



# PACIFIC HALIBUT BYCATCH 2002-2019

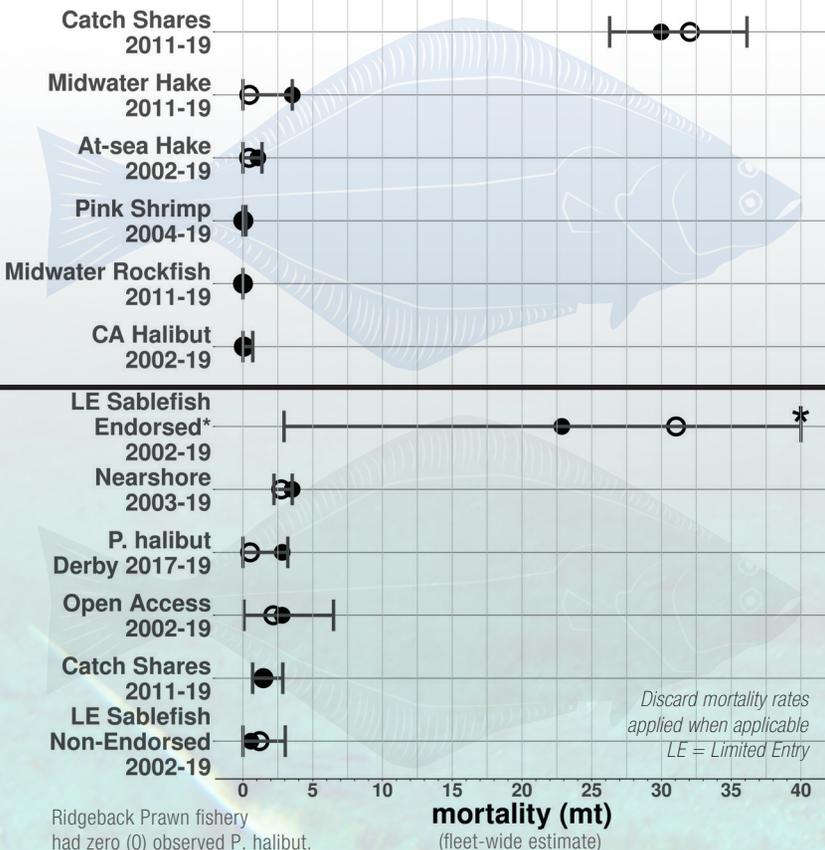
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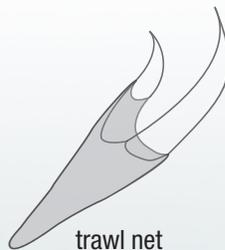
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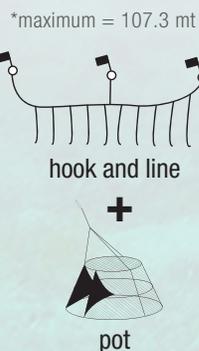
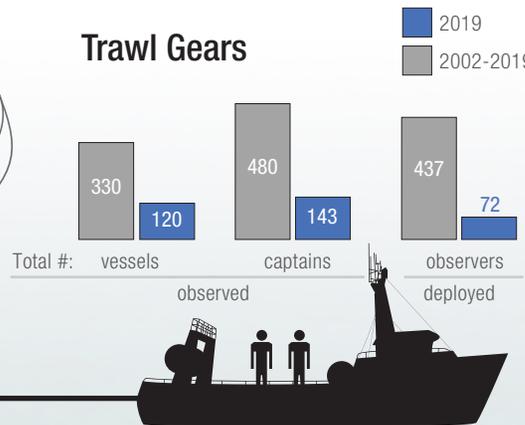
● 2019 estimate ○ mean among years ┃ range among years



2019 Catch Shares IBQ  
Allocation (mt) : 69.58  
Attainment (mt): 31.58



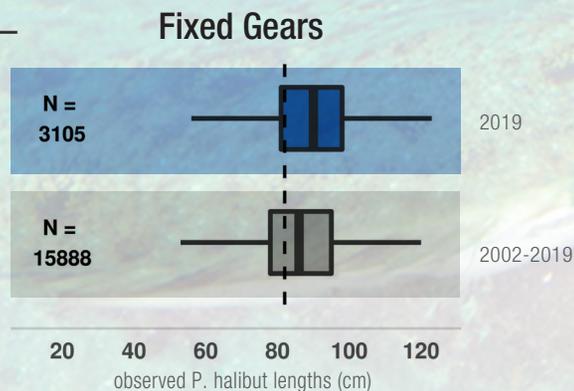
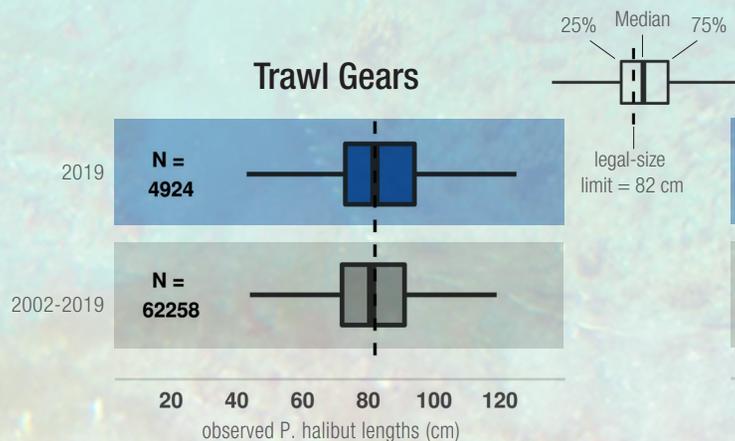
## Trawl Gears



## Fixed Gears



## Pacific Halibut Bycatch Observed 2002-2019



Map by K. Somers

# Pacific Halibut Bycatch in U.S. West Coast Groundfish Fisheries, 2002 - 2019

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DRAFT

## Figure Captions

Figure 1: Total estimated *P. halibut* discard mortality ( $mt \pm 1 SE$ , with mortality rates applied if applicable) from all sectors observed by the NWFSC Groundfish Observer Program. Estimates are not included for sectors and years where there were insufficient observer data. Values are reported in Table 2.<sup>1</sup>Individual Bycatch Quota (IBQ) allocated north of  $40^{\circ} 10'$  N. latitude. <sup>2</sup>IBQ catch includes all Catch Shares sectors and gears except At-sea Hake which is shown separately. <sup>3</sup>Other fisheries includes OR and CA Nearshore, WA, OR, and CA pink shrimp, California halibut, sea cucumber, ridgeback prawn, and IPHC *P. halibut* directed fisheries.

Figure 2: Spatial distribution of Pacific halibut bycatch ( $mt/km^2$ ) observed by West Coast Groundfish Observer Program (2002-2019), off the U.S. West Coast. Gear types observed by the WCGOP include bottom trawl, midwater trawl, shrimp trawl, fixed gear hook & line and pot gear. The five catch classifications were defined by excluding any 0 values and then applying the Jenks natural breaks classification method. Cells (200 sq. km) with less than 3 vessels were omitted from the map to maintain confidentiality.

Figure 3: Number of vessels by month for IFQ bottom trawl vessels in 2019 (solid line) and averaged over the 2011–19 period (dotted line). Grey ribbon represents the monthly maximum and minimum across 2011-2019. Data from vessels using EM is not included.

Figure 4: Number of tows by month for IFQ bottom trawl vessels in 2019 (solid line) and averaged over the 2011–19 period (dotted line). Grey ribbon represents the monthly maximum and minimum across 2011-2019. Data from vessels using EM is not included.

Figure 5: Tow hours by month for IFQ bottom trawl vessels in 2019 (solid line) and averaged over the 2011–19 period (dotted line). Grey ribbon represents the monthly maximum and minimum across 2011-2019. Data from vessels using EM is not included.

Figure 6: Estimated discard mortality of *P. halibut* in the non-nearshore fixed gear fishery by sector and gear for each year. We apply a fixed average discard rate from 2007-08 data to generate 2002-06 discard estimates for the OA sector because only the California portion of the OA fishery was observed 2002-06. The 'Other Pot sectors' includes LE sablefish non-endorsed and OA fixed gear vessels fishing with pot gear.

Figure 7: Length frequency distribution of discarded Pacific halibut on WCGOP observed nonnearshore fixed gear limited entry (LE) and open access (OA) groundfish vessels from September 2003 through December 2019. Visual estimates (grey bars) of *P. halibut* lengths are only estimated in 10 cm increments. The sublegal-legal size cutoff (82 cm) is indicated by a vertical dashed line.

Figure 8: Number of sets, trips, and vessels by opening day for the *P. halibut* directed fishery.

## Table Captions

Table 1: Pacific halibut mortality estimates for 2019 and the years of observation, for all fishery sectors observed by the Northwest Fishery Science Center Groundfish Observer Program. Estimates include both individuals discarded at the dock and with mortality rates applied, where appropriate. \* = confidential

Table 2: Pacific halibut discard mortality estimates (mt, including a small amount discarded at the dock in IFQ Bottom Trawl, Midwater Rockfish, and Midwater Hake fisheries) for all sectors observed by the NWFSC Groundfish Observer Program. Mortality rates of less than 100% were applied in the bottom trawl fisheries (LE and IFQ), IFQ hook and line, IFQ pot, and non-IFQ, nonnearshore fixed gear sectors, for which some information regarding gear specific survivorship was available. For all other sectors, a 100% mortality rate was applied because gear specific survivorship information is not available. Rounding of values might mask very small weights in some categories and are presented here as zero (0). All weights are estimated based on whole fish (a.k.a. round weight, not head-&-gut). Ridgeback Prawn fishery (2017-19) and Sea Cucumber fishery (2017) had zero (0) observed P. halibut catch. Numbers in the headers indicated footnotes at the bottom of the page. \* = confidential data, less than 3 vessels observed; - = no observer coverage.

Table 3: Percent of legal-sized P. halibut (> 82 cm) mortality, by weight (mt) in the IFQ Bottom Trawl fishery north of 40° 10' N. lat.

Table 4: Data collected from P. halibut caught on IFQ vessels using different types of gear.

Table 5: Mortality rates used for each of the viability categories for IFQ bottom trawl vessels (Clark et al. 1992).

Table 6: Mortality rates used for each of the viability categories for IFQ pot gear vessels (IPHC 2011).

Table 7: Mortality rates used for each of the injury categories for Non-Nearshore hook & line vessels (Trumble et al. 2000).

## Supplemental Table Captions

Note: The supplemental tables, along with Tables 1–7, are available in the accompanying Excel file: NWFSC\_Pacific\_Halibut\_Bycatch\_2002\_2019\_Supplemental\_Tables.xlsx.

Table 8: Number of vessels, trips, and tows observed and metric tons of sampled Pacific halibut discarded at-sea and the P. halibut landed and discarded at the dock (from PacFIN fish tickets) on IFQ bottom trawl vessels fishing north of Pt. Chehalis, WA. All participating vessels carry an observer on all fishing trips under IFQ management (100% observed). For clarity, the number of hauls with unsampled catch categories is provided. Some tows are completely unsampled. See Table 8 for bottom trawl vessels fishing under the Electronic Monitoring EFP. (\*) confidential data, (-) not applicable.

Table 9: Number of vessels, trips, and tows observed and metric tons of sampled Pacific halibut discarded at-sea and the P. halibut landed and discarded at the dock (from PacFIN fish tickets) on IFQ bottom trawl vessels fishing south of Pt. Chehalis, WA. All participating vessels carry an observer on all fishing trips under IFQ management (100% observed). For clarity, the number of hauls with unsampled catch categories is provided. Some tows are completely unsampled. See Table 9 for bottom trawl vessels fishing under the Electronic Monitoring EFP. (\*) confidential data, (-) not applicable

Table 10: Number of vessels, trips, and tows observed and metric tons of sampled Pacific halibut discarded at-sea and the P. halibut landed and discarded at the dock (from PacFIN fish tickets) on IFQ midwater trawl vessels. All participating vessels carry an observer on all fishing trips under IFQ management (100% observed). For clarity the number of hauls with unsampled catch categories is provided. Some tows are completely unsampled. Note that starting in 2015, sector names have changed such that trips with P. hake comprising less than 50% of the total landings are renamed Midwater Rockfish whereas trips with P. hake greater than 50% of landings are renamed Midwater Hake. (\*) confidential data, (-) not applicable

Table 11: Number of vessels, trips, and sets observed and metric tons of sampled Pacific halibut discarded at-sea and the P. halibut landed and discarded at the dock (from PacFIN fish tickets) on IFQ pot vessels. All participating vessels carry an observer on all fishing trips under IFQ management (100% observed). For clarity the number of sets with unsampled catch categories is provided. Some sets are completely unsampled. Note in 2015, IFQ vessels using pot gear that fished north of Point Chehalis were all part of the Electronic Monitoring EFP (see Table 11 for summary of these vessels). (\*) confidential data, (-) not applicable

Table 12: Number of vessels, trips, and sets observed and metric tons of sampled Pacific halibut discarded at-sea and the P. halibut landed and discarded at the dock (from PacFIN fish tickets) on IFQ hook & line vessels. All participating vessels carry an observer on all fishing trips under IFQ management (100% observed). For clarity the number of sets with unsampled catch categories is provided. Some sets are completely unsampled. (\*) confidential data, (-) not applicable

Table 13: Values used to calculate the expanded weight of Pacific halibut (PHLB) from each unsampled category on U.S. West Coast groundfish IFQ bottom trawl vessels by year. Unsampled catch weight could be assigned to one of four categories: IFQ flatfish species, IFQ mixed species, non-IFQ species, or unsorted (a mix of both IFQ and non-IFQ species). The sampled weight, discard ratio, unsampled weight and estimated P. halibut gross at-sea discard are presented within each category, as a function of sector, management area, and depth for the area north of Pt. Chehalis, WA. The sum of expanded weight is the sum of the estimated gross P. halibut discard across categories. The sampled discarded PHLB weight is the sum of sampled PHLB. The total discard (gross) is the sum of the PHLB in unsampled hauls plus the sampled PHLB. All weights are metric tons (mt). (\*) confidential data. Note that adding values across columns might give slightly different results because values are rounded to two decimals for reporting.

Table 14: Values used to calculate the expanded weight of Pacific halibut (PHLB) from each unsampled category on U.S. West Coast groundfish IFQ bottom trawl vessels by year. Unsampled catch weight could be assigned to one of four categories: IFQ flatfish species, IFQ mixed species, non-IFQ species, or unsorted (a mix of both IFQ and non-IFQ species). The sampled weight, discard ratio, unsampled weight and estimated P. halibut gross at-sea discard are presented within each category, as a function of sector, management area, and depth for the area south of Pt. Chehalis, WA. The sum of expanded weight is the sum of the estimated gross P. halibut discard across categories. The sampled discarded PHLB weight is the sum of sampled PHLB. The total discard (gross) is the sum of the PHLB in unsampled hauls plus the sampled PHLB. All weights are metric tons (mt). (\*) confidential data. Note that adding values across columns might give slightly different results because values are rounded to two decimals for reporting.

Table 15: Values used to calculate the expanded weight of Pacific halibut (PHLB) from each unsampled category on U.S. West Coast groundfish IFQ midwater trawl vessels by year. Unsampled catch weight could be assigned to one of four categories: IFQ flatfish species, IFQ mixed species, non-IFQ species, or unsorted (a mix of both IFQ and non-IFQ species). The sampled weight, discard ratio, unsampled weight and estimated P. halibut gross at-sea discard are presented within each category, as a function of sector. All midwater trawling occurs north of 40° 10 ' and all depths are included in the summaries. The sum of expanded weight is the sum of the estimated gross P. halibut discard across categories. The sampled discarded PHLB weight is the sum of sampled PHLB. The total discard (gross) is the sum of the PHLB in unsampled hauls plus the sampled PHLB. All weights are metric tons (mt). (\*) confidential data. Samp. = Sampled, Dis. = Discard, Unsamp. = Unsampled, Wt. = weight (mt), PHLB = Pacific halibut

Table 16: Values used to calculate the expanded weight of Pacific halibut (PHLB) from each unsampled category on U.S. West Coast groundfish IFQ fixed gear vessels by year. Unsampled catch weight could be assigned to one of four categories: IFQ flatfish species, IFQ mixed species, non-IFQ species, or unsorted (a mix of both IFQ and non-IFQ species). The sampled weight, discard ratio, unsampled weight and estimated P. halibut gross at-sea discard are presented within each category, as a function of gear, management area, and, for pot gear, by areas north and south of Point Chehalis, WA. All depths fished are included in the summaries. The sum of expanded weight is the sum of the estimated gross P. halibut

discard across categories. The sampled discarded PHLB weight is the sum of sampled PHLB. The total discard (gross) is the sum of the PHLB in unsampled sets plus the sampled PHLB. All weights are metric tons (mt). (\*) confidential data.

Table 17: Pacific halibut viabilities in the U.S. West Coast groundfish IFQ bottom trawl fishery by management area, depth, and year. The condition of sampled P. halibut was identified as Excellent (Exc), Poor, or Dead, consistent with IPHC protocol. The number of fish in each category was weighted based on the length-weight relationship as described in the Methods. In addition, all years combined are also shown. After 2012, LE CA Halibut is combined with IFQ. (\*) confidential data, (-) no estimate provided, see text for explanation.

Table 18: Pacific halibut viabilities in the U.S. West Coast groundfish IFQ midwater trawl fishery by management area and year. The condition of sampled P. halibut was identified as Excellent (Exc), Poor, or Dead, consistent with IPHC protocol. The number of fish in each category was weighted based on the length-weight relationship as described in the Methods. In addition, all years combined are also shown. (\*) confidential data, (-) no estimate provided, see text for explanation.

Table 19: Pacific halibut viabilities in the U.S. West Coast groundfish IFQ pot fishery by management area and year. The condition of sampled P. halibut was identified as Excellent (Exc), Poor, or Dead, consistent with IPHC protocol. The number of fish in each category was weighted based on the length-weight relationship as described in the Methods. In addition, all years combined are also shown. (\*) confidential data, (-) no estimate provided, see text for explanation.

Table 20: Pacific halibut caught in the U.S. West Coast groundfish IFQ hook & line fishery by management area and year. The viabilities are not currently obtained on IFQ vessels. (\*) confidential data, (-) no data collected

Table 21: Estimated Pacific halibut gross at-sea discard (mt) and at-sea discard mortality (mt) in the U.S. West Coast groundfish IFQ bottom trawl fishery by management area, depth, and year. Estimates were allocated to three condition categories based on information presented in Table 17. DMR=Discard Mortality Rate. After 2012, LE CA Halibut has been combined with IFQ. (\*) confidential data, (-) no estimate, see text for explanation.

Table 22: Estimated Pacific halibut gross at-sea discard (mt) and at-sea discard mortality (mt) in the U.S. West Coast groundfish IFQ midwater trawl fishery by management area and year. Estimates were allocated to three condition categories based on information presented in Table 18. DMR=Discard Mortality Rate. (\*) confidential data, (-) no estimate, see text for explanation.

Table 23: Estimated Pacific halibut gross at-sea discard (mt) and at-sea discard mortality (mt) in the U.S. West Coast groundfish IFQ pot fishery by management area and year. Estimates were allocated to three condition categories based on information presented in Table 19. DMR=Discard Mortality Rate. (\*) confidential data, (-) no estimate, see text for explanation.

Table 24: Estimated Pacific halibut gross at-sea discard (mt) and at-sea discard mortality (mt) in the U.S. West Coast groundfish IFQ hook & line fishery by management area, depth, and year. A single discard mortality rate (DMR) of 0.16 is applied in this fishery. Viabilities are not used to determine discard mortality, see text for explanation. (\*) confidential data, (-) no data collected.

Table 25: Estimated Pacific halibut discard (mt), discard mortality (mt), legal-sized (82 cm) mortality (mt), and percent of legal-sized discard by weight in the U.S. West Coast groundfish IFQ bottom trawl fisheries by management area, depth, and year. After 2012, LE CA Halibut was combined with IFQ. (\*) confidential data, (-) no estimate, see text for explanation

Table 26: Estimated Pacific halibut discard (mt), discard mortality (mt), legal-sized (82 cm) mortality (mt), and percent of legal-sized discard by weight in the U.S. West Coast groundfish IFQ midwater trawl fisheries by area and year. (\*) confidential data, (-) no estimate, see text for explanation

Table 27: Estimated Pacific halibut discard (mt), discard mortality (mt), legal-sized (82 cm) mortality (mt), and percent of legal-sized discard by weight in the U.S. West Coast groundfish IFQ pot fisheries by area and year. (\*) confidential data, (-) no estimate, see text for explanation.

Table 28: Estimated Pacific halibut discard (mt), discard mortality (mt), legal-sized (82 cm) mortality (mt), and percent of legal-sized discard by weight in the U.S. West Coast groundfish IFQ hook & line fisheries by area and year. (\*) confidential data, (-) no estimate, see text for explanation.

Table 29: Pacific halibut bycatch by month for vessels fishing bottom trawl gear in the 2019 IFQ fishery. We present coastwide estimates across all depths to maintain confidentiality. Note that adding values across columns might give slightly different results because values are rounded to two decimals for reporting. Monthly estimates do not include bycatch from EM vessels.

Table 30: Physical measurements of P. halibut length (cm) in the U.S. west coast groundfish IFQ fishery (2011-2019) for vessels using bottom trawl gear. Length bins include the lower bound and exclude the upper bound.

Table 31: Physical measurements of P. halibut length (cm) in the U.S. west coast groundfish IFQ fishery (2011-2019) for vessels using pot gear. Length bins include the lower bound and exclude the upper bound.

Table 32: Physical measurements of P. halibut length (cm) in the U.S. west coast groundfish IFQ fishery (2011-2019) for vessels using midwater trawl gear. Length bins include the lower bound and exclude the upper bound.

Table 33: Visual estimates of P. halibut lengths (cm) from the U.S. West Coast groundfish IFQ fishery (2011-2019) for vessels using bottom trawl, pot, and hook & line gear. Length bins include the lower bound and exclude the upper bound. On IFQ hook & line vessels, only visual estimates are taken on P. halibut.

Table 34: Weighted length frequency distributions for Pacific halibut in the IFQ fishery for vessels using bottom trawl gears, by year. Length bins are inclusive of the bin value (lower) and exclude the upper value, e.g., 10 = lengths 10.0 to 11.99 cm. Since 2013, IFQ bottom trawl lengths could also include lengths taken on both IFQ and LE California halibut bottom trawl fisheries. For earlier years, please see <https://doi.org/10.25923/5xz2-zy24>

Table 35: Percentage of weighted length measurements in each viability category, for IFQ bottom trawl vessels by year. Length bins are inclusive of the bin value (lower) and exclude the upper value, e.g., 10 = lengths 10.0 to 11.99 cm. Since 2013, IFQ bottom trawl lengths could also include lengths taken on both IFQ and LE California halibut bottom trawl fisheries. For earlier years please see: <https://doi.org/10.25923/5xz2-zy24>

Table 36: Observed number of dead P. halibut in each length bin, summed across viability categories, for IFQ bottom trawl vessels by year. Length bins are inclusive of the bin value (lower) and exclude the upper value, e.g., 10 = lengths 10.0 to 11.99 cm. Since 2013, IFQ bottom trawl lengths could also include lengths taken on both IFQ and LE California halibut bottom trawl fisheries. This analysis assumes that there is no size-dependent mortality within viability categories. For earlier years, please see <https://doi.org/10.25923/5xz2-zy24>

Table 37: Weighted length frequency distributions for Pacific halibut in the IFQ fishery for vessels using pot gears, by year. Length bins are inclusive of the bin value (lower) and exclude the upper value, e.g., 10 = lengths 10.0 to 11.99 cm. For earlier years, please see <https://doi.org/10.25923/5xz2-zy24>

Table 38: Percentage of weighted length measurements in each viability category, for IFQ pot vessels by year. Length bins are inclusive of the bin value (lower) and exclude the upper value, e.g., 10 = lengths 10.0 to 11.99 cm. For earlier years please see: <https://doi.org/10.25923/5xz2-zy24>

Table 39: Observed number of dead P. halibut in each length bin, summed across viability categories, for IFQ pot vessels by year (2018-19). Length bins are inclusive of the bin value (lower) and exclude the upper value, e.g., 10 = lengths 10.0 to 11.99 cm. This analysis assumes that there is no size-dependent mortality within viability categories. For earlier years, please see <https://doi.org/10.25923/5xz2-zy24>

Table 40: Observed number of dead P. halibut in each length bin for Midwater Hake vessels 2018-19. Length bins are inclusive of the bin value (lower) and exclude the upper value, e.g., 10 = lengths 10.0 to 11.99 cm. This analysis assumes 100% mortality of all individuals because viability has not been determined for P. halibut caught with midwater trawl nets. Starting in 2015, IFQ midwater trawl trips were sorted into Midwater Hake or Midwater Rockfish depending on landing amount of P. hake. For earlier years, please see <https://doi.org/10.25923/5xz2-zy24>

Table 41: Observed number of dead P. halibut in each length bin for Midwater Rockfish vessels 2018-19. Length bins are inclusive of the bin value (lower) and exclude the upper value, e.g., 10 = lengths 10.0 to 11.99 cm. This analysis assumes 100% mortality of all individuals because viability has not been determined for P. halibut caught with midwater

trawl nets. Starting in 2015, IFQ midwater trawl trips were sorted into Midwater Hake or Midwater Rockfish depending on landing amount of P. hake. For earlier years, please see <https://doi.org/10.25923/5xz2-zy24>

Table 42: Coverage information and Pacific halibut bycatch in the At-sea Pacific hake catcher-processor fishery by year. Gear specific mortality rates cannot be applied to P. halibut bycatch in this fishery because mortality rates have not been determined for midwater trawl gear.

Table 43: Coverage information and Pacific halibut bycatch in the At-sea Pacific hake catcher vessels delivering to motherships fishery by year. Gear specific mortality rates cannot be applied to P. halibut bycatch in this fishery because mortality rates have not been determined for midwater trawl gear.

Table 44: Coverage information and Pacific halibut bycatch in the Tribal At-sea Pacific hake fishery by year. Tribal At-sea P. hake fishery has not operated since 2012. Gear specific mortality rates cannot be applied to P. halibut bycatch in this fishery because mortality rates have not been determined for midwater trawl gear. (\*) confidential.

Table 45: Physical P. halibut length frequencies (cm) collected by A-SHOP observers in the At-sea hake fishery (2002-2019). Length bins include the lower bound and exclude the upper bound.

Table 46: Number of vessels, trips, and tows (or sets) and gross metric tons of Pacific halibut discarded at-sea, P. halibut discarded at sea with mortality rate applied (bottom trawl = 0.90) and the P. halibut landed and discarded at the dock (mortality rate = 1.0) under the IFQ Electronic Monitoring Exempted Fishing Permit (EFP). All participating vessels carry electronic monitoring equipment on all fishing trips. Data are summarized from the EM program administered by Pacific States Marine Fisheries Commission

Table 47: Observed number of IFQ Electronic Monitoring bottom trawl vessels, trips, and sets that caught Pacific halibut and the number of P. halibut in each viability category. Exclnt = Excellent.

Table 48: P. halibut observed weight, estimated total at-sea gross weight of discards, and estimated mortality (mt ,with the mortality rate applied based on observer viability), in each viability category from IFQ bottom trawl vessels. Discard mortality rates are shown for the observer viability method and the Time-on-Deck model as applied by the Pacific States Marine Fisheries Commission. Electronic Monitoring (EM) vessels carried electronic monitoring equipment. Viabilities on both EM and non-EM vessels were obtained by at-sea human observers. EM vessels only fished south of Pt. Chehalis. Values north of Pt. Chehalis represent non-EM vessels and are presented for comparison purposes only. All weights are metric tons (mt). Exclnt = Excellent = 0.10 mortality rate; Poor = 0.55 mortality rate; Dead = 0.90 mortality rate; All = all years combined.

Table 49: Number of vessels, trips, and tows (or sets) and gross metric tons of Pacific halibut discarded at-sea, P. halibut discarded at sea with mortality rate applied (pot = 0.18) and the P. halibut landed and discarded at the dock (mortality rate = 1.0) under the IFQ

Electronic Monitoring Exempted Fishing Permit (EFP). All participating vessels carry electronic monitoring equipment on all fishing trips. Data are summarized from the EM program administered by Pacific States Marine Fisheries Commission

Table 50: Observed number of IFQ Electronic Monitoring pot vessels, trips, and sets that caught Pacific halibut and the number of P. halibut in each viability category. Exc = Excellent.

Table 51: P. halibut observed weight, estimated total at-sea gross weight of discards, and estimated mortality (mt, with the mortality rate applied based on observer viability), in each viability category from IFQ pot vessels. Total discard mortality rates are shown for the observer viability method. Electronic Monitoring (EM) vessels carried electronic monitoring equipment. Viabilities on both EM and non-EM vessels were obtained by at-sea human observers. The Time-on-Deck model only applies to bottom trawl gear. All weights are metric tons (mt). Exc = Excellent = 0.0 mortality rate; Poor = 1.0 mortality rate; Dead = 1.0 mortality rate; All = all years combined.

Table 52: Number of vessels, trips, and tows (or sets) and gross metric tons of Pacific halibut discarded at-sea, P. halibut discarded at sea with mortality rate applied (midwater trawl = 1.0) and the P. halibut landed and discarded at the dock (mortality rate = 1.0) under the IFQ Electronic Monitoring Exempted Fishing Permit (EFP). All participating vessels carry electronic monitoring equipment on all fishing trips. Data are summarized from the EM program administered by Pacific States Marine Fisheries Commission

Table 53: Number of observed vessels, trips, and sets by year and gear type in the LE Sablefish Endorsed fishery.

Table 54: Number of observed vessels, trips, and sets by year and gear type in the LE Sablefish Non-Endorsed fishery. The number of observed pot vessels in this fishery is too small to meet confidentiality and thus not reported.

Table 55: Number of observed vessels, trips, and sets by year and gear type in the OA Fixed Gear fishery. OA Fixed Gear fishery was not observed until 2003.

Table 56: Expansion factors and WCGOP observed discard rate by gear type for limited entry (LE) and open access (OA) non-nearshore fixed gear sectors used to expand discard estimates of Pacific halibut to the entire fleet.

Table 57: Total sablefish or groundfish landings (mt) for each sector and gear type in the non-nearshore fixed gear fishery. Sablefish landings were used as the expansion factor in all cases except for the LE Sablefish Non-Endorsed and the OA Fixed Gear sectors, where target species include a variety of groundfish species.

Table 58: Observed discard ratios for each sector and gear type in the non-nearshore fixed gear fishery. Sablefish landings were used as the discard ratio denominator in all cases except for the LE Sablefish Non-Endorsed and the OA Fixed Gear sectors, where target species include a variety of groundfish species.

Table 59: Percent of observed trips that caught Pacific halibut by sector, gear, and area (where applicable). n.o.c. No observed catch of P. halibut and thus a % discard calculation is not possible. – No WCGOP observers were deployed for the sector-year-gear type combination.

Table 60: Observed average, minimum and maximum annual catch of P. halibut catch weight discarded by year. – No WCGOP observers were deployed for the sector-year-gear type combination.

Table 61: Discard weights and the percent of P. halibut catch weight discarded by year. n.o.c. No observed catch of P. halibut and thus a % discard calculation is not possible. – No WCGOP observers were deployed for the sector-year-gear type combination.

Table 62: Pacific halibut viabilities caught by longline vessels in the U.S. west coast Limited Entry Sablefish Endorsed fishery by year and area north and south of Point Chehalis, WA. The condition of sampled P. halibut was identified as Minor (Mi), Moderate (Mo), Serious (Ser) or Dead, consistent with IPHC protocol. Sample sizes allowed for annual weighted percentages as described in the Methods.

Table 63: Pacific halibut viabilities caught by longline vessels in the U.S. west coast Limited Entry Sablefish Non-Endorsed fishery, coastwide by year. The condition of sampled P. halibut was identified as Minor (Mi), Moderate (Mo), Serious (Ser) or Dead, consistent with IPHC protocol. Sample sizes necessitated the use of a five year rolling average to calculate weighted percentages, as described in the Methods.

Table 64: Pacific halibut viabilities caught by hook-&-line vessels in the U.S. west coast Open Access fixed gear fishery, coastwide by year. The condition of sampled P. halibut was identified as Minor (Mi), Moderate (Mo), Serious (Ser) or Dead, consistent with IPHC protocol. Sample sizes necessitated the use of a five year rolling average to calculate weighted percentages, as described in the Methods.

Table 65: Estimated gross discard (mt) in the limited entry (LE) sablefish endorsed, LE sablefish non-endorsed, and open access (OA) fixed gear sectors.

Table 66: Estimated discard mortality (mt) in the limited entry (LE) sablefish endorsed, LE sablefish non-endorsed, and open access (OA) fixed gear sectors. Estimated discard mortality (mt) on longline and hook-&-line vessels was computed by two methods. For the 2002-2010 period, a 16 % discard mortality rate was applied to gross discard estimates because viability data was not available. Since 2011, mortality rates on longline vessels are based on the viability categories assigned to individuals. For all years, an 18% discard mortality rate was applied to gross discard estimates from pot vessels.

Table 67: Estimated P. halibut discard mortality (mt, mortality rate applied, see text for description) from each sector of the non-nearshore fixed gear fishery by year.

Table 68: Physical measurements of P. halibut length (cm) from the U.S. west coast LE Sablefish Endorsed fishery (2002-2019) for vessels using hook & line gear. Length bins include the lower bound and exclude the upper bound.

Table 69: Physical measurements of P. halibut length (cm) from the U.S. west coast LE Sablefish Endorsed fishery (2002-2019) for vessels using pot gear. Length bins include the lower bound and exclude the upper bound.

Table 70: Physical measurements of P. halibut length (cm) from the U.S. west coast LE Sablefish Non-Endorsed fishery (2002-2019) for vessels using hook & line gear. The WCGOP does not cover vessels fishing pot gear in this fishery. Length bins include the lower bound and exclude the upper bound.

Table 71: Physical measurements of P. halibut length (cm) from the U.S. west coast OA Fixed Gear fishery (2002-2019) for vessels using hook & line or pot gear.

Table 72: Visual estimates of P. halibut lengths (cm) from the U.S. West Coast groundfish Non-Nearshore fixed gear fisheries (2002-2019) for vessels using hook & line gear and pot gear. Numbers are the numbers of individuals caught with each gear type. The WCGOP does not observe LE Non-Endorsed Sablefish vessels fishing with pot gear. Length bins include the lower bound and exclude the upper bound.

Table 73: Pacific halibut physically measured lengths and visual estimates of lengths approximating legal (>82 cm) versus sublegal definitions (IPHC), collected by the WCGOP in the IFQ fishery (2011-2019), Non-Nearshore fixed gear fisheries (LE sablefish endorsed, LE non-endorsed, OA fixed gear; 2002-2019), and the At-sea Hake sectors (2002-2019). Note that visual length estimates are not taken in the At-sea Hake sectors.

Table 74: Observer coverage information for the Pacific halibut directed fishery by year. The WCGOP began observing the Pacific halibut directed fishery in 2017 at the request of the International Pacific Halibut Commission.

Table 75: Dates for the International Pacific Halibut Commission (IPHC) P. halibut directed commercial (non-tribal) fishery in IPHC area 2A.

Table 76: Discard ratio and gross discard estimate of P. halibut for the P. halibut directed fishery. LCL = lower confidence limit; UCL = upper confidence limit

Table 77: Pacific halibut viabilities from the Pacific halibut directed fishery. The injury status of sampled discarded P. halibut was identified as minor, moderate, and serious injuries or dead, consistent with International Pacific Halibut Commission protocol. The number of fish in each category was weighted based on the length-weight relationship as described in the Methods.

Table 78: Pacific halibut mortality from the Pacific halibut directed fishery. The injury status of sampled discarded P. halibut was identified as minor, moderate, and serious injuries or dead, consistent with International Pacific Halibut Commission protocol. The number of fish in each category was weighted based on the length-weight relationship as described in the Methods. Mortality rates (Table 7) were applied to each injury category. LCL = lower confidence limit; UCL = upper confidence limit.

Table 79: Physical length measurements of discarded P. halibut from the Pacific halibut directed fishery. Length bins include the lower bound and exclude the upper bound.

Table 80: Visual length estimates of discarded *P. halibut* from the Pacific halibut directed fishery. Length bins include the lower bound and exclude the upper bound.

Table 81: Coverage information, bycatch rates, and bycatch estimates for Pacific halibut in the Oregon nearshore fixed gear groundfish fisheries by state and year. The WCGOP began observing the Oregon nearshore fishery in 2004. Gear specific mortality rates cannot be applied to *P. halibut* bycatch in this fishery because of confidentiality issues. Coverage rate in the state nearshore fisheries is defined as the proportion of nearshore target species landings that were observed. Nearshore target species are listed in the WCGOP Data Processing Appendix. Washington does not allow a state nearshore fishery.

Table 82: Coverage information, bycatch rates, and bycatch estimates for Pacific halibut in the California nearshore fixed gear groundfish fisheries by state and year. The WCGOP began observing the California nearshore fishery in 2003. Gear specific mortality rates cannot be applied to *P. halibut* bycatch in this fishery because of confidentiality issues. Coverage rate in the state nearshore fisheries is defined as the proportion of nearshore target species landings that were observed. Nearshore target species are listed in the WCGOP Data Processing Appendix. Washington does not allow a state nearshore fishery.

Table 83: Coverage information, bycatch rates, and bycatch estimates for Pacific halibut in the Washington and Oregon state pink shrimp fisheries by state and year. The WCGOP began observing the OR state pink shrimp fishery in 2004, but was unable to observe it in 2006. The WA state pink shrimp fishery was added for observation in 2010. Mortality rates are not applied to *P. halibut* bycatch in these fisheries because mortality rates for pink shrimp trawl gear have not been estimated. Coverage rate in the pink shrimp fisheries is defined as the proportion of pink shrimp landings that were observed. (\*) = Confidential data; (-) = not observed; LCL/UCL = lower/upper 95% confidence limit.

Table 84: Coverage information, bycatch rates, and bycatch estimates for Pacific halibut in the California state pink shrimp fisheries by state and year. The WCGOP began observing the CA state pink shrimp fishery in 2004, but was unable to observe it in 2006. Mortality rates are not applied to *P. halibut* bycatch in this fishery because mortality rates for pink shrimp trawl gear have not been estimated. Coverage rate is defined as the proportion of pink shrimp landings that were observed. (\*) = Confidential data; (-) = not observed; LCL/UCL = lower/upper 95% confidence limit.

Table 85: Coverage information, bycatch rates, and bycatch estimates for Pacific halibut in the state California halibut trawl fishery by sector and year. The WCGOP recognizes two sectors; a limited entry sector and an open access sector. In 2010, the LE and OA sectors are combined to maintain confidentiality. Beginning in 2011, the limited entry sector is observed under the IFQ groundfish fishery and estimates for this sector are included in the IFQ tables. Mortality rates are not applied to *P. halibut* bycatch in these fisheries because mortality rates for CA halibut trawl gear have not been estimated. Coverage rate in the CA halibut fishery is defined as the proportion of CA halibut landings that were observed. CHLB = California halibut

Table 86: Observer coverage information for the Ridgeback Prawn fishery by year. The WCGOP began observing the Ridgeback Prawn fishery in 2017.

Table 87: Observer coverage information for the Sea Cucumber fishery by year. The WCGOP began observing the Sea Cucumber fishery in 2017. \* = confidential.

Table 88: Metric tons of Pacific halibut discarded at sea and landed and discarded at the dock on observed Exempted Fishing Permit (EFP) vessels. Note: This does not contain the Catch Shares Electronic Monitoring EFP data

Table 89: Metric tons of Pacific halibut landed in non-groundfish fisheries that are not observed by the NWFSC Observer Program. Data are summarized from the PacFIN fish tickets and do not include any P. halibut landed under the IPHC P. halibut directed fishery.

Table 90: Gross discard estimates for all fishery sectors observed by the NWFSC Groundfish Observer Program, 2002-19. No discard mortality rates were applied. Estimates include individuals discarded at the dock. Ridgeback Prawn (2017-19) and Sea Cucumber (2017 only) fisheries had zero (0) observed P. halibut catch. The 2018-19 Sea Cucumber fishery data is confidential.

Table 91: Total discard estimates for all fishery sectors observed by the NWFSC Groundfish Observer Program, 2002-19. Discard mortality rates were applied in those fisheries where mortality rates are known. Otherwise, mortality is assumed to be 100%. Estimates include individuals discarded at the dock (100% mortality). Ridgeback Prawn (2017-19) and Sea Cucumber (2017 only) fisheries had zero (0) observed P. halibut catch. The 2018-19 Sea Cucumber fishery data is confidential.

Table 92: A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fishery sectors and subsectors in federally managed and monitored U.S. West Coast groundfish catch share fisheries which use Individual Fishing Quotas (IFQ) to manage certain species. Observer coverage in these fisheries is 100%, except for vessels using electronic monitoring (EM). The IFQ program began in 2011, regulations prior to 2011 are excluded. For brevity, management descriptors are generalized and are not meant to be complete or comprehensive. Vessel lengths and fishing depths are based on observed vessels and might not represent the fleet as a whole.

Table 93: A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fishery sectors and subsectors in federally managed and observed U.S. West Coast groundfish non-catch share fisheries. Observer coverage on these vessels is less than 100%. For brevity, management descriptors are generalized and are not meant to be complete or comprehensive. Vessel lengths and fishing depths are based on observed vessels and might not represent the fleet as a whole.

Table 94: A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fishery sectors and subsectors in state-managed, observed fisheries. Observer coverage on these vessels is less than 100%. For brevity, management descriptors are generalized for the given time period and are not meant to be complete or comprehensive. Vessel lengths and fishing depths are based on observed vessels and might not represent the fleet as a whole.

Table 95: IPHC length-weight conversion table for Pacific halibut.

## Acknowledgements

The authors gratefully acknowledge the hard work and dedication of observers from the Northwest Fisheries Science Center Fisheries Observation Science Program, Jim Fellows (NWFSC) for data acquisition assistance, and all the NWFSC Observer Program staff for their hard work and dedication. We thank Su Kim of the NWFSC Scientific Communications Office for producing the infographic in this report. We thank our partners at Pacific States Marine Fisheries Commission who provide us with data from the IFQ Electronic Monitoring EFP and landings data from PacFIN and specifically Aileen Smith for providing us with the data to compare DMRs in the EM fishery.

### A note about tables:

Tables 1–7 have been typeset and included in this report. They are also available, together with all the other mentioned tables (8-95), in the accompanying Excel file: `NWFSC_Pacific_Halibut_Bycatch_2002_2019_Supplemental_Tables.xlsx`.

## Executive Summary

Pacific halibut (*Hippoglossus stenolepis*, henceforth P. halibut) is found in coastal waters throughout the North Pacific. Off the U.S. West Coast of the United States, it inhabits continental shelf areas (<150 fm) from Washington to central California (Clark and Hare 1998). Pacific halibut has long supported a directed commercial fishery in the U.S. and Canada, but it is also caught as bycatch in other fisheries that target demersal species inhabiting similar depths and seafloor habitat types (IPHC & Gustafson 2019).

The objective of this report is to provide estimates of P. halibut bycatch in the U.S. West Coast groundfish fisheries. Bycatch estimates are required for domestic and international management of P. halibut. The International Pacific Halibut Commission (IPHC), a body founded through treaty agreement between the U.S. and Canada, sets the P. halibut annual total allowable catch (TAC) for IPHC Area 2A, the collective U.S. marine waters bordering the states of Washington, Oregon and California. The TAC is based, in part, on bycatch mortality, which takes into account potential survival after being discarded. Regulations for IPHC Area 2A are set by NOAA Fisheries West Coast Regional Office. Pacific halibut catch in Area 2A is divided between tribal and non-tribal fisheries, between commercial and recreational fisheries, and between recreational fisheries in different states (Washington, Oregon and California). The Pacific Fishery Management Council (PFMC) describes this P. halibut catch division each year in a catch-sharing plan.

Pacific halibut bycatch in U.S. West Coast groundfish fisheries is estimated from data collected by fisheries observers, fish sales information, and electronic monitoring equipment mounted on some commercial fishing vessels. Fisheries observer data are the main source of information about P. halibut bycatch in these fisheries. The Northwest Fisheries Science Center (NWFSC) Fisheries Observation Science Program (FOS) has collected discard data from commercial fishing vessels since 2002<sup>1</sup>. Pacific halibut mortality estimates in this report are provided for the years 2002 through 2019 from all fishery sectors observed by the NWFSC Observer Program (Table 1). This report is updated annually by the NWFSC Observer Program and presented to the PFMC and the IPHC for use in P. halibut management.

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<sup>1</sup> Prior to 2001, at-sea hake fisheries were observed by the Alaska Fisheries Science Center.

Table 1: Pacific halibut mortality estimates for 2019 and the years of observation, for all fishery sectors observed by the Northwest Fishery Science Center Groundfish Observer Program. Estimates include both individuals discarded at the dock and with mortality rates applied, where appropriate. \* = confidential

Sector	Years Observed	2019 Total Discard Mortality (mt)
Individual Fishing Quota (IFQ) fisheries <sup>1</sup>	2011-2019	27.46
IFQ Electronic Monitoring (EM) EFP <sup>2</sup>	2015-2019	4.99
At-sea Pacific hake	2002-2019	0.54
Non-nearshore fixed gear targeting groundfish	2002-2019	28.67
Nearshore fixed gear	2003-2019	0.57
Pink shrimp trawl	2004-2019	0.00
California halibut trawl	2002-2019	0.00
P. halibut directed	2017-2019	3.53
Ridgeback Prawn	2017-2019	0.00
Sea Cucumber	2017-2019	*

<sup>1</sup>Does not include estimates from IFQ vessels with Electronic Monitoring, includes all gears

<sup>2</sup>EFP = Exempted Fishing Permit, includes all gears

In 2019 non-nearshore fixed gear targeting groundfish had the largest estimated P. halibut discard mortality of any sector (28.67 mt, Tables 1 and 2). Nearly all of that bycatch (22.94 mt, or ~80%) occurred on the Limited Entry (LE) Sablefish Endorsed vessels. These vessels fish federally permitted sablefish tier quota during the primary season (April-October). Almost all of the LE Sablefish Endorsed bycatch occurred while fishing longline gear north of Point Chehalis, WA (19.01 mt or ~83%, Supplemental Table 66)<sup>2</sup>. A smaller amount of P. halibut mortality also occurred on LE sablefish endorsed vessels fishing longline gear south of Pt. Chehalis (3.49 mt). The LE non-endorsed longline vessels caught a small amount of P. halibut (2.81 mt). Limited entry endorsed and non-endorsed pot vessels caught a combined 0.46 metric tons of P. halibut bycatch. Open access (OA) vessels targeting non-nearshore groundfish species with hook and line gear caught substantially less than the LE sector (2.88 mt) and a trivial amount with pot gear (0.04 mt).

The 2019 IFQ fishery estimate of P. halibut discard mortality, coast-wide, was 27.46 mt, with an additional 4.99 mt caught by IFQ EM EFP vessels (Table 1 and Supplemental Tables 46, 49, 52) which is included in the IFQ estimate in Tables 2 and Supplemental Table 91. The IFQ total (IFQ + IFQ EM EFP: 32.45 mt) is 0.08 mt less than the 2018 estimate (32.53 mt, see Table 2) and, as in past years, well below the IBQ<sup>3</sup>, for P. halibut North of 40° 10' N.

<sup>2</sup> see NWFSC\_Pacific\_Halibut\_Bycatch\_2002\_2019\_Supplemental\_Tables.xlsx

<sup>3</sup> IBQ = Individual Bycatch Quota

lat. allocation (2019 IBQ allocation = 69.59 mt). As in prior years, bottom trawl gear produced the largest component of IFQ discard mortality (IFQ + IFQ EM = 29.98 mt), almost half of which was from bottom trawl vessels fishing between Pt. Chehalis, WA and 40° 10' N. lat., in waters deeper than 60 fathoms (14.87 mt, Supplemental Table 21).

IFQ bottom trawl and LE Sablefish Endorsed longline vessels together comprised approximately 84% of the 2019 P. halibut discard mortality in observed U.S. West Coast groundfish fisheries.

In Supplemental Tables 48 and 51, for the third year, we compare alternative methods for calculating discard mortality rates (DMRs) in the IFQ EM EFP fishery. Electronic monitoring does not yet allow for accurate estimates of Pacific halibut injuries and viability according to gear type based on IPHC criteria. For in-season P. halibut IBQ management, the PSMFC applies a time-on-deck model (PFMC 2017, Smith 2017) to determine mortality rate of P. halibut caught on bottom trawl IFQ vessels carrying EM. For final end-of-year reporting, in this report, we apply a 0.90 mortality rate to all P. halibut bycatch in the IFQ EM bottom trawl fishery (Supplemental Table 46). As an alternative to the 0.90 rate, we also present mortality estimates based on observer assessed viabilities and the PFMC Groundfish Management Team's Time-on-Deck model (see Supplemental Tables 48 and 51). Small sample sizes preclude definitive conclusions from this analysis. The NWFSC Observer Program might revisit this analysis in future reports.

The Pacific halibut discard mortality estimate for the 2019 IPHC directed Pacific halibut fishery was 3.53 mt (Tables 1 & 2). Observer coverage, discard ratios, fleet-wide estimates of gross discards, discard mortality, and retained P. halibut are presented in Supplemental Tables 74, 76, and 78. Discard mortality estimates were calculated using the same methods as for the non-nearshore hook and line fishery, which uses observed estimates of P. halibut viability. Viabilities of observed P. halibut bycatch in the P. halibut directed fishery are given in Supplemental Table 77. Observed lengths of discarded P. halibut in the directed fishery are given in Supplemental Tables 79 and 80.

Pacific halibut discard in the nearshore fixed gear, pink shrimp trawl, California halibut trawl, (combined as Other Fisheries in Figure 1) and at-sea Pacific hake pelagic trawl fisheries combined represents a very small component of total P. halibut mortality (Table 1; Figure 1). There was zero (0) observed catch of P. halibut in the California ridgeback prawn trawl fishery (Supplemental Table 86). Estimates for the 2019 California sea cucumber trawl fishery are confidential and therefore not provided (Supplemental Table 87).

Final estimates of discards in observed fishery sectors, including the IFQ EM EFP, are shown in Tables 1, 2 and Supplemental Table 91. All three tables (and elsewhere in the report), include the small amount of P. halibut landed and subsequently discarded at the dock by IFQ bottom and midwater trawl vessels. The amounts landed and then discarded at the dock are listed by strata in Supplemental Tables 8, 9 and 10. Summaries of P. halibut catch in the IFQ EM EFP are included in Tables 1, 2, and Supplemental Tables 46, 49, 52 and 91.

In addition, we provide historical estimates of *P. halibut* bycatch in the Limited Entry (LE) bottom trawl fishery for the 2002-2010 period (Table 2 & Supplemental Tables 90, 91) and *P. halibut* bycatch estimates for observed, non-IFQ vessels with an exempted fishing permit (EFP) targeting groundfish (2002-2019, Supplemental Table 88). For completeness, we also include the *P. halibut* landed catch from PacFIN fish tickets reported by non-groundfish fisheries that are not observed by the NWFSC Observer Program for the period 2002-2019 (Supplemental Table 89).

The NWFSC Observer Program data used in this report has been updated to include the most recent data available (2002-2019). Pacific Fisheries Information Network (PacFIN) data used in this report were accessed April 2020. The estimates for all sectors and years (except LE Trawl 2002-2010) have been recalculated based on these data. For ease of data access and reporting, the majority of tables have been removed from the written report and provided in the accompanying Microsoft Excel file <sup>4</sup>. In all other respects, this report uses the same methods as in last year's report (Jannot et al. 2020a).

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<sup>4</sup> see NWFSC\_Pacific\_Halibut\_Bycatch\_2002\_2019\_Supplemental\_Tables.xlsx

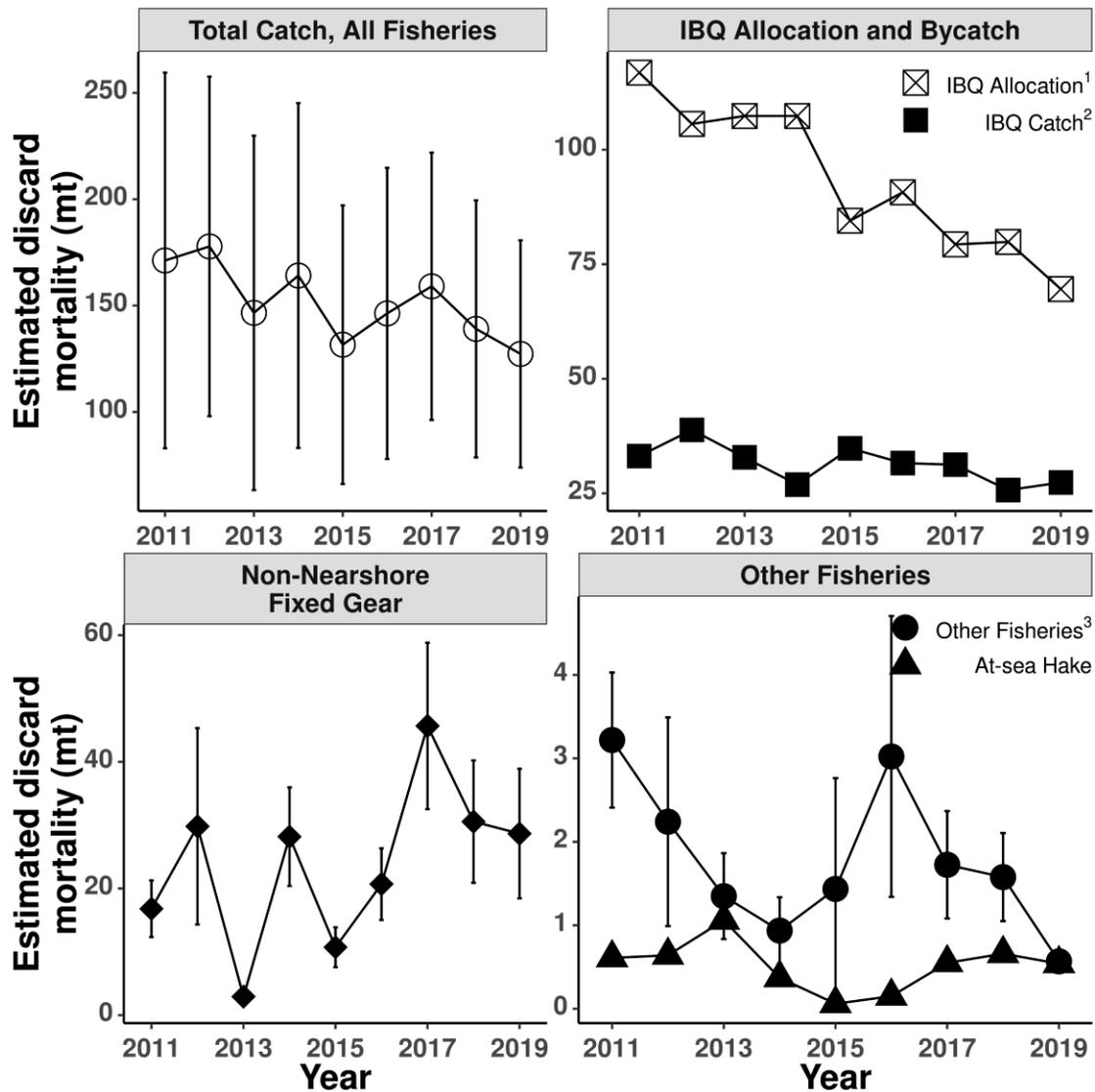


Figure 1: Total estimated *P. halibut* discard mortality (mt  $\pm$  1 SE, with mortality rates applied if applicable) from all sectors observed by the NWFSC Groundfish Observer Program. Estimates are not included for sectors and years where there were insufficient observer data. Values are reported in Table 2.<sup>1</sup>Individual Bycatch Quota (IBQ) allocated north of 40° 10' N. latitude. <sup>2</sup>IBQ catch includes all Catch Shares sectors and gears except At-sea Hake which is shown separately. <sup>3</sup>Other fisheries includes OR and CA Nearshore, WA, OR, and CA pink shrimp, California halibut, sea cucumber, ridgeback prawn, and IPHC *P. halibut* directed fisheries.

Table 2: Pacific halibut discard mortality estimates (mt, including a small amount discarded at the dock in IFQ Bottom Trawl, Midwater Rockfish, and Midwater Hake fisheries) for all sectors observed by the NWFSC Groundfish Observer Program. Mortality rates of less than 1.0 were applied in the bottom trawl fisheries (LE and IFQ), IFQ hook and line, IFQ pot, and non-IFQ, nonnearshore fixed gear sectors, for which some information regarding gear specific survivorship was available. For all other sectors, a 1.0 mortality rate was applied because gear specific survivorship information is not available. Rounding of values might mask very small weights in some categories and are presented here as zero (0). All weights are estimated based on whole fish (a.k.a. round weight, not head-&-gut). Ridgeback Prawn fishery (2017-19) and Sea Cucumber fishery (2017) had zero (0) observed P. halibut catch. Numbers in the headers indicate the footnotes at the bottom of the page. \* = confidential data, less than 3 vessels observed; - = no observer coverage.

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Total Discards mt (no mortality rates applied)

Year	Limited Entry Bottom Trawl 2002-2010	IFQ Bottom Trawl 1,2,10	IFQ CA Halibut 1,3	IFQ LE Hook & Line	IFQ Pot 10	IFQ Midwater Rockfish 3,4,10	IFQ Midwater Hake,2,3,5,10	LE Sablefish Endorsed	LE Sablefish Non-Endorsed	Open Access Fixed Gear 6	Nearshore Fixed Gear 3	Pink Shrimp 3	CA Halibut 3,7	P. halibut Directed	At-sea Hake 3	All Sectors	Sectors with mortality rate less than 1 applied 8	Sectors with mortality rate 1 applied 9
2002	524.41	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	141.76	0	-	-	-	0	-	1.14	667.31	666.17	1.14
2003	186.65	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	197.11	0.17	-	0.00	-	0	-	2.65	386.58	383.93	2.65
2004	212.43	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	238.57	0	-	0.97	0.00	0.7	-	1.13	453.8	451.7	2.1
2005	460.35	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	237.9	0	-	2.20	0.04	0.03	-	1.97	702.49	698.28	4.21
2006	390.91	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	668.62	0	-	0.52	-	0.02	-	0.83	1060.9	1059.55	1.35
2007	294.38	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	132.27	1.73	22.03	0.08	0.21	0.03	-	1.18	451.91	450.44	1.47
2008	305.21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	259.46	2.99	40.51	0.34	0.00	0.31	-	3.98	612.8	608.48	4.32
2009	385.24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	321.6	0.25	35.21	1.28	0.00	0	-	0.33	743.91	742.3	1.61
2010	265.08	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	137.6	0.39	32.60	0.08	0.00	0	-	1.57	437.32	435.67	1.65
2011	n.a.	64.14	0	6.06	3.36	*	0.35	137.11	21.31	13.13	3.03	0.19	0	-	0.61	249.29	245.11	4.18
2012	n.a.	67.13	*	14.66	1.89	0.0	0.62	151.25	16.55	23.68	2.24	0.00	0	-	0.64	278.66	275.16	3.5
2013	n.a.	66.09	see footnote 1	3.00	0.98	0.0	1.34	22.23	0.01	1.81	1.35	0.00	0	-	1.06	97.87	94.12	3.75
2014	n.a.	55.90	see footnote 1	3.80	0.32	0.0	1.36	174.79	0	3.64	0.94	0.00	0	-	0.37	241.12	238.45	2.67
2015	n.a.	69.28	see footnote 1	9.49	2.21	0.0	0.70	123.48	0.46	10.19	1.43	0.01	0	-	0.06	217.31	215.11	2.2
2016	n.a.	58.86	see footnote 1	6.39	1.77	0.0	0.68	174.02	5.14	42.78	3.02	0.00	0	-	0.15	292.81	288.96	3.85
2017	n.a.	64.78	see footnote 1	4.14	1.84	0.0	0.51	295.12	0.76	49.95	1.72	0.00	0	25.35	0.55	444.72	441.94	2.78
2018	n.a.	51.79	see footnote 1	4.66	2.64	0.0	1.34	219.15	13.79	41.73	1.57	0.01	0	15.60	0.66	352.94	349.36	3.58
2019	n.a.	52.97	see footnote 1	3.25	4.22	0.0	1.07	217.99	80.21	40.17	0.57	0.00	0	29.19	0.54	430.18	428	2.18

Total Mortality mt (rates applied)

Year	Limited Entry Bottom Trawl 2002-2010	IFQ Bottom Trawl 1,2,10	IFQ CA Halibut 1,3	IFQ LE Hook & Line	IFQ Pot 10	IFQ Midwater Rockfish 3,4,10	IFQ Midwater Hake,2,3,5,10	LE Sablefish Endorsed	LE Sablefish Non-Endorsed	Open Access Fixed Gear 6	Nearshore Fixed Gear 3	Pink Shrimp 3	CA Halibut 3,7	P. halibut Directed	At-sea Hake 3	All Sectors	Sectors with mortality rate less than 1 applied 8	Sectors with mortality rate 1 applied 9
2002	344.82	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	22.76	0	-	-	-	0	-	1.14	368.72	367.58	1.14
2003	124.43	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	31.54	0.03	-	0.00	-	0	-	2.65	158.65	156	2.65
2004	133.12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	38.82	0	-	0.97	0.00	0.7	-	1.13	174.74	172.64	2.1
2005	286.52	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	38.12	0	-	2.20	0.04	0.03	-	1.97	328.88	324.67	4.21
2006	242.47	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	107.3	0	-	0.52	-	0.02	-	0.83	351.14	349.79	1.35
2007	208.81	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	21.24	0.28	3.54	0.08	0.21	0.03	-	1.18	235.37	233.9	1.47
2008	207.81	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	41.65	0.48	6.49	0.34	0.00	0.31	-	3.98	261.06	256.74	4.32
2009	251.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	51.47	0.04	5.64	1.28	0.00	0	-	0.33	309.86	308.25	1.61
2010	180.97	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	22.12	0.06	5.23	0.08	0.00	0	-	1.57	210.03	208.38	1.65
2011	n.a.	31.30	0	0.97	0.89	*	0.35	11.78	3.06	1.95	3.03	0.19	0	-	0.61	54.13	49.95	4.18
2012	n.a.	36.13	*	2.34	0.51	0.0	0.62	27.53	0.78	1.51	2.24	0.00	0	-	0.64	72.3	68.8	3.5
2013	n.a.	32.41	see footnote 1	0.48	0.21	0.0	1.34	2.85	0	0.07	1.35	0.00	0	-	1.06	39.77	36.02	3.75
2014	n.a.	26.29	see footnote 1	0.61	0.08	0.0	1.36	27.89	0	0.29	0.94	0.00	0	-	0.37	57.83	55.16	2.67
2015	n.a.	33.36	see footnote 1	1.52	0.38	0.0	0.70	10.3	0.02	0.40	1.43	0.01	0	-	0.06	48.18	45.98	2.2
2016	n.a.	33.29	see footnote 1	1.02	0.18	0.0	0.68	16.92	1.07	2.70	3.02	0.00	0	-	0.15	59.03	55.18	3.85
2017	n.a.	35.11	see footnote 1	0.66	0.78	0.0	0.51	42.01	0.03	3.62	1.72	0.00	0	2.22	0.55	87.21	84.43	2.78
2018	n.a.	30.45	see footnote 1	0.75	0.29	0.0	1.34	25.52	0.62	4.43	1.57	0.01	0	2.48	0.66	68.12	64.54	3.58
2019	n.a.	29.98	see footnote 1	0.52	0.96	0.0	1.07	22.94	2.81	2.92	0.57	0.00	0	3.53	0.54	65.84	63.66	2.18

FOOTNOTES

Note: Ridgeback Prawn (2017-18) and Sea Cucumber (2017 only) fisheries had zero (0) observed P. halibut catch. The 2018-19 Sea Cucumber fishery data are confidential.

1 Starting in 2013, LE CA Halibut estimates are combined with IFQ Bottom Trawl estimates.

2 Includes a small amount landed and discarded at the dock.

3 100% mortality

4 from 2011-14, 'Midwater Trawl'

5 from 2011-14, 'Shoreside Hake'

6 Starting in 2011, this sector only includes OA CA halibut.

7 A coast-wide discard ratio and coast-wide discard estimate could not be computed in the OA fixed gear sector for 2002-06 because the WCGOP only covered OA vessels in California during this time.

8 LE Bottom Trawl, IFQ Bottom Trawl, IFQ hook & line, IFQ pot, LE and OA CA Halibut, Non-Nearshore Fixed Gear

9 IFQ Midwater Rockfish, Midwater Hake, Nearshore fixed gear, Pink Shrimp, At-sea Hake

10 Includes P. halibut catch from IFQ electronic monitoring EFP

n.a. = not applicable

Table 3: Percent of legal-sized P. halibut (> 82 cm) mortality, by weight (mt) in the IFQ Bottom Trawl fishery north of 40° 10 ' N. lat.

<b>Year</b>	<b>% legal-sized P. halibut in IFQ bottom trawl north of 40 deg. 10 min. N. lat.</b>
2011	67.11
2012	66.69
2013	64.01
2014	60.07
2015	67.68
2016	67.26
2017	75.61
2018	79.22
2019	73.49

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## Introduction

Pacific halibut (*Hippoglossus stenolepis*) is found in coastal waters throughout the North Pacific. Off the U.S. West Coast of the United States, it inhabits continental shelf areas (< 150 fm) from Washington to central California (Clark and Hare 1998). Pacific halibut has long supported a directed commercial fishery in the U.S. and Canada, but it is also caught as bycatch in other fisheries that target demersal species inhabiting similar depths and seafloor habitat types (IPHC & Gustafson 2019). The objective of this report is to provide estimates of P. halibut bycatch in the U.S. West Coast groundfish fisheries from 2002-2019.

## Observed West Coast Groundfish Fisheries

The U.S. West Coast groundfish fishery is a multi-species fishery that utilizes a variety of gear types. The fishery harvests species designated in the Pacific Coast Groundfish Fishery Management Plan (FMP; PFMC 2019) and is managed by the Pacific Fishery Management Council (PFMC). Over 90 species are listed in the groundfish FMP, including a variety of rockfish, flatfish, roundfish, skates, and sharks. These species are found in both state (0-4.8 km) and federal (> 4.8 km off-shore to the EEZ) waters. Groundfish are both targeted and caught incidentally by trawl nets, hook and line gears, and fish pots. Under the FMP, the groundfish fishery consists of four management components:

- The Limited Entry (LE) component encompasses all commercial fisheries who hold a federal limited entry permit. The total number of limited entry permits available is restricted. Vessels with an LE permit are allocated a larger portion of the total allowable catch for commercially desirable species than vessels without an LE permit.
- The Open Access (OA) component encompasses commercial fishers who do not hold a federal LE permit. Some states require fishers to carry a state issued permit for certain OA sectors.
- The Recreational component includes recreational anglers who target or incidentally catch groundfish species. Estimate of P. halibut bycatch in recreational fisheries are compiled by the IPHC and are not covered by this report.
- The Tribal component includes native tribal commercial fishers in Washington State that have treaty rights to fish groundfish. Estimates of P. halibut bycatch from tribal fisheries are compiled by the IPHC and are not included in this report, with the exception of the observed tribal at-sea Pacific hake (a.k.a. Pacific whiting, henceforth referred to as hake) sector which are included as part of the At-sea hake values in Table 2 and Supplemental Tables 90 and 91.

These four components can be further subdivided into sectors based on gear type, target species, permits, and other regulatory factors as shown in Supplemental Tables 92, 93 and 94.

## NW Fisheries Science Center (NWFSC) Groundfish Observer Program

The NWFSC Groundfish Observer Program observes commercial sectors that target or take groundfish as bycatch. The observer program has two components: the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP).

The WCGOP was established in May 2001 by NOAA Fisheries (a.k.a., National Marine Fisheries Service, NMFS) in accordance with the Pacific Coast Groundfish Fishery Management Plan (50 FR 20609). This regulation requires all vessels that catch groundfish in the U.S. EEZ from 4.8-322 km offshore carry an observer when notified to do so by NMFS or its designated agent. Subsequent state rule-making has extended NMFS's ability to require vessels fishing in the 0-4.8 km state territorial zone to carry observers.

The A-SHOP moved to the NWFSC in 2001. Prior to 2001, observer coverage of the U.S. West Coast at-sea hake fishery was conducted by the North Pacific Groundfish Observer Program and P. halibut samples from that program are available back to the 1970's but are not included in this report. Current (since 2001) A-SHOP program information and documentation on data collection methods can be found in the A-SHOP observer manual (NWFSC 2020b). The at-sea hake fishery has mandatory observer coverage, with each vessel over 38 meters carrying two observers. Beginning in 2011, under IFQ/Co-op Program management, all catcher vessels that deliver catch to motherships are required to carry WCGOP observers or use electronic monitoring equipment.

The NWFSC Groundfish Observer Program's goal is to improve estimates of total catch and discard by observing groundfish fisheries along the U.S. West Coast. The WCGOP and A-SHOP observe distinct sectors of the groundfish fishery. The WCGOP observes multiple sectors of the groundfish fishery, including: IFQ shoreside delivery of groundfish and Pacific hake, at-sea mothership catcher-vessels fishing for Pacific hake, LE and OA fixed gear, and state-permitted nearshore fixed gear sectors. The WCGOP also observes several fisheries that incidentally catch groundfish, including the California halibut trawl and pink shrimp trawl fisheries. The A-SHOP observes the fishery that catches and delivers Pacific hake at-sea including tribal and non-tribal motherships and catcher-processor vessels.

## Pacific Halibut Management and Fishery Interactions

The International Pacific Halibut Commission, a body founded through treaty agreement between the U.S. and Canada, sets the P. halibut annual total allowable catch (TAC) for IPHC Area 2A, the collective U.S. waters off the states of Washington, Oregon and California. The TAC is, in part, based on bycatch mortality, which takes into account potential survival after being discarded. Regulations for IPHC Area 2A are set by NOAA Fisheries West Coast Regional Office. Pacific halibut catch in Area 2A is divided between tribal and non-tribal fisheries, between commercial and recreational fisheries, and between recreational fisheries in different states (Washington, Oregon and California). The Pacific Fishery Management Council describes this P. halibut catch division each year in a catch-sharing plan. Outside the P. halibut directed fishery, P. halibut must be discarded at-sea with two exceptions. In some years, including 2019, the LE fixed gear sablefish endorsed sector is allowed to retain and land P. halibut north of Pt. Chehalis, WA. In addition, the IFQ

midwater Pacific hake fishery is a maximized-retention fishery. Under this fishery, small amounts of incidental *P. halibut* take are allowed to be landed and subsequently donated to food banks or destroyed. Other than these two exceptions, small amounts of *P. halibut* are, on rare occasions, mixed with target species and accidentally landed. These individuals are subsequently donated or destroyed as in the IFQ Midwater hake fishery.

In 2011, the LE bottom trawl sector of the U.S. West Coast groundfish fishery began fishing under an IFQ management program. An IFQ is defined as a federal permit under a limited access system to harvest a quantity of fish, representing a portion of the total allowable catch of a fishery that can be received or held for exclusive use by a person (MSA 16 UIC 1802(23)). The implementation of the IFQ management program in 2011 resulted in changes to Pacific halibut sampling, including the mandate that vessels must carry NMFS observers on all IFQ fishing trips. A full list of changes to the fishery can be found in Jannot et al. (2012).

Under the IFQ program, *P. halibut* is managed at the permit level, through Individual Bycatch Quota (IBQ) pounds. An IBQ accounts for bycatch mortality including any potential survivorship after capture. Currently, this is the only species managed under IBQ for the U.S. West Coast groundfish IFQ fishery. Each federal groundfish permit with a trawl endorsement is allocated IBQ pounds for *P. halibut* caught north of 40° 10' N. latitude. Pacific halibut caught south of 40° 10' N. latitude are not managed by an IBQ quota but are reported here under the IFQ fishery.

Data collection and reporting for this fishery is described by gear type in the methods (section: Pacific Halibut Data Collection in the Shore-based IFQ Fishery). The shore-based IFQ fishery includes all IFQ fishery components with the exception of at-sea motherships and catcher-processors. Motherships and catcher-processors have a bycatch quota for *P. halibut*, but it is not accounted for at the permit level.

With the exception of the IFQ fishery, *P. halibut* bycatch mortality is accounted for at the fishery sector level only. *P. halibut* is regularly caught as bycatch in the LE sablefish endorsed fixed gear, LE sablefish non-endorsed fixed gear, and OA fixed gear sectors.

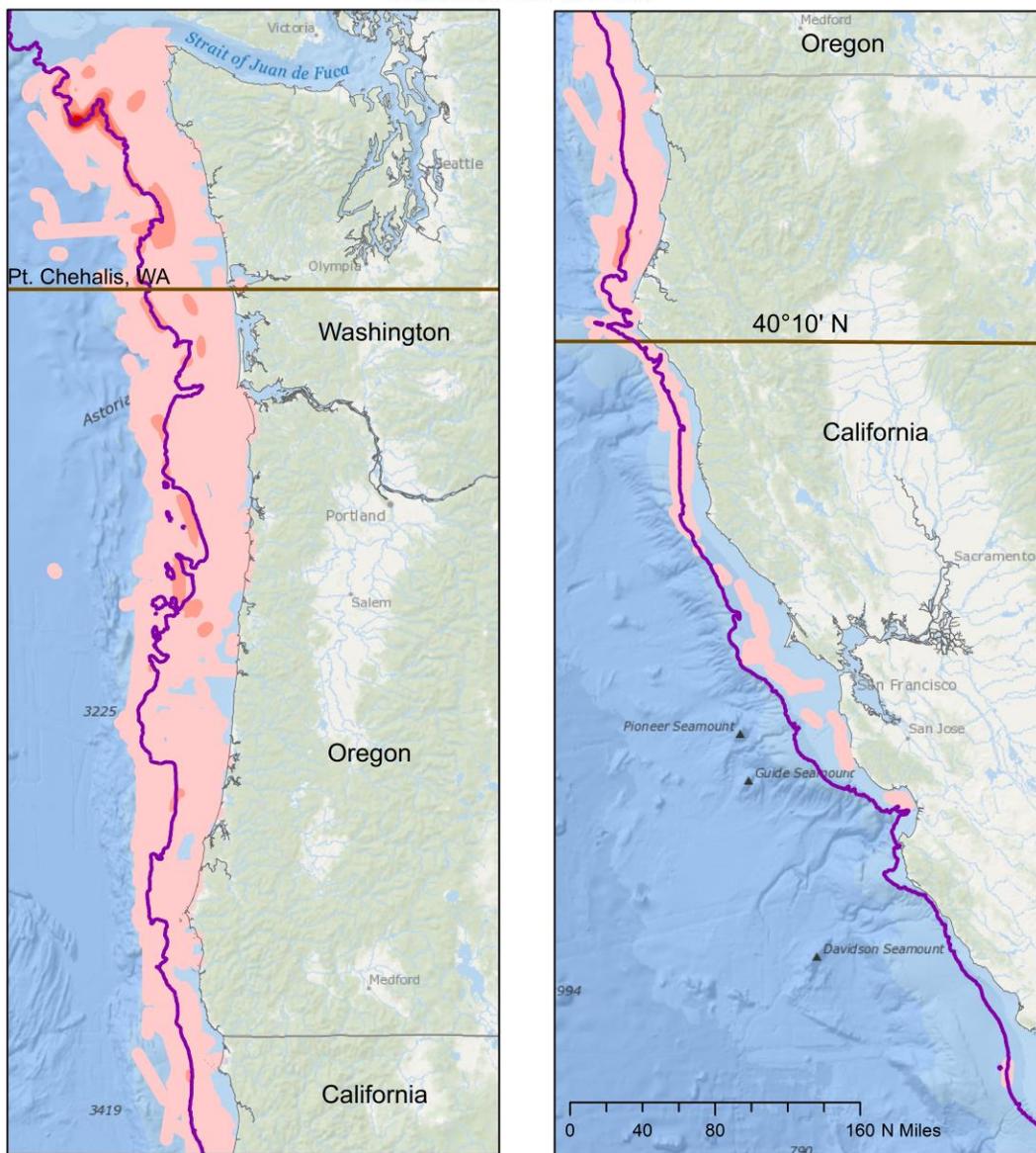
## Results

### Spatial Distribution of Observed Bycatch

Figure 2 portrays the observed *P. halibut* bycatch along the U.S. West Coast for all fishery sectors and gear types. The majority of observed *P. halibut* bycatch occurred north of the 40° 10'N line, with highest concentrations of bycatch north of Pt. Chehalis, WA (Figure 2).

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Observed 2002 to 2019



K. Somers May 2020

Figure 2: Spatial distribution of Pacific halibut bycatch (mt/km<sup>2</sup>) observed by West Coast Groundfish Observer Program (2002-2019), off the U.S. West Coast. Gear types observed by the WCGOP include bottom trawl, midwater trawl, shrimp trawl, fixed gear hook & line and pot gear. The five catch classifications were defined by excluding any 0 values and then applying the Jenks natural breaks classification method. Cells (200 sq. km) with less than 3 vessels were omitted from the map to maintain confidentiality.

## IFQ Fishery

All participating vessels carry an observer on all fishing trips under IFQ management (100% trips observed) except those participating in the EM EFP (see below for EM EFP results). Monthly fishing effort by IFQ bottom trawl vessels is shown in Figures 3, 4, and 5. For all 2019 strata, 99% or more of the observed IFQ tows or sets were sampled (Supplemental Tables 8, 9, 10, 11 and 12). IFQ flatfish, IFQ mixed species, and unsorted catch all contributed to unsampled catch (Supplemental Tables 13, 14, 15 and 16; see NWFSC 2020b for IFQ sampling protocols). The total estimated weight of *P. halibut* from unsampled tows or sets in 2019 represents a small fraction (0.77 mt, or 1.4%) of the total 2019 IFQ gross discard weight of *P. halibut* (Supplemental Tables 13, 14, 15 and 16).

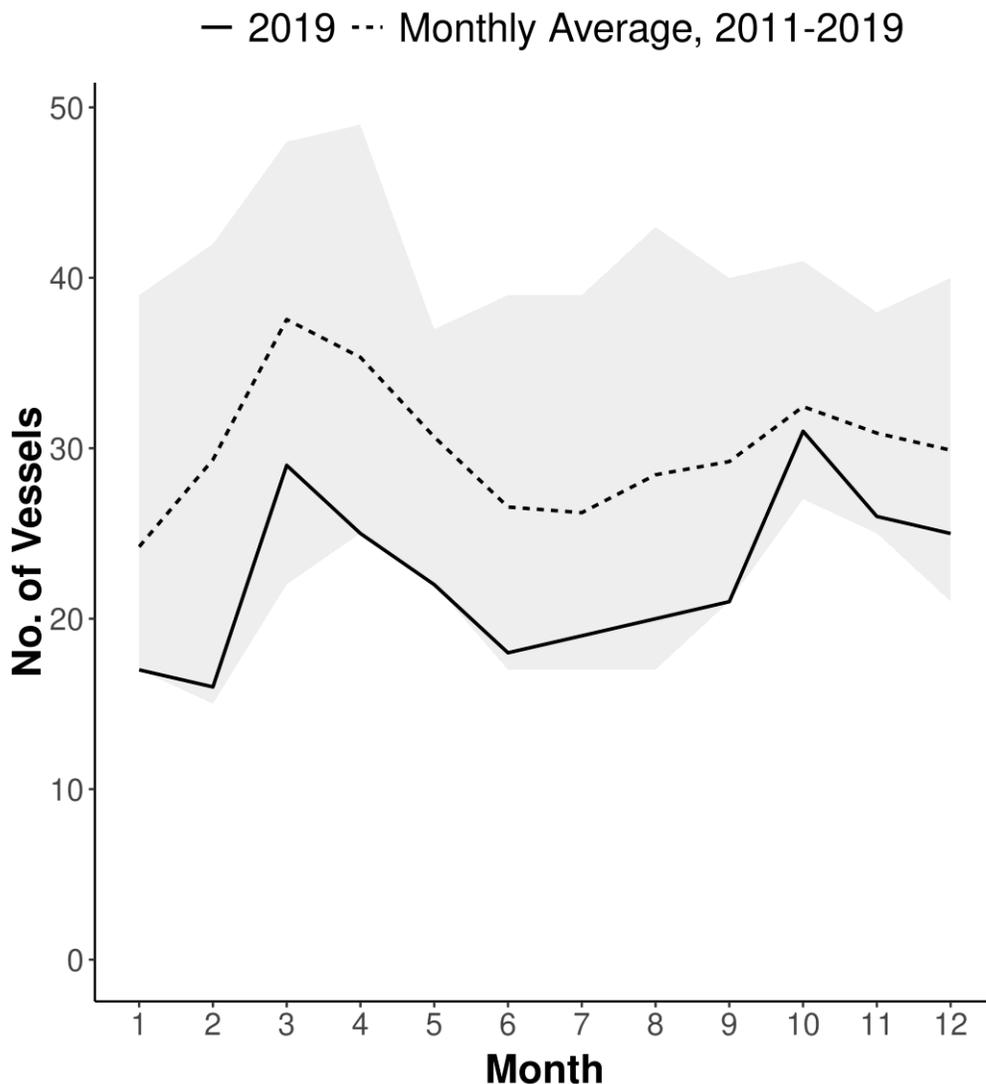


Figure 3: Number of vessels by month for IFQ bottom trawl vessels in 2019 (solid line) and averaged over the 2011–19 period (dotted line). Grey ribbon represents the monthly maximum and minimum across 2011-2019. Data from vessels using EM is not included.

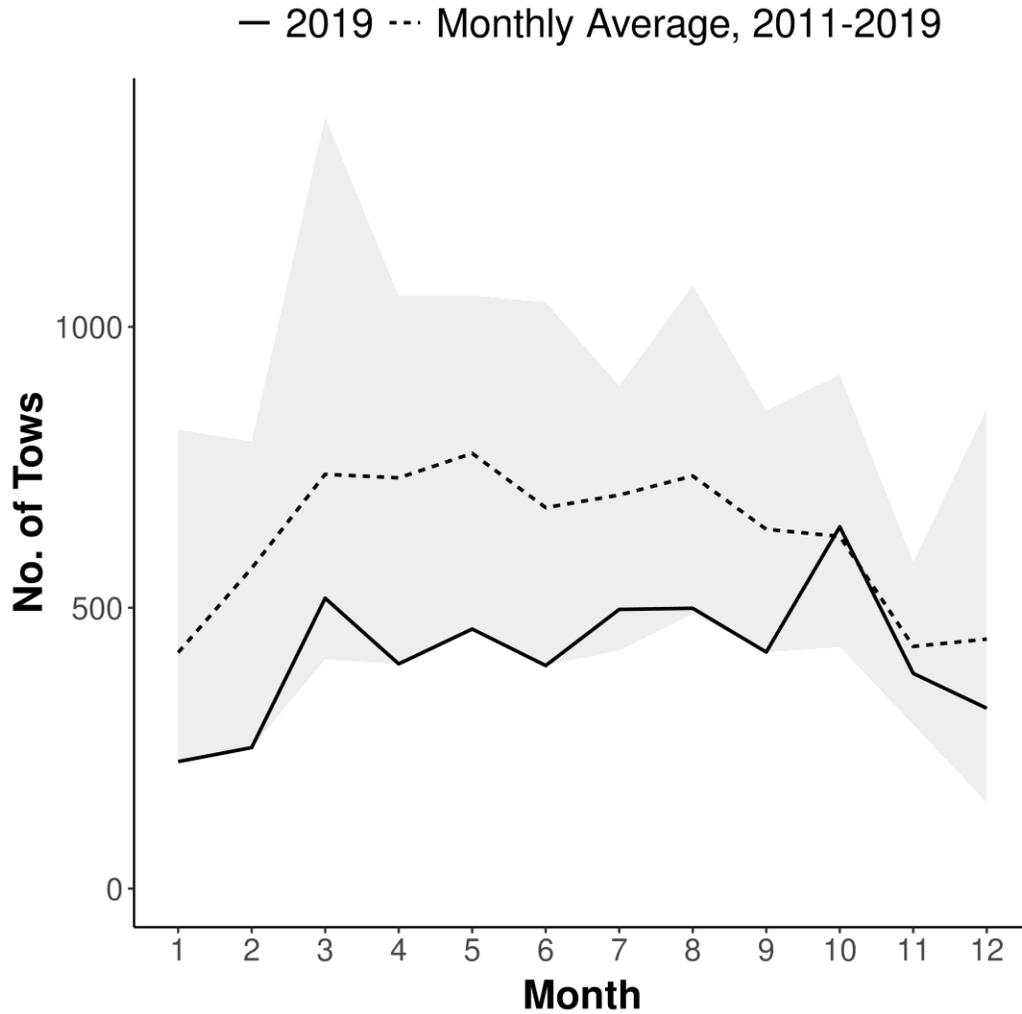


Figure 4: Number of tows by month for IFQ bottom trawl vessels in 2019 (solid line) and averaged over the 2011-19 period (dotted line). Grey ribbon represents the monthly maximum and minimum across 2011-2019. Data from vessels using EM is not included.

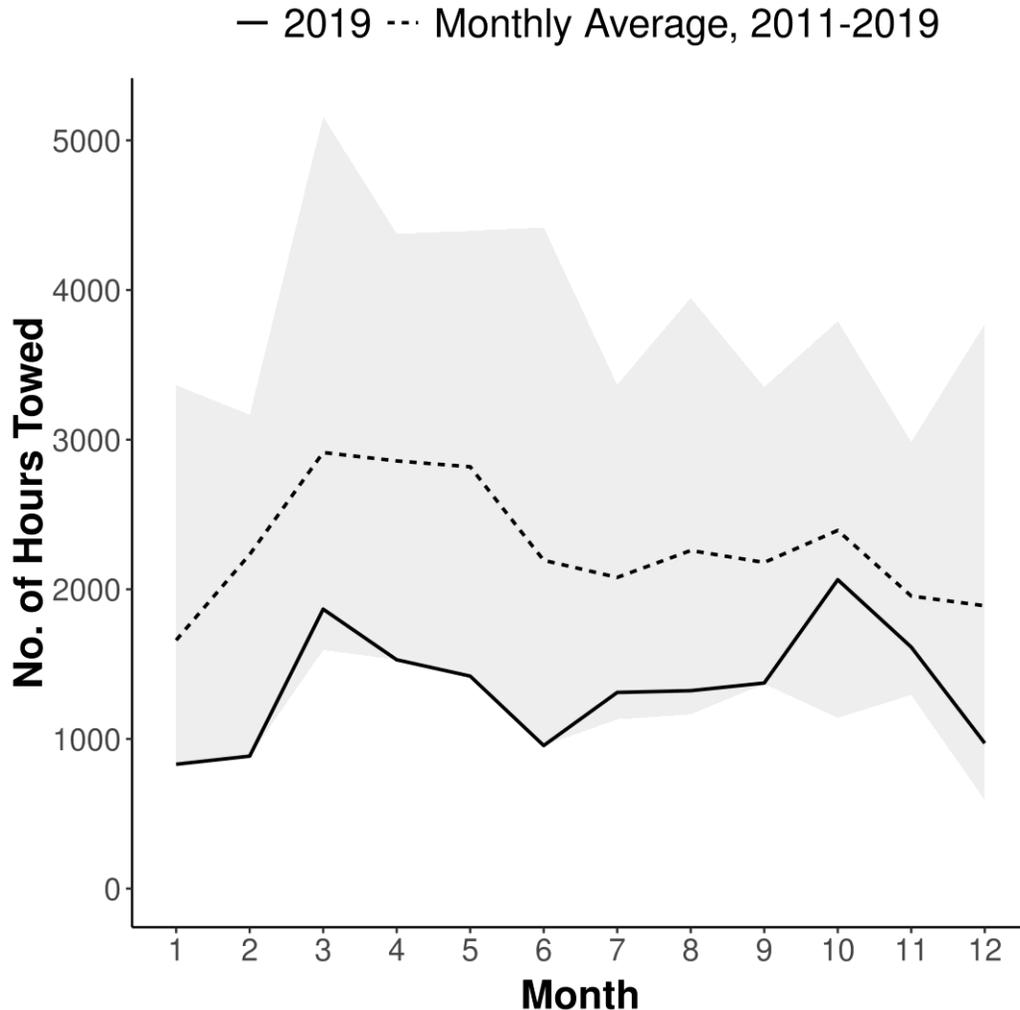


Figure 5: Tow hours by month for IFQ bottom trawl vessels in 2019 (solid line) and averaged over the 2011–19 period (dotted line). Grey ribbon represents the monthly maximum and minimum across 2011-2019 . Data from vessels using EM is not included.

Gross bycatch estimates and total discard mortality estimates were largest for vessels fishing bottom trawl gear, between Pt. Chehalis, WA and the 40° 10' N. latitude management line in depths greater than 60 fathoms (Supplemental Table 21). This gear-area-depth stratum accounts for 55% of the 2019 P. halibut discard mortality in the IFQ fishery. The next largest fraction (37%) of total IFQ discard mortality was caught north of Pt. Chehalis, WA in the deep stratum (>60 fm). Together, bottom trawl gear fishing north of the 40° 10' N. latitude management line accounts for 95% of the 2019 P. halibut discard mortality in the IFQ fishery (Supplemental Table 21).

In terms of viability, the majority of P. halibut on IFQ vessels were classified as either excellent or dead, depending on the stratum (Supplemental Tables 17, 18, 19, and 20). In 2019, the individuals caught with bottom trawl were evenly split between excellent and

dead condition in the area between Pt. Chehalis, WA and 40° 10' N. latitude in depths > 60 fathoms. Individuals caught with bottom trawl north of Pt. Chehalis, WA deeper than 60 fathoms were slightly more likely to be excellent than dead (Supplemental Table 17). Gross and discard mortality for bottom trawl vessels by month for 2019, are presented in Supplemental Table 29.

Estimated 2019 P. halibut discard mortality from all IFQ sectors and gears is 1.34 mt less than the average for the previous 5 years (2014-18 mean = 33.87 mt, 2018 = 32.83 mt, including IFQ EM EFP). Gross and discard mortality for each of the gear types are presented in Supplemental Tables 21-24. Legal-sized (> 82 cm) mortality by gear type are presented in Supplemental Tables 25-28. Length frequencies, weighted length frequencies, and percent weighted length frequency information are presented in Supplemental Tables 30-38. Length frequency of dead individuals are displayed in Supplemental Tables 39-41.

### **At-sea Hake Fishery**

Estimated bycatch weight of P. halibut from the At-sea hake component of the 2019 IFQ fishery decreased very slightly from 2018 (2019 = 0.54 mt, 2018 = 0.66; Supplemental Tables 42, 43, and 91). There has been no fishing in the Tribal sector since 2012 (Supplemental Table 44). At-sea hake P. halibut length frequencies are given in Supplemental Table 45.

### **IFQ Electronic Monitoring EFP**

Estimated P. halibut discard mortality from the 2019 IFQ Electronic Monitoring Exempted Fishing Permit, including fish discarded at the dock, was 3.72 mt from bottom trawl vessels (Supplemental Table 46), 0.19 mt from pot vessels (Supplemental Table 49), and 1.07 mt from midwater trawl vessels (Supplemental Table 52).

Both IFQ EM bottom trawl and IFQ EM pot vessels had higher discard mortality rates than non-EM IFQ vessels when using the observer viability method (Supplemental Tables 48 and 51). However, the observer viability method on IFQ EM bottom trawl vessels appears to give a lower DMR than the Time-on-Deck model (Supplemental Table 48). Caution must be used in interpreting these DMRs because sample sizes were very small. The number of EM vessels catching P. halibut was a small subset of the overall EM fleet and those vessels that did catch P. halibut typically caught very few P. halibut during observer sampling (Supplemental Tables 47 and 50).

### **Non-Nearshore Fixed Gear Fishery**

The 2019 estimated discard mortality of P. halibut in the longline portion of the LE sablefish endorsed sector decreased by 11% from 2018 (2018 = 25.14 mt, 2019 = 22.49 mt; Supplemental Table 66) but is still well within the historical range for this fishery (2.94 - 104.45 mt; See Figure 6 and Supplemental Table 66). Compared to 2018, the 2019 observed discard ratio increased north of Pt. Chehalis, WA and decreased south of Pt. Chehalis, WA (Supplemental Table 58). Estimated discard of P. halibut from the pot portion

of the LE sablefish endorsed sector increased compared to 2018 (2018 = 0.37 mt, 2019 = 0.45 mt; Supplemental Table 66).

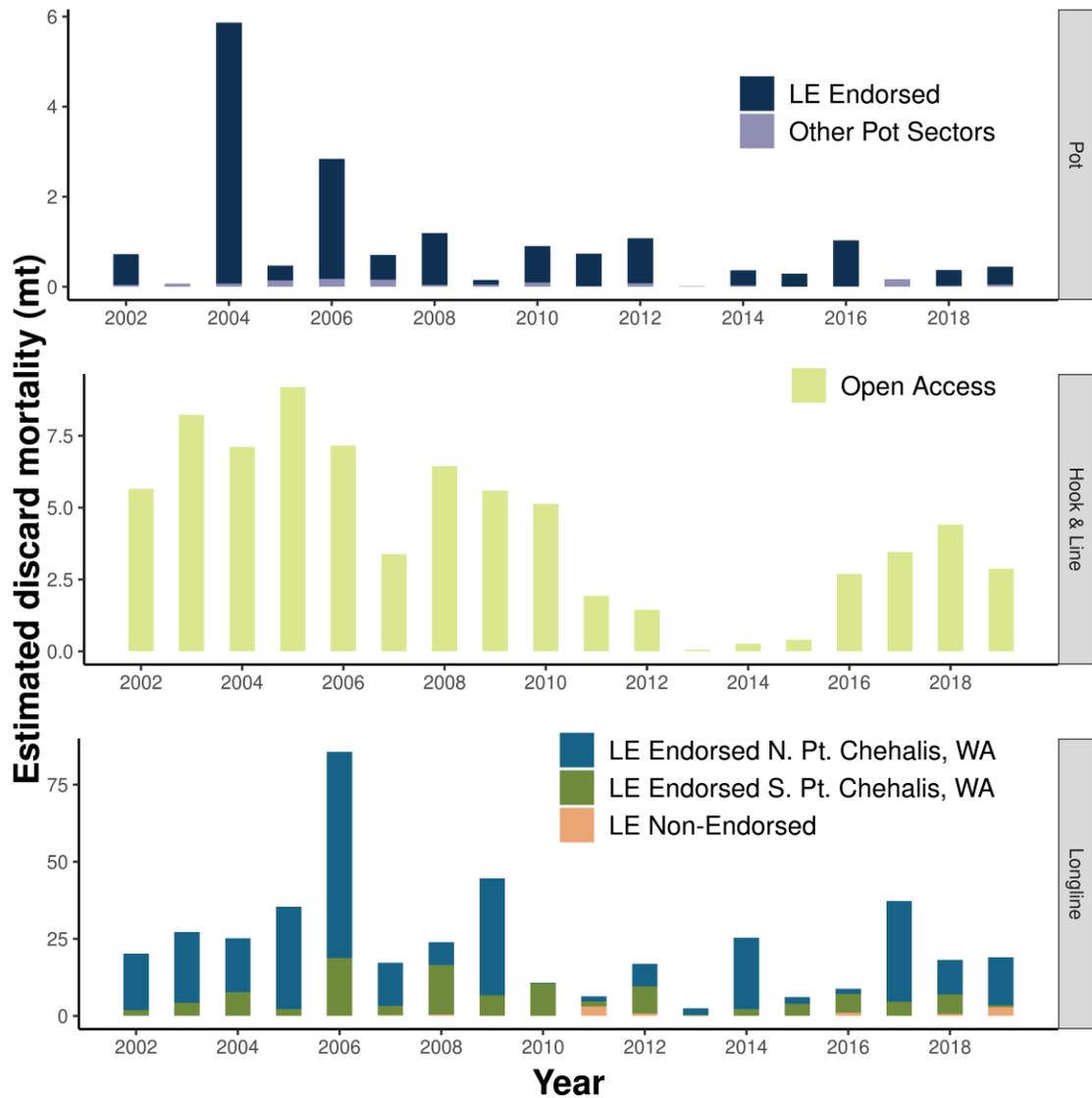


Figure 6: Estimated discard mortality of P. halibut in the non-nearshore fixed gear fishery by sector and gear for each year. We apply a fixed average discard rate from 2007-08 data to generate 2002-06 discard estimates for the OA sector because only the California portion of the OA fishery was observed 2002-06. The 'Other Pot sectors' includes LE sablefish non-endorsed and OA fixed gear vessels fishing with pot gear.

Discard of P. halibut among the LE sablefish non-endorsed longline vessels increased in 2019 relative to 2018 (2018 = 0.61 mt, 2019 = 2.81 mt, Supplemental Table 66); pot vessels in this sector had an increase in P. halibut bycatch (2018 < 0.01 mt, 2018 ~ 0.01 mt) but remain a tiny fraction of total P. halibut discard (Supplemental Table 66). P. halibut bycatch in OA hook and line decreased during 2019 (2018 = 4.41 mt, 2019 = 2.88 mt, Supplemental Table 66) but pot vessels catch increased (2018 = 0.02 mt, 2019 = 0.04 mt). Both OA fixed gear sectors still account for only a small portion of total fixed gear bycatch.

Landings of target species decreased for both LE longline and OA hook and line vessels in all non-nearshore sectors by about 100 mt in 2019 (Supplemental Table 57). Observer coverage was lower than 2018 levels for these vessels (Supplemental Tables 53, 54, and 55) but observed *P. halibut* encounters were about the same (Supplemental Table , 61).

Injury assessments on longline or hook & line vessels by year and sector are presented in Supplemental Tables 62, 63, and 64. Gross discards and discard mortality are presented in Supplemental Tables 65, 66, 90, and 91. Physical measurements of *P. halibut* length frequency from the non-nearshore fixed gear sectors can be found in Supplemental Tables 68, 69, 70, and 71. Visual estimates of length frequencies in the non-nearshore fixed gear sectors can be found in Supplemental Table 72. A comparison of the distribution of physical and visual estimates of length frequency are presented in Figure 7.

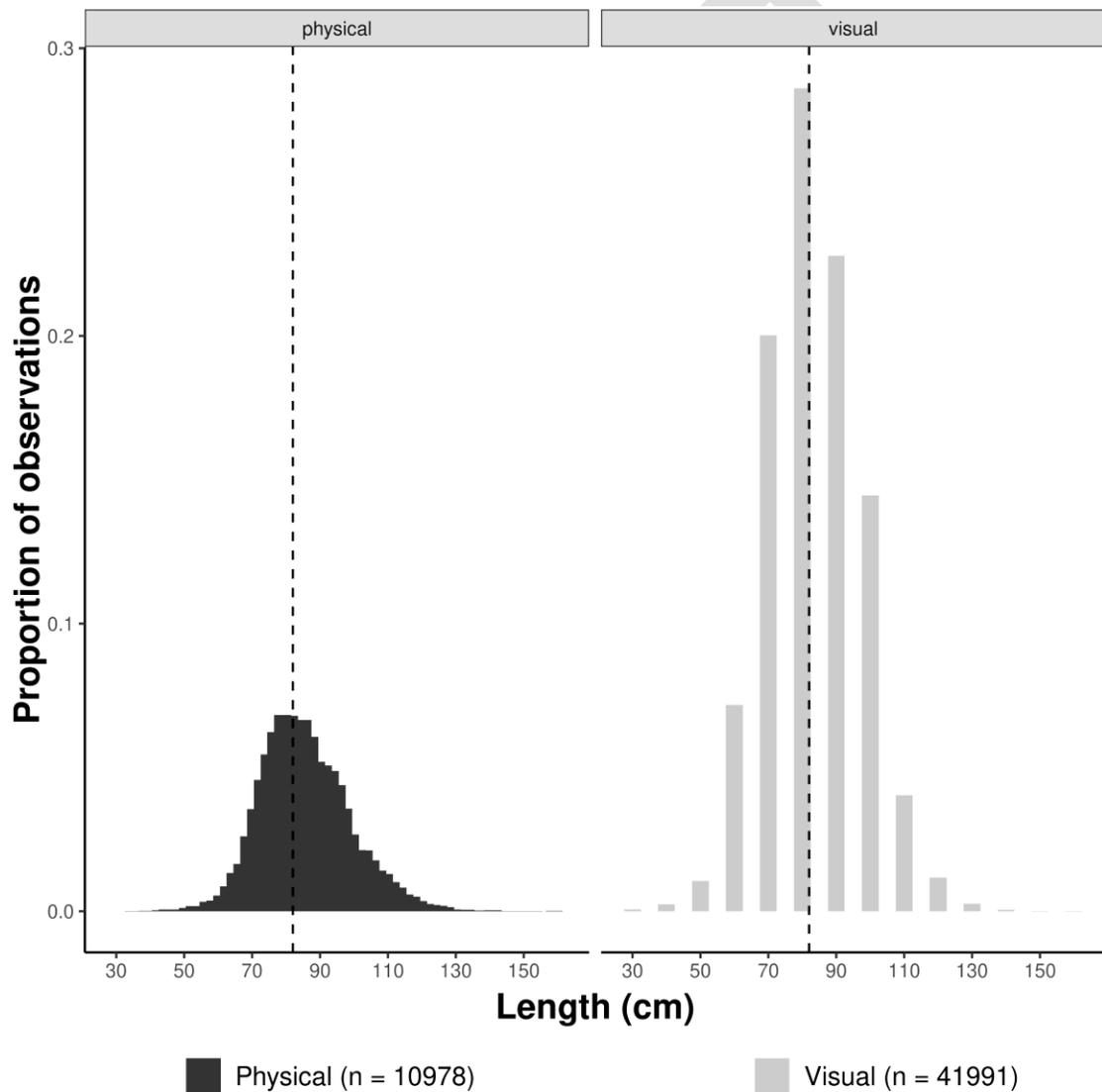


Figure 7: Length frequency distribution of discarded Pacific halibut on WCGOP observed nonnearshore fixed gear limited entry (LE) and open access (OA) groundfish vessels from September 2003 through December 2019. Visual estimates (grey bars) of *P. halibut* lengths

are only estimated in 10 cm increments. The sublegal-legal size cutoff (82 cm) is indicated by a vertical dashed line.

### Legal-Sublegal Length Frequencies

The number and percent of observed *P. halibut* that were of legal (> 82 cm) or sub-legal size by fishery (Catch Shares, Non-Nearshore Fixed Gear, At-sea Hake) are presented in Supplemental Table 73.

### IPHC Pacific halibut Fishery

The NWFSC Observer Program attained a 13% coverage rate (Supplemental Table 74) in the third year of covering the IPHC *P. halibut* directed fishery. Observer coverage was highest during the first opener, compared to the other two openings of the fishery in 2019 (Figure 8. Exact dates of each opener by year are presented in Supplemental Table 75). Observer coverage in this fleet is determined by a number of factors including space on vessels, observer availability, and needed coverage in other, higher priority, fisheries.

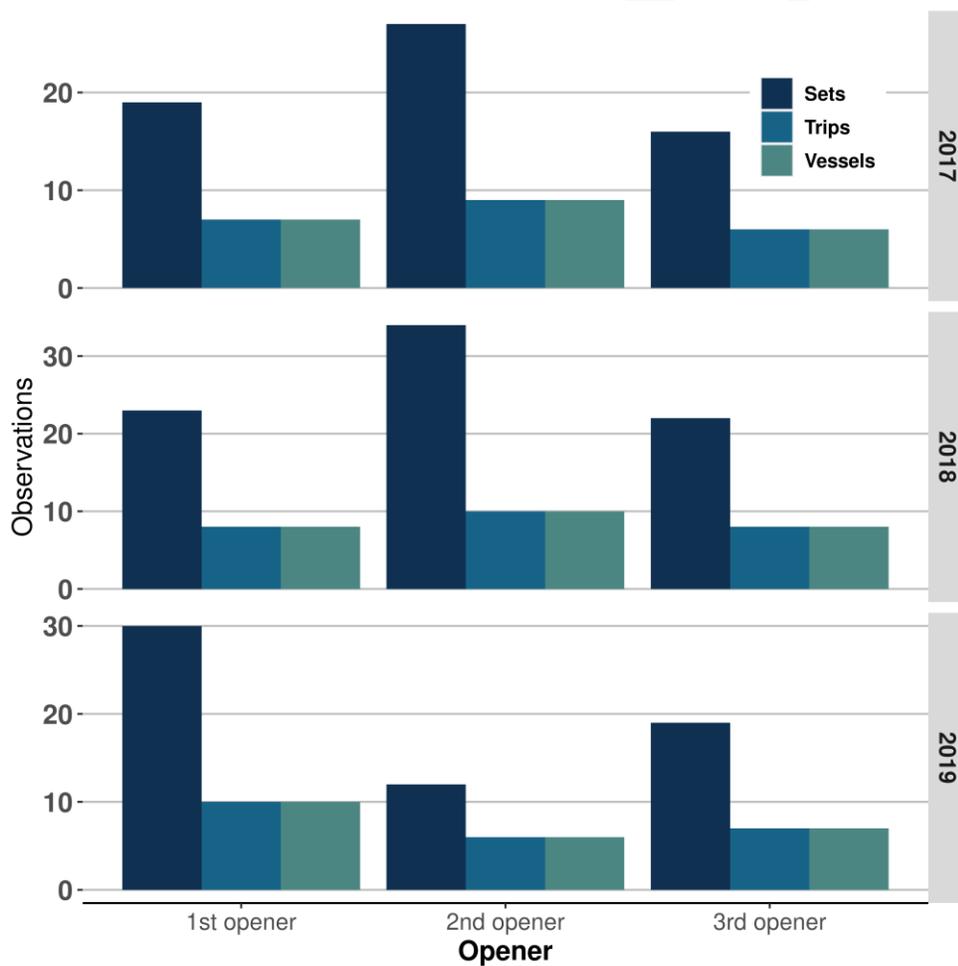


Figure 8: Number of sets, trips, and vessels by opening day for the *P. halibut* directed fishery.

The 2019 P. halibut discard to targeted landings ratio in this fishery was 0.19 leading to a gross discard weight estimate of 29.2 mt (Supplemental Table 76). The majority of discarded fish had only minor or moderate injuries (Supplemental Table 77). Thus, despite the high discard ratio, the estimated total discard mortality after accounting for viability was 3.5 mt. The majority of observed P. halibut discards were less than legal-size (82 cm) although a few were above that size (Supplemental Tables 79 and 80).

## **Observed State Fisheries, EFPs and Non-Groundfish Fisheries**

Very small amounts of P. halibut bycatch were recorded in state managed observed fisheries. Even assuming 100% mortality, bycatch estimates for the nearshore groundfish fixed gear sector, pink shrimp trawl fishery, and the OA sector of the California halibut trawl fishery made up a minor portion of the 2019 total mortality estimate for P. halibut (Supplemental Tables 81, 82, 83, 84 and 85). Zero (0) catch of P. halibut was observed in the California ridgeback prawn fishery (Supplemental Table 86). Data from the 2019 California sea cucumber fishery is confidential (Supplemental Table 87), but in 2017 (the only non-confidential observed year) the fishery recorded zero P. halibut bycatch.

Pacific halibut bycatch by year, from non-EM EFP vessels has been zero since 2004 (Supplemental Table 88). Pacific halibut landings from non-groundfish fisheries not observed by NWFSC Observer Program were 26.14 mt in 2019. (Supplemental Table 89).

## Conclusions

### IFQ Fishery

- Estimated *P. halibut* discard mortality in 2019 from IFQ non-EM vessels was 27.21 mt and from IFQ EM vessels was 4.99 mt; both of which are similar to previous years.
- EM vessels had very slightly higher discard mortality rates than non-EM IFQ vessels. DMR on EM bottom trawl vessels was lower when using observer viabilities compared to the Time-on-Deck model. However samples sizes are still very small, complicating interpretation.
- *P. halibut* discard from the at-sea Pacific hake fishery in 2019 (0.54 mt) showed a slight decrease relative to 2018 (0.66 mt) and remains below the historical average (2002-18: 1.11 mt).

### Non-IFQ Fisheries

- The 2019 estimates of *P. halibut* discard mortality in the LE sablefish endorsed sector (22.86 mt) decreased relative to 2018 (25.76 mt) possibly due to lower effort, but it is not completely clear from available data. The 2019 Pacific halibut mortality estimates on LE sablefish non-endorsed vessels increased on both longline (2019: 2.81 mt) and pot vessels (2019: ~0.01 mt), relative to 2018. *P. halibut* mortality decreased relative to last year on OA fixed gear hook and line (2.77 mt) but increased on OA pot vessels (0.04 mt) relative to last year.
- In the IPHC *P. halibut* directed fishery, observer coverage was 13%. The total *P. halibut* discard mortality after accounting for viability was 3.5 mt.
- Zero (0) *P. halibut* catch was observed in the California ridgeback prawn fishery.
- Estimated *P. halibut* mortality in all other non-IFQ observed fisheries remained low relative to the IFQ and non-nearshore sectors, and were within the range observed in previous years.

## Methods

### Data Sources

Data sources for this analysis include on-board observer data (from the WCGOP and A-SHOP), landing receipt data (referred to as fish tickets, obtained from PacFIN) and data generated from vessels carrying electronic monitoring (a.k.a. EM) equipment. Currently only vessels in the IFQ sector fishing on an exempted fishing permit (EFP) carry EM equipment. EM data are obtained from Pacific States Marine Fisheries Commission. To date, observer data are the sole source for discard estimation in the IFQ sectors, except for vessels using EM under an EFP, as stated above. All other sectors use a combination of observer and PacFIN data to estimate discard mortality. A list of fisheries, coverage priorities and data collection methods employed by WCGOP in each observed fishery can be found in the WCGOP manuals (NWFSC 2020b). A-SHOP program information, documentation and data collection methods can be found in the A-SHOP observer manual (NWFSC 2020b).

The sampling protocol employed by the WCGOP is primarily focused on the discarded portion of catch. To ensure that the recorded weights for the retained portion of the observed catch are accurate, haul-level retained catch weights recorded by observers are adjusted based on trip-level fish ticket records. This process is described in further detail on the WCGOP Data Processing webpage (NWFSC 2020a) and was conducted prior to the analyses presented in this report. All weights of *P. halibut* presented in this report are round weights, that is, whole fish. IPHC converts these weights to dressed weight (i.e., head and organs removed).

For data processing purposes, species and species groups were defined based on management (see Table A-1 in Somers et al. 2020). A complete listing of groundfish species is defined in the Pacific Coast Groundfish Fishery Management Plan (PFMC 2019).

Fish ticket landing receipts are completed by fish-buyers in each port for each delivery of fish by a vessel. Fish tickets are trip-aggregate sales receipts for market categories that may represent single or multiple species. Fish tickets are issued to fish-buyers by a state agency and must be returned to the agency for processing. Fish ticket and species-composition data are submitted by state agencies to the PacFIN regional database. Annual fish ticket landings data were retrieved from the PacFIN database (May 2020) and subsequently divided into various sectors of the groundfish fishery (Somers et al. 2020).

### Shore-based IFQ Fishery

The methods used to report in-season IBQ estimates via the Vessel Account System (VAS) are separate from those methods used to estimate final fleet-wide *P. halibut* mortality. Methods for in-season IBQ estimation are discussed in Jannot et al. 2020b. Results obtained by methods described here resulted in fleet-wide estimates of *P. halibut* mortality that are very close to those reported by the VAS.

## Pacific Halibut Data Collection in the Shore-based IFQ Fishery

The WCGOP discard sampling methodologies ensure that P. halibut mortality can be estimated, regardless of the limitations imposed by the vessel, catch composition, or catch quantity. Three pieces of information are necessary to estimate P. halibut mortality (also see Table 4):

1. A count of individual P. halibut in the haul or sample
2. Actual or visual length measurements (cm)
3. A viability obtained by physical assessment of individual P. halibut using IPHC designed dichotomous keys that relate the physical condition of the fish to a viability code (NWFSC 2020b). A unique key is used for each gear type (trawl, longline, pot).

Observers could sample all or a subset of P. halibut caught in a haul/set. The proportion of P. halibut sampled is based on the number of P. halibut caught in the haul/set, the level of assistance provided by the crew, as well as other variables (e.g., physical space, weather). Sampling and assessment of P. halibut is dependent on crew assistance and cooperation. Regulations prohibit vessel crew from discarding any P. halibut without first notifying the observer. The vessel crew must comply with requests by the observer to ensure proper P. halibut sampling, including but not limited to: modifying P. halibut sorting procedure, assisting the observer by delivering the P. halibut to the observer, and modifying operations to ensure P. halibut sampling is completed. Table 4 describes the P. halibut data obtained on IFQ-permitted vessels fishing different gear types.

On vessels fishing fixed gear (pot or hook and line), observers must sample at least 50% of the gear per set. Actual length measurements are obtained on bottom trawl, midwater trawl, and pot vessels, but only visual length estimates are made on vessels fishing hook and line gear in the IFQ fishery. Visual estimations use 10 cm increments (55-64 cm, 65-74 cm, etc.).

The crew's cooperation is vital to the observer's sampling success during hook and line fishing. When an observer samples for P. halibut, the crew are not permitted to shake loose or discard any P. halibut before the observer can estimate the fish length, nor can they restrict the observer's view of the line as it comes out of the water. If requested by the observer, the crew is required to physically hand individual fish to the observer or slow the gear retrieval.

Table 4: Data collected from P. halibut caught on IFQ vessels using different types of gear.

Gear	Years	Count	Length Measurement (cm)	Is Viability Collected?
Bottom trawl	2011-present	all in the haul	actual, all or subset	yes
Midwater trawl	2011-present	all in the sample	actual, all or subset	yes
Pot	2011-present	all in the sample	actual, all or subset	yes
Hook & line	2011-2016	all in the sample	visual, all or subset	no
Hook & line	2016-present	all in the sample	actual, all or subset	yes

Note: Midwater trawl only applies to Catcher Processor vessels and Catcher-Only vessels delivering to Motherships. Catcher-Only vessels delivering hake or rockfish shoreside dump hauls directly into the vessel hold and any P. halibut are delivered to the dock for discard or donation.

Viability is assessed at the point of fish release when returned to sea. On vessels using “resuscitation boxes” or other techniques to increase the likelihood of survival, condition sampling is performed prior to the fish being returned to sea. Observations of several condition characteristics are used to assign each fish to one of three viability categories for trawl and pot gear: Excellent, Poor, or Dead (NWFSC 2020; Williams and Chen 2004). Observer field estimates of viability for *P. halibut* discarded in the IFQ fishery by vessels fishing bottom trawl or pot gear are used to compute the total estimated mortality of discarded *P. halibut*. IBQ weight (or simply IBQ) refers to the estimated mortality of discarded *P. halibut*, with the appropriate mortality rate applied based on viability.

Viability categories are used to assign mortality rates to *P. halibut*. Mortality rates for vessels fishing bottom trawl gear are based on mortality data collected by Hoag (1975), who found some survivorship among fish in the dead condition category. Mortality rates for vessels fishing pot gear are based on conservative assumptions of likely survival from pot-induced injuries (Williams and Wilderbuer 1995). Because of the difficulties of collecting *P. halibut* viability on hook and line vessels, we used a discard mortality rate (DMR) of 0.16, which represents an average of DMRs over all years for the Bering Sea/Aleutian region longline fishery (Williams 2008). Discard mortality was assumed to be 100% for all midwater trawl bycatch estimates.

Table 5: Mortality rates used for each of the viability categories for IFQ bottom trawl vessels (Clark et al. 1992).

Catch Shares	Gear	Viability	Mortality Rate
Catch Shares	Bottom Trawl	Excellent	0.20
Catch Shares	Bottom Trawl	Poor	0.55
Catch Shares	Bottom Trawl	Dead	0.90

Table 6: Mortality rates used for each of the viability categories for IFQ pot gear vessels (IPHC 2011).

Catch Shares	Gear	Viability	Mortality Rate
Catch Shares	Pot	Excellent	0.00
Catch Shares	Pot	Poor	1.00
Catch Shares	Pot	Dead	1.00

### Shore-based IFQ fishery Bycatch Estimation

We stratified IFQ *P. halibut* bycatch data based on sector (shoreside non-hake groundfish, shoreside Pacific hake, at-sea Pacific hake, and LE California halibut) and gear (bottom trawl, midwater trawl, pot, hook and line). LE California halibut tows were separated from IFQ bottom trawl tows in 2011-12, but have been combined with IFQ bottom trawl since 2013 because of minimal fishing and to maintain confidentiality. Within the shoreside non-hake groundfish sector, we further stratified using area and depth within each gear type. When confidentiality criteria were met (> 2 vessels per strata), we maintained area and depth strata that were applied to bottom trawl, hook and line, and pot gear in previous reports (Heery et al. 2010, Jannot et al. 2011, 2012, 2013) because prior work

demonstrated that these variables were correlated with P. halibut bycatch (Heery et al. 2010). Observations from IFQ vessels fishing midwater trawl gear targeting Pacific hake or other midwater target species were not post-stratified. In addition to the strata described above, we also provide bycatch estimates north and south of the groundfish management line (40° 10' N. lat.) for each sector and gear type.

Despite the 100% observer coverage mandate since 2011, there were some rare occasions (e.g., observer illness, trawl net ripped) when tows or sets were only partially or not sampled, or sampled data failed quality control. Data that failed quality control are treated as completely unsampled hauls. In all these cases, we used ratio estimators to apportion unsampled weight to P. halibut, within each stratum. To obtain the estimated weight of P. halibut ( $\widehat{W}$ ) when the entire haul or set was unsampled (or data failed), the unsampled discard weight, summed across unsampled hauls within the stratum, was multiplied by the ratio of the weight of P. halibut discard (summed across fully sampled hauls within a stratum) divided by the total discard weight of all species in all fully sampled hauls within a stratum:

$$\widehat{W}_{u,s} = \sum_u x_{u,s} \times \frac{\sum w_{f,s}}{\sum x_{f,s}}$$

where, for each stratum:

$s$  = stratum, which includes sector and year and could include, area, depth, gear

$u$  = unsampled haul

$f$  = fully sampled haul

$x$  = weight of discarded catch

$\widehat{W}$  = estimated weight of unsampled P. halibut in the stratum

$w$  = sampled weight of P. halibut

The unsampled weight of partially sampled hauls or sets was categorized into weight of non-IFQ species (NIFQ) or IFQ species. Unsampled IFQ species weight was further categorized into IFQ flatfish (IFQFF), IFQ rockfish (IFQRF), IFQ roundfish (IFQRD) and IFQ mixed species (IFQM). Unsampled P. halibut would only occur in NIFQ (south of 40° 10' N. lat. only), IFQM, or IFQFF unsampled categories. Thus, those are the only categories for which P. halibut is estimated. IFQM included all 2019 IFQ managed species (see [76 FR 27508](#) for a listing of IFQ species). NIFQ included all species encountered that were not designated as an IFQ managed species. IFQFF included all IFQ flatfish species managed as a complex under the groundfish FMP. North of the 40° 10' north latitude groundfish management line, P. halibut would be included in unsampled IFQFF or IFQM categories. South of the groundfish management line, P. halibut would only be included in the unsampled NIFQ category.

To obtain the estimated weight of P. halibut ( $\widehat{W}$ ) in partially sampled hauls or sets, the unsampled discard weight, summed across partially sampled hauls within the stratum, was multiplied by the ratio of the weight of P. halibut (summed across fully sampled hauls within a stratum) divided by the total discard weight of all species occurring within a

category (NIFQ, IFQFF, IFQM) in all fully sampled hauls within a stratum. Estimated P. halibut weight was summed across unsampled categories.

$$\widehat{W}_{p,s} = \sum_y \left( \sum_p x_{p,y,s} \times \frac{\sum W_{f,s}}{\sum x_{f,y,s}} \right)$$

where, for each stratum:

$s$  = stratum, which includes year and sector, and could include, area, depth, gear

$y$  = unsampled category (either NIFQ, IFQFF, or IFQM)

$p$  = partially sampled haul

$f$  = fully sampled haul

$x$  = weight of discarded catch

$\widehat{W}$  = estimated weight of unsampled P. halibut in the stratum

$w$  = sampled weight of P. halibut

Expanded weights of P. halibut obtained using the equations above for unsampled or partially sampled hauls were then added to the sampled weight of P. halibut within each stratum to obtain the total P. halibut weight per stratum.

## Viability Analysis

We used observer field estimates of viability for P. halibut discarded in the IFQ fishery by vessels fishing bottom or pot gear to compute the total estimated mortality of discarded P. halibut by IFQ gear/sector and stratum.

To account for the impact of fish size on survivorship, we computed a weighted mortality rate for each condition category. Length measurements associated with each viability record were converted to weight based on the IPHC length-weight table provided Supplemental Table 95.

A discard mortality rate for each condition category was then computed as the proportion of P. halibut sampled weight in a viability category multiplied by the viability category-specific mortality rate (see Supplemental Tables 5 and 6 above):

$$DMR_{csj} = m_c \times P_{csj}$$

where:

$s$  = stratum, which could include, area, depth, gear, and sector

$c$  = viability condition (Excellent, Poor, Dead)

$j$  = year

$m$  = mortality rate

$P$  = proportion of sampled P. halibut weight ( $w$ )

$DMR$  = discard mortality rate

Discard mortality rates for each condition category  $c$  and stratum  $s$  were then multiplied by gross discard estimates to compute total estimated discard mortality for each gear type separately :

$$\hat{F}_{sj} = \sum_c (B_{sj} \times DMR_{sj})$$

where:

$s$  = stratum, which could include, area, depth, gear, and sector

$c$  = viability condition (Excellent, Poor, Dead)

$j$  = year

$F$  = total estimated discard mortality

$B$  = gross estimated discard weight

$DMR$  = discard mortality rate

Viability data are collected from only a sub-sample of the P. halibut that observers encounter. Based on previous evaluations by Wallace and Hastie (2009), we expect that survivorship of P. halibut in bottom trawl tows are most directly affected by the length of the tow and the amount of catch that fills the net. These variables are not part of the bycatch ratio stratification process (above), and their use in stratifying viability data would make it difficult to then apply discard mortality rates to initial gross estimates of bycatch. We found that tow duration was directly related to depth, one of the variables used to stratify discard ratios and initial gross discard estimates for bottom trawl gear. Because depth and tow duration appeared to co-vary, we used depth and area to stratify IFQ viability data collected from bottom trawl gear. For IFQ viability data collected from pot gear, only area is used to stratify the data. For longline gear, we used a discard mortality rate of 16%, which represents an average of DMRs over all years for the Bering Sea/Aleutian region longline fishery (Williams 2008).

Final estimates of P. halibut bycatch and discard mortality are also presented in the context of the estimated mortality of legal-sized halibut. This was computed by applying the proportion of sampled P. halibut weighed in each depth stratum that was from legal-sized fish (82 cm or larger) to initial estimates. Viabilities were then applied to gross legal-sized discard estimates in the same manner as described above.

## IFQ Electronic Monitoring DMR comparison

PFMC staff, the NOAA Western Regional Office, and IPHC have requested a comparison of discard mortality rates (DMR) for bottom trawl and pot vessels in the IFQ program that carry electronic monitoring (EM) equipment versus those that carry observers on 100% of the fishing trips. When notified, EM vessels are required to carry observers for scientific observation, including collection of Pacific halibut viabilities. The WCGOP aims to observe approximately 30% of EM fishing trips. DMRs for EM vessels were calculated and compared using two methods:

1. Observer Viability Method
2. Time on Deck Model

The Observer Viability Method used human observer data collected on EM vessels. These data were stratified to match, as closely as possible, the current stratification used in the IFQ fishery while meeting confidentiality requirements. Confidentiality of EM data required combining strata across years, depths, and areas. Mortality data from non-EM IFQ vessels is also shown for comparison purposes. Other than slight modification of stratification to maintain confidentiality, the observer viability method is identical to the method described in the section Pacific Halibut Data Collection in the Shore-based IFQ Fishery.

The Time-on-Deck model was developed in a collaborative process between PSMFC and the PFMC's Groundfish Management Team (GMT). The model measures the time each fish spends out of the water which correlates with P. halibut viability: the less time a fish spends out of the water the higher probability of the fish being in 'excellent' viability condition and therefore results in a lower estimated mortality rate. The Time-on-Deck model substitutes for a viability assessment on EM vessels when fisheries observers are not present on the vessel to assess viabilities. The model and discussion are detailed in a PSMFC report to the PFMC (Smith 2017) and a PFMC Groundfish Management Team report (PFMC 2017).

The comparison is provided for informational purposes only. Due to low sample sizes the NWFSC Observer Program cautions against using these estimates for management purposes. Data from 2015-2019 were obtained on pot vessels using EM, and from 2016-2019 on bottom trawl vessels using EM. The corresponding non-EM data (i.e., 2015-2019 pot; 2016-2019 bottom trawl) were used to allow direct comparison between vessels with and without EM. Confidentiality in the EM fleet precluded the use of the full stratification currently used in the Catch Shares fishery.

## Length Frequencies

The length frequency distribution for P. halibut in the 2011-2019 IFQ fishery is provided in Supplemental Tables 30, 31 and 32. Pacific halibut pose unique challenges for observer sampling. Observers typically measure the length of P. halibut and then convert the measurement to weight using the IPHC length-weight conversion table (Supplemental Table 95). Occasionally, observers weigh individual fish. Sometimes crew members presort the catch by removing P. halibut and immediately return them to sea. Vessel crews presort P. halibut to increase the likelihood of survival of the discarded fish. Presorting is prevalent on vessels fishing with hook and line gear. Fishers have raised concerns regarding crew safety when landing large P. halibut. In addition, hook and line fishers are concerned that P. halibut individuals would be injured during landing because of their interaction with the vessel crucifier (gear used to strip the bait and any catch off of the hook and ganglion line). Therefore, shake-offs prior to the crucifier (a form of pre-sorting) is almost universal on IFQ hook and line vessels. Another case of pre-sorting can occur when halibut are too heavy and/or awkward to weigh in observer baskets. In all cases of pre-sorting, random samples are not available. Therefore, observers visually estimate the length of the halibut in ten-centimeter units (40cm, 50cm, 60cm, etc.), which are later converted to weight using the IPHC length-weight conversion table (Supplemental Table 95).

The weighted length frequency distributions of discarded *P. halibut* for vessels fishing IFQ using bottom trawl or pot gear are provided in Supplemental Tables 34 and 37 and Jannot et al. (2019). Length frequencies have been weighted based on the ratio of total estimated *P. halibut* discard weight to the weight of *P. halibut* that was measured in each stratum (see Jannot et al. 2019 for further details). We have summarized the proportion of length measurements in each condition category (Excellent, Poor, and Dead) in Jannot et al. (2019) to inform size-specific modeling of mortality. Within each of these three condition categories, the frequency of sampled fish was weighed in the same manner as length frequency distributions and then summarized for each 2 cm length bin. In addition, we also provide an estimated count of the number of dead individuals in each 2 cm length bin (Jannot et al. 2019). These values were obtained by multiplying the number of individuals in a length bin within a viability category, by the condition specific mortality rate (Supplemental Tables 5 and 6) or 1.0 in the case of midwater trawl, and summed these values across viabilities, and rounded to an integer, to obtain the number of dead per length bin. This method assumes there is no size-specific mortality.

## Non-nearshore Fixed Gear Fishery

The WCGOP samples each non-nearshore fixed gear sector through separate random selection processes, with the limited entry (LE) sablefish endorsed season permits receiving the highest level of coverage, then LE sablefish non-endorsed permits, and open access (OA) fixed gear the lowest. LE sablefish endorsed vessels that fish outside of the primary season or that have reached their tier quota in the primary season are not randomly chosen for observation. Given this sampling structure and anticipated differences in variance from one sector to the next, we chose to maintain sector as a stratification variable in our analysis. Testing of alternative stratification schemes (Heery et al. 2010) indicated that latitude and gear type were the most important variables with respect to *P. halibut* bycatch in the non-nearshore fixed gear groundfish fishery. Bycatch estimates were produced separately for each sector and gear combination. Two latitudinal strata were applied to the LE sablefish endorsed longline sector (north and south of Pt. Chehalis, WA = 46° 53.30' N. lat.) because previous modeling demonstrated that these strata significantly improved the fit of predicted bycatch amounts to the amounts observed (Heery et al. 2010). Pt. Chehalis, WA was used in previous estimates of *P. halibut* bycatch in the LE sablefish endorsed season longline sector because of its relevance to groundfish management and its apparent ability to split out higher bycatch rates off the northern coast of Washington (Heery and Bellman 2009). Evaluations of latitudinal strata for the other fixed gear sectors did not improve the fit of models to an extent that justified their use. Thus, we maintained previous stratifications for the other groundfish fixed gear sectors (Heery and Bellman 2009, Heery et al. 2010, Jannot et al. 2011, 2012, 2013).

## Discard Estimation

A deterministic approach was used to estimate *P. halibut* discard for all sectors of the non-nearshore groundfish fixed gear fishery. Discard ratios were computed from observer data as the discarded weight of *P. halibut* divided by the retained weight (Supplemental Table 57). Retained weight varies by sector in this fishery and can be either sablefish or all FMP

groundfish (except Pacific hake, see Supplemental Table 56 for type of retained used; for list of FMP groundfish species, see: PFMC 2019). Ratio denominators were identified for each sector of the non-nearshore fixed gear fishery based on the targeting behavior of that sector. Discard ratios were then multiplied by the total sector landed weight of either sablefish or FMP groundfish (except Pacific hake), corresponding to the denominator used to compute the observed discard ratio for each sector. This provided an expanded gross estimate of *P. halibut* discard for each sector. A discard mortality rate (discussed below) was then applied to compute estimated discard mortality.

Total landed weights for each sector are obtained from fish ticket landing receipts. Fish tickets for fixed gear that included recorded weights for sablefish were included in the non-nearshore fixed gear sector. In addition, fixed gear fish tickets without recorded sablefish were included in the non-nearshore fixed gear sectors only if groundfish landings were greater than non-groundfish landings on a unique vessel and landing date. Any *P. halibut* caught on fixed gear fish tickets with majority of non-groundfish landings are either captured in the estimates from the *P. halibut* directed fishery (Supplemental Table 78) or non-groundfish fisheries (Supplemental Table 89).

Fish tickets from the non-nearshore fixed gear sector were partitioned into the three commercial fixed-gear sectors (LE sablefish endorsed season, LE sablefish non-endorsed, and OA fixed gear) through the following process. Commercial fixed-gear fish tickets were first divided out by whether the vessel had a federal groundfish permit (limited entry) or no federal groundfish permit (open access). OA fish tickets were placed in the OA fixed gear groundfish sector. Next, LE fish tickets were separated based on whether the vessel's federal groundfish permit(s) had a sablefish endorsement with tier quota for the primary season or if it was not endorsed (also referred to as 'zero' tier). Fish tickets for all LE sablefish vessels with tier endorsements that were operating within this period and within their allotted tier quota were placed in the LE sablefish endorsed sector. If LE sablefish endorsed vessels fished outside of the primary season (season = April to September) or made trips within the season after they had reached their tier quota, the fish tickets were placed in the LE sablefish non-endorsed sector. In addition, fish tickets from non-endorsed LE vessels were also placed in the LE sablefish non-endorsed sector.

Further processing of fish tickets identified and removed the directed commercial *P. halibut* fishery landings from the non-nearshore fixed gear analysis. The directed *P. halibut* fishery occurs for only a few days each year, during 10-hour openings that are designated by the IPHC. LE and OA fixed gear vessels that typically target groundfish can participate in the directed fishery. For most fixed gear vessels, (other than LE sablefish endorsed vessels north of Pt. Chehalis) this is the only time during which they are allowed to land *P. halibut*. For prior years (2002-2018), we identify *P. halibut* directed fishery fish tickets using definitions supplied by IPHC. For the current year (2019), fish tickets that included *P. halibut* landings on or within the 2 days after a directed fishery opening were considered to be part of the directed fishery and not part of the non-nearshore fixed gear fishery targeting federal FMP groundfish. These fish tickets are excluded from the non-nearshore fixed gear analyses. This approach may have resulted in the removal of some non-directed fishery landings north of Pt. Chehalis, but any bias introduced by this step is considered to be extremely small given the short time period across which fish tickets were removed.

WCGOP observer data were stratified according to sector and gear type (longline and pot/trap). As previously described, one additional latitudinal stratum at Pt. Chehalis, WA (46° 53.30' N. lat.) was used for the LE sablefish endorsed longline sector. Some retention of *P. halibut* was allowed in the LE sablefish endorsed season in the area north of Pt. Chehalis. The Pt. Chehalis line was the only latitudinal stratification incorporated into this portion of the analysis and was only applied to the LE sablefish endorsed sector. Discard amounts provided for the other two gear sectors represent coast-wide estimates.

The number of observed trips, sets, and vessels are summarized for each sector, gear type, and area (where applicable) (Supplemental Tables 53, 54 and 55). The landed weight of sablefish and FMP groundfish (excluding Pacific hake) is used as a measure for expanding discard from observed trips to the entire fleet (Supplemental Tables 56 and 57). Observed discard ratios were calculated by sector, gear type and area based on the following equation:

$$\hat{D}_s = \frac{\sum_t d_s}{\sum_t r_s} \times F_s$$

where:

$s$  = stratum, including gear, sector, gear type, and area

$t$  = observed sets

$d$  = observed discard (mt) of *P. halibut*

$r$  = observed retained weight (mt) of sablefish or all FMP groundfish except Pacific hake

$F$  = weight (mt) of retained sablefish or all FMP groundfish excluding Pacific hake recorded on fish tickets in strata  $s$

$\hat{D}_s$  = discard estimate for stratum  $s$

For all strata except the LE sablefish non-endorsed longline and the OA sectors, discard ratios were calculated by dividing the stratum discard weight of *P. halibut* by the retained catch weight of sablefish. Retained groundfish was used as the ratio denominator for the LE sablefish non-endorsed longline and the OA sectors because these sectors target a wider range of groundfish species. A broader denominator was therefore necessary to effectively capture the level of fishing effort in these sectors.

Where FMP groundfish (excluding Pacific hake) was used to compute discard ratios, retained weights recorded by the observer not appearing on fish tickets were excluded from the denominator. This prevents double-counting associated with differences in the species codes used by observers and processors. For instance, while observers may record rockfish catch at the species level, various species of rockfish are often grouped, weighed, and recorded together on the fish ticket by the processor under a grouped market category, e.g., northern unspecified scope rockfish. In some cases, this difference in species coding prevents observer and fish ticket weights from being matched and adjusted properly. Species coding on fish tickets varies considerably between processors and over time, and it is not possible to make assumptions regarding which individual observer-recorded species likely coincide with species grouping codes on fish tickets. By using only the retained groundfish weight from fish tickets in discard ratio denominators, we prevent double-counting of retained weights. This is not a factor when using a single species in the

denominator, such as sablefish, as any retained weights in observer and fish ticket data that share the same species code will match and adjust properly.

The expansion factors for each fishery sector and gear type can be found in Supplemental Table 57. The discard rate multiplied by the expansion factor yielded an expanded gross P. halibut discard estimate for each stratum (Supplemental Table 65). If landings were made by a fixed gear sector for which there were zero or very few WCGOP observations, the most appropriate observed discard ratio was selected and applied to those landings based on similarities in the fishery management structure, fishing and discard behavior, and the gear fished. The LE sablefish endorsed vessels fishing outside of the primary season with pot gear often land a small amount of groundfish; however, this portion of the fleet is not observed by the WCGOP. Given similarities in gear type and catch composition, OA fixed gear pot observations were selected as the most appropriate source of information for an observed discard rate (Supplemental Table 56).

### Discard Mortality Rates

Once an initial gross P. halibut discard weight was estimated, this value was multiplied by a discard mortality rate (Table 7) to generate final discard mortality estimates (Supplemental Tables 66 and 67, Figure 6). Discard mortality is approximated based on viabilities in a manner similar to the approach used for IFQ bottom trawl. Observers have systematically collected viability data on hook and line vessels in the non-nearshore fixed gear sector since 2011. Current methods require observers to collect a length and viability on the first 5 P. halibut observed in each set on these vessels and to ignore any injuries incurred during landing when assessing viability. For the period 2002-2010, we used a single mortality rate for all bycatch (16%) on longline and hook and line vessels, which represents an average of DMRs over all years for the Bering Sea/Aleutian region longline fishery (Williams 2008). For the period 2011-2019, we used observer field estimates of discarded P. halibut viability on non-nearshore fixed gear vessels fishing longline or hook and line gear to estimate mortality of discarded P. halibut. (Note: Observers currently do not take viability of P. halibut caught on IFQ hook and line vessels).

Methods used to calculate discard mortality based on viability condition are almost identical to those methods currently accepted for use with IFQ bottom trawl vessels (see subsection Shore-based IFQ fishery Bycatch Estimation Viability Analysis). To account for the impact of fish size on survivorship, we computed an annual weighted mortality rate for P. halibut in each condition category in the LE Sablefish Endorsed fishery (Supplemental Table 62). For the LE Sablefish Non-Endorsed and OA Fixed Gear sectors, sample sizes were too small to calculate an annual rate. Therefore, we calculated a five year running average of weighted mortality rate for each condition category in these two sectors (Supplemental Tables 63 and 64). Length measurements associated with each viability record were converted to weight based on the IPHC length-weight table provided in Supplemental Table 95.

Table 7: Mortality rates used for each of the injury categories for Non-Nearshore hook & line vessels (Trumble et al. 2000).

Sector	Gear	Injury Status	Mortality Rate
Non-nearshore Fixed Gear	Hook & Line	minor	0.04
Non-nearshore Fixed Gear	Hook & Line	moderate	0.36
Non-nearshore Fixed Gear	Hook & Line	severe	0.66
Non-nearshore Fixed Gear	Hook & Line	dead	1.00

The proportion of *P. halibut* sampled weight in a viability category was multiplied by the viability category-specific mortality rate (Table 7). Discard mortality rates for each condition category *c* and stratum *s* were then multiplied by gross discard estimates to compute total estimated discard mortality for each sub-sector separately.

Viabilities from pot gear would be appropriate to use in estimating discard mortality, however bycatch of *P. halibut* in pot gear is infrequent and the sample size is too small to utilize in this analysis. Consistent with past reports, we relied on DMR computed for Alaska groundfish fisheries (Williams 2008). An 18% DMR was applied to estimates for pot gear, coinciding with the DMR used for the sablefish pot fishery in Alaska.

For additional context, we present the length frequency distribution of *P. halibut* from visual length estimates and physically measured lengths in non-nearshore fixed gear sectors (Supplemental Tables 68, 69, 70, 71, and 72) and the proportion of sampled *P. halibut* discard of legal (> 82 cm) and sub-legal (< 82 cm) sizes in non-nearshore fixed gear sectors (Supplemental Table 73). The majority of *P. halibut* lengths recorded in these fisheries were visual estimates of length, rounded to the nearest 10 cm. In other words, specimens that are 76 cm and 82 cm are both visually estimated to be 80 cm. With this level of resolution, it was not possible to compute the exact proportion of sub-legal versus legal *P. halibut* from visually estimated lengths. Visual estimates were instead summarized in the manner in which they are recorded; with sub-legal and legal sized halibut falling within the 75-84 cm length bin.

## IPHC Pacific halibut Directed Fishery

In 2017, the WCGOP began observing the Pacific halibut directed fishery and estimating fleet-wide discard mortality using WCGOP observer and fish ticket data. This fishery was defined based on using fixed gear and landing Pacific halibut within two days of the halibut directed openings (Somers et al. 2020). Prior to 2017, landings in this fishery were identified using criteria from IPHC and reported in the non-groundfish fisheries not observed by the NWFSC in previous versions of this report. No estimates of discards were calculated prior to 2017. Effort in this fishery occurs primarily in Washington and Oregon and uses only hook and line gear. Gross discard and mortality estimates for *P. halibut* were computed based on the same methods as described above for the non-nearshore hook and line fisheries. However, for the *P. halibut* directed fishery, we used Pacific halibut as the retained weight for both discard rates and expansion factors. We estimated landings, discard, and total mortality in the Pacific halibut directed fishery (Supplemental Tables 74, 76, and 78). Because the gear and effort in this fishery is similar to the non-nearshore hook

and line fisheries, the same mortality rates based on viability (Table 7) were applied to discarded P. halibut in the directed fishery (Supplemental Table 77). We also present the number of observed vessels, trips, and sets for each opening of the fishery (Figure 9) and the observed physical and visual length frequencies of discarded P. halibut (Supplemental Tables 79 and 80).

## Observed State Fisheries

If present, Pacific halibut bycatch was also sampled in the following state managed fisheries:

- Oregon and California nearshore groundfish fixed gear sectors (Supplemental Tables 81 and 82)
- Washington, Oregon, and California pink shrimp trawl fisheries (Supplemental Tables 83 and 84)
- OA California halibut trawl fishery (Supplemental Table 85)
- California ridgeback prawn trawl fishery (Supplemental Table 86)
- California sea cucumber trawl fishery (Supplemental Table 87)

Note that the LE California halibut fishery is covered under the IFQ fishery. Bycatch estimates for these fishery sectors were computed within each fishery based on the following equation:

$$\hat{B} = \frac{\sum_t b}{\sum_t r} \times F$$

where:

$b$  = observed discard (mt) of P. halibut on set/haul  $t$

$t$  = observed sets

$r$  = observed retained weight (mt) of target species on set/haul  $t$

$F$  = weight (mt) of retained target species in the fishery in question in a particular year

$\hat{B}$  = Discard estimate of P. halibut (mt) in the fishery in question in a particular year

The nearshore fixed gear fishery targets a variety of groundfish and state managed nearshore species that inhabit areas less than 50 fathoms deep. All species included in the nearshore target group, as listed in the WCGOP data processing appendix (NWFSC 2020a), were included in the denominator when calculating bycatch ratios for the nearshore fixed gear sector. Pink shrimp and California halibut were considered the target species in their respective fisheries. Discard mortality rates are not available for California halibut and pink shrimp fisheries due to a lack of information regarding survivorship. To maintain confidentiality, the Nearshore fisheries cannot be split out by gear type (hook and line

vs. pot). For these reasons, we assumed 100% mortality in the Nearshore, Pink Shrimp, and CA halibut fisheries.

In 2017, the WCGOP began placing observers on California sea cucumber trawl and the California ridgeback prawn trawl vessels. Prior to 2017, landings in these fisheries were included in non-groundfish fisheries not observed by the NWFSC and no estimates of discards were calculated. Effort in these fisheries occurs only in California, uses shrimp and bottom trawl gears, and targets sea cucumbers or ridgeback prawns. Discard estimates for each species was computed based on the same equation as described above for the OA California halibut fishery, but utilizing sea cucumber or ridgeback prawn as the retained weight for both discard rates and expansion factors. We assume 100% mortality. In the 2017, there was no observed catch of *P. halibut* in the CA sea cucumber trawl fishery (Supplemental Table 86). Confidentiality protections prevent reporting of the 2018-19 CA sea cucumber trawl fishery *P. halibut* bycatch (Supplemental Table 87).

## Exempted Fishing Permits

EFPs are federal permits issued by NMFS authorizing vessels to engage in fishing operations that otherwise would be prohibited by regulation ([PFMC Council Operating Procedure 19](#)). EFPs directed toward groundfish species have been required to carry WCGOP observers on 100% of trips. Thus to obtain the catch from EFPs, we sum the at-sea discards and landed *P. halibut* catch.

Since 2015, vessels in the IFQ fishery could elect to participate in an EM EFP. To obtain the catch from the IFQ EM EFP, we sum the *P. halibut* catch from the electronic monitoring data supplied to NWFSC Observer Program by the Pacific States Marine Fisheries Commission. Unlike the normal IFQ program, IFQ vessels fishing under an EM EFP are not required to carry an observer on every fishing trip because EM is used to ensure compliance with the IFQ program. The NWFSC Observer Program targets 30% of randomly selected IFQ EM trips for observer coverage for the purposes of scientific observation (e.g., biological sampling). A comparison of the discard mortality rates between the EM and non-EM IFQ vessels and between observer viability method versus the time-on-deck model are presented in Supplemental Tables 48 and 51.

## Non-groundfish Fisheries Not Observed by NWFSC

Non-groundfish fisheries that are not observed by the NWFSC Observer Program occasionally record *P. halibut* catch on fish tickets. Data from these fisheries are only available to the NWFSC Observer Program from PacFIN fish ticket records. We provide a summary of landed *P. halibut* from these fisheries by year (Supplemental Table 89).

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