounter rates and age-structure of large Pacific halibut that could be included in a potential MaxSL.
3) An evaluation of removing the MinSL using the 2019 stock assessment models as a tool to simultaneously evaluate the effects of shifting sex-ratio, age composition of the catch (landings plus discards), and allocation among IPHC Regulatory Areas on the available yield.
4) A similar evaluation using the 2019 stock assessment to explore the effects of one potential MaxSL (60", 152 cm).

Data relevant to the current MinSL

Discard mortality in the directed commercial fishery is estimated each year using a combination of fishery-dependent and fishery-independent information along with historically estimated discard mortality rates (Stewart and Webster 2020). Specifically, U32 encounter rates by IPHC Regulatory Area observed during FISS sampling are used to provide an estimate of likely U32 encounter rates in the directed commercial fishery. The exception to this method occurs in IPHC Regulatory Area 2B, where logbooks are required to include U32 discards (in numbers of Pacific halibut) and therefore a direct estimate is available. The average encounter rate for each IPHC Regulatory Area is applied to the total landings (to account for landings that lack a corresponding logbook records) to generate an estimate of total discarded U32 Pacific halibut. A discard mortality rate of 16% (25% in IPHC Regulatory Area 2A where the fishery operates under 'derby' conditions) is applied to total discards to generate an estimate of discard mortality (Stewart and Webster 2020). Finally, sex-specific age distributions were summarized from 2019 FISS catches in order to better understand the biological properties of U32 Pacific halibut.

Data relevant to a MaxSL

A similar approach was taken to summarize large Pacific halibut encountered by the recent (2017-2019) directed commercial fishery (and subsequently sampled as part of the landings). For a range of large sizes (55-70"; 140-178 cm) the average individual fish weight, average age (and distribution of ages), percent female (by weight) and percent of the landings comprising fish larger than the specified size was summarized. For the commercial fishery, weights were derived from measured individual fish sampled by IPHC field staff. Sex-specific information was only available for 2017-2018.

For comparison with fishery observations, the percent of FISS catches comprising the same large fish sizes was also summarized; however, this summary relied on predicted weights derived from the general length-weight relationship (Stewart and Webster 2020), as sampled weights were only available for individual fish captured in 2019 (Erikson 2020).

Removing the MinSL

In order to evaluate the MinSL, the 2019 stock assessment ensemble (including all updated sex-ratio information) was used to compare key management quantities for 2020 mortality limits (last year's decision) in the absence of the MinSL. The specific process for making the yield calculations is outlined in Appendix A. In short, the SPR, which represents the lifetime reproductive output of the stock, is used to measure and balance the effects of removing differing total mortality and demographic components from the population. The results can therefore be interpreted simply, as: How would the mortality limits need to change in order for fishing intensity to remain constant if the MinSL were removed?

In order to characterize the sensitivity of the results to alternative fishery responses, six alternative cases were also investigated: 10, 20 and 30% avoidance, and 10, 20 and 30% targeting of U32 Pacific halibut. For the base analysis and each sensitivity, the change in yield to the directed commercial fishery, the percent of that yield comprised of U32 Pacific halibut and the 'critical price ratio' (see Appendix B for calculation details) were estimated. The critical price ratio indicates the price that would need to be paid for U32 Pacific halibut as a percentage of the price paid for O32 fish in order for the fishery to be of equal or larger value in the absence of the MinSL (assuming no difference in O32 price between the two regulatory setups).

Implementing a MaxSL

Based on the summary of data relevant to a MaxSL, an example MaxSL of 60 inches (152 cm) was selected for further evaluation. This size of fish represents a compromise in that it is large enough to avoid converting a substantial fraction of the current landings to discards, but small enough to represent a demographically meaningful portion of the current spawning biomass. The approach taken for evaluation of potential MaxSLs was similar to that for the MinSL, although slightly more complex as it required additional modeled fleets and partitioning of existing age data in order to approximate the fishery landings and discards under a MaxSL (Appendix A).

RESULTS

Data relevant to the current MinSL

The FISS and mandatory logbook information available in IPHC Regulatory Area 2B provided similar estimates of the fraction of the total catch comprised of U32 Pacific halibut (Figure 1). Not only was a similar scale estimated from both series, but the relative trend was also very similar, including an increase in the proportion of U32 fish in 2019, apparently due to the 2011 and 2012 year-classes which comprised a large proportion of the age distributions observed in the FISS in most IPHC Regulatory Areas (especially for female Pacific halibut (Figure 2). Of note in both data summaries is the variability among IPHC Regulatory Areas. In recent years the percent of the total catch comprised of U32 fish has ranged from near 20% in IPHC Regulatory Area 4B to around 65-70% in IPHC Regulatory Areas 3B and 4A. Similarly, in the age composition information there are male Pacific halibut greater than 15 years old in all IPHC Regulatory Areas; however, Area 3A has a much higher overall fraction of older males than any other Area. A detailed summary of the size structure of U32 FISS catches is provided in Appendix C.

When the FISS and commercial data are used in tandem with discard mortality rates to estimate the total discard mortality of U32 Pacific halibut, there is a clear decreasing trend over the last 10 years, with a notable increase in 2019 (Table 2). The magnitude of discard mortality by IPHC Regulatory Area is a function of both the landings as well as the encounter rate, with considerable differences among Areas. In aggregate, this source of mortality contributes 0.88 (the three-year average) to 1.49 (the ten-year average) million pounds representing 3-5% of the coastwide total (Table 3). These fish are legally required to be discarded, so they provide no value to the fishery, although they are included in all assessment calculations and in the estimate of overall fishing intensity.

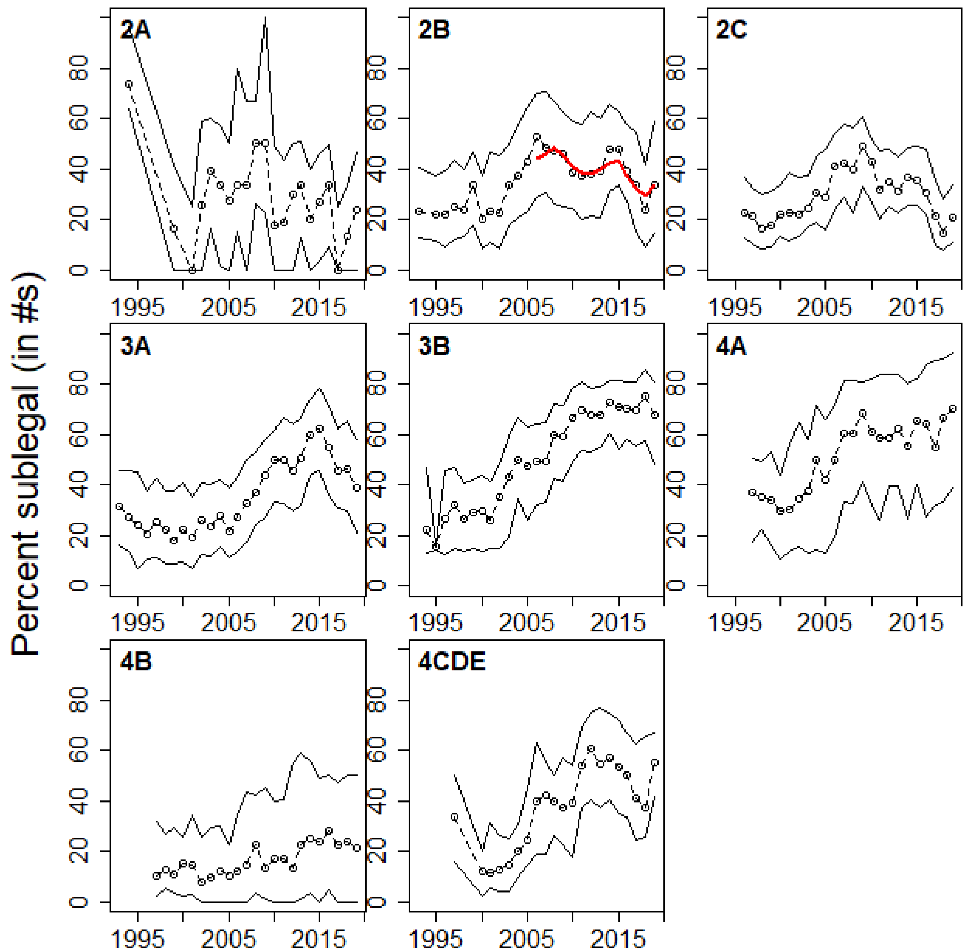

Figure 1. Percent sublegal (U32) in recent (1993-2019) FISS catches (median station value indicated by the connected black circles, 25th and 75th percentiles of station values indicated by solid black lines) and reported commercial fishery logbooks (IPHC Regulatory Area 2B, 2006-2019 average annual value across sets; solid red line).

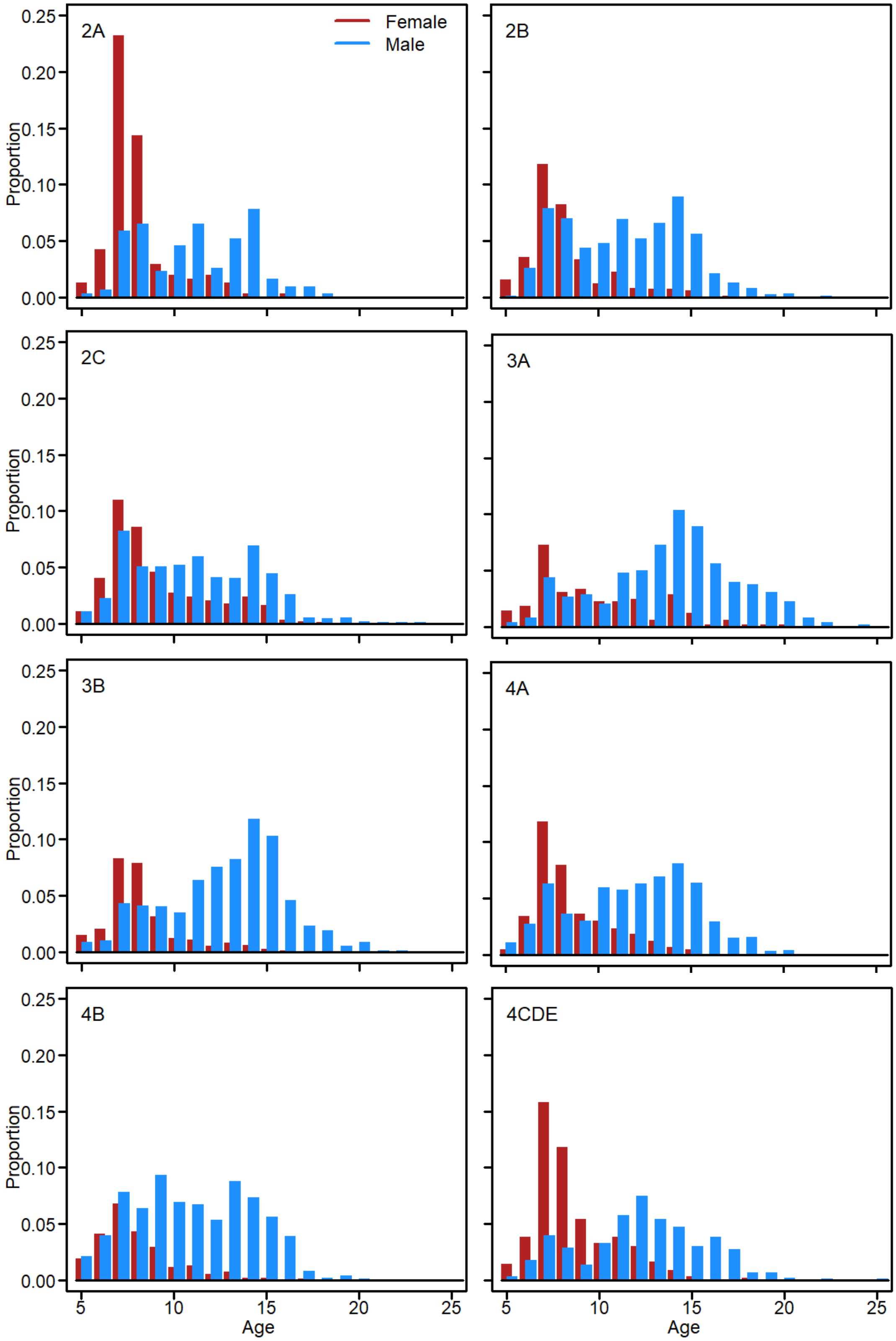

Figure 2. Sex-specific age distributions (by number) for U32 Pacific halibut captured by the 2019 FISS. Females (red bars) and males (blue bars) sum to a value of 1.0 in each panel (IPHC Regulatory Area).

Table 2. Recent discard mortality estimates from the directed commercial fishery for Pacific halibut less than the 32 inch (81.3 cm) minimum size limit length (U32; million net pounds).

Year	2A	2B	2C	3A	3B	4A	4B	4CDE	Coastwide
2010	0.03	0.28	0.26	1.47	0.88	0.13	0.04	0.08	3.16
2011	0.02	0.26	0.08	0.91	0.77	0.14	0.04	0.17	2.39
2012	0.02	0.21	0.09	0.59	0.52	0.09	0.04	0.08	1.62
2013	0.01	0.20	0.09	0.53	0.39	0.06	0.03	0.05	1.37
2014	0.01	0.23	0.12	0.45	0.32	0.03	0.05	0.05	1.26
2015	0.02	0.23	0.12	0.52	0.22	0.07	0.04	0.05	1.26
2016	0.03	0.21	0.12	0.39	0.23	0.05	0.05	0.06	1.15
2017	0.01	0.17	0.08	0.36	0.23	0.06	0.03	0.03	0.97
2018	0.01	0.12	0.05	0.28	0.21	0.07	0.02	0.03	0.78
2019	0.03	0.13	0.07	0.32	0.16	0.09	0.03	0.07	0.90
3-year average	0.02	0.14	0.07	0.32	0.20	0.07	0.03	0.04	0.88
5-year average	0.02	0.17	0.09	0.37	0.21	0.07	0.03	0.05	1.01
10-year average	0.02	0.20	0.11	0.58	0.39	0.08	0.04	0.07	1.49

Table 3. Recent U32 percent mortality (discard mortality/(discard mortality + landings), by weight) from the directed commercial fishery for Pacific halibut.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE	Coastwide
2010	6%	4%	5%	7%	8%	5%	2%	2%	6%
2011	3%	4%	3%	6%	9%	6%	2%	5%	6%
2012	3%	3%	3%	5%	9%	5%	2%	3%	5%
2013	3%	3%	3%	5%	9%	5%	2%	3%	5%
2014	2%	4%	3%	6%	10%	3%	4%	4%	5%
2015	4%	4%	3%	6%	7%	5%	3%	4%	5%
2016	5%	3%	3%	5%	8%	3%	5%	4%	4%
2017	2%	3%	2%	4%	7%	4%	3%	2%	4%
2018	2%	2%	1%	4%	8%	5%	2%	2%	3%
2019	3%	2%	2%	4%	6%	6%	3%	4%	4%
3-year average	2%	2%	2%	4%	7%	5%	3%	3%	3%
5-year average	3%	3%	2%	5%	7%	5%	3%	3%	4%
10-year average	3%	3%	3%	5%	8%	5%	3%	3%	5%

Data relevant to a MaxSL

The relative catch of large Pacific halibut varied substantially across the coast, ranging from <1% for fish greater than 55 inches (140 cm) in IPHC Regulatory Area 2A to 17% in Area 2C (Table 4). A MaxSL of 70 inches (178 cm), would affect less than 2% of the commercial landings in any IPHC Regulatory Area coastwide. Larger potential MaxSLs corresponded to larger average weights of fish above these limits; however, there was again considerable variability among IPHC Regulatory Areas. Although almost all large fish were found to be female (92-100%), there was a considerable range of ages represented even among females larger than 60 inches (152 cm; Figure 3). These fish ranged in age from nine to 42 years, depending on the Area, with the youngest fish on average in IPHC Regulatory Area 2C and the oldest in Area 4B. This pattern illustrates clearly that a MaxSL would not map directly to a maximum age limit, and that even at 70 inches (178 cm) there is the potential for some female Pacific halibut to remain immature. The FISS observed relatively higher catches of large Pacific halibut when compared to the commercial fishery, and showed differing relative patterns among IPHC Regulatory Areas (discussed below).

Table 4. Summary of 2017-2019 commercial fishery landings and FISS catch of large Pacific halibut by IPHC Regulatory area. Values in italics represent only a single fish.

IPHC Regulatory Area	Length greater than (in, cm)	Average net weight (lb, kg)	Average age (range)	% female (weight)[1]	% of Landings (weight)	% of legal FISS catch (weight)[2]
2A	55, 140	66, 30	16 (10-23)	100%	<1%	2%
	60, 152	*109, 49*	*22 (22-22)*	*100%*	*<1%*	<1%
	65, 165	*109, 49*	*22 (22-22)*	*100%*	*<1%*	<1%
	70, 178	NA	NA	NA	0%	0%
2B	55, 140	75, 34	18 (9-39)	100%	8%	16%
	60, 152	92, 42	20 (14-39)	100%	4%	8%
	65, 165	112, 51	22 (15-31)	100%	1%	3%
	70, 178	129, 59	21 (17-25)	100%	<1%	1%
2C	55, 140	71, 32	17 (9-36)	100%	17%	26%
	60, 152	86, 39	17 (9-36)	100%	6%	15%
	65, 165	114, 52	18 (13-36)	100%	2%	8%
	70, 178	148, 67	20 (15-32)	100%	<1%	4%
3A	55, 140	69, 31	16 (11-31)	100%	4%	28%
	60, 152	85, 39	18 (12-31)	100%	2%	18%
	65, 165	119, 54	20 (18-21)	100%	<1%	11%
	70, 178	119, 54	20 (18-21)	100%	<1%	6%
3B	55, 140	70, 32	14 (11-23)	96%	5%	17%
	60, 152	92, 42	16 (13-23)	100%	1%	11%
	65, 165	144, 65	20 (17-23)	100%	<1%	6%
	70, 178	194, 88	23 (23-23)	100%	<1%	3%
4A	55, 140	70, 32	18 (11-39)	100%	5%	10%
	60, 152	100, 45	19 (12-39)	100%	1%	6%
	65, 165	118, 54	23 (14-39)	100%	1%	3%
	70, 178	137, 62	32 (25-39)	100%	<1%	2%
4B	55, 140	80, 36	21 (8-42)	94%	11%	18%
	60, 152	100, 45	23 (12-42)	92%	7%	11%
	65, 165	120, 54	23 (12-40)	100%	4%	6%
	70, 178	147, 67	26 (20-40)	100%	2%	3%
4CDE	55, 140	74, 34	16 (11-24)	100%	9%	14%
	60, 152	88, 40	17 (11-24)	100%	4%	8%
	65, 165	108, 49	18 (11-22)	100%	1%	4%
	70, 178	112, 51	17 (11-20)	100%	<1%	2%

[1]Sex-specific information from the commercial fishery was only available from 2017-2018 for this analysis.
[2]Percent of O32 catch was predicted from individual lengths and the historical length-weight relationship, and therefore may not be comparable with fishery catch percentages.

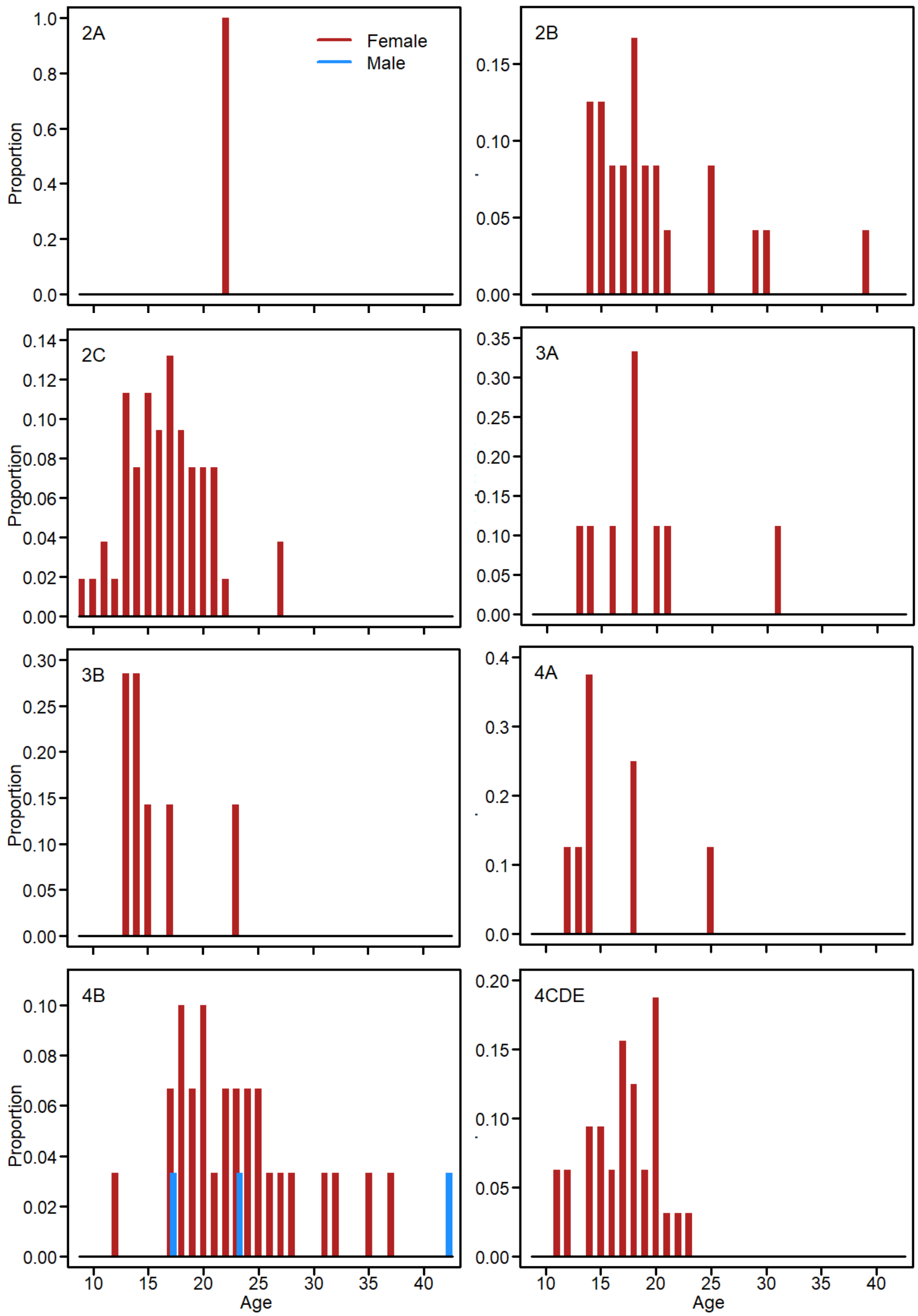

Figure 3. Sex-specific age composition distributions (by number) for Pacific halibut greater than 60 inches (152 cm) in length captured by the commercial fishery in 2017-2018. Females (red bars) and males (blue bars) sum to a value of 1.0 in each panel (IPHC Regulatory Area). Note that the y-axes differ by panel.

Removing the MinSL

If the Commission had removed the MinSL for 2020, the coastwide mortality limit could have been increased to 107% of the adopted limits with the same projected level of fishing intensity (Table 5, Figure 4). This indicates that the additional effects of harvesting smaller and younger Pacific halibut would be more than offset by the reduction in discard mortality (converted to retained catch) and increased yield associated with harvesting fish closer to the ages producing peak yields under current size-at-age and sex-ratios. The additional yield would not be uniformly distributed across the coast, as the proportional increase would depend on the absolute amount of discard mortality converted to landings within the TCEY as well as the distribution of TCEY among Biological Regions and IPHC Regulatory Areas. Not surprisingly, the largest gains would be realized in IPHC Regulatory Areas 3B and 4A, where the highest encounter rates of U32 fish currently occur, even under the same coastwide TCEY distribution (discard mortality currently taken off the TCEY to project commercial landings could be landed in the absence of the MinSL). This general result was found to be largely insensitive to either targeting or avoidance of U32 Pacific halibut: under all alternatives evaluated there was a potential gain in yield by removing the MinSL (Table 5, Figure 4).

Table 5. Yield changes (commercial landings without MinSL/commercial landings with MinSL) for alternatives removing the current commercial fishery minimum size limit.

Fishery	No MinSL	U32 avoidance			U32 targeting		
		10%	20%	30%	10%	20%	30%
Coastwide	107%	107%	106%	106%	107%	108%	108%
Region 2	105%	105%	105%	104%	106%	106%	107%
2A	106%	106%	106%	105%	107%	107%	108%
2B	106%	106%	105%	105%	106%	107%	107%
2C	105%	105%	104%	104%	106%	106%	106%
Region 3	108%	107%	107%	106%	108%	109%	109%
3A	107%	107%	107%	106%	108%	108%	108%
3B	110%	109%	109%	110%	110%	111%	111%
Region 4	110%	109%	109%	109%	110%	111%	111%
4A	109%	109%	108%	108%	110%	110%	110%
4CDE	108%	107%	107%	107%	108%	109%	109%
Region 4B	106%	106%	106%	105%	107%	107%	108%

The projected coatswide landings would be comprised of 18% U32 Pacific halibut in the absence of the current MinSL, ranging from 13 to 22% under the avoidance and targeting alternatives evaluated (Table 6, Figure 4). As observed in other results, there were important differences among Biological Regions and IPHC Regulatory Areas, spanning 7% U32 fish (Area 2C with 30% avoidance) up to 33% (Area 3B with 30% targeting). Biological Region 2, with the lowest encounter rates for U32 fish was the most insensitive to targeting or avoidance, ranging from 9-15% among alternatives.

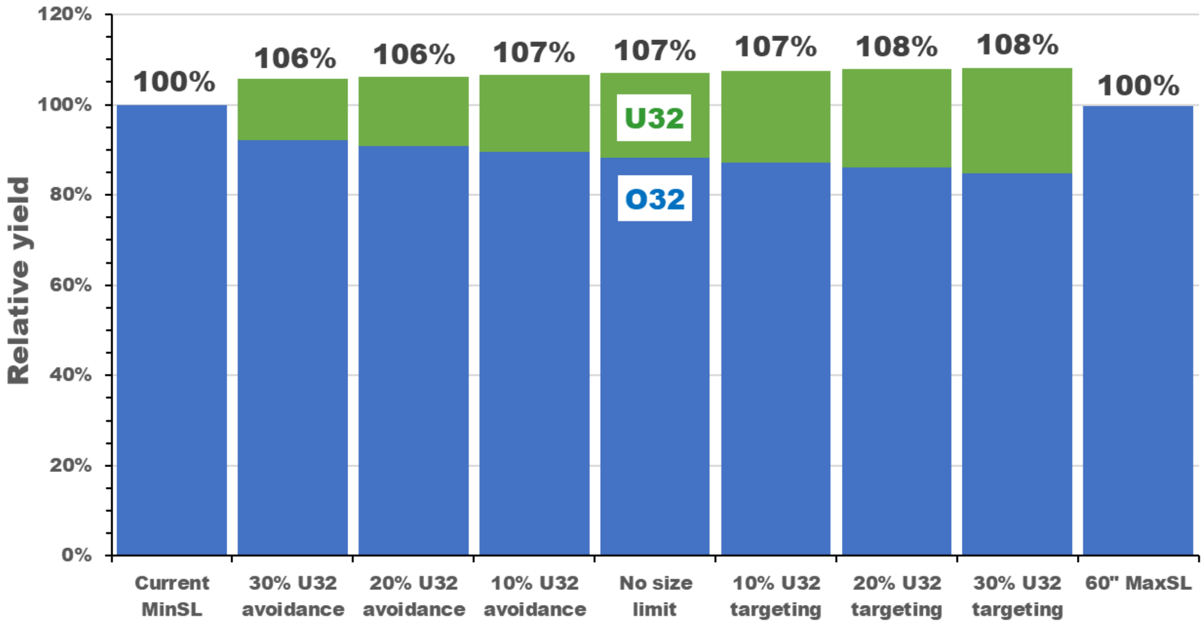

Figure 4. Relative yield (height of bars) for size limit alternatives considered in this analysis, colors indicate the component contributions (O32 and U32) of the total. Refer to Table 6 for percent U32 values.

Table 6. Percent U32 in the landed catch for alternatives removing the current commercial fishery minimum size limit.

Fishery	No MinSL	U32 avoidance			U32 targeting		
		10%	20%	30%	10%	20%	30%
Coastwide	18%	16%	15%	13%	19%	20%	22%
Region 2	12%	11%	10%	9%	13%	14%	15%
2A	15%	14%	13%	11%	17%	18%	19%
2B	13%	12%	11%	10%	14%	15%	16%
2C	9%	8%	7%	7%	10%	11%	12%
Region 3	21%	20%	18%	16%	23%	24%	26%
3A	19%	17%	16%	14%	20%	22%	23%
3B	28%	26%	23%	21%	30%	31%	33%
Region 4	23%	21%	19%	17%	25%	27%	28%
4A	26%	24%	22%	19%	27%	29%	31%
4CDE	21%	19%	17%	16%	23%	24%	26%
Region 4B	16%	15%	13%	12%	18%	19%	20%

The critical price ratio was projected to be 63% coastwide (Table 7); this means that if the price for U32 Pacific halibut is greater than 63% of the price for O32 fish then the fishery will increase in value if the MinSL is removed. Prices are known to vary substantially among IPHC Regulatory Areas, and the critical price ratio was also projected to vary, from a low of 47% in Area 2C (a low price is less important where encounter rates are lowest as U32 fish are projected to comprise a smaller fraction of the total landings) to a high of 68% in IPHC Regulatory Area 3B. Targeting or avoidance further changes the critical price ratio; however, even under the most extreme targeting alternative the fishery value would be equal or larger to that under the current

MinSL in all IPHC Regulatory Areas if the price for U32 Pacific halibut was at least 70% of that for O32 fish.

Table 7. Critical price ratio (price for U32/price for O32; see Appendix B) at which fishery value is unchanged from that under the current MinSL for alternatives removing the current commercial fishery minimum size limit.

Fishery	No MinSL	U32 avoidance			U32 targeting		
		10%	20%	30%	10%	20%	30%
Coastwide	63%	61%	59%	58%	63%	64%	65%
Region 2	57%	55%	54%	53%	57%	57%	58%
2A	61%	59%	57%	56%	62%	62%	63%
2B	58%	56%	54%	53%	58%	59%	59%
2C	47%	45%	43%	43%	47%	48%	49%
Region 3	67%	65%	63%	62%	67%	68%	68%
3A	64%	63%	61%	59%	65%	65%	66%
3B	68%	66%	65%	63%	69%	69%	70%
Region 4	62%	60%	57%	55%	63%	64%	65%
4A	67%	66%	64%	62%	68%	69%	70%
4CDE	66%	64%	62%	60%	66%	67%	68%
Region 4B	62%	60%	58%	57%	62%	63%	64%

Implementing a MaxSL

Implementing a 60 inch (152 cm) MaxSL is projected to result in little net change to fishery yield (Figure 4). However, this MaxSL would create a new (and largely unobserved) source of mortality through discarding of approximately 0.12 million pounds (~54 mt) large female Pacific halibut at the 2020 adopted mortality limits. As this is a one-year calculation, and Pacific halibut can live to at least 55 years of age, it is expected that the level of discard mortality would increase gradually over many years until the abundance of large fish equilibrated with average fishing intensity. At least in the short-term, discard mortality would be approximately offset by increased yield due to a higher fraction of males in the retained catch and average size closer to the peak yields under current size-at-age. If the relative price of fish larger than 60” (O60) remains slightly lower than the average for fish less than 60” (U60), then the average fish size in the landings is projected to result in no change in the aggregate fishery value (Appendix D).

Introduction of a MaxSL would provide an increase in the proportion of the Spawning Biomass (SB) comprised of large female Pacific halibut, and increased opportunity to encounter these fish in recreational fisheries in some IPHC Regulatory Areas (e.g., IPHC Regulatory Area 2C). The long-term change in age composition of the SB and its distribution among Biological Regions and IPHC Regulatory Areas will depend on future spatial patterns and overall levels of stock productivity and fishery management. A 60” MaxSL would reduce fishery efficiency by approximately 3%, and also reduce the data quality on fish in the total vs. landed commercial fishery catch.

DISCUSSION

Summary

This evaluation has provided a general framework for consideration of size limits for Pacific halibut. It includes series of projected responses, both positive and negative to the removal of the MinSL or implementation of a MaxSL (Table 1) as well as detail on the IPHC Regulatory Area specific results likely to be realized. Specific projected results are a key component in informed decision-making and recommended by the IPHC's Scientific Review Board (SRB) during the most recent size limit analysis. That review highlighted the adaptive management aspects of a potential action on the size limit (see Appendix E).

Removing the current MinSL is projected to increase potential yield by 7%, using the 2020 adopted mortality limits for comparison. This yield comes from a combination of reduced discard mortality, as well as harvest of fish sizes closer to the peak yields under current estimated size-at-age and sex-ratios. Building on concerns raised during the previous evaluation of size limits, we explored the relative price at which the fishery would be of equal of greater net value (accounting for the change in size structure of the landings), and found the critical price ratio for U32 Pacific halibut to be 63% of the price for O32 fish. This calculation likely provides a slight (but unknown) underestimate of the fishery value, implying the realized critical price ratio may be somewhat lower (Appendix B). With increased landings and decreased discards, the fishery efficiency (landings relative to total catch) is projected to increase by 18%. Improved efficiency should result in some level of savings to operational costs (fuel, bait, trip duration, etc.); however, such changes will be highly dependent on individual business plans and fishing grounds. Currently, discarding of U32 Pacific halibut creates an important data gap, due to sparse to no sampling at-sea (depending on the IPHC Regulatory Area). Assuming that full retention of all legal catch is retained in regulation, removing the MinSL will result in improved data on total catch through the existing port sampling program.

Introduction of a MaxSL was evaluated based on fishery and survey data over a range of potential maximum sizes. A 60 inch (152 cm) MaxSL was found to result in a very small reduction net fishery yield (rounding to 100% of the 2020 adopted mortality limits). Any MaxSL is projected to result in a new source of discard mortality, almost entirely comprised of female Pacific halibut, but in this example that mortality would be offset through increased yield due to a higher fraction of males in the retained catch and average size closer to the peak yields under current size-at-age. A MaxSL is also projected to result in an increase in older/larger female Pacific halibut in the stock, and therefore available to the recreational fishery. This increase would continue over time, depending on the level of fishing intensity resulting from commission mortality limits, as well as future size-at-age and recruitment levels. A 60” (152 cm) MaxSL is projected to reduce fishery efficiency by approximately 3%, due to the additional handling of large female halibut that would have to be discarded. This handling would also lead to a reduction in data quality as these discards would not be sampled for biological information. The reduction in average fish size in the landings is projected to result in no aggregate change in fishery value. As for the MinSL, the effects of a MaxSL would not be uniformly distributed among IPHC Regulatory Areas; Area 2C would likely see the greatest changes in both the fishery and stock, at least in the short-term, based on recent fishery landings.

Other considerations

A relatively large difference was observed between the fishery and FISS catches of large (primarily female) Pacific halibut. Although the fishery is known to capture a larger proportion of females across all ages (Stewart and Webster 2020), landings of fish larger than 55 inches were consistently estimated to be a greater fraction of the total in the FISS data. There are several potential reasons for this. Commercial fishery effort may be focused on fishing grounds with higher average catch rates, which must comprise smaller fish, as there are far more numerous in the population and may be behaviorally segregated from the largest fish investigated here. This represents potential avoidance of large fish, consistent with the slightly lower price (Appendix D). In addition, some large fish may be either lost from the gear during retrieval, or currently not retained by the directed commercial fishery during normal fishing operations. Finally, the difference may be simply an artifact of the calculation method; the survey catch percentages for large fish are based on individual predicted weights from the historical length-weight relationship (due to only 1 partial year of measured weights being available), and the length-weight relationship is known to over-predict the individual weights of the largest Pacific halibut.

This analysis did not examine trade-offs in yield between the commercial and recreational sectors as would likely occur due to existing domestic catch agreements. However, the results do account for the existing TCEY distribution. This means that estimated potential yield would be available without making major changes to the current distribution of the TCEY among IPHC Regulatory Areas. Removing the current MinSL or introduction of a MaxSL is also likely to affect the contribution of Pacific halibut resource to the economy through the recreational sector. This could be a potential avenue for an economic analysis that is currently under development by the IPHC.

The IPHC landed and sold U32 Pacific halibut that were sacrificed for scientific data collection as part of the 2020 FISS design (see **IPHC-2021-AM097-06**). These fish, although very limited in number, provide the first direct information on the price for U32 Pacific halibut for comparison with the critical price ratios found in this analysis. However, it is unclear whether a broader market response would differ if, as projected under the removal of the current MinSL, 13-22% of the coastwide landings comprised U32 fish. Further, it may take several years before a robust market for U32 fish develops and the relative price of U32 vs. other size categories stabilizes. Moreover, interpretation of these prices may be confounded by highly disrupted market conditions in 2020 (due to COVID-19). As of early 2020, news reports of small (3-8 pound; 1.4-3.6 kg) frozen Pacific halibut from the Russian fishery ("Fish Factor", Laine Welch, March 23, 2020) suggested U32 fish are already present in the global marketplace. Discovering the relative price for U32 Pacific halibut from IPHC Convention waters represents a clear adaptive management component of removing the MinSL.

This evaluation included consideration of both fishery targeting and avoidance of U32 Pacific halibut if the MinSL were removed. There are factors that could lead to both outcomes under the right circumstances. Targeting could occur if there was a small (or no) price differential for U32 fish, as fishery catch rates (efficiency) could be improved via increased effort on fishing grounds that produce smaller fish. Conversely, under a larger price differential there may be very strong economic reasons to avoid fishing grounds with small fish in order to avoid having to retain those fish under current regulation. This has been observed in recent years in the sablefish (*Anoplopoma fimbria*) fishery occurring in the same waters of Alaska as strong recruitment events have resulted in reduced prices for small fish and changes in fishery behavior (Hanselman et al. 2019). Both targeting and avoidance could be affected by future whale depredation; it is unknown whether this is likely to become a greater or lesser problem in the absence of a MinSL.

The previous evaluation of size limits (Stewart and Hicks 2018) considered the potential of a conservation benefit of the MinSL due to creating a ‘reproductive refuge’, where fish were allowed to mature before harvest. Although this concept forms the basis for the use of MinSLs in species from crustaceans to reef fish (e.g., Hilborn and Walters 1992), for Pacific halibut, much of the current fishery landings even with the MinSL in place are juvenile (immature) females. Another well recognized aspect of size-limits reflects the shape of the fishery yield curve: the yield available as a function of varying levels of fishing intensity tends to be a flatter relationship through the use of size limits. This means that a larger range of fishing intensity level (or similarly, of errors in intended fishing intensity) tend to produce more similar yields when a size limit is in place. This buffering of management actions (and errors) was noted in the previous size-limit analysis (Stewart and Hicks 2018). In the extreme, for a species where at least one spawning is ensured through the use of a MinSL (e.g., many crustaceans), there is much less importance of annual quotas or fishing intensity, and in some cases a MinSL may successfully provide the sole source of management. Similarly, a slot limit (a combination of both a MinSL and MaxSL) may provide both a management buffer and reproductive outputs, especially in the presence of very large maternal effects (Ahrens et al. 2020). Due to the wide range of ages represented by a single size of Pacific halibut, as well as the relatively late maturity (approximately 50% between ages 11 and 12), Pacific halibut management does not provide a ready analog for these simpler cases.

There are a variety of policy and procedural implications for a change to the current MinSL or introduction of a MaxSL. This analysis does not address the timeline or logistic aspects of such a change, as these would be primarily domestic management issues. However, with regard to data collection, the IPHC may need to request that domestic at-sea observer programs (either electronic or traditional) begin to identify the reason for discarding in the future so that adequate delineation of sub-legal, legal-regulatory (quota attainment), and supra-legal discards can occur.

Effects on size-at-age

Despite a long history of investigation, the mechanisms behind trends in Pacific halibut size-at-age remain poorly understood. Density dependence (Clark and Hare 2002), temperature (Holsman et al. 2018), dietary overlap (Barnes et al. 2018), and fishing (Sullivan 2016) may all be contributing factors. In the presence of a minimum size limit, fishing mortality can affect size-at-age in at least two ways: 1) by reducing the fastest growing fish in each cohort, such that the observed size-at-age is lower than it would be in the absence of fishing (e.g., Martell et al. 2015b; Taylor and Methot Jr 2013), and 2) cumulative effects over cohorts of removing the fastest growing genetic components of the stock (e.g., Conover and Munch 2002). This reconstructed historical time-series does not seem consistent with either of these, as size-at-age is understood to have increased from the 1930s through the 1970s, a period of high levels of exploitation combined with a (26”) MinSL. However, removing the current MinSL would likely reduce the selective removal of faster growing individuals. Some selectivity for faster growing Pacific halibut would remain even in the absence of a MinSL: hook sizes used by the commercial fishery also select for larger fish (and therefore faster growing fish as younger ages). Although conceptually this aspect of the decision to retain or remove the current MinSL could be considered to be adaptive management, in practice it could be decades before trends in size-at-age were clearly identified and those may be confounded with changes in the stock and ecosystem.

Importance of spatial differences

The detailed results of this evaluation illustrate the spatial variability in effects of removing the MinSL or implementing a MaxSL. This analysis is structured around the current demographic patterns (observed recent distributions of U32 and O60 Pacific halibut), and also the recent distribution of the TCEY. Management decisions to appreciably change the TCEY distribution will have both immediate and delayed effects on both the fishery and stock. Specifically, the net effect of removing the MinSL will depend on the proportion of the TCEY assigned to Areas of higher and lower encounter rates of U32 Pacific halibut. This analysis assumed no changes to the current distribution.

The effects of either removing the MinSL or introducing a MaxSL will not only vary by Biological Region and IPHC Regulatory Area, but will also vary at finer scales. Based on analyses of fine-scale spatial and temporal persistence in size-at-age patterns, broad changes observed over time and IPHC Regulatory Areas mask even more complex patterns among fishing grounds (B. Ritchie, MS Thesis in preparation, Alaska Pacific University). This means that the effects on individual fishermen will differ based on where they choose to fish their quota within the larger Regulatory Areas. Therefore, there is the potential for changes in the selection of fishing grounds to create targeting or avoidance that introduce additional uncertainty in this analysis.

The stock distribution also represents both an important input, and to some degree an output of any decision regarding size limits. Ontogenetic movement patterns observed for Pacific halibut suggest higher relative movement at younger ages/smaller size, but continued movement throughout their life-span, with a clear net movement toward eastern IPHC Regulatory Areas (Webster et al. 2013). This means that large changes in the distribution of the TCEY and/or the size structure of the mortality are likely to have an effect on long-term stock distribution. Evaluation of this feedback requires a spatially-structured simulation model and accounting for all aspects of the management system (see management procedure discussion below).

Spawning biomass and recruitment

The IPHC's Interim Management procedure relies on a reference SPR, this means that regardless of allocation, selectivity and current age structure of the stock, the long-term reproductive output of the stock is maintained at a constant level. The age-structure of the spawning biomass has been found to be important for some marine species, particularly long-lived rockfishes (e.g., Berkeley et al. 2004), through 'maternal effects' or increasing survival/fitness of offspring produced by older females. Some species also show evidence of an increasing relationship between size and fecundity, indicating that eggs produced per unit of body mass may be greater for larger females (Dick 2009). However, for Pacific halibut, there are currently no data that indicate either maternal effects or increasing fecundity with size or age. Both maturity and fecundity are part of the ongoing IPHC research program (Planas 2020).

As part of a broader review of stock-recruitment modelling in the Pacific halibut stock assessment, models have been explored that allow for maternal effects, in order to determine whether they are more consistent with the historical time-series. Although this is not an experimental evaluation with high statistical power, no support was found in the historical age composition and other information available (IPHC-2020-SRB016-07). Therefore, it is unlikely that implementing a MaxSL would increase projected recruitment to the Pacific halibut stock.

Public perception

Globally, in recent decades there has been decrease in discarding of non-target species and sizes (bycatch) in many fisheries (Zeller et al. 2017). In some regions this change has been driven by regulation based 'full' retention, including the highly publicized ban on discarding of all quota species in the North Sea in 2014 causing changes in the way many affected fisheries are conducted (e.g. Catchpole et al. 2017). For Pacific halibut, the last decade has seen increasing interest in quantifying the effects of discard mortality both within the directed commercial fishery and in non-directed commercial fisheries. A similar trend has been notable among previous size-limit analyses, ranging from little emphasis on discarding as a decision point in early evaluations, to a major focus on the magnitude and distribution of discards in 2018. There would seem to be some benefit for the directed fishery in public perception, and beyond simple yield calculations, in eliminating all discard mortality by removing the MinSL and requiring the retention of all catch.

Size limits within a comprehensive management procedure

This evaluation provides tactical decision-making information for consideration of removing the current MinSL and/or implementing a MaxSL. The focus is on short-term yield, fishery and stock performance while retaining all other aspects of the IPHC's Interim Management Procedure. It is not intended to provide a comparison of long-term performance of size limits as one part of a comprehensive management procedure. Such a comprehensive analysis is ongoing, via the MSE process. Questions regarding long-term change in spatial distribution and scale of recruitment and spawning biomass require the full 'closed-loop' approach used in the MSE. As such, size limits provide a potential avenue for future MSE analysis depending on prioritization by the Management Strategy Advisory Board.

ADDITIONAL INFORMATION FOR 2021

The IPHC secretariat will prepare a projection of detailed management results for 2021 mortality limits in the absence of the commercial MinSL for presentation at AM097. This information will be provided in early January 2021, in order to include end-of-year 2020 updated mortality estimates, consistent with the mortality projection tool.

RECOMMENDATIONS

That the Commission:

a) **NOTE** paper IPHC-2021-AM097-09 which provides an evaluation of directed commercial fishery size limits in response to the discussion and request from AM096.

b) **AGREE** on whether the minimum size limit should be removed for the 2022 fishing period, noting that a Fishery Regulation proposal would need to be submitted to the Commission for consideration in accordance with the IPHC Rules of Procedure (2020).

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APPENDIX A: CALCULATION OF CHANGE IN FISHERY YIELD

This evaluation is focused on the short-term effects of removing the MinSL and/or adding a MaxSL. Therefore, the approach taken to make yield calculations is based on current conditions and is intended to guide IPHC management in 2021-2022, pending the development and implementation of a comprehensive management procedure through the MSE process.

In order to estimate the change in yield associated with removing the MinSL (as well as the related calculations of the percent of that yield comprising U32 Pacific halibut and the critical price ratio; see Appendix B), the following procedure was applied using the 2019 stock assessment ensemble:

1) Begin with the directed fishery landings equating to the mortality limits adopted for 2020. This level of yield and projected fishing intensity ($F_{42\%}$) provides the baseline for comparisons.
2) Inflate the estimated discard mortality (U32) to reflect a removal of the MinSL, such that all fish captured by the directed commercial Pacific halibut fishery are retained. The magnitude of this source of mortality increases substantially from those fish discarded dead, due to the 16% discard mortality rate (catch = discard mortality/0.16).
3) Because the total mortality is now greater, the directed fishery O32 landings must be scaled downward to achieve the same level of fishing intensity for 2020. However, U32 Pacific halibut are now included in the landed fishery yield.
4) After iteratively finding the scale of the new set of removals that matches the target fishing intensity, the fishery yield by IPHC Regulatory Area, Biological Region, and Coastwide can be compared with the adopted mortality limits for 2020.
5) Because the response of the fishery to removal of the MinSL is unknown, several alternative levels of targeting (10, 20 and 30% more U32 catch) and avoidance (10, 20 and 30% less U32 catch) were also compared with regard to yield and catch characteristics.

A similar, but slightly more complicated approach was required to evaluate the MaxSL:

1) Add another commercial fleet to the assessment models to represent the capture of large (O60) Pacific halibut.
2) Add another fleet to represent the directed fishery ages without the O60 fish included.
3) Add 2017-2018 age composition data (with the appropriate sizes of fish added/removed) to inform the selectivity curve of new fleets.
4) Iteratively fit the assessment model to these data to generate selectivity curves consistent with a change in both the landings and new source of discard mortality under a MaxSL, then fix the selectivity parameters at those estimates allowing the models to be projected to 2020 without any change in the time-series.
5) Use the observed percentages of large Pacific halibut in the landed catch to assign a fraction of the projected catch for 2020 to the new large fish discard fleet. Discount that catch by 84% to account for release survival.
6) Reduce the existing fishery mortality by the amount transferred to the discard fleet and transfer remaining mortality for the fishery to the new fleet where selectivity does not represent O60s.
7) Iterate to find the new fishery yield and discard associated with the MaxSL that satisfies the SPR from the 2020 projection.
8) Compare with the adopted mortality limits for 2020.

APPENDIX B: CALCULATION OF CRITICAL PRICE RATIO

The value of the current fishery can be approximated by:

$$value_{SL} = L_{O32,SL} x P_{O32}$$

Where *L* denotes the landings of legal-size (*O32*) Pacific halibut in the presence of the current size limit (*SL*), and *P* denotes the price.

In the absence of a size-limit (*NSL*) a similar approximation using the same notation is:

$$value_{NSL} = L_{O32,NSL} x P_{O32} + L_{U32,NSL} x P_{U32}$$

Where the additional term reflects the contribution of sublegal (*U32*) Pacific halibut to the overall fishery value. In order to find the point at which the fishery value would be equal with and without the size limit, these two equations can be set equal and re-arranged, yielding a ‘critical price ratio’:

$$\frac{P_{U32}}{P_{O32}} = \frac{L_{O32,SL} - L_{O32,NSL}}{L_{U32,NSL}}$$

This formulation in convenient for comparisons because it does not require that the price for either O32 or U32 Pacific halibut is known in order to determine if the fishery is likely to gain or lose overall value. Only the relative landings must be known. Further, given important differences in the relative proportions of O32 and U32 in potential fishery landings by IPHC Regulatory Area and Biological Regions, this critical price ratio can be estimated at each scale to provide more information on the likely spatial distribution of effects on the fishery.

An important simplifying assumption in this approach is that the price for O32 Pacific halibut will remain the same regardless of the presence or absence of the MinSL. Theoretically, we might expect an increase in the O32 price in the absence of the MinSL as the supply would be lower and therefore demand may be higher. This would lead to the reported critical price ratio to be conservative relative to the likely outcome: fishery value may actually be higher than predicted, and the critical ratio of U32 to O32 price lower than calculated using this method.

APPENDIX C: SUMMARY OF U32 FISS CATCHES BY SIZE, 2017-2019

The most comprehensive source of size- and sex-delineated information for U32 Pacific halibut comes from the annual catches by the FISS. In order to evaluate the distribution of U32 Pacific halibut by number and biomass, the most recent three years of FISS catches (2017-2019) were summarized in 1-inch (~2.5 cm) increments. Results are provided in the form of alternative potential MinSLs by individual IPHC Regulatory in Figures C.1 to C.8. Across all IPHC Regulatory Areas, the catch of Pacific halibut discarded at alternative potential size limits less than 32 inches decreases rapidly with fish size. Catches of Pacific halibut less than 26 inches (66 cm) are small, corresponding a maximum of 19.8% by number and 7.1% of the catch by weight in IPHC Regulatory Area 4A. This suggests that removing the current MinSL entirely would not likely produce a large amount of catch smaller than 26 inches without significant changes in fishing behavior. In most IPHC Regulatory Areas, male Pacific halibut comprise an increasing percentage of the catch at smaller sizes; this change in sex-ratio is included in the yield analyses reported in this document. Also evident in these results is the broad range of encounter rates among IPHC Regulatory Areas from 2C (the lowest) to 3B (the highest).

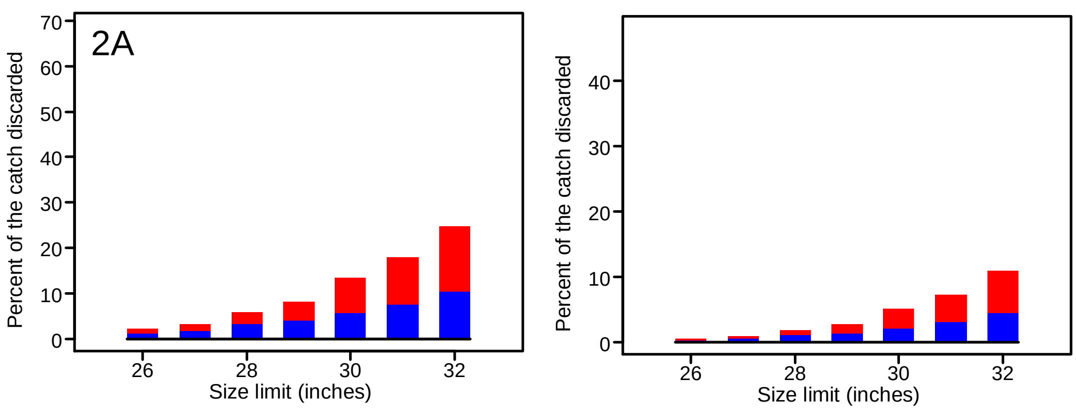

Figure C.1. Percent of the catch discarded (bars) based on alternative potential size limits less than 32 inches for IPHC Regulatory Area 2A. Left panel is based on numbers of fish, right panel is based on estimated weight of the catch. Each bar is divided into the male (blue) and female (red) components of the catch.

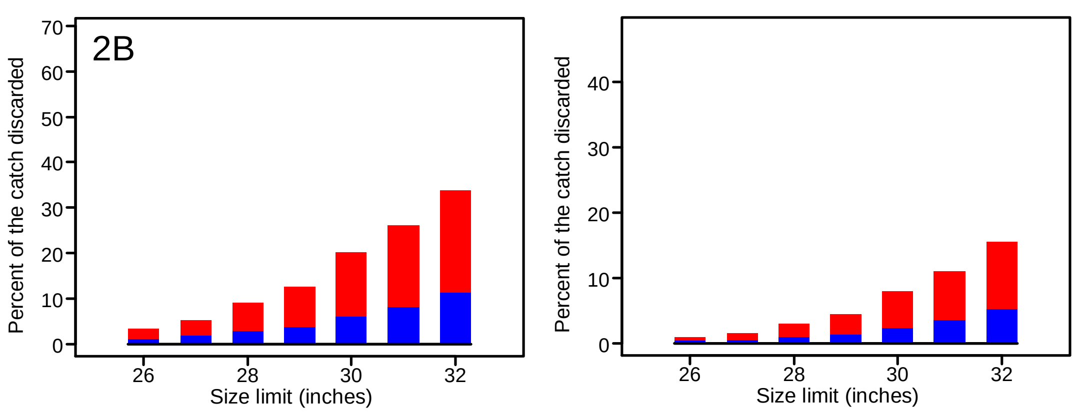

Figure C.2. Percent of the catch discarded (bars) based on alternative potential size limits less than 32 inches for IPHC Regulatory Area 2B. Left panel is based on numbers of fish, right panel is based on estimated weight of the catch. Each bar is divided into the male (blue) and female (red) components of the catch.

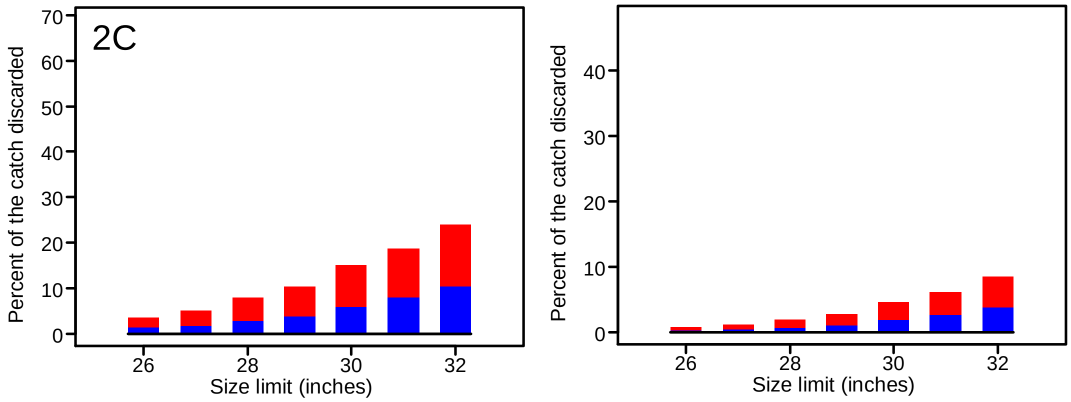

Figure C.3. Percent of the catch discarded (bars) based on alternative potential size limits less than 32 inches for IPHC Regulatory Area 2C. Left panel is based on numbers of fish, right panel is based on estimated weight of the catch. Each bar is divided into the male (blue) and female (red) components of the catch.

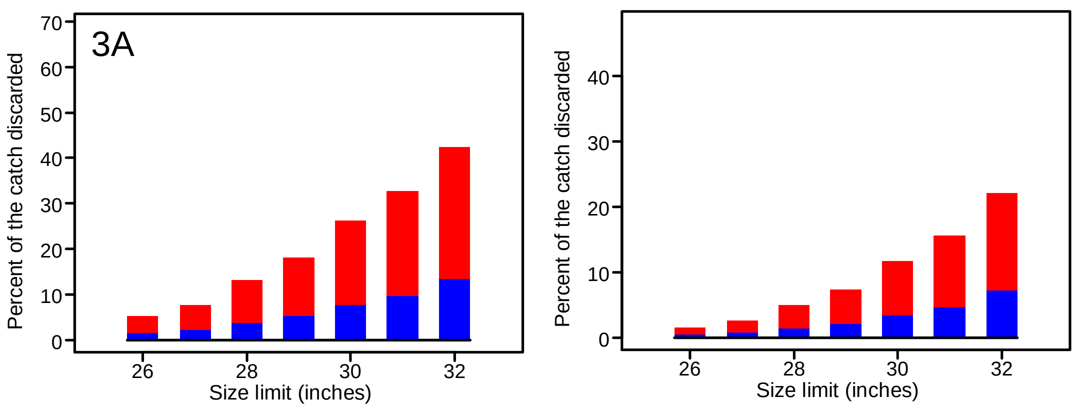

Figure C.4. Percent of the catch discarded (bars) based on alternative potential size limits less than 32 inches for IPHC Regulatory Area 3A. Left panel is based on numbers of fish, right panel is based on estimated weight of the catch. Each bar is divided into the male (blue) and female (red) components of the catch.

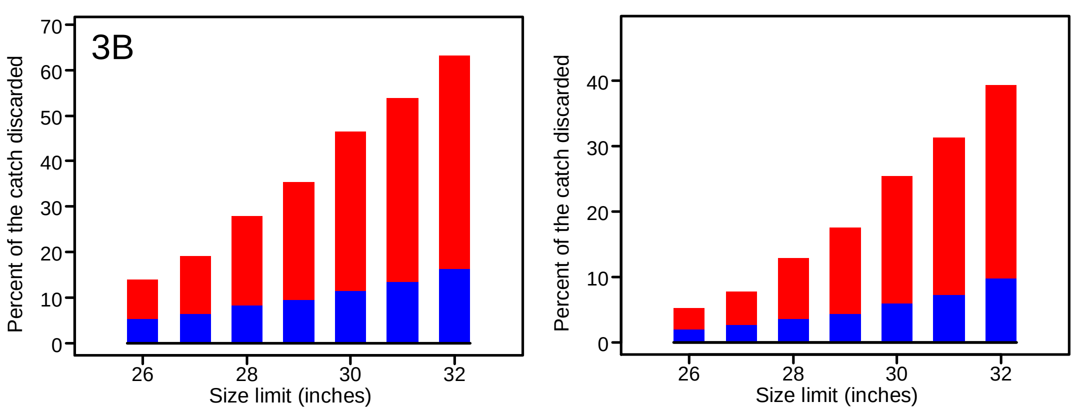

Figure C.5. Percent of the catch discarded (bars) based on alternative potential size limits less than 32 inches for IPHC Regulatory Area 3B. Left panel is based on numbers of fish, right panel is based on estimated weight of the catch. Each bar is divided into the male (blue) and female (red) components of the catch.

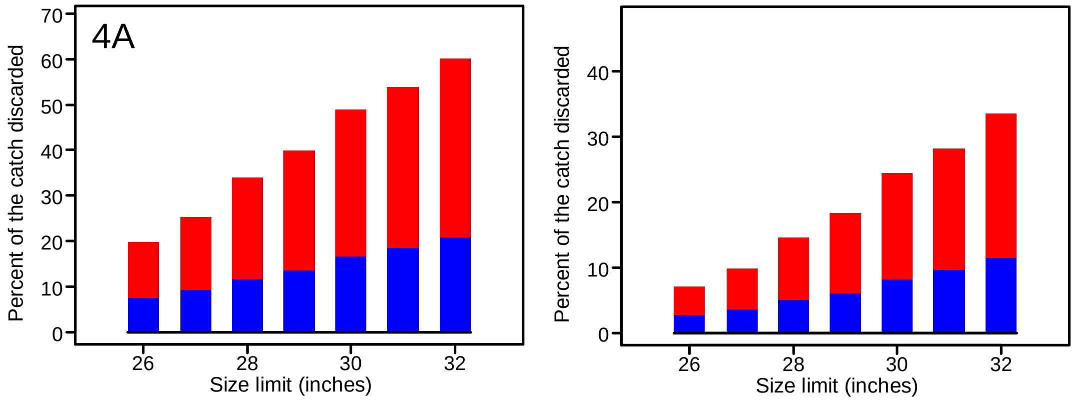

Figure C.6. Percent of the catch discarded (bars) based on alternative potential size limits less than 32 inches for IPHC Regulatory Area 4A. Left panel is based on numbers of fish, right panel is based on estimated weight of the catch. Each bar is divided into the male (blue) and female (red) components of the catch.

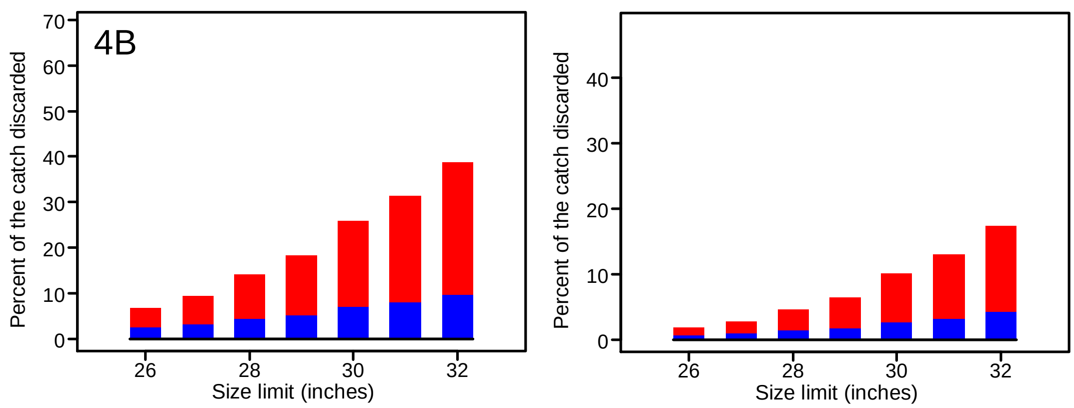

Figure C.7. Percent of the catch discarded (bars) based on alternative potential size limits less than 32 inches for IPHC Regulatory Area 4B. Left panel is based on numbers of fish, right panel is based on estimated weight of the catch. Each bar is divided into the male (blue) and female (red) components of the catch.

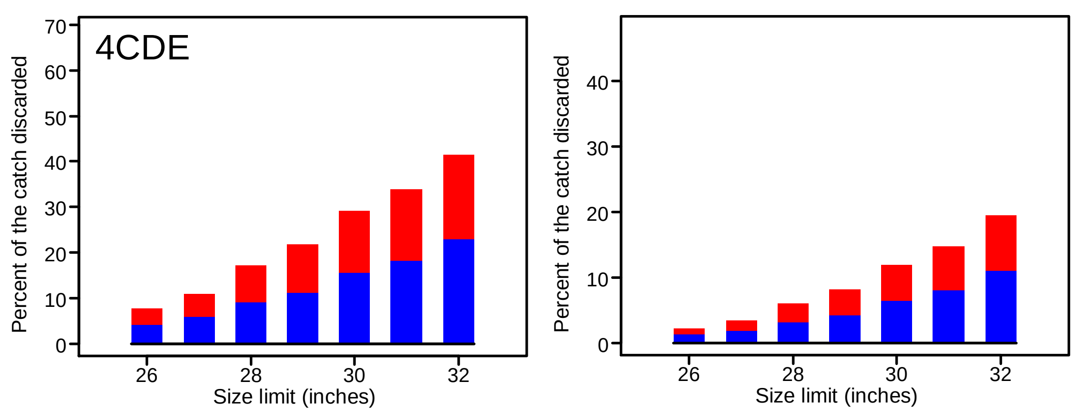

Figure C.8. Percent of the catch discarded (bars) based on alternative potential size limits less than 32 inches for IPHC Regulatory Area 4CDE. Left panel is based on numbers of fish, right panel is based on estimated weight of the catch. Each bar is divided into the male (blue) and female (red) components of the catch.

APPENDIX D: 2019 PACIFIC HALIBUT PRICES IN ALASKA

Recent prices and differences in price among size (weight) categories of the commercial fishery landings differ by year, IPHC Regulatory Area, port and buyer. In order to provide context for the critical price ratio, and the relative importance of different size categories, landings data were summarized from 2019 (Table D.1).

Table D.1: Average reported 2019 landings, revenue and price by aggregated weight category for Pacific halibut landed in Alaska (raw data from the eLandings system).

Aggregated weight category (net lbs)	Reported landings (net lbs)	Revenue ($US)	Price ($US)
<=20	5,397,552	27,350,760	5.07
20-40	4,492,190	24,046,953	5.35
40-60	1,821,392	10,391,435	5.71
60-80	375,098	2,060,299	5.49
80+	209,932	1,135,090	5.41
Unassigned[1]	3,270,674	17,566,759	5.37

[1]Categories reported in recent years have been inconsistent, including various levels of aggregation. The categories assigned here represent those that could be categorized unambiguously; therefore a large fraction of the landings remained unassigned.

APPENDIX E: ADAPTIVE MANAGEMENT CONSIDERATIONS

During the review of the 2018 MinSL evaluation (Stewart and Hicks 2018), the SRB made the following request:

***SRB10–Req.02** (para. 28):*

> *"The SRB REQUESTED an evaluation of the potential to try different size limits in different regions given the diversity of impacts on Pacific halibut fishing sectors and areas. MSL [MinSL] changes may need an adaptive management experiment approach that considers the biological, economic, and sociological consequences MSL [MinSL] changes. Indeed, predictions of consequences in each IPHC Regulatory Area should be a pre-requisite to any proposed MSL [MinSL] changes.*"

Adaptive management consists of actions taken in order to learn specific information that will subsequently improve future management (Walters 1986). In some cases, actions may be sub-optimal (or even negative) in the short term, but the information that they generate may facilitate improved performance (e.g., yield), and thus a positive result in the long term. An important aspect of adaptive management is that the focus of the action is on gaining information about the system and not on the specific results of that action.

The 2018 MinSL analysis provided an appendix containing detailed projections of likely effects by IPHC Regulatory Area of a reduced (or no) MinSL. During SRB11 (IPHC 2017b), after reviewing the options developed by the Secretariat, the IPHC's Scientific Review Board made an additional recommendation:

SRB11–Req.05 (para. 21):

> *"NOTING the thoughtful and detailed presentation on the potential impacts of changing the minimum size limit presented in Appendix E (Evaluation of adaptive management approaches) of paper IPHC-2017-SRB11-07, the SRB REQUESTED that the IPHC Secretariat, between now and SRB12, seek feedback from the Commissioners, Conference Board, Processors Advisory Board, and the Management Strategy Advisory Board, on a modified version of Appendix E. In particular, a modified version would include (i) a process for starting and possibly ending an experiment, (ii) performance metrics, and (iii) criteria for making conclusions based on the experimental outcomes.*"

Discussion of alternative and potentially adaptive approaches for removing or modifying the MinSL included both the Commission and advisory bodies. One proposal allowed for the MinSL to be removed in a single IPHC Regulatory Area on a voluntary basis in order to learn more about the price for U32 Pacific halibut (and therefore potential change in fishery value). There were no IPHC Regulatory Areas that volunteered to remove the MinSL as an adaptive management measure at that time.