# Potential yield and female spawning biomass gains from proposed Pacific halibut prohibited species catch limit reductions in Gulf of Alaska groundfish fisheries

**Steven R. Hare, Gregg H. Williams, Juan L. Valero, and Bruce M. Leaman**

## Abstract

Estimated gains in directed halibut yield and female spawning biomass from reductions in groundfish prohibited species catch (PSC) limits are derived and tabulated. Summing both immediate and delayed increases in CEY, the benefit to the directed halibut fishery is slightly greater than the amount of PSC limit reduction. Increases in total female spawning biomass would be on the order of twice any trawl PSC reduction, and approximately equal to any hook-and-line PSC reduction.

## Introduction

The North Pacific Fishery Management Council (NPFMC) is considering reducing the Pacific halibut (*Hippoglossus stenolepis*) prohibited species catch (PSC) limits for Gulf of Alaska (GOA) groundfish fisheries. To assist in its deliberations, NPFMC staff requested information on the potential benefits/impacts on halibut constant exploitation yield (CEY) and female spawning biomass (FSBio) for various levels of PSC limit reductions. This document provides the details and characterizes the nature of the information we are able to provide. As background to the IPHC catch limit determination process, the Appendix contains a flowchart illustrating how annual CEY and directed fishery catch limits are set, including accounting for PSC under the proposed Area 2C/3A halibut Catch Sharing Plan (CSP).

## NPFMC information request

The NPFMC is contemplating reducing the halibut PSC limits for trawl and/or hook-and-line groundfish vessels in the GOA by 5, 10, or 15 percent. Presently, the GOA PSC limits are 2000 mt and 300 mt for the trawl and hook-and-line fisheries, respectively. The potential PSC limit reductions would lower the trawl limit to 1900, 1800, or 1700 mt while the hook-and-line limit would be reduced to 285, 270, or 255 mt. Including the potential for no PSC limit reduction, results in a matrix of 16 possible PSC limit reduction combinations. As the GOA spans three IPHC regulatory areas (2C, 3A, and 3B), the Council request was for three 16-cell matrices to be populated, and further that IPHC staff estimate how values in the matrices would change over a 15-year projection time horizon. Two sets of information were requested for the sets of matrices: changes in directed halibut fishery CEY and changes in halibut FSBio.

## What is actually feasible

Recent history has illustrated that even short-term projections of halibut biomass and yield are problematic and can be unreliable. Reasons for unreliable projections are numerous (Hare 2011a, Valero 2011), but include the following: retrospective behavior of the halibut stock assessment (i.e.,

subsequent downward revisions of earlier biomass estimates with each new annual assessment), ongoing changes in size-at-age, variable recruitment, changes in accounting for under-32 (U32) inch halibut, changes in target harvest rate, poor harvest control of sport fisheries, and uncertainty over bycatch mortality estimates. Given these myriad difficulties, attempting to project actual levels of catch or spawning biomass are, at best, of questionable value and likely to be counter-productive. This is not to imply that no useful information can be provided about the benefits that would accrue from reduced halibut PSC limits. Thus, IPHC staff suggested rephrasing the data request and framing it in a manner that allows a more straightforward depiction of how CEY and FSBio would be impacted at differing levels of PSC limit reductions.

We begin with a clarification of terms. Throughout this analysis, reference is made to PSC reductions. Technically, this term would more accurately be termed "Prohibited Species Mortality (PSM)" as the quantity references estimated halibut bycatch mortality, not halibut catch. Halibut bycatch mortality (PSC, in NPFMC terms) is computed by multiplying estimated halibut bycatch times an estimated Discard Mortality Rate (DMR) that is computed annually on the basis of groundfish observer data. A potential reduction in PSC of, say 100 mt, is assumed in this work to be an actual reduction in halibut mortality of 100 mt; the catch of halibut is generally substantially larger than the mortality due to release survival (more so for hook-and-line fisheries than trawl fisheries, which tend to have much higher DMRs).

Quantification of the impact on CEY and FSBio will be broken into two parts, corresponding to two size categories of halibut PSC: that above 26 inches (O26) in length, and that smaller than (or equal to) 26 inches (U26). The directed halibut IFQ fishery has a 32-inch size limit, however all bycatch mortality (as well as directed fishery wastage) 26 inches and above is deducted from total CEY in the determination of fishery CEY (Hare 2011b). For CEY, reductions in O26 PSC will have immediate benefits as the catch is simply transferred to the directed halibut fishery. Assuming the transferred O26 catch is taken, there is little anticipated impact on FSBio. There are quantifiable benefits to both CEY and FSBio from the U26 component of PSC limit reductions. The benefits are distributed "downstream" both in time and space, and potentially more complicated to quantify as well as to explain.

## Immediate effect of O26 PSC limit reductions on halibut CEY

The approach we take to quantify the benefits to halibut CEY is to consider how reductions in halibut PSC limits would have affected the 2011 CEY. Bycatch mortality that is larger than 26 inches is deducted from total CEY in the area where the bycatch mortality occurred. Until 2010, only that portion of the mortality larger than 32 inches (O32) was counted as part of "other removals" but that was expanded to include halibut between 26 and 32 inches (O26U32) beginning in 2010 and will likely remain as such for the foreseeable future. The change in how the IPHC accounted for O26U32 bycatch mortality had the effect of changing the target harvest rate in Areas 2C and 3A from 0.20 to 0.215, and in 3B from 0.15 to 0.161. In essence, a higher harvest rate led to a higher total CEY to offset the direct deduction (accounting) of O26U32 which previously had only been factored into determination of the target harvest rate. The end result was little change in directed fishery CEY, but served the purpose of providing a more consistent treatment of different removal types (sport, bycatch mortality, wastage, and subsistence). Details of the analysis supporting the change in target harvest rate are given in Hare (2011b). In that analysis, a number of assumptions regarding the current, and anticipated future, distribution of halibut removals among fisheries

(commercial, sport/subsistence, and bycatch mortality) as well as each fishery's average catch size distribution were made. It was emphasized in the analysis that the revised harvest rate might need to be revisited if substantial changes occur in the relative distribution of removals among the fisheries. Because the level of PSC reduction being considered by the NPFMC is relatively modest (i.e., no greater than 15%), we do not feel that revisiting the target harvest rate is warranted. As such, any reduction in O26 PSC simply translates as a 1:1 increase in fishery CEY since the level of "other removals" would be reduced. It is important to note here that this analysis assumes that any reduction in halibut PSC limits translates exactly as a reduction in actual halibut bycatch mortality.

To estimate the increase in fishery CEY from a decrease in the halibut PSC limits, we first require an estimate of the relative O26 and U26 fractions of the trawl and hook-and-line bycatch mortality. For this analysis, we examined the most recent (fishing year 2008) raw GOA halibut trawl and hook-and-line length frequencies we had available, obtained from the North Pacific Groundfish Observer Program. A more detailed analysis might attempt to refine the raw length frequencies by accounting for a number of factors including size-dependent release condition and weighting by estimated target fishery halibut PSC. While such corrections to the raw length frequencies would be more precise, they still would not account for other factors, including the absence of both lengths and release condition data for the under 60' fleet and the nominal 30% coverage level of the 60-125' fleet. As such, we feel that use of the raw length frequencies is satisfactory for the current exercise and that the more time-consuming work entailed in deriving more precise "mortality length frequencies" would likely not produce results markedly different than when using raw length frequency distributions.

Observers collected length measurements on 7,188 trawl caught and 1,171 hook-and-line caught halibut in 2008 (Williams 2010). The 2008 observer-collected halibut length frequencies for both trawl and hook-and-line groundfish fisheries are plotted in Figure 1. As evidenced by the length frequency modes, trawl caught halibut tend to be smaller than hook-and-line caught halibut. However, the largest hook-and-line caught halibut was 113 cm while a number of trawl caught halibut exceeded 150 cm. By weight, 62.5% of trawl caught and 75.2% of hook-and-line caught halibut are over 26 inches (66 cm). In terms of numbers of halibut caught, 26.5% of trawl caught and 53.3% of hook-and-line caught halibut are over 26 inches. These data are summarized in Table 1.

The second piece of information we require, in order to estimate IPHC regulatory area CEY gains from reduced PSC limits, is an estimate of the relative distribution of both trawl and hook-and-line halibut mortality in the groundfish fisheries. These values represent the most uncertain component of estimating total bycatch mortality impact because of the low observer coverage, hence lack of data reliability, for the GOA groundfish fisheries. These data are assembled annually for the Bycatch section of the IPHC Report of Assessment and Research Activities ( RARA). For 2010, the relevant data are listed on page 287 (Williams 2011) and are reproduced as Table 2 in this report. The RARA values are in the IPHC metric of "thousands of net pounds" and have been converted to the NPFMC metric of "mt" in Table 2. Note that the values for 2010 are preliminary estimates based on bycatch mortality reported through November 15, 2010 and projected through year end. In-season reports of bycatch mortality are obtained from the NMFS Alaska Region web site. NMFS reporting areas are converted to IPHC regulatory area as follows: NMFS areas 610+620 = IPHC Area 3B; NMFS areas 630+640 = Area 3A; and NMFS area 650 = IPHC Area 2C. Reported bycatch mortality is aggregated up to area and gear strata.

With the above information, and noting the strong caveats on its reliability, the PSC reduction tables can be completed with the expected amount of CEY gains for the directed halibut fisheries. The cells within each table are computed by multiplying the level of gear-specific PSC limit reduction times the fraction of gear-specific O26 bycatch mortality times the regulatory area percentage of GOA-wide PSC limit. Computationally, this is done most simply by computing the marginal values for trawl-only and hook-and-line-only PSC limit reduction, and then completing the combination cells as a simple addition of the marginal values. The resultant CEY gains from a reduction of O26 halibut PSC are listed in Table 3, and list values in both mt round weight and thousands of net pounds. These are current-year or immediate impacts to O26 halibut CEY by changes in the PSC limit.

To quickly estimate the direct effect of a reduced PSC limit, the following guide can be used. As the NPFMC PSC reduction options proceed in 100 mt (trawl) and 15 mt (hook-and-line) increments we need only know the increases to the halibut CEY per gear increment.

Each 100 mt reduction in trawl PSC limit (of which 62.5 mt is O26) results in the following CEY gains:

| Area | 2C | 3A | 3B | Total |
|---|---|---|---|---|
| CEY gain (mt) | 0 | 46.376 | 16.138 | 62.514 |
| CEY gain (net lbs) | 0 | 76,681 | 26,684 | 103,365 |

Each 15 mt reduction in hook-and-line PSC limit (of which 11.3 mt is O26) results in the following CEY gains:

| Area | 2C | 3A | 3B | Total |
|---|---|---|---|---|
| CEY gain (mt) | 0.090 | 4.163 | 7.022 | 11.275 |
| CEY gain (net lbs) | 150 | 6,883 | 11,611 | 18,644 |

There is no expected effect on FSBio from a reduction in the O26 component of the PSC because spawning females not killed as bycatch mortality would instead be taken by the directed halibut fishery. While there are size differences between the O26 bycatch and the directed catch, they are small enough that it can be assumed they are essentially equal. This is not the case for the U26 component of the bycatch mortality, which is covered next.

## Delayed effect of U26 PSC limit reduction on CEY and FSBio

Quantifying the effect of reducing the PSC limit on the U26 component requires simulating the life history of the small halibut and tabulating future gains to both CEY and FSBio. This is necessary because halibut do not begin to contribute to the exploitable biomass until they reach 32 inches and female halibut do not begin contributing to the spawning biomass until around 10 years of age (when they are on average around 30 inches in length). The level of eventual contribution to future CEY and FSBio is determined both by the actual size distribution of the U26 halibut taken as bycatch mortality as well as which area the bycatch mortality reduction occurs; this last factor is due to the fact that growth rates differ by regulatory area. The full details of the simulation model used to estimate future CEY and FSBio gains are given in Hare (2010) and are not reproduced here. However, a summary of the key features and assumptions is provided next.

Halibut bycatch in the groundfish fisheries is sampled for length data but not for age or sex. As life history simulation modeling requires both age and sex data (to accurately estimate harvest impacts on CEY and FSBio), a methodology was developed in Hare (2010) to decompose a length sample to age and sex components. In essence, halibut mean size and standard deviation at age data, from both trawl and setline survey samples, for halibut aged 2-30 were used to estimate sex and age proportions at length. Ages 2-10, for which trawl data are used, have the same mean size and standard deviation at age for all three GOA regulatory areas. Ages 11-30 differ for each area and are based on IPHC setline survey data. We note here that U26 bycatch mortality is almost entirely less than 10 years in age, thus the decompositions are essentially identical for Areas 2C, 3A, and 3B. The age and sex proportions, scaled to the level of PSC, are then projected forward using a standard population dynamics model. Growth is governed by regulatory area mean size at age and "yield" is determined using the commercial fishery selectivity-at-age curve estimated in the halibut stock assessment model, and regulatory area-specific harvest rates applied to the exploitable biomass. We make two important notes here. First, while selectivity-at-length is fixed (though estimated), selectivity-at-age varies among regulatory areas due to their differences in sizes at age. Second, the harvest simulations use the most recent target harvest rate: 0.215 in Areas 2C and 3A and 0.161 in Area 3B and a fixed natural mortality rate of 0.15 $yr^{-1}$. Annual gains that would accrue to the FSBio are estimated using the age-specific maturity curve also used in the halibut stock assessment. The forward simulations are run for 30 years, which is long enough for even the youngest bycaught halibut to essentially complete their CEY and FSBio contributions.

In the previous section (and in Tables 1 and 2), the distribution of bycatch mortality by size category (U26 and O26) and regulatory area was specified. The length to age/sex decompositions, expanded to the numbers that would be killed per 100 mt of trawl, or 15 mt of hook-and-line, PSC are illustrated in Figures 2a (Area 2C), 2b (Area 3A), and 2c (Area 3B). To summarize the figures, and provide a simple reference, the following tables are provided:

One hundred metric tons of trawl PSC (of which 37.5 mt is U26) results in the following amounts of U26 bycatch mortality:

| Area | 2C | 3A | 3B | Total |
|---|---|---|---|---|
| No. of U26 halibut | 0 | 17,999 | 6,263 | 24,262 |
| Wt. of U26 halibut (mt) | 0 | 27.809 | 9.677 | 37.486 |
| Wt. of U26 halibut (lbs) | 0 | 45,981 | 16,001 | 61,982 |

Fifteen metric tons of hook-and-line PSC (of which 3.7 mt is U26) results in the following amounts of U26 bycatch mortality:

| Area | 2C | 3A | 3B | Total |
|---|---|---|---|---|
| No. of U26 halibut | 13 | 620 | 1,046 | 1,679 |
| Wt. of U26 halibut (mt) | 0.030 | 1.375 | 2.320 | 3.725 |
| Wt. of U26 halibut (lbs) | 49 | 2,274 | 3,835 | 6,185 |

The results of running the life history simulations are illustrated in Figures 3a (Area 2C), 3b (Area 3A) and 3c (Area 3B). The results are again plotted as reductions in PSC limits per 100 mt of trawl PSC and 15 mt of hook-and-line PSC. The bulk of both CEY and FSBio gains from PSC reductions in Year 0 occur between 5 and 12 years in the future with peaks at about 8 years. Total CEY gain is computed by simply adding the gains across the 30 years. The cumulative,

delayed CEY gain is approximately 14% more than the weight of trawl U26 bycatch mortality, and is approximately 10% less than the weight of hook-and-line U26 bycatch mortality. The FSBio gains are bit different than the CEY gain in that females can contribute to the FSBio for multiple years whereas a fish contributes to the CEY just once. Nonetheless, summing the FSBio contributions across all years does accurately portray the benefit to the FSBio. The total FSBio contribution summed across all years amounts to approximately 475% more than the weight of the U26 trawl bycatch mortality, and 386% more than the weight of the U26 hook-and-line bycatch mortality. Note that when computed relative to the entire (i.e., U26 plus O26) bycatch mortality, the FSBio contribution is 115% and 21% more than the weight of the trawl and hook-and-line bycatch mortality, respectively. The following table summarizes the accumulated gains to CEY and FSBio.

Each 100 mt of trawl PSC reduction (of which 37.5 mt is U26) results in the following delayed (cumulative over 30 years) CEY and FSBio gains:

| Area | 2C | 3A | 3B | Total |
|---|---|---|---|---|
| CEY gain (mt) | 0 | 32.479 | 10.175 | 42.654 |
| CEY gain (lbs) | 0 | 53,703 | 16,824 | 70,527 |
| FSBio gain (mt) | 0 | 156.752 | 58.776 | 215.528 |
| FSBio gain (lbs) | 0 | 259,184 | 97,183 | 356,367 |

Each 15 mt of hook-and-line PSC reduction (of which 3.7 mt is U26) results in the following delayed (cumulative over 30 years) CEY and FSBio gains:

| Area | 2C | 3A | 3B | Total |
|---|---|---|---|---|
| CEY gain (mt) | 0.048 | 1.324 | 2.011 | 3.383 |
| CEY gain (lbs) | 80 | 2,189 | 3,325 | 5,594 |
| FSBio gain (mt) | 0.146 | 6.378 | 11.595 | 18.119 |
| FSBio gain (lbs) | 241 | 10,545 | 19,172 | 29,958 |

These numbers can be used to complete a table for CEY gains from reduced bycatch mortality of U26 halibut as was done for the O26 component (which was given in Table 3). Table 4 has the U26 CEY gains and Table 5 is a summation of Table 3 and 4, thus providing a complete accounting of CEY gains. Finally, Table 6 lists expected gains in FSBio across the range of PSC reductions. Note that Table 6 for FSBio contains only contributions from the U26 component as there is no gain to the FSBio from the O26 component – those fish are assumed taken directly by the directed fishery instead of by the groundfish fisheries.

We stress that the assignment of impacts by area as presented in Tables 4-6 does not account for lifetime movement potential of the bycaught halibut. There is considerable uncertainty about the precise timing and destination of movements **and the impacts are presented here as if the impacts are localized to the areas of occurrence of the U26 bycatch mortality (i.e., migration is assumed not to occur)**. The impact of the PSC reductions on the cumulative coastwide lost CEY and FSBio are correct to the extent that our understanding of growth, maturity, and mortalities are correct. However, results of this analysis will tend to overestimate the impacts in Areas 3A and 3B and underestimate the impacts in Area 2C when not taking into account migration. When migration is taking into account, some gains would accrue outside of the GOA, such as in Areas 2B and 2A.. The "downstream" distribution of impacts from the bycatch mortality of U32 halibut

(both O26 and U26) is an active area of research with the most recent analyses contained in Valero and Hare (2010, 2011). The uncertainty about the precise cumulative impacts of PSC reduction by area, while important, does not change the understanding of the cumulative coastwide impacts on total CEY or FSBio.

## Conclusions

We have estimated both the immediate (O26) and delayed (U26) increases to halibut CEY and FSBio from reductions in the groundfish halibut PSC limits. Summed across the GOA (i.e., the three IPHC regulatory areas combined, and assuming all gains occur on the GOA), there would be an immediate increase in CEY equal to 62.5% of any reduction in trawl PSC limits and 75.2% of any reduction in hook-and-line PSC limits. This immediate benefit derives from the O26 portion of the bycatch mortality. Additionally, there would be a delayed cumulative benefit to future CEY from the U26 component of the bycatch mortality, equal to approximately 114% and 90% of the weight of the trawl and hook-and-line U26 inch components, respectively. Added together, the total benefit to directed halibut CEY is slightly greater than 1:1 for any trawl PSC limit reduction and is essentially 1:1 for any hook-and-line PSC limit reduction. Since the effects of migration are not considered in this report, the CEY increases are assumed to occur in the areas where the current PSC occurs. Thus, Area 3A would obtain 74.2% of the direct trawl PSC limit reduction increases while Area 3B would obtain 25.8%, based on the distribution of 2010 bycatch mortality. For hook-and-line PSC limit reductions, the gains would accrue 0.8% to Area 2C, 36.9% to Area 3A, and 62.3% to Area 3B. The delayed gains would have a slightly different distribution due to differential growth rates among the three IPHC regulatory areas.

Increases to the FSBio would accrue entirely from the U26 component of the bycatch mortality and would be cumulative over 30 years. Because the total PSC limit also includes O26 halibut, the cumulative increases in FSBio resulting from any PSC limit reductions amount to just greater than 215% of any trawl PSC reductions and a bit over 125% of any hook-and-line PSC limit reduction. These gains would similarly accrue approximately in proportion to current FSBio distribution, with slight variations due to differential growth rates between Areas 2C, 3A, and 3B.

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**Table 1. Sample sizes and proportions of halibut smaller, and greater than, 26 inches (66 cm) in length. All data collected by NMFS observers aboard vessels in the 2008 groundfish fisheries in the GOA. U26 are halibut 26 inches and under and O26 halibut over 26 inches.**

| | Number collected | | Percent (by number) | | Percent (by weight) | |
|---|---|---|---|---|---|---|
| | U26 | O26 | U26 | O26 | U26 | O26 |
| Trawl | 5285 | 1903 | 73.5% | 26.5% | 37.5% | 62.5% |
| Hook-and-line | 547 | 624 | 46.7% | 53.3% | 24.8% | 75.2% |

**Table 2. Distribution of halibut bycatch mortality (mt) in IPHC regulatory Areas 2C, 3A and 3B in the trawl and hook-and-line groundfish fisheries. The percentages represent distribution within gear types across regulatory areas.**

| Area | Trawl | Hook-and-Line |
|---|---|---|
| 2C | 0 (0%) | 3.0 (0.8%) |
| 3A | 1307.0 (74.2%) | 139.1 (36.9%) |
| 3B | 454.8 (25.8%) | 234.7 (62.3%) |

**Table 3. Estimated additional Constant Exploitation Yield (CEY) that would have been immediately available to the 2011 directed halibut fisheries at various levels of PSC limits and if total PSC estimates are accepted as valid. This table is only for the over 26-inch (O26) component.**

A) Values in metric tons (mt)

| GOA | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 62.5 | 125.0 | 187.5 |
| | 285 | 11.3 | 73.8 | 136.3 | 198.8 |
| | 270 | 22.6 | 85.1 | 147.6 | 210.1 |
| | 255 | 33.8 | 96.3 | 158.9 | 221.4 |

| 2C | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 285 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 270 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 255 | 0.3 | 0.3 | 0.3 | 0.3 |

| 3A | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 46.4 | 92.8 | 139.1 |
| | 285 | 4.2 | 50.5 | 96.9 | 143.3 |
| | 270 | 8.3 | 54.7 | 101.1 | 147.5 |
| | 255 | 12.5 | 58.9 | 105.2 | 151.6 |

| 3B | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 16.1 | 32.3 | 48.4 |
| | 285 | 7.0 | 23.2 | 39.3 | 55.4 |
| | 270 | 14.0 | 30.2 | 46.3 | 62.5 |
| | 255 | 21.1 | 37.2 | 53.3 | 69.5 |

B) Values in 1000s of net pounds

| GOA | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 103.4 | 206.7 | 310.1 |
| | 471 | 18.6 | 122.0 | 225.4 | 328.7 |
| | 446 | 37.3 | 140.7 | 244.0 | 347.4 |
| | 422 | 55.9 | 159.3 | 262.7 | 366.0 |

| 2C | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 471 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 446 | 0.3 | 0.3 | 0.3 | 0.3 |
| | 422 | 0.4 | 0.4 | 0.4 | 0.4 |

| 3A | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 76.7 | 153.4 | 230.0 |
| | 471 | 6.9 | 83.6 | 160.2 | 236.9 |
| | 446 | 13.8 | 90.4 | 167.1 | 243.8 |
| | 422 | 20.6 | 97.3 | 174.0 | 250.7 |

| 3B | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 26.7 | 53.4 | 80.1 |
| | 471 | 11.6 | 38.3 | 65.0 | 91.7 |
| | 446 | 23.2 | 49.9 | 76.6 | 103.3 |
| | 422 | 34.8 | 61.5 | 88.2 | 114.9 |

**Table 4. Estimated additional Constant Exploitation Yield (CEY) that would be available cumulatively over 30 years to the directed halibut fisheries at various levels of PSC limits. This table is only for the under 26-inch (U26) component.**

A) Values in metric tons (mt)

| GOA | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 42.7 | 85.3 | 128.0 |
| | 285 | 3.4 | 46.0 | 88.7 | 131.3 |
| | 270 | 6.8 | 49.4 | 92.1 | 134.7 |
| | 255 | 10.1 | 52.8 | 95.5 | 138.1 |

| 2C | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 285 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 270 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 255 | 0.1 | 0.1 | 0.1 | 0.1 |

| 3A | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 32.5 | 65.0 | 97.4 |
| | 285 | 1.3 | 33.8 | 66.3 | 98.8 |
| | 270 | 2.6 | 35.1 | 67.6 | 100.1 |
| | 255 | 4.0 | 36.5 | 68.9 | 101.4 |

| 3B | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 10.2 | 20.4 | 30.5 |
| | 285 | 2.0 | 12.2 | 22.4 | 32.5 |
| | 270 | 4.0 | 14.2 | 24.4 | 34.5 |
| | 255 | 6.0 | 16.2 | 26.4 | 36.6 |

B) Values in 1000s of net pounds

| GOA | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 70.5 | 141.1 | 211.6 |
| | 471 | 5.6 | 76.1 | 146.6 | 217.2 |
| | 446 | 11.2 | 81.7 | 152.2 | 222.8 |
| | 422 | 16.8 | 87.3 | 157.8 | 228.4 |

| 2C | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 471 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 446 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 422 | 0.2 | 0.2 | 0.2 | 0.2 |

| 3A | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 53.7 | 107.4 | 161.1 |
| | 471 | 2.2 | 55.9 | 109.6 | 163.3 |
| | 446 | 4.4 | 58.1 | 111.8 | 165.5 |
| | 422 | 6.6 | 60.3 | 114.0 | 167.7 |

| 3B | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 16.8 | 33.6 | 50.5 |
| | 471 | 3.3 | 20.1 | 37.0 | 53.8 |
| | 446 | 6.7 | 23.5 | 40.3 | 57.1 |
| | 422 | 10.0 | 26.8 | 43.6 | 60.4 |

**Table 5. Estimated total additional Constant Exploitation Yield (CEY) that be available both immediately and cumulatively over 30 years to the directed halibut fisheries at various levels of PSC limits. This table is a summation of Tables 3 and 4.**

A) Values in metric tons (mt)

| | | Trawl PSC (mt) | | | |
|---|---|---|---|---|---|
| **GOA** | | 2000 | 1900 | 1800 | 1700 |
| HAL PSC (mt) | 300 | 0.0 | 105.2 | 210.3 | 315.5 |
| | 285 | 14.7 | 119.8 | 225.0 | 330.2 |
| | 270 | 29.3 | 134.5 | 239.7 | 344.8 |
| | 255 | 44.0 | 149.1 | 254.3 | 359.5 |

| | | Trawl PSC (mt) | | | |
|---|---|---|---|---|---|
| **2C** | | 2000 | 1900 | 1800 | 1700 |
| HAL PSC (mt) | 300 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 285 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 270 | 0.3 | 0.3 | 0.3 | 0.3 |
| | 255 | 0.4 | 0.4 | 0.4 | 0.4 |

| | | Trawl PSC (mt) | | | |
|---|---|---|---|---|---|
| **3A** | | 2000 | 1900 | 1800 | 1700 |
| HAL PSC (mt) | 300 | 0.0 | 78.9 | 157.7 | 236.6 |
| | 285 | 5.5 | 84.3 | 163.2 | 242.1 |
| | 270 | 11.0 | 89.8 | 168.7 | 247.5 |
| | 255 | 16.5 | 95.3 | 174.2 | 253.0 |

| | | Trawl PSC (mt) | | | |
|---|---|---|---|---|---|
| **3B** | | 2000 | 1900 | 1800 | 1700 |
| HAL PSC (mt) | 300 | 0.0 | 26.3 | 52.6 | 78.9 |
| | 285 | 9.0 | 35.3 | 61.7 | 88.0 |
| | 270 | 18.1 | 44.4 | 70.7 | 97.0 |
| | 255 | 27.1 | 53.4 | 79.7 | 106.0 |

B) Values in 1000s of net pounds

| | | Trawl PSC (1000 lbs) | | | |
|---|---|---|---|---|---|
| **GOA** | | 3307 | 3142 | 2976 | 2811 |
| HAL PSC (1000 lbs) | 496 | 0.0 | 173.9 | 347.8 | 521.7 |
| | 471 | 24.2 | 198.1 | 372.0 | 545.9 |
| | 446 | 48.5 | 222.4 | 396.3 | 570.2 |
| | 422 | 72.7 | 246.6 | 420.5 | 594.4 |

| | | Trawl PSC (1000 lbs) | | | |
|---|---|---|---|---|---|
| **2C** | | 3307 | 3142 | 2976 | 2811 |
| HAL PSC (1000 lbs) | 496 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 471 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 446 | 0.5 | 0.5 | 0.5 | 0.5 |
| | 422 | 0.7 | 0.7 | 0.7 | 0.7 |

| | | Trawl PSC (1000 lbs) | | | |
|---|---|---|---|---|---|
| **3A** | | 3307 | 3142 | 2976 | 2811 |
| HAL PSC (1000 lbs) | 496 | 0.0 | 130.4 | 260.8 | 391.2 |
| | 471 | 9.1 | 139.5 | 269.8 | 400.2 |
| | 446 | 18.1 | 148.5 | 278.9 | 409.3 |
| | 422 | 27.2 | 157.6 | 288.0 | 418.4 |

| | | Trawl PSC (1000 lbs) | | | |
|---|---|---|---|---|---|
| **3B** | | 3307 | 3142 | 2976 | 2811 |
| HAL PSC (1000 lbs) | 496 | 0.0 | 43.5 | 87.0 | 130.5 |
| | 471 | 14.9 | 58.4 | 102.0 | 145.5 |
| | 446 | 29.9 | 73.4 | 116.9 | 160.4 |
| | 422 | 44.8 | 88.3 | 131.8 | 175.3 |

**Table 6. Estimated additional female spawning biomass (FSBio) that would have been available cumulatively over 30 years to the halibut population had various levels of PSC limit reduction occurred. This table is for all size components (U26 and O26) of bycatch mortality.**

A) Values in metric tons (mt)

| GOA | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 215.5 | 431.1 | 646.6 |
| | 285 | 18.1 | 233.6 | 449.2 | 664.7 |
| | 270 | 36.2 | 251.8 | 467.3 | 682.8 |
| | 255 | 54.4 | 269.9 | 485.4 | 700.9 |

| 2C | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 285 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 270 | 0.3 | 0.3 | 0.3 | 0.3 |
| | 255 | 0.4 | 0.4 | 0.4 | 0.4 |

| 3A | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 156.8 | 313.5 | 470.3 |
| | 285 | 6.4 | 163.1 | 319.9 | 476.6 |
| | 270 | 12.8 | 169.5 | 326.3 | 483.0 |
| | 255 | 19.1 | 175.9 | 332.6 | 489.4 |

| 3B | | Trawl PSC (mt) 2000 | 1900 | 1800 | 1700 |
|---|---|---|---|---|---|
| HAL PSC (mt) | 300 | 0.0 | 58.8 | 117.6 | 176.3 |
| | 285 | 11.6 | 70.4 | 129.1 | 187.9 |
| | 270 | 23.2 | 82.0 | 140.7 | 199.5 |
| | 255 | 34.8 | 93.6 | 152.3 | 211.1 |

B) Values in 1000s of net pounds

| GOA | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 356.4 | 712.7 | 1069.1 |
| | 471 | 30.0 | 386.3 | 742.7 | 1099.1 |
| | 446 | 59.9 | 416.3 | 772.7 | 1129.0 |
| | 422 | 89.9 | 446.2 | 802.6 | 1159.0 |

| 2C | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 471 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 446 | 0.5 | 0.5 | 0.5 | 0.5 |
| | 422 | 0.7 | 0.7 | 0.7 | 0.7 |

| 3A | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 259.2 | 518.4 | 777.6 |
| | 471 | 10.5 | 269.7 | 528.9 | 788.1 |
| | 446 | 21.1 | 280.3 | 539.5 | 798.6 |
| | 422 | 31.6 | 290.8 | 550.0 | 809.2 |

| 3B | | Trawl PSC (1000 lbs) 3307 | 3142 | 2976 | 2811 |
|---|---|---|---|---|---|
| HAL PSC (1000 lbs) | 496 | 0.0 | 97.2 | 194.4 | 291.6 |
| | 471 | 19.2 | 116.4 | 213.5 | 310.7 |
| | 446 | 38.3 | 135.5 | 232.7 | 329.9 |
| | 422 | 57.5 | 154.7 | 251.9 | 349.1 |

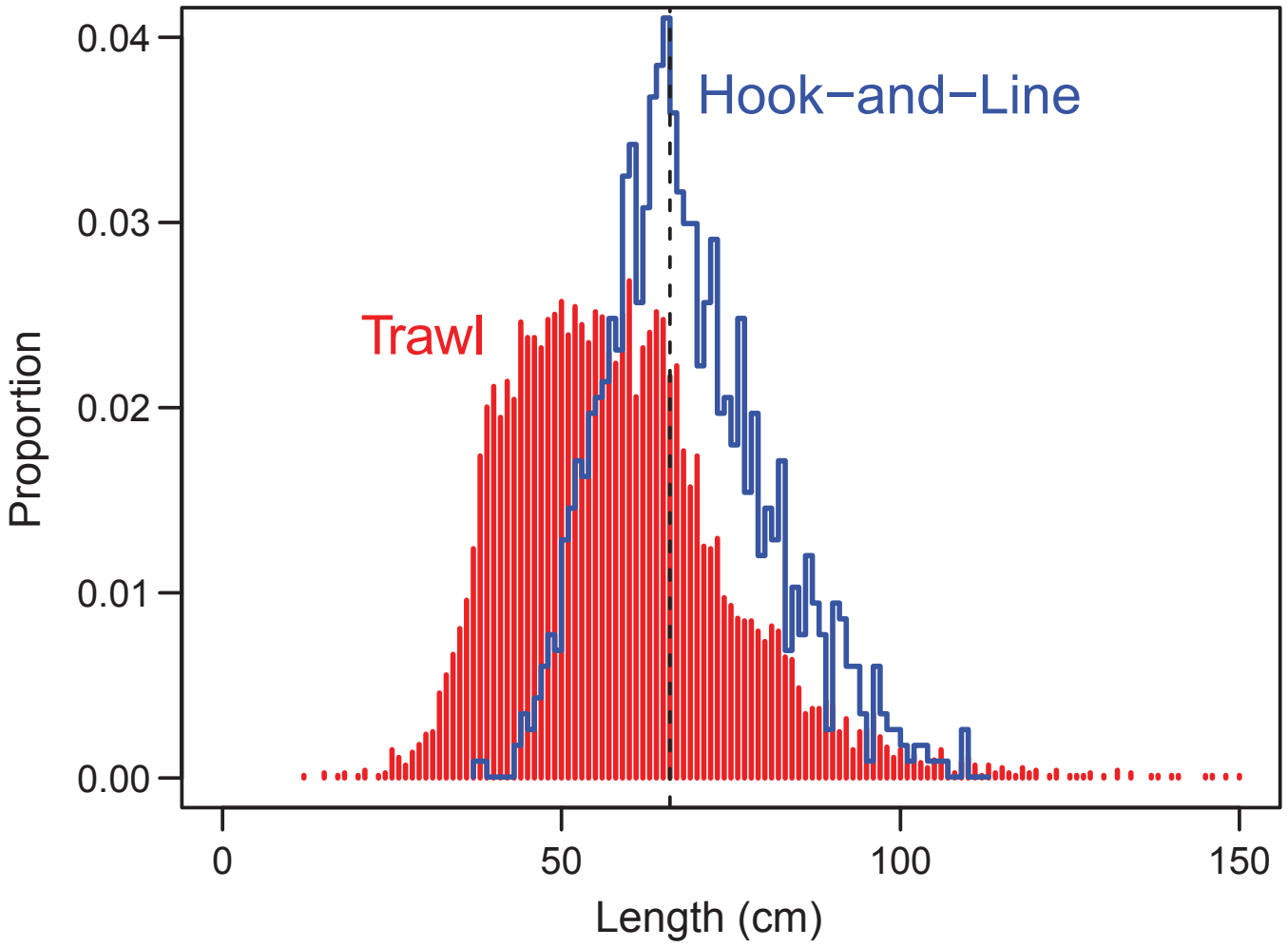


**Figure 1. Halibut length-frequencies collected by observers during 2008 trawl (red vertical bars) and hook-and-line (blue histogram) groundfish fisheries. A dashed vertical black line is shown at 66 cm (26 inches).**

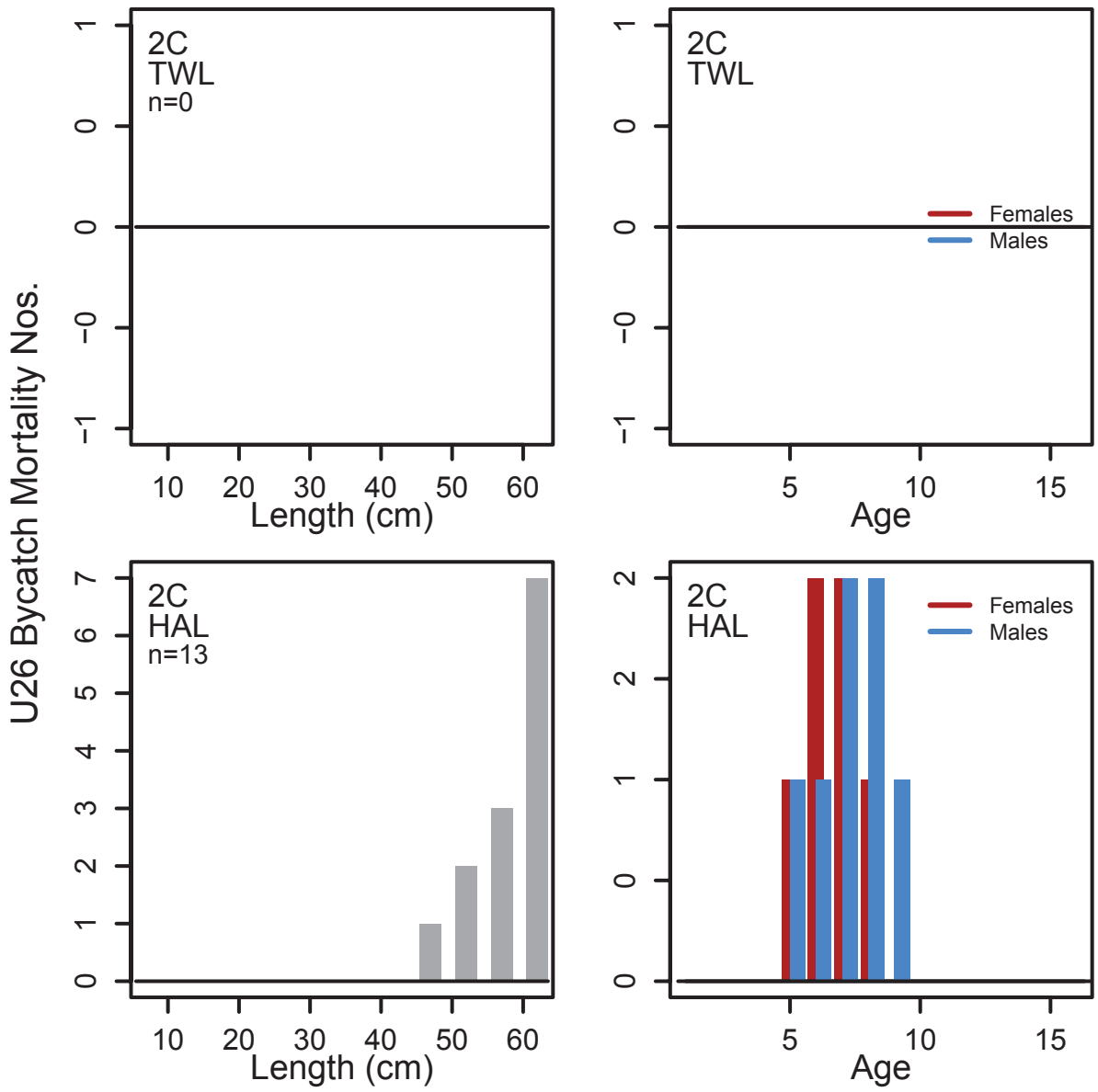


**Figure 2a. Estimated under-26 inch (U26) halibut bycatch distributions from the trawl (TWL) and hook-and-line (HAL) groundish fisheries for IPHC Regulatory Area 2C. The left hand panels show the estimated numbers at length (5 cm groupings) and the right hand panels illustrate the sex and age decompositions (see text for details). The sample size is the estimated number of U26 halibut taken per 100 mt of trawl bycatch mortality or 15 mt of hook-and-line bycatch mortality in the Gulf of Alaska.**

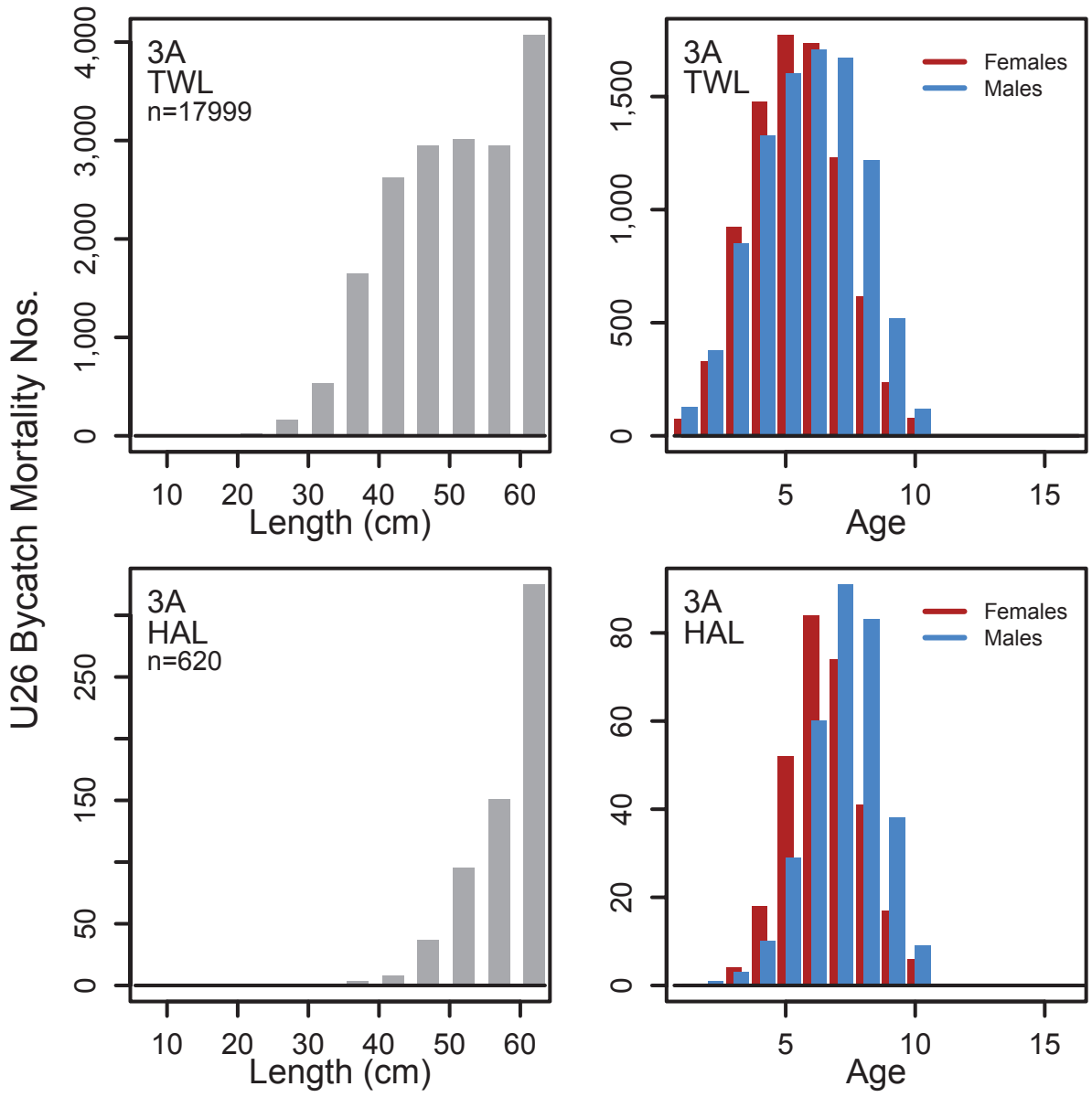


**Figure 2b. Same as Fig. 2a, but for IPHC Regulatory Area 3A.**

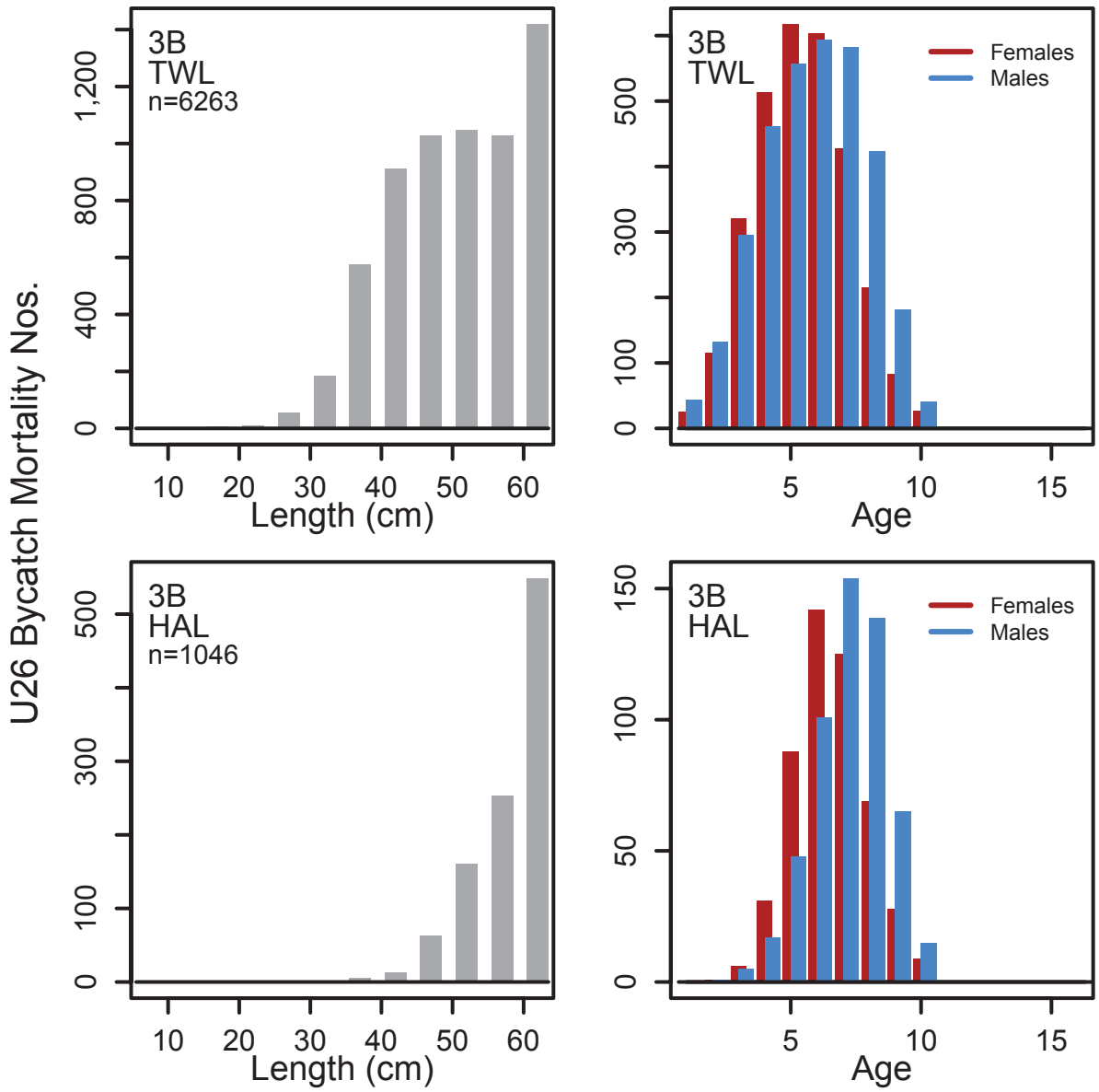


**Figure 2c. Same as Fig. 2a, but for IPHC Regulatory Area 3B.**

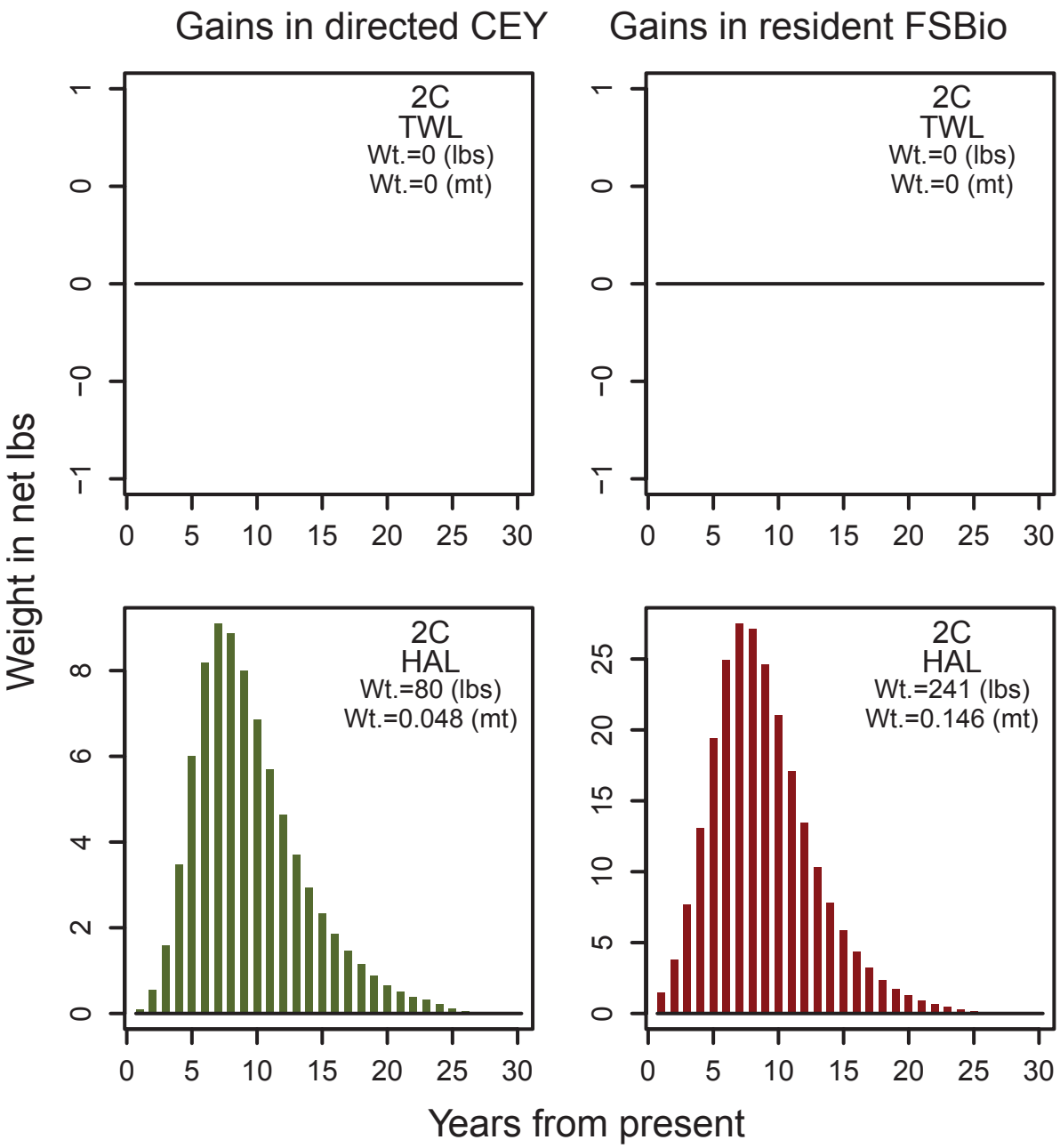


**Figure 3a. Illustration of the expected gains in directed Constant Exploitation Yield (CEY) and female spawning biomass (FSBio) from a 100 mt reduction in trawl (TWL) bycatch mortality (top panes) and 15 mt reduction in hook-and-line (HAL) bycatch mortality (bottom panes) for IPHC Regulatory Area 2C.**

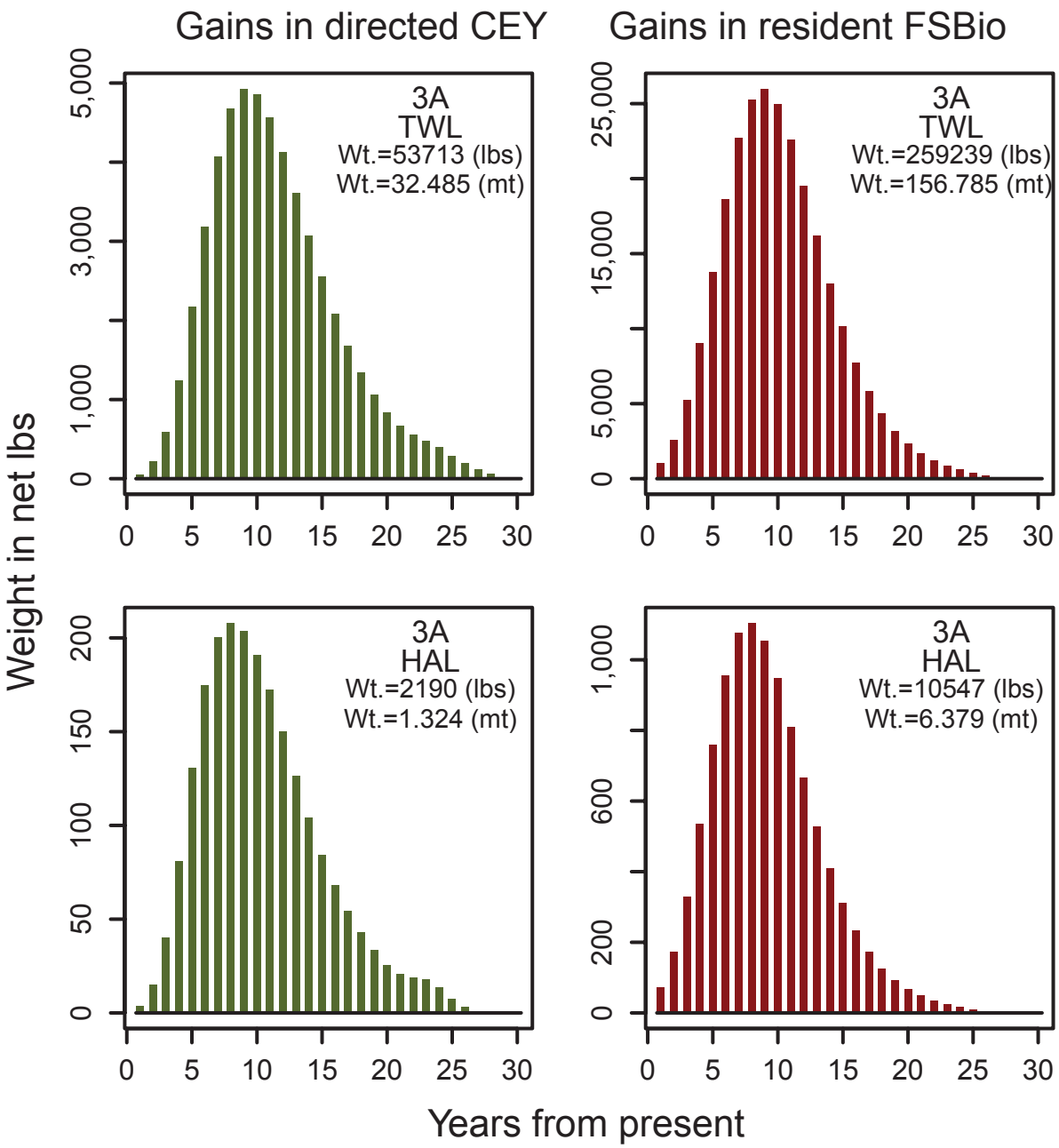


**Figure 3b. Same as Figure 3a, but for IPHC Regulatory Area 3A.**

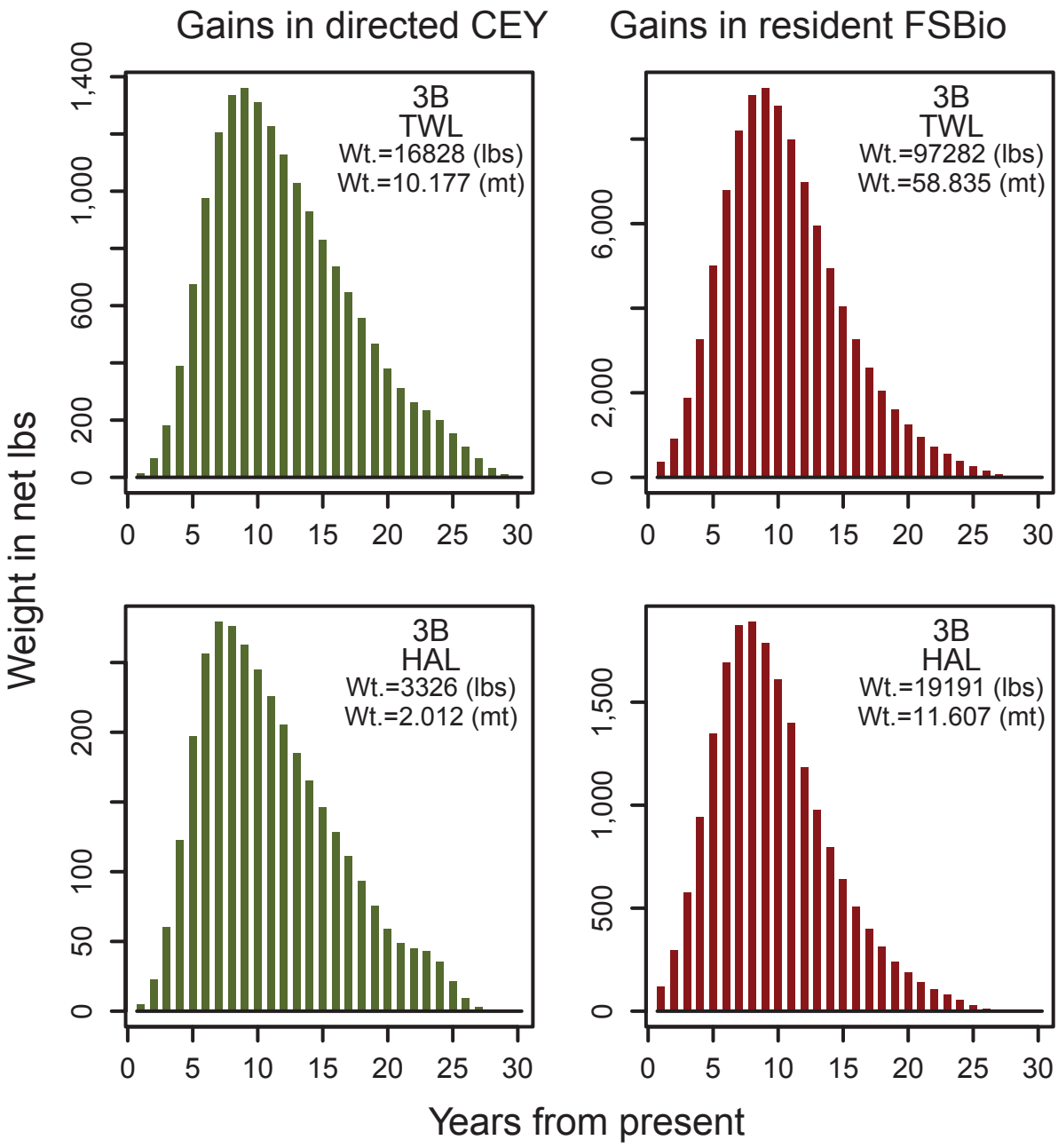


**Figure 3c. Same as Figure 3a, but for IPHC Regulatory Area 3B.**

## Appendix. The IPHC process for determining CEY and directed fishery catch limits

Under a combined charter/commercial catch limit system, the IPHC would:

1. Compute Total Constant Exploitation Yield, or TCEY (Exploitable Biomass times target Harvest Rate)
2. Subtract from TCEY, the Other Removals to determine Fishery CEY. Other Removals would include only unguided sport harvest, subsistence, over-26 inch (O26) wastage, and O26 bycatch mortality.
3. The Fishery CEY is the basis of the combined commercial + charter fishery catch limit. A Slow Up Full Down (SUFullD) harvest control rule is applied to determine the staff's Catch Limit Recommendation (CLR): if the Fishery CEY is greater than the previous year's Catch Limit, the staff's CLR for the subsequent year would be the previous year's Catch Limit PLUS one third of the difference between the two. If the Fishery CEY is less than the previous year's Catch Limit, then the CLR is equal to the Fishery CEY.