Evaluation of the IPHC's 32" minimum size limit

PREPARED BY: IPHC SECRETARIAT (I. STEWART AND A. HICKS; 28 AUGUST 2017)

PURPOSE

To provide an update of IPHC-2017-SRB10-08, including options for potential adaptive management actions as requested during SRB10 (IPHC 2017):

"***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 changes may need an adaptive management experiment approach that considers the biological, economic, and sociological consequences MSL changes. Indeed, predictions of consequences in each IPHC Regulatory Area should be a pre-requisite to any proposed MSL changes.*"

BACKGROUND

This paper reflects input on an earlier draft presented to the Scientific Review Board (SRB) during SRB10 (IPHC 2017). Included is a review of relevant information for the Commission to consider the current 32" (81.3 cm) Minimum Size Limit (MSL) in the directed commercial Pacific halibut (*Hippoglossus stenolepis*) fishery. This document provides a review of relevant information based on the following sections:

Introduction: summary of historical analyses.

Scope: context on the estimated magnitude of Pacific halibut captured and discarded in all relevant fisheries in 2015.

Survey information: catch information by size and sex from the IPHC's 2016 setline survey

Observer information: catch information by size from the North Pacific Observer Program's 2016 at-sea sampling program.

Yield calculations: change in short term-yield associated with removal of the MSL and alternative fishery responses, estimated using the 2016 stock assessment ensemble.

Other considerations: Non-quantitative factors relevant to the MSL.

Summary: condensed overview of positive, negative and unknown responses to a reduced or eliminated MSL relative to the *status quo*.

Additional and/or more detailed information for each major analysis section is contained in the associated appendices.

INTRODUCTION

The IPHC first imposed a size-limit on the Pacific halibut fishery in 1940 (Myhre 1973). At that time, the limit (5 pounds; 2.27 kg) was based on "dressed" weight (gilled and gutted). This limit was converted to length (26"; 66 cm) in 1944 in order to facilitate easier compliance at sea. Based on historical analyses (Myhre 1973) and more recently reconstructed trajectories of size-at-age (Stewart 2017), the percentage of small fish encountered by the fishery likely declined steadily from the 1940s through the 1970s. For most of this period, catches of fish smaller than the Minimum Size Limit (MSL) were likely low, based on contemporary reports (Myhre 1974), and historical age composition data. In 1973, the MSL was revised to 32" (81 cm; Myhre 1973), still likely not causing substantial amounts of discard due to large size-at-age. Yield-Per-Recruit (YPR) analysis in the 1960s indicated that, at that time, the age of entry to the fishery was near optimal under equilibrium conditions based on the landed catch from the 26" MSL (IPHC 1960). It is not clear that discard mortality ('wastage'; fish that are captured, discarded, and subsequently die) was a significant concern at that time.

After an apparent peak in the late 1970s, the average Pacific halibut size-at-age declined steadily through around 2010, after which is has been relatively stable, although the coastwide trend masks differences among geographic regions (Stewart 2017). The largest declines in size-at-age have been observed in the Gulf of Alaska (GOA). During this period of decline in size-at-age, there have been several analyses evaluating the effects on the stock and fishery of the MSL. Myhre (1974) found that a 32" MSL was 'optimal' (with regard to fishery yield) only under the lowest discard mortality rates, and that rates above 25% would indicate a 75 cm or lower MSL even at the very high size-at-age observed at that time. He argued that the fishery would likely adjust selectivity by moving away from areas of smaller fish and thus reduce the magnitude of discard mortality. He further noted that the value of larger fish would be higher, and thus the fishery would benefit from the 32" MSL.

Clark and Parma (1995) also used equilibrium methods (YPR and Spawning Biomass Per Recruit, SBPR) to evaluate the MSL based on sampled landings in 1990-91 with more detail in the specific IPHC Regulatory Areas considered. Their analysis found that the 32" MSL 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. Of note was the result that removing the MSL in IPHC Regulatory Area 2B would result in no loss in YPR.

Parma (1999) updated the previous MSL analysis, and reached similar conclusions: that there were small gains in YPR with smaller MSLs, but these were slightly offset by losses in SBPR; she recommended retaining the 32" MSL. That analysis suggested the conservation benefit of a 'reproductive refuge', created by the use of a MSL for management, a concept that is widely used as justification for MSLs in species from crustaceans to reef fish (e.g., Hilborn and Walters 1992).

Valero and Hare (2012) used female maturity-at-age, YPR, SBPR, and a migratory model to evaluate the 32" MSL. 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. Small reductions (3-12 cm) in the MSL were found to have a slight positive effect on YPR (<=3%), and only modest effects on the sex-ratio of the catch (increasing the proportion male by <10%), while larger reductions in the MSL were found to produce reduced YPR and SBPR. The migratory analysis was the first to clearly identify differential effects among the Regulatory Areas. Their analysis conserved the Spawning Biomass Per Recruit ratio ($SBPR_{ratio}$), and concept similar to the Spawning Potential Ratio (SPR) on which the IPHC's current harvest policy is based; however, it appears that their calculation of $SBPR_{ratio}$ took into consideration long-term average conditions rather than only current size-at-age and selectivity such that the absolute values are not comparable to recent estimates (Stewart and Hicks 2017). They further noted that 'precise control' over harvest rates would be more important under younger female age-of-entry into the landed catch (the management buffer concern), and focused much of the discussion on the precautionary nature of retaining the MSL, and risks to spawning biomass of eliminating it.

The most recent evaluations of the MSL occurred in 2014-15 (Martell et al. 2015a, Martell et al. 2015b). The Commission requested the IPHC Secretariat to evaluate specifically the implications of reducing the MSL from 32” to 30”. A response was presented by the IPHC Secretariat (Martell et al. 2015a) at the IPHC’s Annual Meeting in 2015 (AM091). That analysis used an equilibrium model (loosely based on Pacific halibut dynamics) to compare long-term average yield at the stock size and fishing mortality rate that is estimated to produce Maximum Sustainable Yield (MSY). Importantly, that approach is adjusting the harvest policy and size limit simultaneously in order to maximize yield. One salient result, found in Table 1(of that document; Martell et al. 2015a) was that both total and directed fishery average yield were estimated to be larger, and wastage lower, for incremental reductions in the MSL down to 26”. Based on an assumed price-per-pound of small Pacific halibut (due to the reduction in average weight of the landed catch) reducing the MSL below 30” was found to result in a slight loss in total fishery value. The authors noted that potential changes in fishery selectivity of smaller Pacific halibut would be highly important in determining the relative changes in yield, wastage, and profitability. Both the Discard Mortality Rate (DMR) as well as the level of bycatch in non-Pacific halibut fisheries were also found to have a substantial scaling effect of the equilibrium yield (Martell et al. 2015b); however, a 30” MSL was always found to produce a larger yield than a 32” MSL given constant selectivity. The authors also reported that equilibrium female spawning biomass would be reduced with a lower MSL. The yield curves, particularly for scenarios where selectivity is shifted toward smaller fish, became more peaked under a reduced size limit, illustrating that managing precisely at the optimal harvest rate would become more important (the management buffer concern again).

In aggregate, despite using differing methods and data sets, these historical studies provide a reflection of the contemporary fishery and biological properties, and suggest a shift in optimal MSLs from small (26”) to larger (32”), and then progressively greater benefits estimated for smaller size limits in the more recent studies.

This working paper provides an extension to previous efforts, using data sources updated to be as current as possible, and bases yield calculations on the ensemble of stock assessment models currently used to inform management decisions. By focusing on current fishery and biological conditions, the emphasis is on potential gains or losses realized in the short-term, rather than those under equilibrium or long term projections.

SCOPE

This section presents estimates of recent commercial Pacific halibut catch, landings, and wastage, and compares them to the estimates of recreational and bycatch (non-Pacific halibut fisheries) catch, discards, and mortality. Because the observer data for non-Pacific halibut fisheries generally lags at least one year in complete reporting (Jannot et al. 2016, NMFS 2016), all estimates included in this section are based on 2015 for comparability across all sources.

In any fishery that does not require full retention of the catch some fish will be discarded at sea. Trip limits, size-limits, and other regulatory actions all create discards; and some of the fish that are discarded ultimately die. As a conceptual framework, total catch can be divided into three portions: 1) the retained catch (which may be zero for fisheries prohibited from retaining Pacific halibut), 2) the discarded catch that survives, and 3) the discarded catch that subsequently dies due to catch related injuries (a function of the total discards and the DMR). Only the retained catch is effectively known without significant observation uncertainty, and uncertainty in both the magnitude of discards as well as the DMRs applying to those discards. Figure 1 provides a representation of these components.

There are several sources of mortality[1] from the Pacific halibut population in the Northeast Pacific Ocean: the directed commercial Pacific halibut fishery (Goen et al. 2017a), the recreational fisheries (Dykstra 2017a), the personal use and subsistence fisheries (Goen 2017; not summarized in this section), and the non-Pacific halibut fisheries capturing but not retaining Pacific halibut (Dykstra 2017b). In order to simplify this detailed comparison of the sources of mortality, they are summarized by regions specific to the management agencies responsible for each: the Bering Sea and Aleutian Islands (BSAI), and the GOA. More detail on IPHC Regulatory Area-specific components is available in the references noted above, as well as the overview of data sources produced each year (Stewart 2017, Stewart and Monnahan 2016).

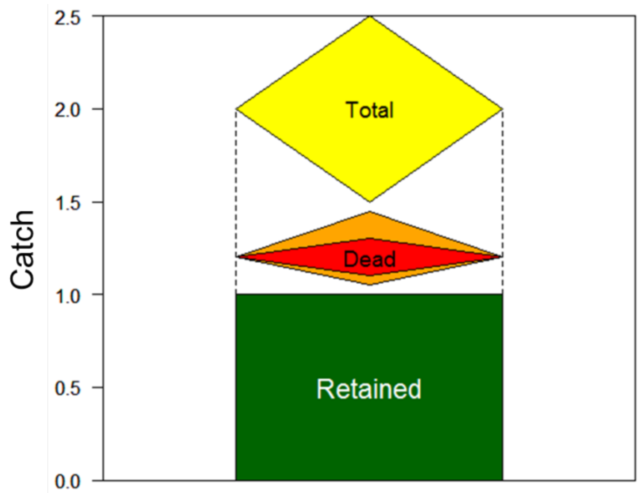

FIGURE 1. Schematic representation of total catch indicating the portions that were retained, discarded and subsequently died, and discarded and subsequently survived. Polygons denote relative uncertainty due to discard mortality rates (red), observer coverage (yellow), and discard mortality rates combined with observer coverage (orange). See Appendix A for calculation details.

The sum of the retained catch, the fish that were discarded and died, and the fish that were discarded and survived represents the total catch handled (Table 1). Across all these sources, roughly half of the total Pacific halibut catch is landed, with nearly 1/3rd of the total catch estimated to have survived the capture process. The magnitude of each component varies substantially by fishery and region, with the directed Pacific halibut fishery in the GOA handling roughly twice the catch of any other source in 2015 (Figure 2).

[1] This term is used interchangeably with removals in this document; both reflect the total quantity of dead Pacific halibut.

TABLE 1. Disposition of all estimated Pacific halibut catch (millions net pounds) estimated for 2015. See Appendix A for calculation details.

Fishery	Retained	Discarded and died	Discarded and survived	Total catch handled	Aggregate DMR	Aggregate observer coverage[7]
BSAI Directed[1]	3.68	0.16	0.82	4.66	0.16	0.13[8]
GOA Directed[2]	14.44	0.85	4.48	19.77	0.16	0.16[8]
B.C. Directed[3]	5.99	0.24	1.25	7.48	0.16	100%
2A Directed	0.57	0.03	0.16	0.77	0.16	0%
Alaska Sport[4]	5.81	0.14	2.21	8.13	0.06	0%
B.C. Sport[5]	1.00	0.06	0.91	1.96	0.06	0%
2A Sport	0.45	<0.01	0.05	0.49	0.07	0%
BSAI Trawl	0	3.69	0.76	4.44	0.83	94%
BSAI non-trawl	0	0.60	4.87	5.47	0.11	87%
GOA Trawl	0	2.33	1.25	3.58	0.65	37%[9]
GOA non-trawl	0	0.45	4.01	4.45	0.10	19%[9]
B.C. Trawl	0	0.33	0.35	0.68	0.48[6]	100%
2A All gears	0	0.10	0.27	0.36	0.27	69%[10]
Total	31.89 (51%)	8.97 (14%)	21.39 (34%)	62.24	0.30	36%

[1] BSAI includes Regulatory Areas 4A, 4B, and 4CDE.
[2] GOA includes Regulatory Areas 2C, 3A, and 3B.
[3] Includes a small quantity of legal halibut not landed but counted against quota.
[4] Includes GAF.
[5] Includes XRQ.
[6] No direct estimate available; estimated via aggregated 2015 2A bottom trawl rates.
[7] Estimated via pounds observed/total estimated pounds as reported in observer summaries.
[8] Rate based on the ratio of observed retained pounds to total retained pounds in order to exclude non-Individual Fishing Quota (IFQ) fishing.
[9] Rate includes both directed and non-directed, as IFQ halibut fishing was not separated from other ho0k-and-line fishing in observer reports.
[10] A 25% average coverage rate was assumed for non-IFQ fishing in Area 2A.

For the purposes of evaluating the Minimum Size Limit (MSL), it is helpful to compare across only the discards of Pacific halibut (Figure 3). Here, it can be seen that the largest sources of discards include the directed fishery in the GOA, the Alaskan sport fisheries, and the BSAI and GOA Trawl and Hook and Line (H&L) bycatch fisheries. Relative uncertainty is greatest for those fisheries with low observer coverage: the GOA directed H&L and Trawl bycatch fisheries as well as the recreational fishery in Alaska (See Appendix A for detail on the calculation of relative uncertainty).

In this context, it is clear that the current MSL is producing a substantial magnitude of Pacific halibut handled and discarded each year, although the mortality of these discards is estimated to be relatively low. Low observer coverage rates in combination with uncertainty in the DMRs

(Leaman and Stewart 2017), result in the directed fishery's handled catch representing an important source of uncertainty in overall removals.

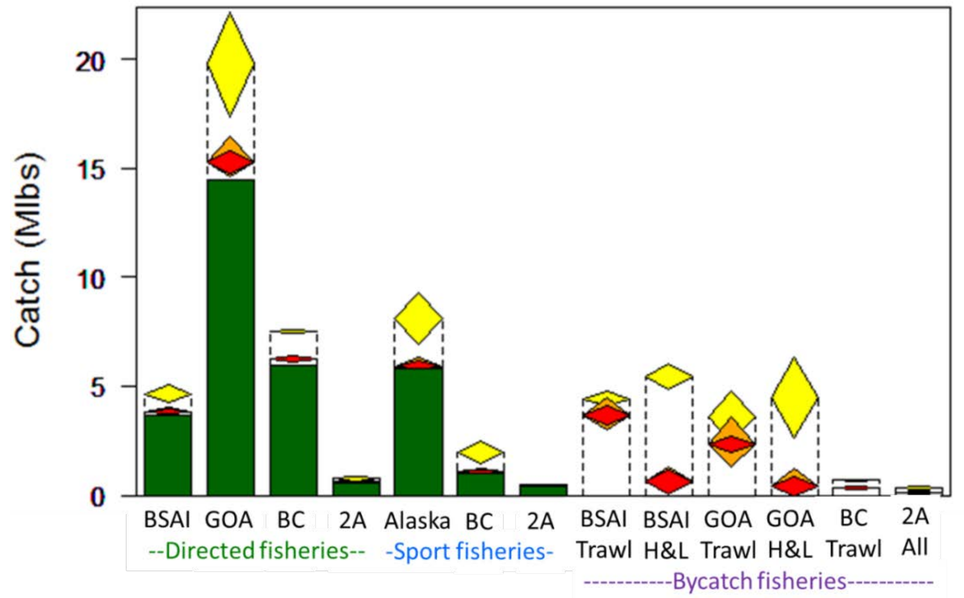

FIGURE 2. Disposition of estimated Pacific halibut catch by source and region in 2015. See Appendix A for calculation details.

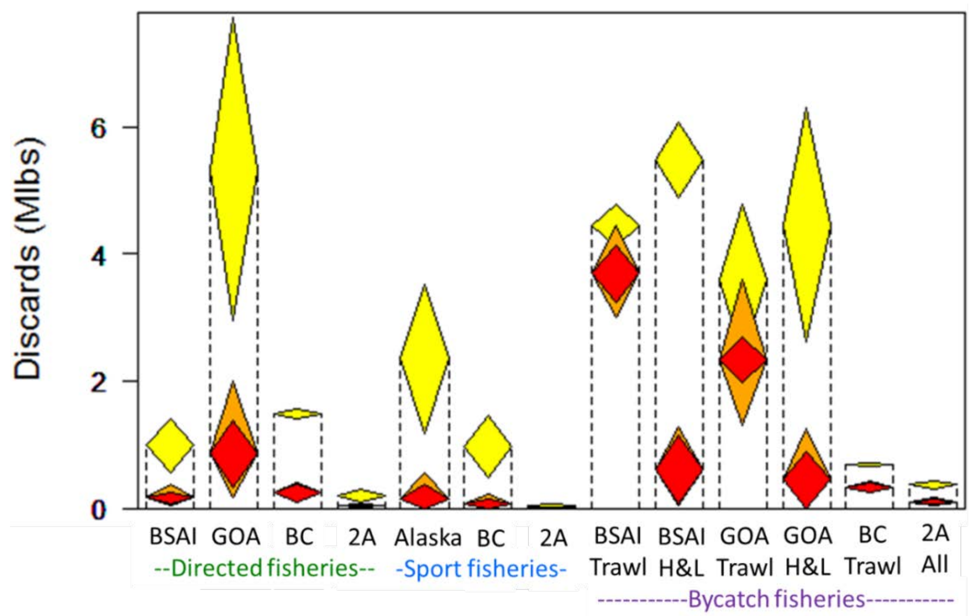

FIGURE 3. Disposition of estimated Pacific halibut discards by source and region in 2015. See Appendix A for calculation details.

SURVEY INFORMATION

The IPHC fishery-independent setline survey (setline survey) is used annually to estimate both the magnitude and size/age structure of halibut discarded by the directed commercial fishery in most IPHC Regulatory Areas (Goen et al. 2017b). IPHC Regulatory Area 2B is the exception, where comprehensive mandatory logbook reporting of sublegal Pacific halibut discards results in a count of individual fish that is used to determine the magnitude of discards (See

Appendix B for a comparison of these data with survey estimates). Because all Pacific halibut captured on the setline survey are measured (Henry et al. 2017), the catch can be partitioned into size bins, and evaluated as a proxy for potential encounter rates in the directed commercial fishery. Summarizing these data in one-inch (2.54 cm) increments reveals three important salient results (Table 2):

1) A substantial portion of the setline survey catch (by weight) across all IPHC Regulatory Areas occurs between 26" and 32".
2) The variability across IPHC Regulatory Areas is large, with 45% of the catch (by weight) below 32" in Area 3B, but only 13.5% in 2C.

A more detailed breakdown of the setline survey catch by both weight and numbers is provided in Appendix B. Because these fish < 32" are light relative to larger individuals the proportions are much larger in numbers than in weight. This may be a consideration for fishery efficiency as small and large fish still occupy a hook.

TABLE 2. Percentage of the 2016 setline survey catch (net weight) that would be discarded in each IPHC Regulatory Area for MSLs from 26 to 32 inches.

	Size limit (inches)						
	26	**27**	**28**	**29**	**30**	**31**	**32**
2A	0.3	0.9	3.0	5.1	10.4	13.9	20.4
2B	0.7	1.8	4.7	7.4	12.7	17.0	22.9
2C	0.6	1.2	2.8	4.2	6.8	9.4	13.5
3A	2.5	3.9	6.9	10.5	16.9	20.6	26.7
3B	10.7	15.0	21.7	26.5	33.6	38.7	45.0
4A	6.3	8.3	11.8	14.0	18.2	21.4	26.1
4B	2.5	4.0	7.4	10.4	16.4	20.7	26.0
4CDE	2.4	4.1	7.6	11.0	17.3	21.2	27.3

Because all of the Pacific halibut randomly sampled for age are also sampled for sex, the change in sex ratio of the retained catch above various MSLs can be summarized. This calculation is provided in Table 3. Similar to the change in weight, there are also two salient points with regard to sex-ratio:

1) The ratio of females in the catch can be reduced by reducing or removing the MSL, however the magnitude of this change in some IPHC Regulatory Areas is modest.
2) The ratio of females in the catch is also highly variable among IPHC Regulatory Areas, with a very high proportion female in IPHC Regulatory Area 2 regardless of MSL, and IPHC Regulatory Area 4B showing a lower proportion female with a 32" MSL than any of the other IPHC Regulatory Areas, even with the MSL removed.

Age composition data from the setline survey indicate generally older males (including some greater than age-20) in the setline survey catch less than 32" (Appendix B). This suggest that some of the change in sex ratio estimated from the setline survey data under reduced MSLs may serve to include males in the retained catch that may not have been available during their average life-span.

TABLE 3. Percent female in the retained 2016 setline survey catch (net weight) in each IPHC Regulatory Area for size-limits from 26 to 32 inches.

	Size limit (inches)							
	None	**26**	**27**	**28**	**29**	**30**	**31**	**32**
2A	81.3	81.4	81.8	83.0	84.1	86.1	87.3	89.3
2B	75.9	76.4	76.9	78.5	79.8	82.3	83.6	85.9
2C	82.9	83.3	83.6	84.3	84.9	85.7	86.2	87.2
3A	73.7	75.1	75.7	77.0	78.6	81.5	83.2	85.9
3B	58.1	62.9	64.9	68.5	71.4	74.8	76.8	79.6
4A	70.3	73.3	74.2	75.7	76.5	78.1	79.1	80.9
4B	45.7	46.2	46.6	47.5	48.3	49.9	51.1	52.4
4CDE	81.0	81.8	82.3	83.1	84.0	86.0	86.8	87.8

OBSERVER INFORMATION

Prior to 2013, there were no observers deployed by the North Pacific Observer Program in the directed commercial fishery in Alaska. Since then, although coverage has been expanded, rates of catch observed remain low (Table 1), and no vessels under 40’ (12.2m) in length are currently observed (NMFS 2016). Because the under 40’ portion of the directed Pacific halibut fishery is large, and tends to fish in different areas and, on with a different mix of fishing gears than the larger vessels, it is not possible to draw unbiased statistical inference through expansion of the sampled portion of the fleet to the total. However, because the observer data represent the only direct observations of the size structure of the entire catch for the fishing fleet, these data may be useful for comparison with the estimates produced from the IPHC’s setline survey. Through a data-sharing agreement between the National Marine Fisheries Service (NMFS) and the IPHC, the observed length frequencies from IFQ fishing in Alaska were provided for this analysis. By converting lengths to weights via the IPHC’s standard equation (Stewart 2017), the percentage of the catch in weight was summarized for each IPHC Regulatory Area in Alaska (See Appendix C for more details on these calculations and comparable summaries in numbers). It is not possible to partition these estimates into males and females, because sex-specific information is not currently collected at-sea.

The Pacific halibut commercial fishery observer data suggest a much lower fraction of the catch occurring between 26 and 32” (Table 4). The magnitude of these estimates is roughly half that estimated from the setline survey, although the relative patterns across IPHC Regulatory Areas and sizes is similar. It is not clear to what degree these estimates are representative of the fishery as a whole; however, the reduced catch at smaller sizes is consistent with avoidance of spatial and temporal fishing opportunities that would be sampled more uniformly by the setline survey.

TABLE 4. Percentage of the observed 2016 catch (net weight) that would be discarded in each IPHC Regulatory Area for size-limits from 26 to 32 inches.

	Size limit (inches)						
	26	**27**	**28**	**29**	**30**	**31**	**32**
2A	NA	NA	NA	NA	NA	NA	NA
2B	NA	NA	NA	NA	NA	NA	NA
2C	0.7	1.1	2.0	2.8	4.6	5.8	9.1
3A	1.6	2.5	4.6	6.9	11.1	14.6	21.7
3B	3.9	5.2	8.0	10.0	13.3	15.7	19.8
4A	2.7	3.7	5.7	6.9	9.5	10.8	14.1
4B	0.7	1.1	2.6	3.9	6.9	8.9	12.2
4CDE	1.1	1.4	2.6	3.9	6.7	8.6	13.2

YIELD CALCULATIONS

Previous Minimum Size Limit (MSL) analyses spent considerable effort addressing how the IPHC's harvest policy might change in order to accommodate a change to the MSL. For 2017, the Commission decided to base the reference level of removals in the decision table (the interim harvest policy) on a constant SPR target of 46%. This section evaluates how the yield and yield characteristics could change given a change in the MSL. Further, as in most historical analyses, we consider the possibility that targeting of smaller Pacific halibut could increase under a reduced or removed MSL.

Briefly, the 2016 stock assessment (an ensemble of four individual models) was used to project the removals consistent with fishing at a level corresponding to $SPR_{46\%}$ in 2017. With this level of removals as a baseline, the removals were rescaled to continue to achieve $SPR_{46\%}$ under four alternative cases: removing the MSL with no response in fishery selectivity (noting that the mortality of U32 fish increases by a factor of 6.25, from 16% of those handled to 100% of those handled), and under targeting of the directed fishery increasing the U32 component of the catch by 10%, 20% and 30%. Targeting of smaller Pacific halibut could be achieved via changes in spatial fishing effort, hook size and/or bait size, and may be expected in some IPHC Regulatory Areas where catch rates could be increased to the greatest degree. From each of these cases, the change in total retained catch (Figure 4), as well as the change in the proportion of the retained catch comprised by U32 Pacific halibut (Figure 5) was estimated. Further details of these calculations are provided in Appendix D.

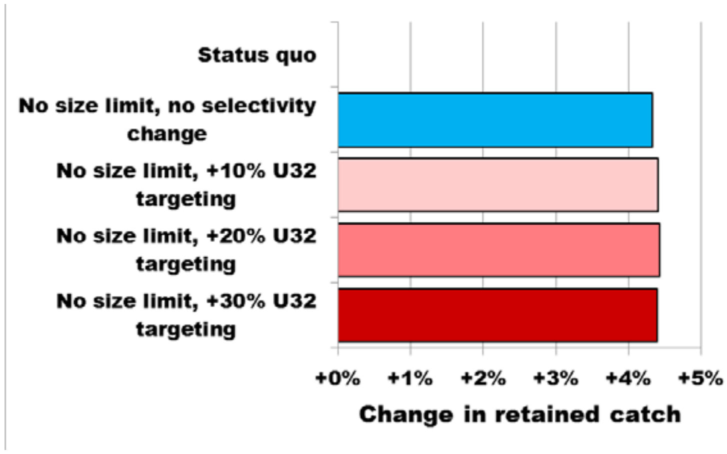

FIGURE 4. Change in yield associated with the *status quo* ($SPR_{46\%}$) harvest policy based on the 2016 assessment ensemble.

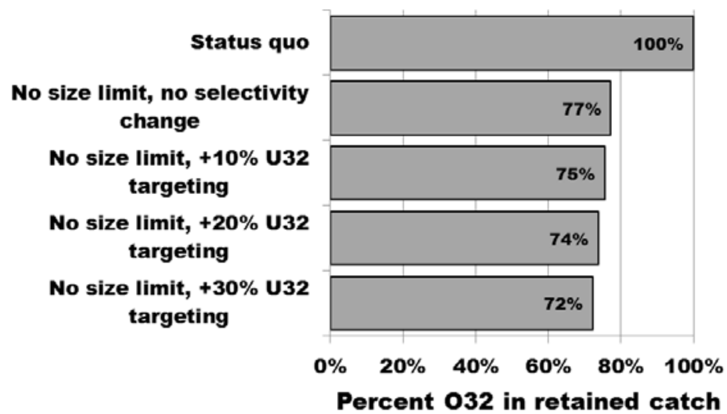

FIGURE 5. Change in directed commercial Pacific halibut fishery catch composition associated with the *status quo* ($SPR_{46\%}$) harvest policy based on the 2016 assessment ensemble.

These results suggest an increase in retained catch of just over 4% regardless of increased targeting of small Pacific halibut. However, the retained catch for all four cases consists of around 25% U32 Pacific halibut, which means that the magnitude of O32 retained catch would decrease relative to recent limits for a similar stock size.

OTHER CONSIDERATIONS

There are a number of considerations relevant to the evaluation of Minimum Size Limits (MSL) that are difficult or impossible to quantify given current information. These can be divided into two categories: those that are primarily biological and those that are largely technical and/or operational.

Biological.

Biological considerations include implications for stock distribution, density dependence, observed size-at-age, and biological-management interactions. Potential effects on the spatial distribution of the stock may be created by taking more or less small/young Pacific halibut in each IPHC Regulatory Area. Our broad understanding of movement rates by age (Stewart 2017) suggests that reducing the MSL without adjusting the management distribution may result in a larger proportion of the catch occurring in the western portions of the stock (parts of 3A, 3B and parts of 4A in particular). This is where most of the juvenile habitat and production is believed to occur, and where the highest proportion of small/young Pacific halibut is encountered by the survey. However, the management (or catch) is also a function of management decisions, so this potential effect is difficult, if not impossible to predict.

Female and especially male Pacific halibut are more numerous at smaller sizes (as seen in the analyses above). Density dependence within the Pacific halibut stock has been suggested as a potential factor contributing to changes in size-at-age (Clark and Hare 2002, Clark et al. 1999); however there appear to be additional (or alternative) factors (Loher 2013) influencing recent trends that have resulted in relatively low size-at-age even after a decade of declining number in the early 2000s. Although fishery effects on size-at-age due to the MSL are likely present (Martell et al. 2015b, Sullivan 2016), there is currently no evidence for fishery induced evolution, or genetic effects on size at age. In fact, the variability of size-at-age remains high, despite changes in the average, and historical trends indicate increasing size-at-age over much of the 1900s during intense fishery exploitation. Further, longline gear is inherently size selective (e.g., Kaimmer 2015) even in the absence of a MSL, and it is unclear whether a change in the MSL would have clear effects on density dependent processes or size-at-age.

A MSL provides a reduction in the fishing mortality on immature Pacific halibut that would be reduced under a lower or no MSL. Higher survival results in a larger spawning biomass, on average (and especially under equilibrium conditions) as has been identified by several previous analyses of the MSL (Clark and Parma 1995, Martell et al. 2015a, Martell et al. 2016, Valero and Hare 2012). However, the current understanding of the stock and recruitment dynamics suggest only a weak relationship between spawning biomass and subsequent cohort strengths (Clark and Hare 2006, Clark et al. 1999), with the most dominant covariate being the environmental conditions, as referenced by the Pacific Decadal Oscillation (PDO; Stewart and Hicks 2017). Perhaps more important for consideration, is the shape of estimated yield curves under differing MSLs. Reducing or removing the MSL would result in equilibrium yields maximized over a more narrow range of fishing intensities (upper middle panel of Figure 3 in Martell et al. 2015a), potentially amplifying the variability in estimation and observation errors in stock size and productivity translated into realized yield. However; it is unclear that the magnitude of these uncertainties would be appreciable relative to the many other sources of uncertainty in the assessment and implementation of the IPHC's previous harvest policy.

Operational.

Operational considerations include technical aspects of implementing a change in the MSL in the stock assessment and harvest policy, as well as data needs and effects on non-biological aspects of the fishery such as market structure and price.

The use of an SPR target does not pose a technical impediment to a change in the MSL, in contrast to previous evaluations of the MSL where a revision to the harvest policy would have been necessitated by any change to the MSL. However, the current metric for describing stock distribution, relative O32 setline survey catch (Webster and Stewart 2017) would retain little meaning under a reduced or no MSL. In that case (and perhaps for the 32" MSL as well), it may be preferable to describe stock distribution via total survey catch. There are already, and would be further removals of U32 Pacific halibut under any change to the MSL. YPR and other harvest policy calculations relating to the relative harvest rates among IPHC Regulatory Areas depend on the selectivity of the fishery, and so would need to be adjusted, likely over several years, if the MSL were changed and the fishery subsequently adapted. There would be a lag in this response, due to the need for data with which to estimate the change in selectivity: if there were rapid changes, they would not be reflected in these calculations until the following year when data became available. The stock assessment already includes time-varying selectivity for the directed commercial fishery. A reduced MSL could be modelled with no technical changes to this approach, and removal of the MSL would simplify the assessment framework and assumptions in creating the data sources, as the commercial catch would be comprehensively sampled in port. This sampling would be dependent on full retention of all fish caught in the fishery.

For reduced MSLs, and particularly for removal of the MSL, there likely would be fewer Pacific halibut which are not retained; therefore the importance of DMRs and the uncertainty in DMRs for the directed commercial Pacific halibut fishery is reduced or eliminated. It is unknown how the processing industry and the market for Pacific halibut would respond to a change in the average size and the introduction of much smaller Pacific halibut to the landed catch. Finally, there is a potential public perception benefit in increasing fishery efficiency and reducing wasted fish even if there is a net reduction in overall fishery value (depending on price).

SUMMARY

This analysis suggests the following general conclusions (Table 5):

- Discard mortality (wastage) – the quantity of Pacific halibut discarded which is either dead or dies from catch related injuries, as a function of having a Minimum Size Limit (MSL) would remain unknown under a reduced size limit (as it is currently), but would be eliminated (and observed) if all Pacific halibut were retained and the MSL were removed.
- Total yield – the retained catch in pounds is predicted to increase slightly given a constant SPR target of 46%, under a reduced or no MSL.
- Harvest of male Pacific halibut – the yield (retained catch) from male Pacific halibut would increase under a reduced or no MSL. This catch does not influence the SPR.
- Selectivity – the response of the directed commercial Pacific halibut fishery to a reduced or no MSL is unknown, and would likely depend on how the ex-vessel price for U32 fish compares to the current price structure.
- Biological data – the size/age composition of the entire directed commercial Pacific halibut fishery catch is currently estimated only indirectly. Under full retention of Pacific halibut and no MSL these fish could be sampled directly in port (assuming an absence of high-grading).
- Management buffer - MSLs provide a management 'buffer', flattening yield curves (producing near-optimal yields over a broader range of harvest rates), and reducing the potential effects of harvest rates that differ modestly from those that would be optimal, either by design or due to observation and estimation error.
- Recruitment refuge – the current 32" MSL appears to provide for a reduction in harvest rates on immature fish. The degree to which it benefits stock and recruitment dynamics or serves as a precautionary tool has not been determined.
- Fishery efficiency – fishing efficiency would increase with a reduced or no MSL, as less gear would be required to land the same volume of catch in all IPHC Regulatory Areas; however, this change would differ in magnitude among areas, with some (e.g., 3B), likely showing the greatest response.
- Price – The value/price for U32 Pacific halibut would become known if the MSL were reduced (for some sizes) or removed entirely. It is unclear how long this would take and what specific factors may be relevant.

- Fishery value – The net value of the directed commercial Pacific halibut fishery may change in a positive or negative direction depending on the emergent price for U32 Pacific halibut. If the price were comparable to current prices, the increased yield (~4%) would suggest increased fishery value; however, the projected proportion of U32 fish in the catch is large enough (~25%) to offset the increased yield if the value of these fish is low.

TABLE 5. Summary of MSL considerations.

	Status quo 32" MSL	Reduced MSL	No MSL
Discard mortality (wastage)	No change	unknown	Down
Total yield	No change	Up	Up
Harvest of males	No change	Up	Up
Selectivity	No change	unknown	unknown
Biological data on total catch	Incomplete	Incomplete	Sampled in port
Management buffer	No change	Down	Down
Recruitment refuge	No change	Down	Down
Fishery efficiency (retained catch-rate)	No change	Up	Up
Price	No change	Emergent	Emergent
Fishery value	No change	Depends on price	Depends on price

The IPHC Secretariat developed several options for adaptive management approaches that are included in Appendix E. The IPHC Secretariat is not currently advising the Commission on a particular course of action with regard to the MSL. A working paper reflecting this updated document will be presented to the Commission during the IPHC's Work Meeting, 20-21 September, 2017. Pending the outcome of that meeting, further review of the topic may be undertaken at the 2017 Interim meeting (IM093).

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2017-SRB11-07 which provides an updated review of the '*effectiveness'* of a range of size limits in the directed commercial Pacific halibut fishery.
b) **REQUEST** any modifications to the adaptive management alternatives (presented in Appendix E).
c) **REQUEST** any modifications necessary to provide for further consideration of the MSL by the Commission during upcoming Session of the IPHC Interim and Annual Meetings.

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APPENDICES

Appendix A: Distribution of all Pacific halibut catch estimates in 2015.

Appendix B: Distribution of 2016 setline survey Pacific halibut catch by size, sex, and age.

Appendix C: Distribution of 2016 observed commercial Pacific halibut catch by size.

Appendix D: Yield calculations.

Appendix E: Evaluation of adaptive management approaches.

APPENDIX A
Distribution of all Pacific halibut catch estimates in 2015

There are two important aspects to the disposition of the catch as estimated in this document, these are: 1) the basis for the estimates, and 2) the uncertainty in these estimates that is assumed.

The estimates in Table 1 for the retained catch and the discarded and died (D_d) catch all come from the best available estimates used in the 2016 stock assessment as referenced in the main text. The discarded and survived (D_s) estimates were calculated from the dead discards (D_d) and the DMR via:

$$D_s = \left(\frac{D_d}{DMR}\right) - D_d$$

In several cases, the DMR values are based on literature review and/or historical analyses. These include the 16% DMR applied to the directed commercial Pacific halibut fishery (Leaman and Stewart 2017), and the DMR underlying the recreational estimates from Alaskan waters (Meyer 2007). The aggregate DMRs also represent the combination of several components. For the recreational estimates from Alaska, the aggregate DMR was calculated from the sum of the component (c) specific DMRs:

$$DMR = \left(\frac{\sum_c DMR_c * \left(D_{d,c} + D_{s,c}\right)}{\sum_c\left(D_{d,c} + D_{s,c}\right)}\right)$$

In some cases the observer coverage was reported directly for the fishery of interest, and in others, such as the aggregate trawl fisheries in the BSAI and GOA, the aggregate was approximated based on the relative magnitude of catch for each of the reported component fisheries contributing. For this reason, the estimates in Table 1 should be considered merely approximations, for use in a broad comparison among sources of Pacific halibut discards and mortality.

The second important aspect of this analysis is the degree of uncertainty assumed to arise from the DMRs and from the rate of observer coverage. The estimates reported here should not be mistaken for statistical variance estimates. The largest impediment to statistically-based variance estimates is the ‘observer effect’, whereby fishing behavior can differ in the presence or absence of an observer on the vessel, and therefore an unknown degree of bias exists in the expansion from observed to unobserved activity. Recent observer reports indicate that this effect does exist (Faunce and Barbeaux 2011, Faunce et al. 2016). There is currently no method for estimating the variance in observer estimates due to lack of coverage (<40’ vessels), non-random coverage (e.g., vessels making longer trips, landing more fish, etc. when not carrying an observer), and statistical variance associated with subsampling of fish, fishing events, and fishing trips.

In order to qualitatively evaluate which sources have more or less uncertainty related to the level of observer coverage, a simple relationship was used for graphical analysis. The Coefficient of Variation (CV) in the quantity of halibut discarded is assumed to be a simple linear function of the observer coverage (*O*, pounds landed and observed/total pounds landed):

$$CV = 5\% + [45\% * (100\% - O)]$$

This relationship results in the following: 100% observer coverage corresponds to a 5% CV, 50% observer coverage corresponds to a 27.5% CV, and 0% observer coverage corresponds to a 50% CV.

Uncertainty in DMRs is assumed to be +/- 10% regardless of scale or source. We currently have no method for quantifying this uncertainty in either static values (e.g., the 16% assumed for the directed commercial halibut fishery) or values based on viability assessments by at-sea observers which are subject to measurement error, as well as including uncertainty in the underlying survival rates associated with the measured condition of the sampled Pacific halibut at the point of release.

As all of the inputs to Table 1 have inter-annual variability, and are representative of 2015, their applicability to future years is uncertain. For this reason, the information is just intended to provide a general guide to the magnitude of sources and uncertainty for comparative purposes.

APPENDIX B
Distribution of 2016 setline survey Pacific halibut catch by size, sex, and age

All Pacific halibut captured on the IPHC's fishery independent setline survey are measured to the nearest centimeter (Henry et al. 2017). However, only a portion of the sublegal halibut captured are sacrificed for otolith sampling (the rest are released alive whenever possible). Sex determination is done after the fish have been sacrificed, therefore only those Pacific halibut that have been fully sampled have an age, length and sex estimate. For this analysis only the random sample of Pacific halibut with this complete information has been included.

The results are summarized in terms of both numbers of fish as well as weight of fish in each one-inch (2.54 cm) size-increment from 26" to 32". Individual fish weights were estimated via the IPHC's length-weight relationship (Stewart 2017) between fork length (L_f), and individual net (headed and gutted) weights (W_n):

$$W_n = 0.00000692 \cdot L_f^{\,3.24}$$

Although there are ongoing projects to evaluate this relationship (Planas 2017), the direct information is not yet comprehensive enough to allow for the use of measured weights for survey catch at this point. However, this is a potential source of bias in the analysis, as measured weights from commercially captured halibut have shown some evidence of divergence from the length-weight relationship (Webster and Erikson 2017).

The weight and number of fish discarded in each size-increment and cumulatively from 26" to 32" were calculated for each regulatory area, with males and females separated (Tables B1-B8 and figures B1-B8). Although the sex-ratio for each size-increment is reported in the main text, a related question regards the partial recruitment of males to the survey and fishery catch. Specifically, given the variability in size-at-age, it is possible that some male halibut may not exceed the current MSL during their average life-span. The distribution of ages for male and female Pacific halibut less than 32" captured by the setline survey indicates, in some areas (particularly 3A), as many as 10% of sublegal male halibut may be older than 15 years (Figure B10).

An alternative method for summarizing the sublegal catch-rates from the setline survey is used each year for the calculation of wastage (Goen et al. 2017b). In that approach, the catch at each survey station is summarized as the ratio of numbers of sublegal fish to total numbers of fish captured. Then, the distribution of survey stations within a Regulatory Area is characterized by the median, 25th and 75th percentiles of this ratio. The results indicate similar encounter rates among Regulatory Areas, and considerable variability within Areas which could translate to differences between these survey-based estimates and actual catch encountered by the directed commercial fishery (Figure B10). This is an important consideration for the interpretation of this analysis all survey-based approaches assume that the setline survey is encountering and selecting the same size distribution of Pacific halibut as the commercial fishery. Differences in spatial and seasonal fishing patterns, as well as fishing gear and bait could all lead to differences in the total catch encountered by the directed commercial fishery relative to the setline survey. Because the IPHC's sampling program occurs when the fish are landed, there are no direct and unbiased estimates of the total fishery catch currently available.

TABLE B1. Percentage of the 2016 survey catch that would be discarded in Area 2A for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch by sex greater than the current 32-inch minimum size limit is reported at the right margin.

	Size limit (inches)							
	26	**27**	**28**	**29**	**30**	**31**	**32**	**> 32**
Numbers								
Males	0.7	1.3	3.4	2.9	4.9	2.7	3.7	9.3
Females	0.1	0.3	1.4	1.4	4.8	3.3	6.0	53.9
Cumulative males	0.7	2.0	5.4	8.3	13.2	15.8	19.5	
Cumulative females	0.1	0.4	1.8	3.3	8.1	11.3	17.3	
Cumulative total	0.8	2.4	7.2	11.6	21.2	27.1	36.8	
Weight								
Males	0.2	0.5	1.5	1.4	2.6	1.6	2.4	8.5
Females	0.0	0.1	0.6	0.7	2.6	2.0	4.0	71.2
Cumulative males	0.2	0.7	2.2	3.6	6.3	7.9	10.3	
Cumulative females	0.0	0.1	0.8	1.5	4.1	6.1	10.1	
Cumulative total	0.3	0.9	3.0	5.1	10.4	13.9	20.4	

TABLE B2. Percentage of the 2016 survey catch that would be discarded in Area 2B for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch by sex greater than the current 32-inch minimum size limit is reported at the right margin.

	Size limit (inches)							
	26	**27**	**28**	**29**	**30**	**31**	**32**	**> 32**
Numbers								
Males	2.0	2.2	5.2	3.9	6.1	3.3	4.1	11.3
Females	0.2	0.8	1.7	1.8	4.1	4.1	5.0	44.1
Cumulative males	2.0	4.3	9.4	13.3	19.4	22.7	26.9	
Cumulative females	0.2	1.0	2.6	4.5	8.6	12.7	17.7	
Cumulative total	2.2	5.2	12.1	17.8	28	35.4	44.6	
Weight								
Males	0.6	0.8	2.2	1.8	3.2	1.9	2.7	10.9
Females	0.1	0.3	0.7	0.9	2.1	2.4	3.2	66.3
Cumulative males	0.6	1.5	3.6	5.4	8.6	10.5	13.2	
Cumulative females	0.1	0.4	1.1	1.9	4.1	6.5	9.7	
Cumulative total	0.7	1.8	4.7	7.4	12.7	17	22.9	

TABLE B3. Percentage of the 2016 survey catch that would be discarded in Area 2C for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch by sex greater than the current 32-inch minimum size limit is reported at the right margin.

	Size limit (inches)							
	26	**27**	**28**	**29**	**30**	**31**	**32**	**> 32**
Numbers								
Males	1.8	1.4	3.0	1.8	2.7	1.6	2.6	13.5
Females	0.5	0.7	1.5	1.6	3.5	3.7	5.1	55.0
Cumulative males	1.8	3.2	6.1	8.0	10.7	12.3	14.9	
Cumulative females	0.5	1.2	2.7	4.4	7.8	11.5	16.6	
Cumulative total	2.3	4.4	8.9	12.4	18.5	23.8	31.5	
Weight								
Males	0.5	0.4	1.0	0.7	1.2	0.8	1.4	11.1
Females	0.1	0.2	0.5	0.6	1.5	1.8	2.7	75.3
Cumulative males	0.5	0.9	1.9	2.7	3.8	4.6	6.0	
Cumulative females	0.1	0.3	0.9	1.5	3.0	4.8	7.5	
Cumulative total	0.6	1.2	2.8	4.2	6.8	9.4	13.5	

TABLE B4. Percentage of the 2016 survey catch that would be discarded in Area 3A for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch by sex greater than the current 32-inch minimum size limit is reported at the right margin.

	Size limit (inches)							
	26	**27**	**28**	**29**	**30**	**31**	**32**	**> 32**
Numbers								
Males	6.0	2.2	4.0	4.4	6.3	3.1	4.1	10.4
Females	1.5	1.0	2.4	2.3	4.5	2.4	4.3	41.1
Cumulative males	6.0	8.2	12.2	16.6	22.9	26	30.1	
Cumulative females	1.5	2.5	4.9	7.2	11.7	14.1	18.4	
Cumulative total	7.5	10.7	17.1	23.8	34.6	40.2	48.5	
Weight								
Males	2.0	0.9	1.9	2.3	3.7	2.1	3.0	10.3
Females	0.5	0.4	1.1	1.2	2.6	1.6	3.1	63.0
Cumulative males	2.0	3.0	4.9	7.2	11.0	13.0	16.0	
Cumulative females	0.5	0.9	2.0	3.3	5.9	7.5	10.6	
Cumulative total	2.5	3.9	6.9	10.5	16.9	20.6	26.7	

TABLE B5. Percentage of the 2016 survey catch that would be discarded in Area 3B for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch by sex greater than the current 32-inch minimum size limit is reported at the right margin.

	Size limit (inches)							
	26	**27**	**28**	**29**	**30**	**31**	**32**	**> 32**
Numbers								
Males	19.1	5.6	7.7	4.9	5.2	2.7	3.0	8.3
Females	4.3	1.6	2.4	1.6	3.3	2.8	3.3	24
Cumulative males	19.1	24.8	32.5	37.4	42.6	45.4	48.3	
Cumulative females	4.3	6.0	8.3	9.9	13.2	16.1	19.3	
Cumulative total	23.5	30.7	40.8	47.4	55.9	61.4	67.7	
Weight								
Males	8.8	3.3	5.1	3.7	4.3	2.5	3.0	11.2
Females	1.9	1.0	1.6	1.2	2.7	2.6	3.3	43.8
Cumulative males	8.8	12.1	17.2	20.9	25.2	27.7	30.7	
Cumulative females	1.9	2.9	4.4	5.6	8.4	11.0	14.3	
Cumulative total	10.7	15	21.7	26.5	33.6	38.7	45.0	

TABLE B6. Percentage of the 2016 survey catch that would be discarded in Area 4A for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch by sex greater than the current 32-inch minimum size limit is reported at the right margin.

	Size limit (inches)							
	26	**27**	**28**	**29**	**30**	**31**	**32**	**> 32**
Numbers								
Males	14.2	3.2	4.5	2.2	3.8	2.2	3.0	11.9
Females	5.3	1.4	2.6	1.9	3.0	2.5	3.3	35.0
Cumulative males	14.2	17.4	22.0	24.2	28.0	30.2	33.2	
Cumulative females	5.3	6.7	9.2	11.1	14.1	16.6	19.8	
Cumulative total	19.5	24.1	31.2	35.3	42.1	46.8	53.0	
Weight								
Males	4.6	1.4	2.2	1.2	2.3	1.5	2.3	14.1
Females	1.6	0.6	1.3	1.0	1.8	1.7	2.4	59.8
Cumulative males	4.6	6.0	8.3	9.5	11.8	13.3	15.6	
Cumulative females	1.6	2.2	3.5	4.5	6.4	8.1	10.5	
Cumulative total	6.3	8.3	11.8	14	18.2	21.4	26.1	

TABLE B7. Percentage of the 2016 survey catch that would be discarded in Area 4B for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch by sex greater than the current 32-inch minimum size limit is reported at the right margin.

	Size limit (inches)							
	26	27	28	29	30	31	32	> 32
Numbers								
Males	5.7	2.9	5.9	4.6	7.7	4.9	5.0	27.8
Females	2.0	0.7	1.5	1.3	2.8	1.8	2.5	22.8
Cumulative males	5.7	8.7	14.5	19.1	26.8	31.7	36.7	
Cumulative females	2.0	2.8	4.3	5.6	8.4	10.2	12.7	
Cumulative total	7.8	11.4	18.8	24.7	35.2	41.9	49.4	
Weight								
Males	1.9	1.2	2.7	2.3	4.4	3.1	3.5	35.3
Females	0.7	0.3	0.7	0.7	1.6	1.1	1.8	38.8
Cumulative males	1.9	3.1	5.8	8.1	12.5	15.6	19.1	
Cumulative females	0.7	1.0	1.6	2.3	3.9	5.1	6.8	
Cumulative total	2.5	4.0	7.4	10.4	16.4	20.7	26.0	

TABLE B8. Percentage of the 2016 survey catch that would be discarded in Area 4CDE for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch by sex greater than the current 32-inch minimum size limit is reported at the right margin.

	Size limit (inches)							
	26	27	28	29	30	31	32	> 32
Numbers								
Males	3.8	1.9	2.9	2.6	4.5	1.9	2.1	7.7
Females	3.6	2.1	4.6	3.9	6.3	4.2	6.4	41.6
Cumulative males	3.8	5.7	8.6	11.2	15.7	17.6	19.7	
Cumulative females	3.6	5.7	10.3	14.2	20.5	24.7	31.1	
Cumulative total	7.3	11.4	18.9	25.4	36.2	42.3	50.7	
Weight								
Males	1.2	0.8	1.4	1.4	2.6	1.2	1.5	8.9
Females	1.2	0.9	2.2	2.1	3.7	2.7	4.6	63.8
Cumulative males	1.2	2.0	3.4	4.7	7.3	8.6	10.1	
Cumulative females	1.2	2.1	4.2	6.3	9.9	12.6	17.2	
Cumulative total	2.4	4.1	7.6	11	17.3	21.2	27.3	

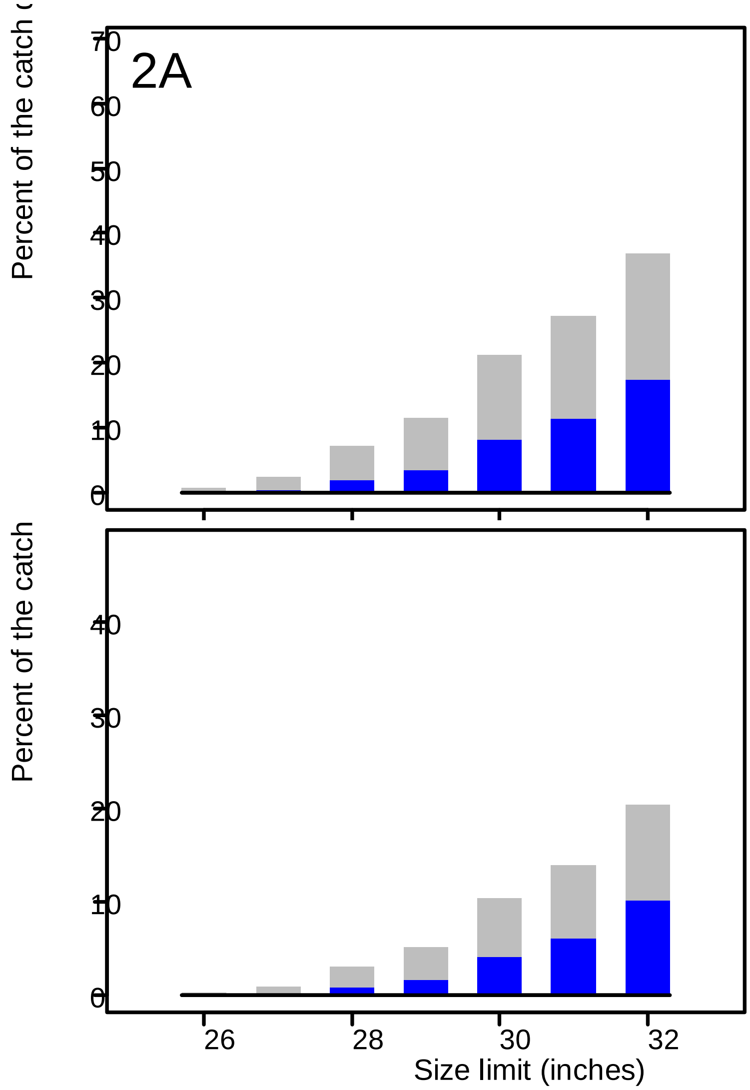

FIGURE B1. Percentage of the 2016 survey catch discarded in Area 2A for size-limits from 26 to 32 inches, based on the number of fish (upper panel) and the weight of fish (lower panel). Height of the bars represents the total, and the darker (lower) portion the contribution of male halibut. Note that the y-axes differ. See tables for percentage values.

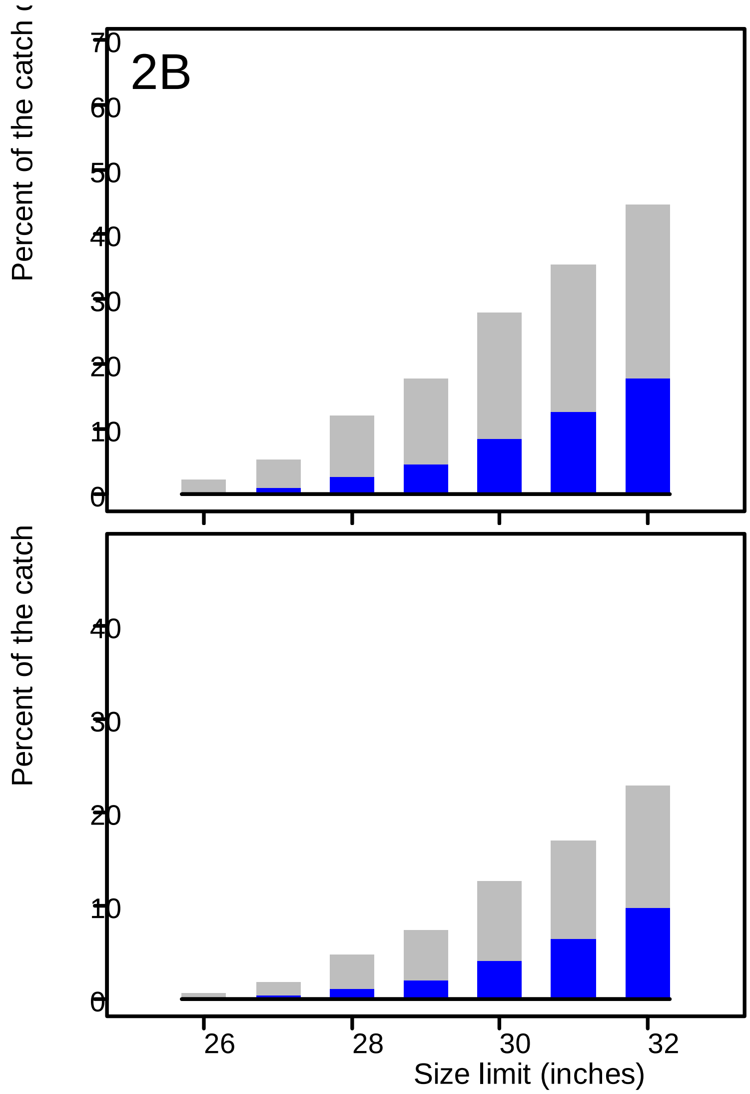

FIGURE B2. Percentage of the 2016 survey catch discarded in Area 2B for size-limits from 26 to 32 inches, based on the number of fish (upper panel) and the weight of fish (lower panel). Height of the bars represents the total, and the darker (lower) portion the contribution of male halibut. Note that the y-axes differ. See tables for percentage values.

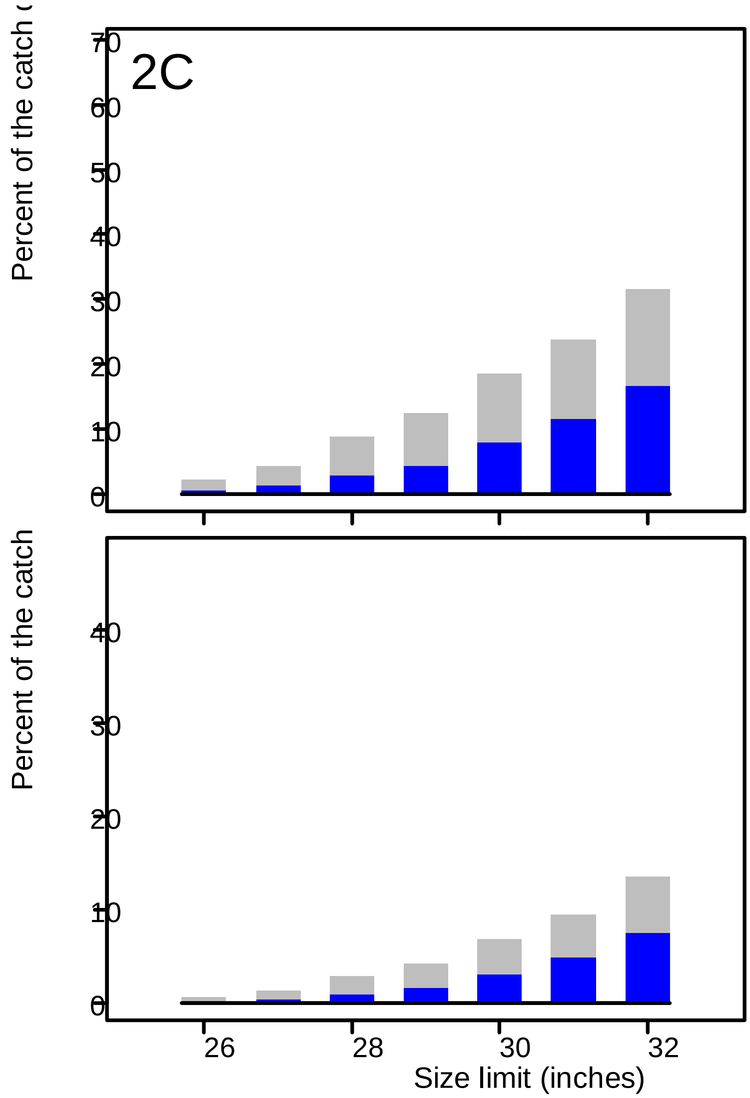

FIGURE B3. Percentage of the 2016 survey catch discarded in Area 2C for size-limits from 26 to 32 inches, based on the number of fish (upper panel) and the weight of fish (lower panel). Height of the bars represents the total, and the darker (lower) portion the contribution of male halibut. Note that the y-axes differ. See tables for percentage values.

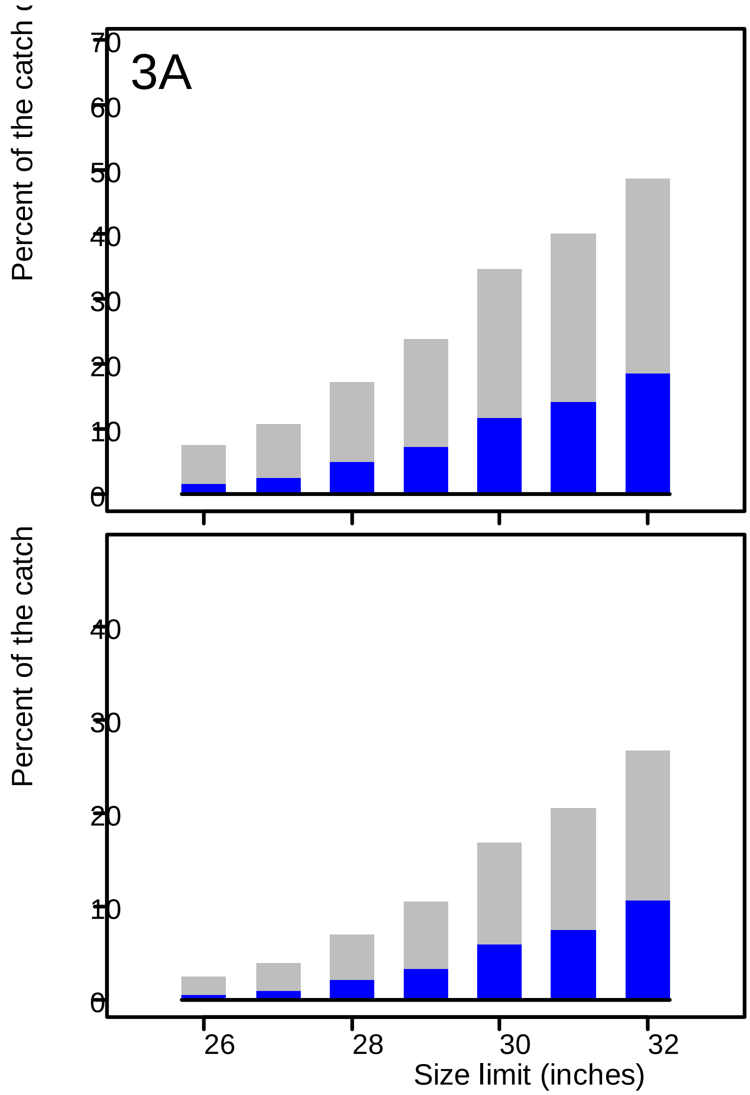

FIGURE B4. Percentage of the 2016 survey catch discarded in Area 3A for size-limits from 26 to 32 inches, based on the number of fish (upper panel) and the weight of fish (lower panel). Height of the bars represents the total, and the darker (lower) portion the contribution of male halibut. Note that the y-axes differ. See tables for percentage values.

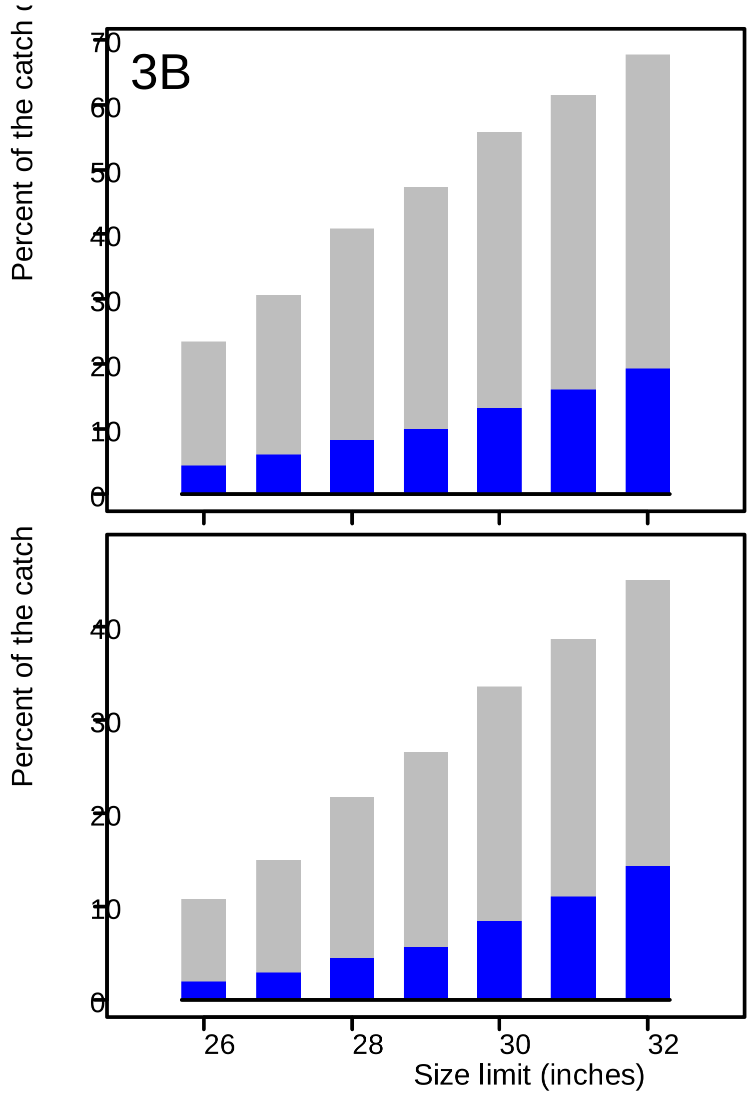

FIGURE B5. Percentage of the 2016 survey catch discarded in Area 3B for size-limits from 26 to 32 inches, based on the number of fish (upper panel) and the weight of fish (lower panel). Height of the bars represents the total, and the darker (lower) portion the contribution of male halibut. Note that the y-axes differ. See tables for percentage values.

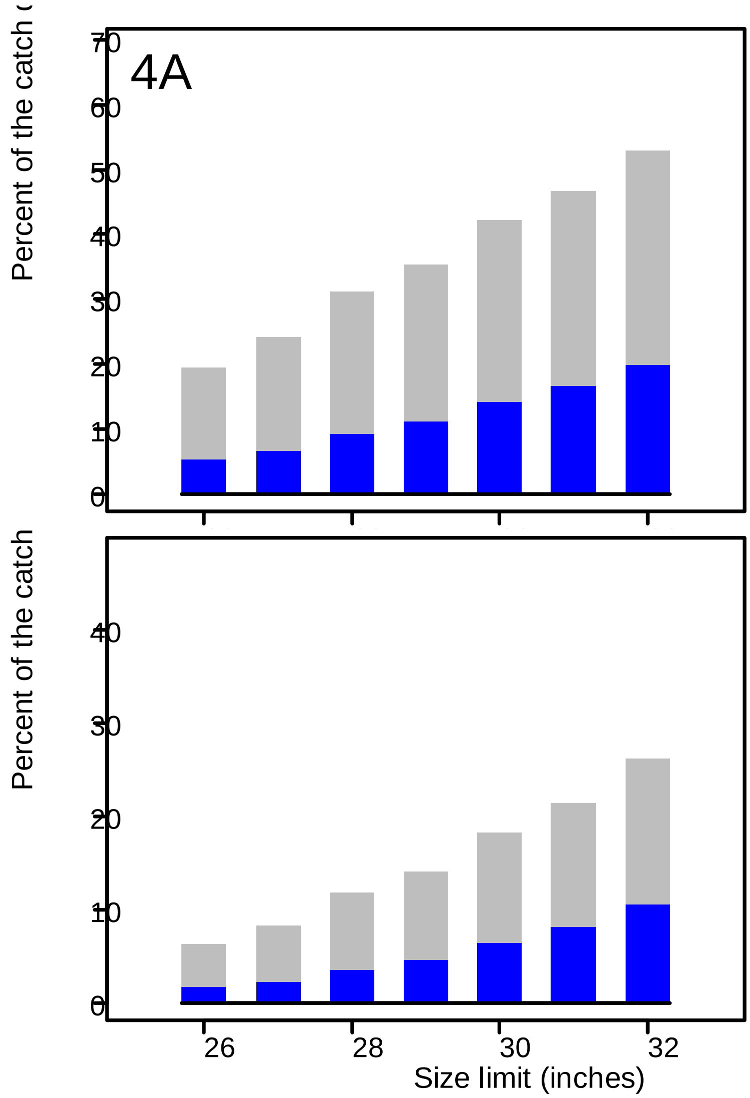

FIGURE B6. Percentage of the 2016 survey catch discarded in Area 4A for size-limits from 26 to 32 inches, based on the number of fish (upper panel) and the weight of fish (lower panel). Height of the bars represents the total, and the darker (lower) portion the contribution of male halibut. Note that the y-axes differ. See tables for percentage values.

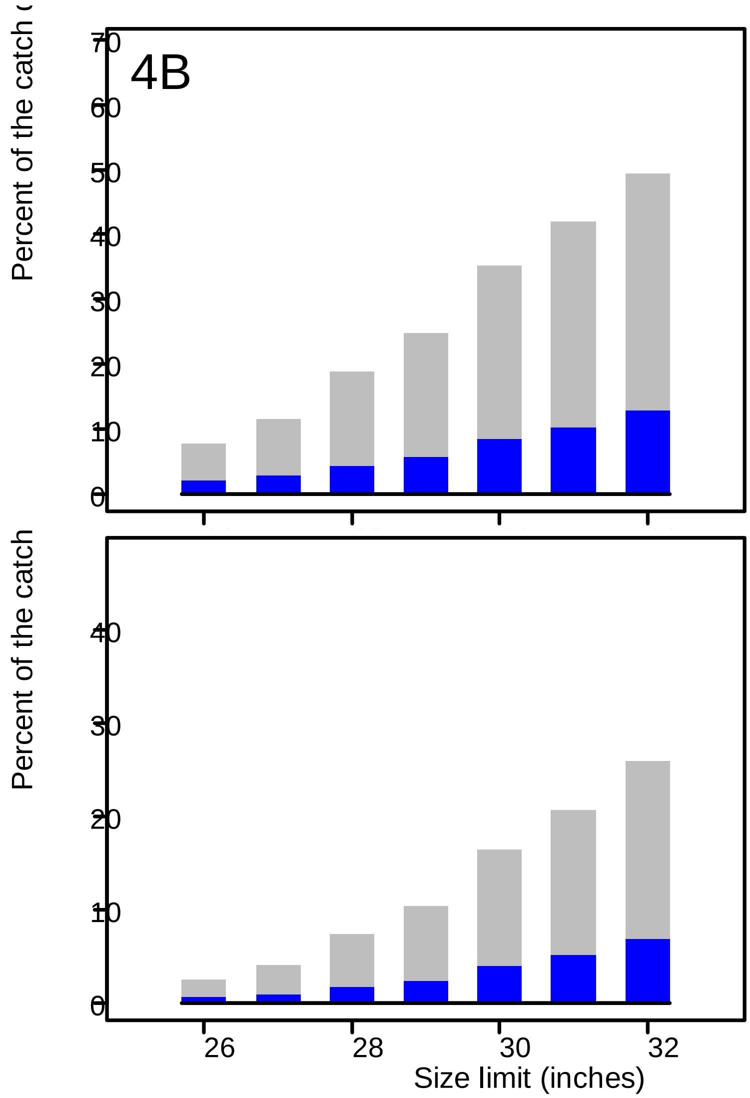

FIGURE B7. Percentage of the 2016 survey catch discarded in Area 4B for size-limits from 26 to 32 inches, based on the number of fish (upper panel) and the weight of fish (lower panel). Height of the bars represents the total, and the darker (lower) portion the contribution of male halibut. Note that the y-axes differ. See tables for percentage values.

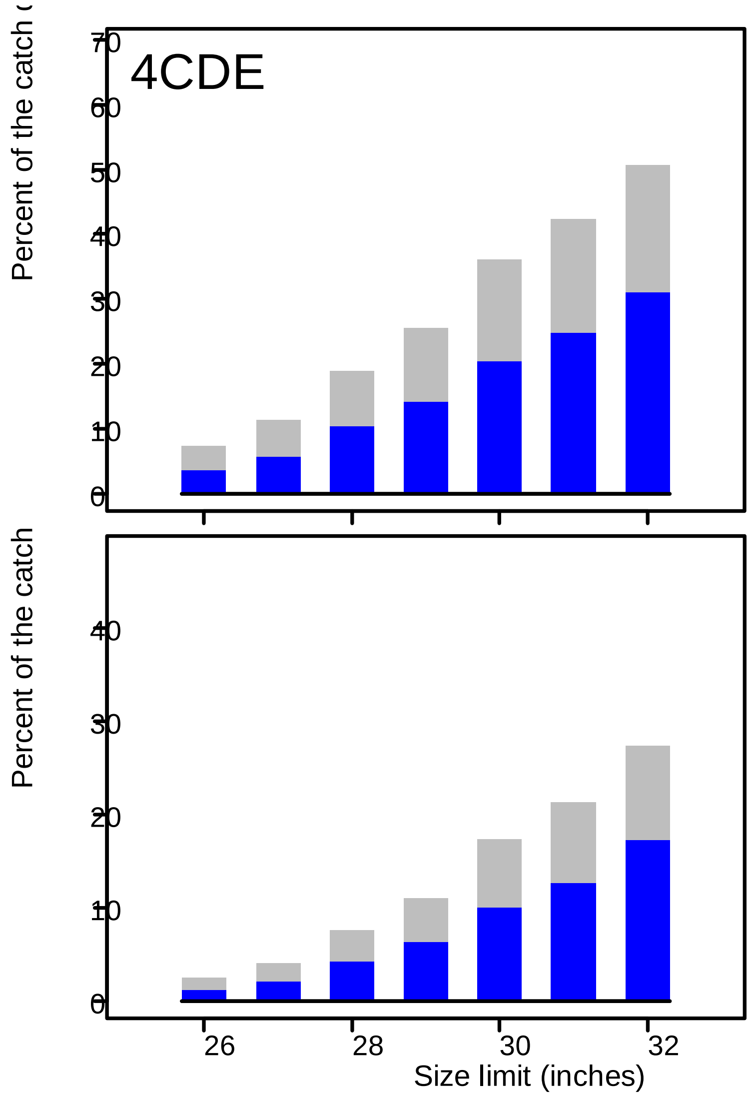

FIGURE B8. Percentage of the 2016 survey catch discarded in Area 4CDE for size-limits from 26 to 32 inches, based on the number of fish (upper panel) and the weight of fish (lower panel). Height of the bars represents the total, and the darker (lower) portion the contribution of male halibut. Note that the y-axes differ. See tables for percentage values.

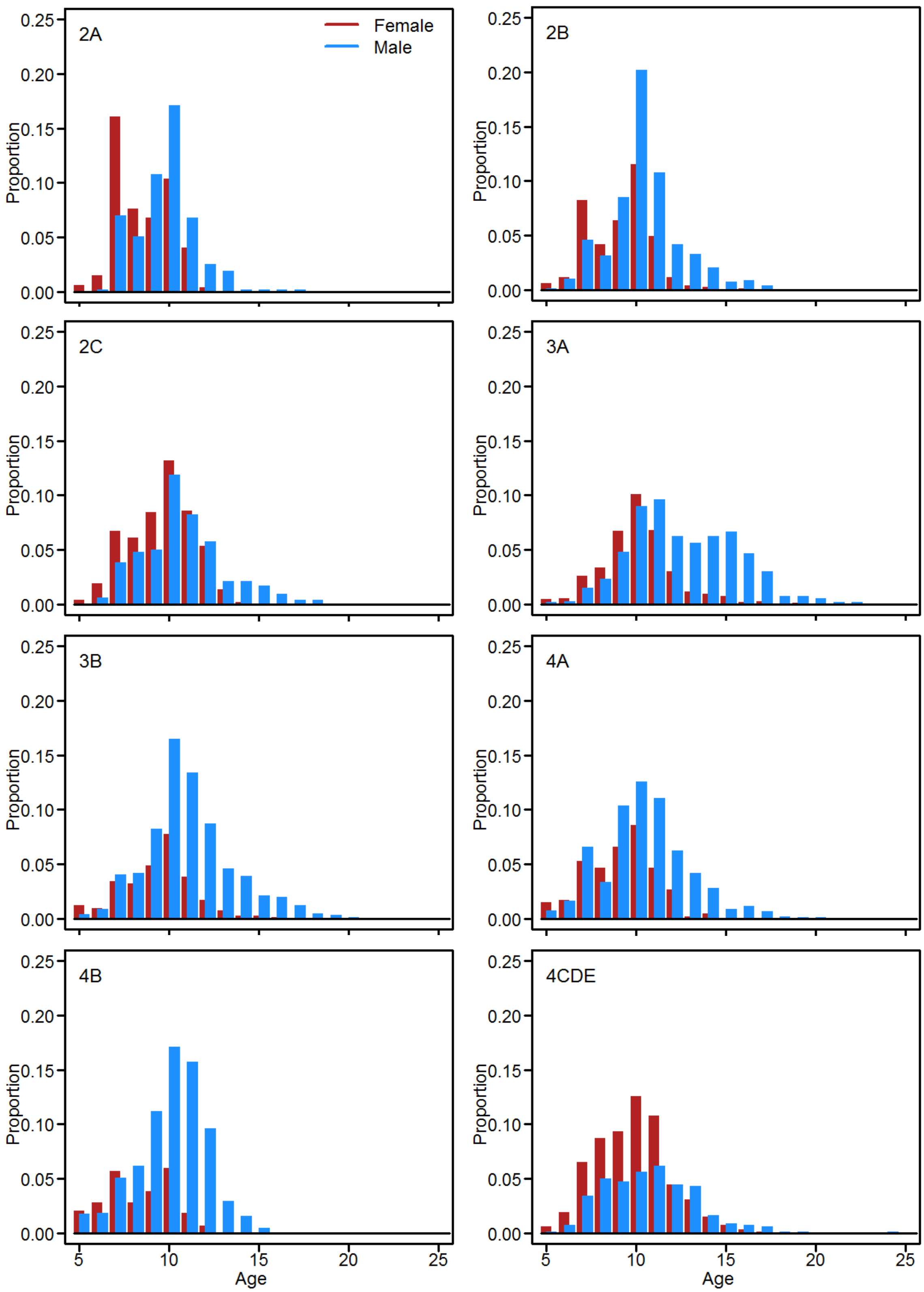

FIGURE B9. Proportions-at-age of sublegal (< 32”) Pacific halibut by Regulatory Area captured by the 2016 setline survey. Blue bars denote male halibut, red bars denote female halibut; all bars in each panel sum to a value of 1.0 (From: Stewart 2017).

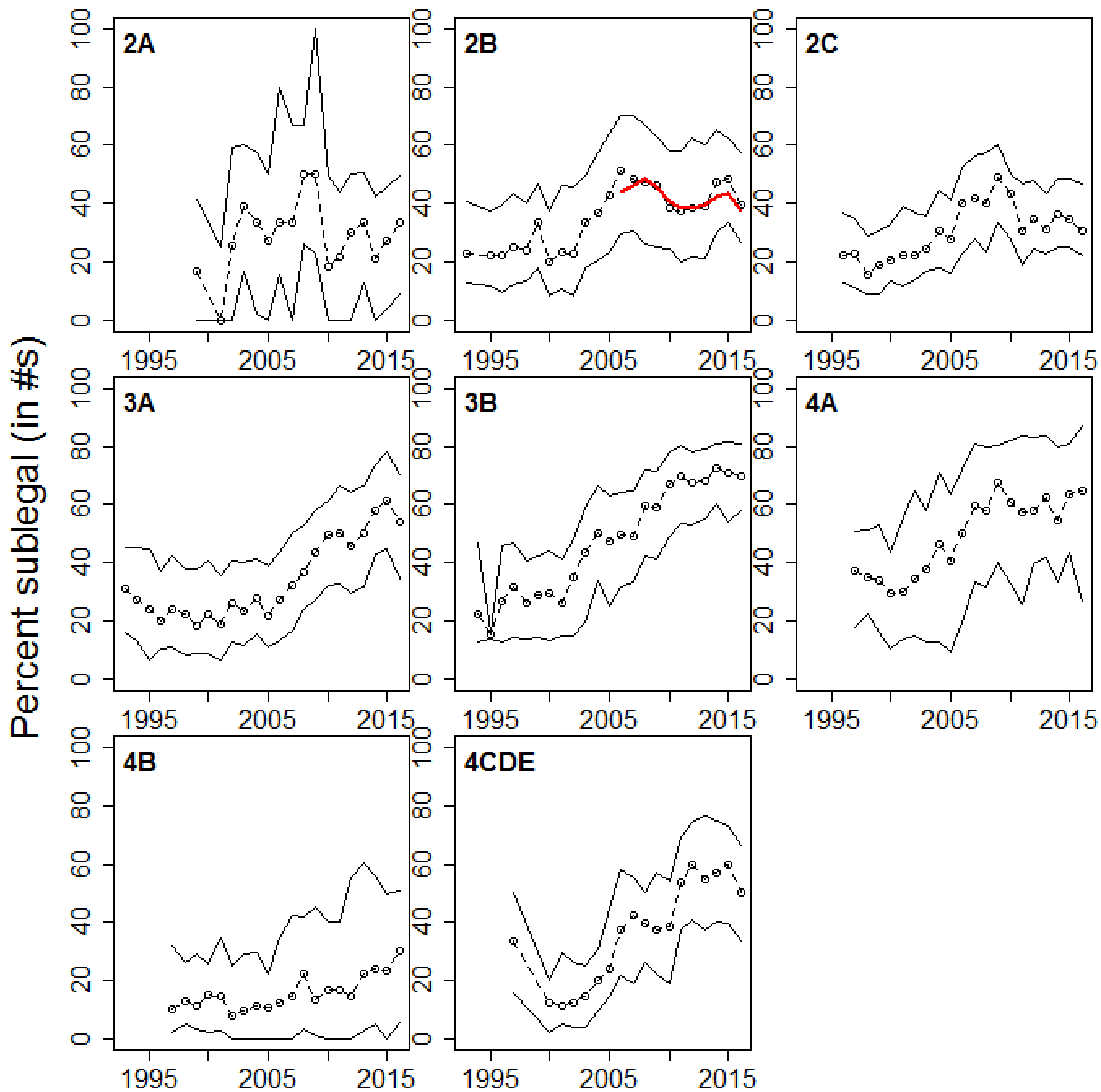

FIGURE B10. Trends in percent sublegal (<32”) halibut catch by the setline survey 1993-2016 (From: Goen et al. 2017b). Circles denote median survey station percent sublegal; lines denote the 25th and 75th percentiles. Solid line in Area 2B denotes the percent sublegal reported in directed commercial Pacific halibut fishery logbooks

APPENDIX C
Distribution of 2016 observed commercial Pacific halibut catch by size

The methods used to describe the directed Pacific halibut fishery observer data are very similar to those used for the setline survey. These data are only available for Regulatory Areas in Alaska, as the Area 2A fishery is not observed, and the Area 2B fishery is observed electronically (with audited logbooks) and there is no length-frequency data collected for sublegal Pacific halibut during the directed commercial fishery for Pacific halibut. Randomly sampled halibut with measured lengths are summarized in number and weight, based on the length-weight relationship. There is no sex-specific information, as the observers do not do any internal sampling of Pacific halibut.

Interpretation of these data requires caution: as noted in the main text, the unobserved majority of the commercial Pacific halibut fishery is assumed to be encountering and selecting the same size frequency of halibut as the observed portion of the fishery. This is unlikely to be strictly true, given that smaller unobserved vessels are more likely to use snap gear and fish in inshore waters than larger vessels that are included in the partial observer coverage pool. However, the information available provides an alternative to the setline survey-based approach which is at least based directly on commercial fishery data.

The observer program does not stratify deployment or sampling by target species, and there is considerable mixing between fishing activity targeting sablefish and Pacific halibut. Further, under scenarios of a reduced or no MSL, if the current requirement to retain all legal halibut were maintained, then some fishing for sablefish that does not result in landings of appreciable quantities of halibut may include a greater quantity of landings. For these reasons, all halibut observations collected during IFQ fishing (sablefish, halibut or both) were included in the analysis.

To provide additional detail in catch-rates by number of Pacific halibut in addition to weight, the directed fishery observer data have been summarized similarly to the setline survey (Table C1).

TABLE C1. Percentage of observed halibut in 2016 that would be discarded in Area XX for size-limits from 26 to 32 inches based on numbers of fish and weight of fish. For comparison, the percentage of the catch greater than the current 32-inch minimum size limit is reported at the right margin.

Regulatory Area		Size limit (inches)							
		26	**27**	**28**	**29**	**30**	**31**	**32**	**> 32**
2C	**Numbers**								
	Percentage	4.2	1.7	3.3	2.5	5.1	3.3	7.8	72.1
	Cumulative	4.2	5.9	9.1	11.7	16.8	20.1	27.9	
	Weight								
	Percentage	0.7	0.4	0.9	0.8	1.8	1.3	3.3	90.9
	Cumulative	0.7	1.1	2.0	2.8	4.6	5.8	9.1	
3A	**Numbers**								
	Percentage	5.4	2.3	4.6	4.8	7.5	5.7	10.5	59.2
	Cumulative	5.4	7.7	12.3	17.1	24.6	30.3	40.8	
	Weight								
	Percentage	1.6	0.9	2.0	2.4	4.2	3.5	7.1	78.3
	Cumulative	1.6	2.5	4.6	6.9	11.1	14.6	21.7	
3B	**Numbers**								
	Percentage	15.2	3.6	6.9	4.2	6.5	4.2	6.6	52.6
	Cumulative	15.2	18.8	25.8	30.0	36.6	40.8	47.4	
	Numbers								
	Percentage	3.9	1.3	2.8	1.9	3.3	2.4	4.1	80.2
	Cumulative	3.9	5.2	8.0	10.0	13.3	15.7	19.8	
4A	**Numbers**								
	Percentage	11.3	2.9	5.5	2.7	5.7	2.5	5.7	63.7
	Cumulative	11.3	14.3	19.7	22.4	28.1	30.6	36.3	
	Weight								
	Percentage	2.7	1.0	2.0	1.1	2.6	1.3	3.3	85.9
	Cumulative	2.7	3.7	5.7	6.9	9.5	10.8	14.1	
4B	**Numbers**								
	Percentage	3.3	1.4	4.7	3.6	7.3	4.5	6.5	68.8
	Cumulative	3.3	4.7	9.3	12.9	20.2	24.7	31.2	
	Weight								
	Percentage	0.7	0.4	1.5	1.3	2.9	2.0	3.2	87.8
	Cumulative	0.7	1.1	2.6	3.9	6.9	8.9	12.2	
4CDE	**Numbers**								
	Percentage	4.0	1.0	3.0	3.0	5.8	3.7	7.8	71.6
	Cumulative	4.0	5.0	8.0	11.0	16.8	20.5	28.4	
	Weight								
	Percentage	1.1	0.3	1.1	1.3	2.8	2.0	4.6	86.8
	Cumulative	1.1	1.4	2.6	3.9	6.7	8.6	13.2	

APPENDIX D
Yield calculations

Historical MSL analyses have relied heavily on equilibrium models to determine the relative yield under differing sizes, and assumptions of fishery selectivity and stock productivity. A detailed consideration of the performance of alternative MSLs could be undertaken as part of the ongoing Management Strategy Evaluation (MSE). However, the MSE process is ongoing, and will be gradually increasing in complexity over the next several years, precluding a comprehensive analysis in time for this working paper. Further, many of the concerns regarding the current MSL relate to factors outside the scope of an MSE, or are related very specifically to current conditions rather than the long-term behavior of the stock and fishery under a wide range of conditions. For these reasons, just as the annual stock assessment produces tactical information for annual management, the approach taken to yield calculations in this working paper is intended to provide tactical information regarding the current stock and fishery, specific to the biological conditions at this time. This approach represents a departure from historical analyses, providing immediate utility and interpretation, but it should not be misconstrued as a long-term harvest policy analysis.

In order to estimate the change in yield and the catch characteristics arising from a reduced or no MSL the following procedure was applied to the 2016 stock assessment ensemble:

1) Begin with the yield (all directed fishery landings, recreational and personal use catch) equating to the application of the *status quo* harvest policy ($SPR_{46\%}$) for 2017. This level of yield provides the baseline for comparisons.
2) Inflate the estimated wastage mortality (U32) to reflect a removal of the MSL, 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 (D_d), based on the DMR of 16%, to all fish in this size range that have been captured (D_d /0.16).
3) Because the total removals are now greater, all sources of mortality must be scaled downward to achieve the *status quo* harvest policy ($SPR_{46\%}$) for 2017. However, fish less than 32" are now included in the yield as they would be retained and landed. After iteratively finding the scale of the new set of removals, the yield is stored for comparison with (1) from above. The fraction of the yield comprised of fish less than 32" is also retained for comparison.
4) Because the response of the fishery to removal of the MSL is unknown, it may be important to consider how the yield and catch composition may vary if a greater degree of targeting of U32 Pacific halibut occurs. Several alternative ratios of sublegal to legal harvest were considered with regard to yield and catch characteristics as described below.

To evaluate whether additional targeting of U32 halibut might reduce or increase the overall yield from the fishery, three alternative configurations were considered: inflating the U32 catch by 10, 20, and 30% relative to the O32 catch. For each alternative, the total mortality was rescaled to meet the SPR target, and yield was summarized. This differs from making an explicit assumption regarding the shape of selectivity for the smallest halibut, in that it implicitly assumes that no halibut smaller than the smallest currently observed would be captured, but that all U32 catch would increase proportionally. However, because the current stock assessment ensemble models selectivity in terms of age (rather than size explicitly) any change in average size-at-age due to the change in MSL (i.e., the potential size-selective fishing effect) would result in these alternatives representing some effective shift in selectivity toward smaller fish.

Based on discussion with the SRB, this sensitivity analysis was further evaluated via inspection of the modelled mortality at age for the short coastwide stock assessment model. Results showed that removing the MSL increased the mortality at age of male halibut from approximately ages 8-15, and slightly reduced the mortality of older male halibut (Figure D1). In contrast, female mortality was increased over younger ages (~6-12) and decreased the mortality to a greater degree for the older demographic components of the stock. Additional targeting of U32 Pacific halibut only slightly increased these predicted effects.

This approach to yield calculation does not require a stock-recruitment relationship, nor does it consider the potential for recruitment overfishing, where the long-term yield of the stock could be reduced if the average level of spawning biomass is reduced and there exists a relationship between spawning biomass and recruitment over the range of stock sizes considered. This approach does very clearly reflect the current age- and size-structure in the population and interaction between this structure and the current fishery.

An important distinction between the approach provided by this working paper and that in Martell et al. (2015) is that it is conditioned on the current SPR target of 46%. The 2015, and some previous analyses solved for a new target fishing intensity as each MSL considered such that MSY was obtained in all cases.

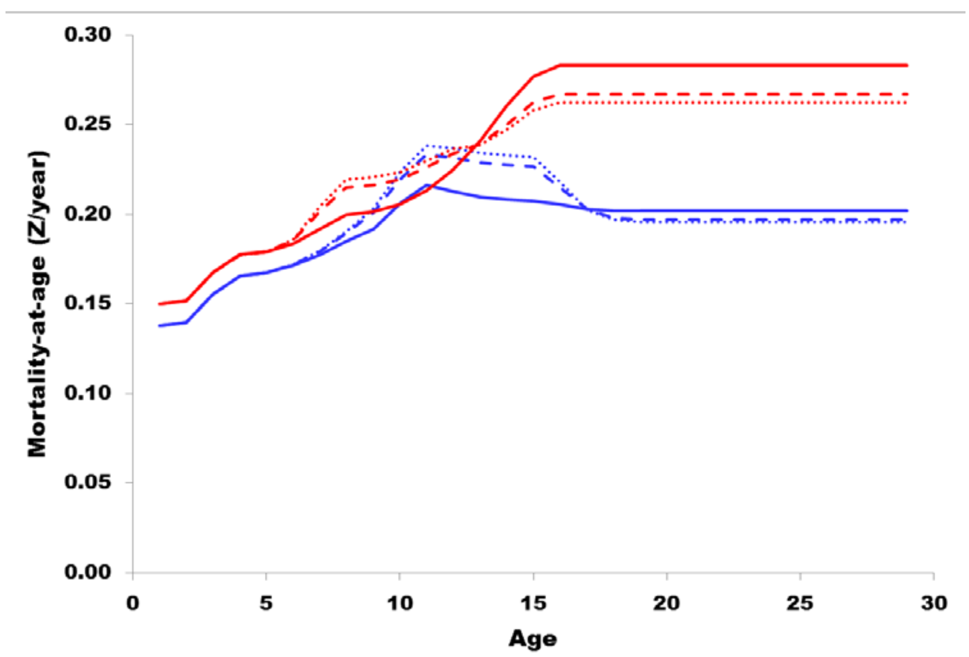

FIGURE D1. Total mortality (*Z*; including estimated natural and fishing mortality from all sources) at age for female (red upper series) and male (blue, lower series) Pacific halibut projected for the *status quo* (32” MSL; solid lines), a 10% increase in U32 targeting (thick dashes) and a 30% increase in U32 targeting (dotted series).

APPENDIX E
Evaluation of adaptive management approaches

During the June, 2017 Meeting (SRB10), 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 changes may need an adaptive management experiment approach that considers the biological, economic, and sociological consequences MSL changes. Indeed, predictions of consequences in each IPHC Regulatory Area should be a pre-requisite to any proposed MSL changes.*"

The IPHC Secretariat agrees that if the Commission chooses to modify the MSL, an adaptive approach should be taken given the range of potential objectives, many unknown biological and operational responses, and dynamic nature of the Pacific halibut stock. This section therefore expands upon that request to provide a range of options for adaptive approaches at differing spatial and temporal scales.

Adaptive management consists of a decision that is made in order to learn specific information that will subsequently improve future management (Walters 1986). In some cases, such a decision may be sub-optimal in the short term, but may allow for improved performance (e.g., yield) 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.

Potential management actions can be divided into four general categories based on: the time-frame for the proposed change, the rate at which the change is introduced, the interaction between a change and the monitoring of the fishery, and the spatial scale of the change. Each of these is illustrated with one or more examples below, but other options could be considered within this general framework.

Single year action: Remove the MSL for one year, with the potential to maintain this change for a longer duration depending on the results.

1) What would be learned:
    - The price that would be paid for fish <32"; this would represent the general market response (over a short time frame) and would be important relative to incentives toward targeting or avoidance (see above).
    - The degree of fishery catch-rate (efficiency) improvement in each of the IPHC Regulatory Areas.
    - The age distribution of the fish currently encountered but not retained under the 32" MSL.

2) Predicted outcomes:
    - Wastage would be reduced to just those fish associated with lost gear. Although the magnitude of this reduction would depend on the coastwide catch limit as well as the distribution of this catch among the regulatory areas, this could be 1.1

to 1.6 million pounds based on the last five years of fishery estimates of sublegal wastage.
- Landed catch rates (and therefore fishery efficiency) would increase in all areas, likely to a level intermediate between that suggested by observer data (Table 3) and survey data (Table 2).

3) Potential negative effects:
   - Price and market responses may not stabilize over a single year.
   - Similarly, fishing behavior could take longer than one year to reflect the change in MSL.
   - A temporary change could cause a processing/marketing burden.
   - The transition from and back to an MSL could cause an enforcement and regulatory burden in the short term.
   - Although a single year would not be long enough to detect (with any appreciable certainty) a biological response, there would be an improvement in the age data available from port sampling, as it would much more closely represent the directed fishery mortality, rather than just the landings.

Incremental action: Reduce the MSL by 1" per year, with the potential to discontinue all changes or making additional changes at any point.

1) What would be learned:
   - The incremental price that would be paid for fish <32"; this would represent the general market response (over a short time frame) and would be important relative to incentives toward targeting or avoidance (see above).
   - The incremental degree of fishery catch-rate (efficiency) improvement in each of the Regulatory Areas.
   - The incremental age distribution of the fish currently encountered but not retained under the 32" MSL.

2) Predicted outcomes:
   - Would allow for gradual fishery and market responses to change, such that there would be less disruption of current practices.
   - Wastage would be reduced by only a small degree (~1-5%) in each year, depending on the coastwide catch limit and distribution among areas.
   - In many areas, there would likely be little fishery response in efficiency or targeting/avoidance.
   - It would be difficult to determine whether small changes in landed catch rates (and therefore fishery efficiency) were a function of the change in MSL or stock dynamics.

3) Potential negative effects:
   - This approach would likely take several to many years before any clear information was gained from the changes, and it would therefore be more confounded with other changing factors.
   - Price and market responses, as well as fishing behavior may not stabilize under constant change.
   - Ongoing change could cause a processing/marketing burden.
   - Ongoing change to the MSL could cause an enforcement and regulatory burden.

Monitoring-based action: Remove the MSL for all directed commercial fishing activity that is monitored at sea (observed via people or electronically).

1) What would be learned:
   - The price that would be paid for fish <32"; these fish would likely be widely available and encountered in large enough numbers to elicit a market response.
   - The degree of fishery catch-rate (efficiency) improvement in each of the Regulatory Areas. Some degree of monitoring is in place in all regions.
   - The age distribution of the fish currently encountered but not retained under the 32" MSL; monitoring would ensure that for the trips without an MSL al fish captured would be landed.

2) Predicted outcomes:
   - Would allow for gradual fishery and market responses to change, such that there would be less disruption of current practices.
   - Wastage would be reduced by only a small degree (<5%), depending on the coastwide catch limit and distribution among areas, as monitoring rates remain low relative to the coastwide removals.

3) Potential negative effects:
   - There would likely be little biological information generated due to the limited overall scope of the change under current monitoring.
   - This could create differing (and potentially unexpected) incentives relative to existing monitoring programs.
   - Mixed fishing within and among Regulatory Areas could cause a processing/marketing burden.
   - Mixed fishing within and among Regulatory Areas could cause an enforcement and regulatory burden.

Spatially restricted action: Remove the MSL for only a single biological region (i.e., Area 2, Area 3, Area 4, and Area 4B) or an individual IPHC Regulatory Area.

1) What would be learned:

<u>Area 3</u>

   - Area 3 (3A and 3B) would provide the largest biological impact of any region, and therefore the largest increase in information relevant to the coastwide stock dynamics.
   - This region is likely to produce sufficient landings to evaluate market and price response to smaller Pacific halibut.

<u>Area 3B</u>

   - Selecting only Area 3B would provide the greatest biological impact of any single Regulatory Area.
   - Area 3B is likely to have the greatest potential change in targeting/fishing behavior as this area is estimated to have the highest encounter rates for fish <32".

- This Area is likely to produce sufficient landings to evaluate market and price response to smaller Pacific halibut.

Area 2

- Area 2 would have the lowest biological impact of any region, such that little information on the effect of the MSL on the coastwide stock would be generated.
- Price and market information may be emergent; however it may not be generalizable to other Regions.

Area 2B

- Area 2B has 100% electronic monitoring, such that full accounting of all fish captured would be achieved, and the age data collected via port sampling would represent the total catch

Area 4CDE

- This region is likely to produce sufficient landings to evaluate how markets and price will respond to smaller Pacific halibut although these conditions already differ in this Area due to its geographic location.
- Fishery catch rates, market response and other dynamics could be of utility in informing ongoing analysis of abundance-based management in the Bering Sea.

2) Predicted outcomes:

Area 3

- Based on the survey results, retained catch rates would likely increase by 26.7-45.0%, and the percent male in the catch would increase by 12.2-21.5%, and wastage would decrease by 0.65 million pounds for catch limits similar to those in 2017.

Area 3B

- Based on the survey results, retained catch rates would likely increase by as much as 45.0%, the percent male in the catch would increase by 21.5%, and wastage would decrease by 0.24 million pounds for catch limits similar to those in 2017.

Area 2

- Based on the survey results, retained catch rates would likely increase by 13.5-22.9%, the percent male in the catch would increase by 4.3-10.0%, and wastage would decrease by 0.31 million pounds for catch limits similar to those in 2017.

Area 2B

- Based on the survey results, retained catch rates would likely increase by as much as 22.9%, the percent male in the catch would increase by 10.0%, and wastage would decrease by 0.23 million pounds for catch limits similar to those in 2017.

Area 4CDE

- Based on the survey results, retained catch rates would likely increase by 27.3%, the percent male in the catch would increase by 6.8%, and wastage would decrease by 0.07 million pounds for catch limits similar to those in 2017.

- Improvements in fishery efficiency may assist in ongoing management concerns over all sources of halibut removals.

3) Potential negative effects:

Any region or Area

- Changes in fishery behavior observed in any single region or Area will not be representative of other regions, and so information will not be useful in predicting response to further spatial changes.
- With the exception of Area 2B, changing the MSL in any single region or Area would create regulatory differences within a single enforcement program and potentially within the operations of a single vessel.

Area 3

- The directed commercial fishery is not fully monitored in this region; therefore there could be differences between the total catch and landings.

Area 3B

- The directed commercial fishery is not fully monitored in this Area; therefore there could be differences between the total catch and landings.

Area 2

- The directed commercial fishery is not fully monitored in all parts of this Region; therefore there could be differences between the total catch and landings.
- Changing the MSL in Area 2 would require enforcement and regulatory changes in all three jurisdictions (Alaska, Canada, and the U.S. west coast).

Area 2B

- The integrated fishery in Area 2B would need to account for Pacific halibut <32” in quota calculations during all activity in which they are encountered.

Area 4CDE

- The directed commercial fishery is not fully monitored in this region; therefore there could be differences between the total catch and landings.