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Pacific Halibut Bycatch in U.S. West Coast Groundfish Fisheries, 2002–18

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Pacific Halibut Bycatch in U.S. West Coast Groundfish Fisheries, 2002–18

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Northwest Fisheries Science Center

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PACIFIC HALIBUT BYCATCH 2002-2018

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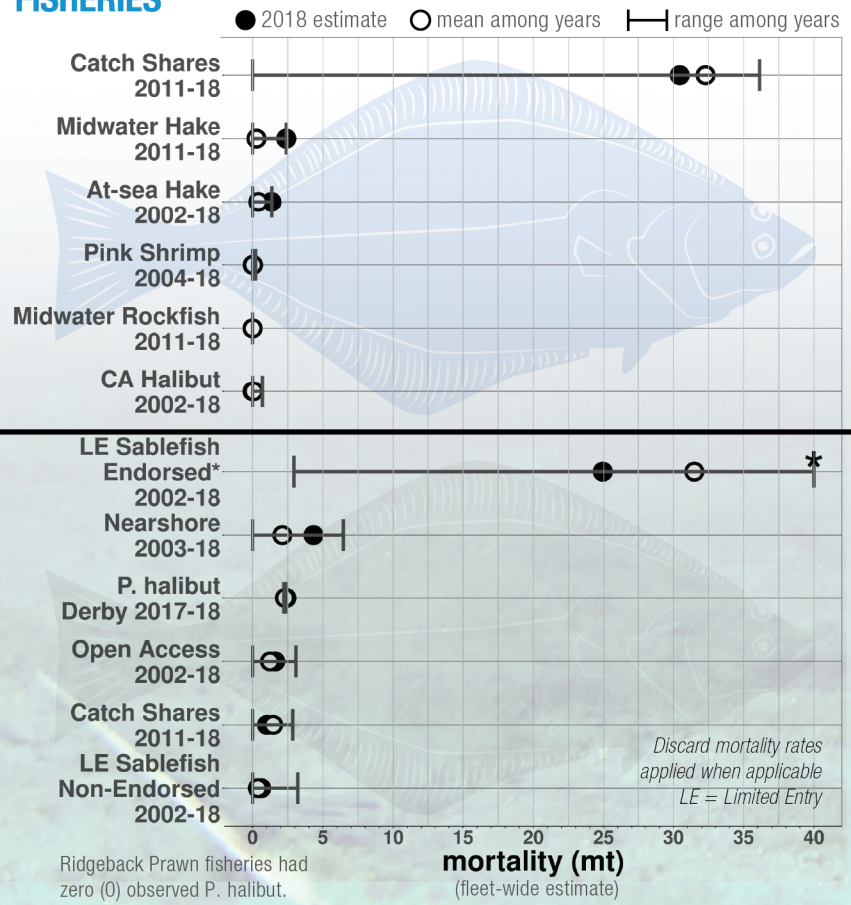
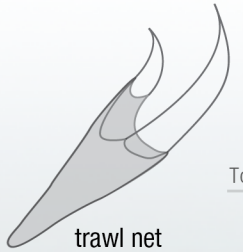
http://tinyurl.com/PhalibutReports

NOAA FISHERIES

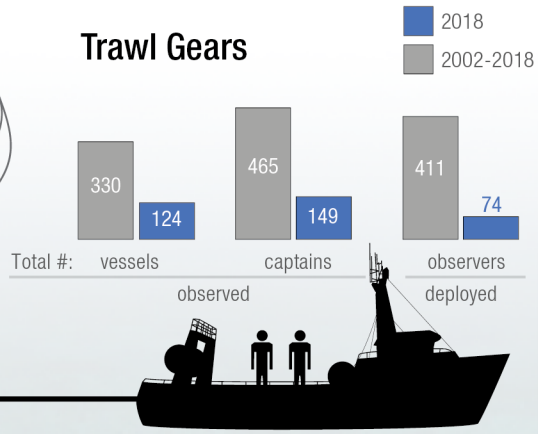


Ridgeback Prawn fisheries had zero (0) observed P. halibut.

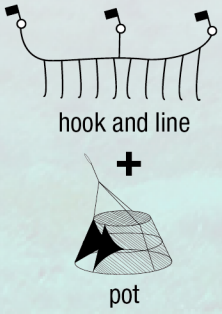
2018 Catch Shares IBQ
Allocation (mt) : 79.9
Attainment (mt): 31.3



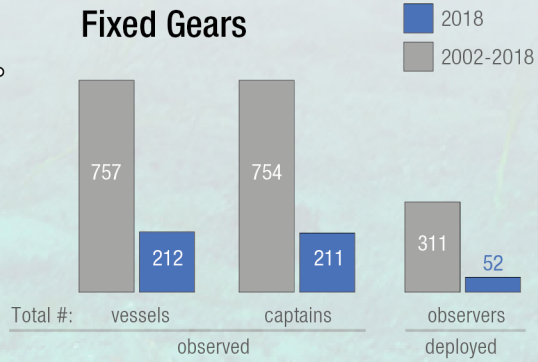
Trawl Gears



*maximum = 107.3 mt



Fixed Gears

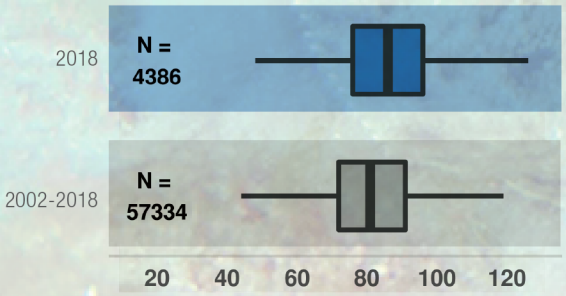


Pacific Halibut Bycatch
Observed 2002-2018

Map by K. Somers

25% Median 75%

Trawl Gears



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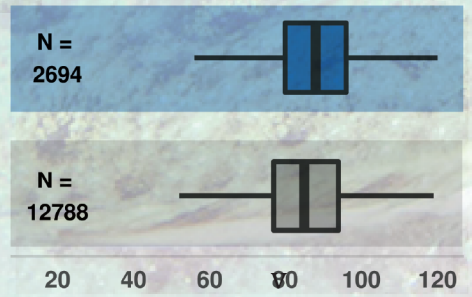

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A note about tables:

Tables 1–10 and the IPHC length–weight conversion table (Appendix B) have been typeset and included in this report. They are also available, together with all the other mentioned tables (11–91), in the accompanying Excel file. Download the file from the report's NOAA Institutional Repository* record by clicking on the "Supporting Files" tab.

* https://repository.library.noaa.gov

Executive Summary

Pacific halibut (*Hippoglossus stenolepis*) is found in coastal waters throughout the North Pacific. Off the U.S. West Coast, it inhabits continental shelf areas (<150 fth) 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 and 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 managment 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 the NOAA Fisheries West Coast Region (WCR). Pacific halibut catch in Area 2A is divided between tribal and nontribal 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. Therefore, Pacific halibut mortality estimates in this report are provided for the years 2002 through 2018 from all fishery sectors observed by FOS (Table 1). This report is updated annually by FOS and presented to PFMC and IPHC for use in P. halibut management.

Table 1. Pacific halibut total discard mortality estimates, in metric tons (mt), for 2018 and the years of observation, for all fishery sectors observed by the Northwest Fishery Science Center's West Coast Groundfish Observer Program. Estimates include individuals discarded both at the dock and at sea, with mortality rates applied where appropriate.

Sector	Years Observed	Total Discard Mortality
Individual Fishing Quota (IFQ) fisheries	2011–18	25.77
IFQ Electronic Monitoring (EM) Exempted Fishing Permit	2015–18	6.88
At-sea Pacific hake	2002–18	0.66
Non-nearshore fixed gear targeting groundfish	2002–18	29.87
Nearshore fixed gear	2003–18	1.60
Pink shrimp trawl	2004–18	0.01
California halibut trawl	2002–18	0.00
Pacific halibut directed	2017–18	2.39
Ridgeback prawn	2017–18	0.00
Sea cucumber	2017–18	—

In 2018, non-nearshore fixed gear targeting groundfish had the largest estimated P. halibut discard mortality of any sector (29.87 mt; Tables 1 and 2). Nearly all of that bycatch (24.93 mt, or 84%) occurred on the limited entry (LE) sablefish endorsed vessels. These vessels fish federally permitted sablefish tier quotas during the primary season (Apr–Oct). Almost all of the LE sablefish endorsed bycatch occurred fishing longline gear north of Point Chehalis,

Table 2. Pacific halibut discard mortality estimates (in mt, including a small amount discarded at the dock in IFQ bottom trawl, midwater rockfish, and midwater hake fisheries) for all sectors observed by FOS. Mortality rates of less than 100% were applied in the bottom trawl (BT) fisheries (LE and IFQ), IFQ H&L, IFQ pot, and non-IFQ, non-nearshore fixed gear (FG) 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; they are presented here as zero (0). All weights are estimated based on whole fish (a.k.a. round weight, not head-and-gut). The ridgeback prawn (2017–18) and sea cucumber (2017) fisheries had zero (0) observed P. halibut catch. *Key*: IFQ = individual fishing quota; FOS = Fisheries Observation Science; BT = bottom trawl; LE = limited entry; H&L = hook-and-line; hal. = halibut; MW = midwater; rf = rockfish; end. = endorsed; OA = open access; NS = nearshore; A-S = at-sea; mort. = mortality rate; * = confidential data, less than three vessels observed; — = no observer coverage.

	Total Discard Mortality (mt)																
		IFQ Fishery[h]						Non-NS FG									
Year	LE BT 2002–10	BT[a,b,j]	LE CA hal.[a,c]	H&L	Pot[j]	MW rf[c,d,j]	MW hake[b,c,e,j]	LE end.	LE non-end.	OA[f]	NS FG[c]	Pink shrimp[c]	CA hal.[c,g]	P. hal. directed	A-S hake[c]	All sectors	All w/ <100% mort.[h]	All w/ 100% mort.[i]
2002	344.82							22.76	0.00	—	—	—	0.00	—	1.14	368.72	367.58	1.14
2003	124.43							31.54	0.03	—	0.00	—	0.00	—	2.65	156.65	156.00	2.65
2004	133.12							38.82	0.00	—	1.00	0.00	0.70	—	1.13	174.77	172.64	2.13
2005	286.52							38.12	0.00	—	2.22	0.04	0.03	—	1.97	328.90	324.67	4.23
2006	242.47							107.30	0.00	—	0.53	—	0.02	—	0.83	351.15	349.79	1.36
2007	208.81							21.24	0.28	3.48	0.09	0.21	0.03	—	1.18	235.32	233.84	1.48
2008	207.81							41.65	0.48	6.45	0.35	0.00	0.31	—	3.98	261.03	256.70	4.33
2009	251.10							51.47	0.04	5.63	1.28	0.00	0.00	—	0.33	309.85	308.24	1.61
2010	180.97							22.12	0.06	5.22	0.08	0.00	0.00	—	1.57	210.02	208.37	1.65
2011		31.30	0.00	0.97	0.89	*	0.35	12.10	3.21	2.09	3.08	0.19	0.00	—	0.61	54.79	50.56	4.23
2012		36.13	*	2.34	0.51	0.00	0.62	24.94	0.73	1.61	2.26	0.00	0.00	—	0.64	69.78	66.26	3.52
2013		32.41	see [a]	0.48	0.21	0.00	1.34	2.94	0.00	0.07	1.37	0.00	0.00	—	1.06	39.88	36.11	3.77
2014		26.28	see [a]	0.61	0.08	0.00	1.36	30.16	0.00	0.36	0.96	0.00	0.00	—	0.37	60.18	57.49	2.69
2015		33.36	see [a]	1.52	0.38	0.00	0.70	10.37	0.02	0.46	1.45	0.01	0.00	—	0.06	48.33	46.11	2.22
2016		33.28	see [a]	1.02	0.18	0.00	0.68	16.65	0.91	2.54	3.04	0.00	0.00	—	0.15	58.45	54.58	3.87
2017		35.11	see [a]	0.66	0.78	0.00	0.51	38.17	0.03	3.75	1.79	0.00	0.00	2.22	0.55	83.57	80.72	2.85
2018		30.45	see [a]	0.74	0.29	0.00	1.34	24.93	0.61	4.33	1.60	0.01	0.00	2.39	0.66	67.35	63.74	3.61

Note: Ridgeback prawn (2017-18) and sea cucumber (2017 only) fisheries had zero (0) observed P. halibut catch. The 2018 sea cucumber fishery data are confidential.
[a] Starting in 2013, LE CA halibut estimates are combined with IFQ bottom trawl estimates.
[b] Includes a small amount landed and discarded at the dock.
[c] 100% mortality rate.
[d] From 2011–14, "midwater trawl."
[e] From 2011–14, "shoreside hake."
[f] Starting in 2011, this sector only includes OA CA halibut.
[g] A coastwide discard ratio and coastwide discard estimate could not be computed in the OA FG sector for 2002-06, because WCGOP only covered OA vessels in CA during this time.
[h] LE bottom trawl, IFQ bottom trawl, IFQ H&L, IFQ pot, LE and OA CA halibut, and non-nearshore fixed gear.
[i] IFQ midwater rockfish, midwater hake, nearshore fixed gear, pink shrimp, and at-sea hake.
[j] Includes P. halibut catch from IFQ EM EFP.

Due to the amount of data it contains, this table has been typeset on legal-sized paper. Printing it on regular, letter-sized paper may result in reduced legibility.

Washington (17.48 mt or 71%, Table 55). A smaller amount of P. halibut mortality also occurred on LE sablefish endorsed vessels fishing longline gear south of Pt. Chehalis (7.07 mt). Open access (OA) vessels targeting non-nearshore groundfish species with hook-and-line (H&L) gear caught substantially less than the LE sector (4.31 mt). The remainder came from LE nonendorsed longline vessels (0.61 mt) or vessels fishing pot gear (0.39 mt).

The 2018 individual fishing quota (IFQ) fishery estimate of P. halibut discard mortality, coastwide, was 25.77 mt, with an additional 6.88 mt caught by IFQ electronic monitoring (EM) exempted fishing permit (EFP) vessels (Tables 1, 40, 41, and 42), which are included in the IFQ estimate in Tables 2 and 78. The IFQ total (IFQ + IFQ EM EFP: 32.65 mt) is 4.23 mt less than the 2017 estimate (36.88 mt, see Table 2) and, as in past years, well below the IBQ allocation (79.86 mt).[1] As in prior years, bottom trawl gear produced the largest component of IFQ discard mortality (IFQ + IFQ EM = 30.45 mt), almost half of which was from bottom trawl vessels fishing between Pt. Chehalis and lat 40°10′N deeper than 60 fathoms (15.02 mt, Table 24). Legal-sized P. halibut mortality on IFQ bottom trawl vessels fishing north of lat 40°10′N was ~80% (Table 3).

Combined, IFQ bottom trawl and LE sablefish endorsed longline vessels together comprised approximately 82% of the 2018 P. halibut discard mortality in observed U.S. West Coast groundfish fisheries.

In Appendix A, we present the second year comparing alternative methods for calculating discard mortality rates (DMRs) in the IFQ EM EFP fishery. Electronic monitoring does not yet allow for accurate estimates of P. halibut viability. For in-season P. halibut IBQ management, the Pacific States Marine Fisheries Commission (PSMFC) applies a time-on-deck model 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 (Tables 40, 41, and 42). 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 (GMT) time-on-deck model (see Appendix A). Small sample sizes preclude definitive conclusions from this analysis. FOS might revisit this analysis in future reports.

The Pacific halibut discard mortality estimate for the 2018 IPHC directed Pacific halibut fishery was 2.39 mt (Tables 1 and 2). Observer coverage, discard ratios, fleetwide estimates of gross discards, discard mortality, and retained P. halibut are presented in Tables 63, 64, and 66. Discard mortality estimates were calculated using the same methods as for the non-nearshore H&L fishery, which uses observed estimates of P. halibut viability. Viabilities of observed P. halibut bycatch in the P. halibut directed fishery are given in Table 65. Observed lengths of discarded P. halibut in the directed fishery are given in Tables 67 and 68.

Table 3. Percent of legal-sized Pacific halibut mortality, by weight (mt), in the IFQ bottom trawl fishery north of lat 40°10′N.

Year	% P. halibut	Year	% P. halibut
2011	67.11	2015	67.68
2012	66.69	2016	67.26
2013	64.01	2017	75.61
2014	60.07	2018	79.22

[1] IBQ = Individual Bycatch Quota, which is used for P. halibut north of lat 40°10′N.

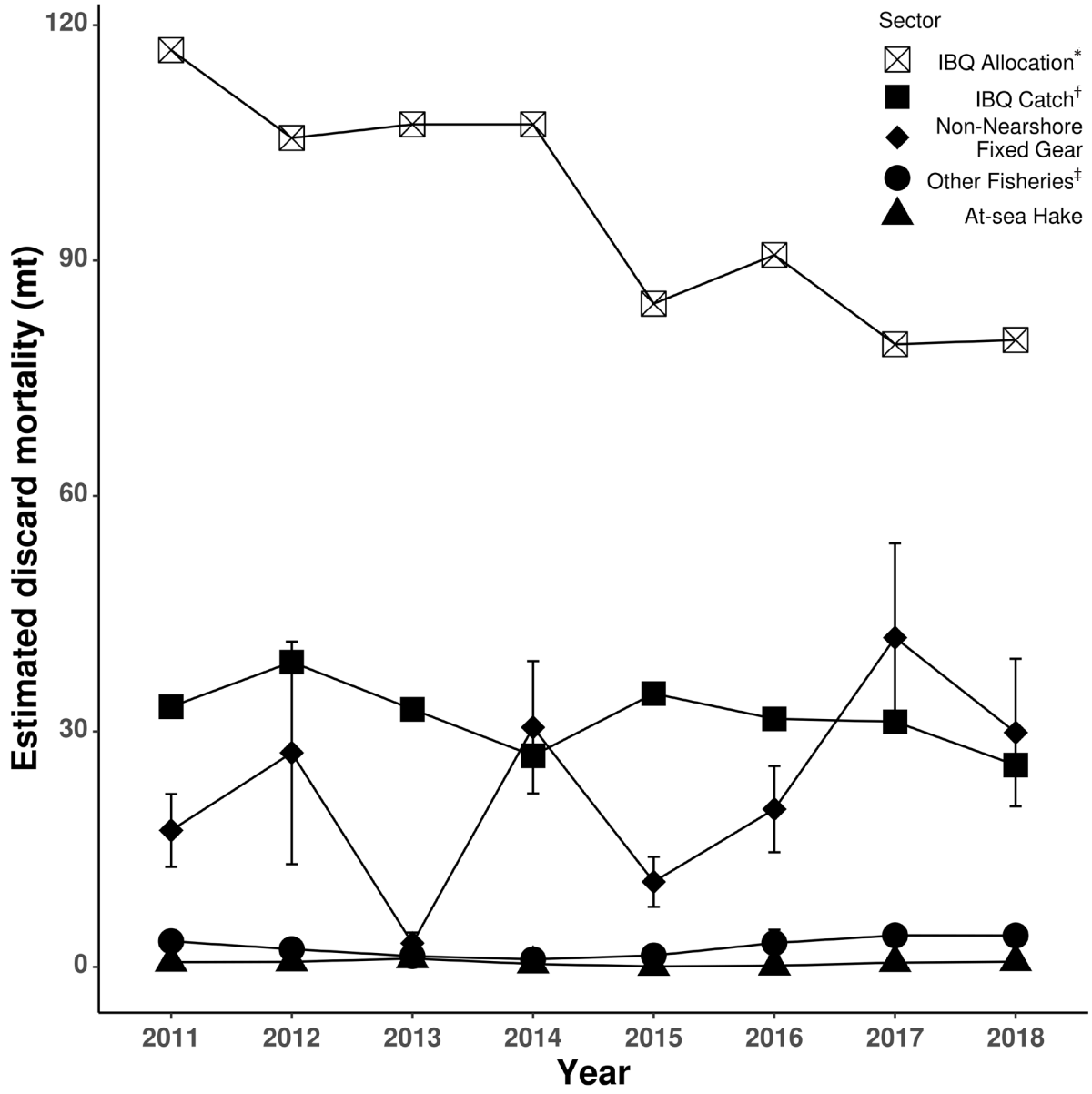

Figure 1. Total estimated P. halibut discard mortality (mt ±1 SE, with mortality rates applied if applicable) from all sectors observed by FOS. Estimates are not included for sectors and years where there were insufficient observer data. Values are reported in Table 2.

* Individual bycatch quota (IBQ) allocated north of lat 40°10′N.

† IBQ catch includes all catch share sectors and gears except at-sea hake, which is shown separately.

‡ "Other Fisheries" includes: OR and CA nearshore; WA, OR, and CA pink shrimp; CA halibut; sea cucumber; ridgeback prawn; and IPHC P. halibut directed fisheries.

Pacific halibut discard in the nearshore fixed gear, pink shrimp trawl, California halibut trawl, 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 (Table 75). Estimates for the 2018 California sea cucumber trawl fishery are confidential and therefore not provided (Table 74).

Final estimates of observed fishery sectors, including the IFQ EM EFP, are shown in Tables 1, 2, and 78. We include in these tables (and elsewhere in this report) the small amount of P. halibut landed and subsequently discarded at the dock by IFQ bottom and midwater trawl vessels. These landed and then discarded at the dock amounts are listed by strata in Tables 11, 12, and 13. IFQ EM EFP Pacific halibut catch is included in the summaries found in Tables 1, 2, 40, 41, 42, and 78.

In addition, we provide historical estimates of P. halibut bycatch in the Limited Entry (LE) bottom trawl fishery for the 2002–10 period and P. halibut bycatch estimates for observed, non-IFQ vessels with an EFP targeting groundfish (2002–18). For completeness, we also include the P. halibut landed catch from Pacific Fisheries Information Network (PacFIN) fish tickets reported by nongroundfish fisheries that are not observed by FOS for the period 2002–18.

The FOS data used in this report have been updated to include the most recent available (2002–18). PacFIN data used in this report were accessed in April 2018. The estimates for all sectors and years (except LE trawl 2002–10) have been recalculated based on these base data. In all other respects, this report uses the same methods as reported in Jannot et al. (2017).

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 fth) 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 and Gustafson 2019). The objective of this report is to provide estimates of P. halibut bycatch in the U.S. West Coast groundfish fisheries from 2002–18.

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 offshore to the U.S. exclusive economic zone [EEZ]) waters. Groundfish are both targeted and caught incidentally by trawl nets, hook-and-line (H&L) 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 LE permit. The total number of LE 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. Estimates of P. halibut bycatch in recreational fisheries are compiled by the International Pacific Halibut Commission (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 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 included in Tables 2 and 78.

These four components can be further subdivided into sectors based on gear type, target species, permits, and other regulatory factors as shown below in Tables 4, 5, and 6.

Table 4. 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.

Sector	Subsector	Permit(s)	Gear(s)	Target(s)	Vessel lengths (m)	Depths (m)	Management since 2011
Limited entry (LE) trawl	LE Trawl	LE permit with trawl endorsement[a]	Bottom trawl; H&L; pot	Groundfish[b]	15–40	10–1,600	IFQ; some vessels use EM in lieu of 100% observer coverage
	Midwater rockfish	LE permit with trawl endorsement[a]	Midwater trawl	Midwater rockfish[c]	15–33	>70	IFQ; some vessels use EM in lieu of 100% observer coverage
	Midwater hake	LE permit with trawl endorsement[a]	Midwater trawl	Pacific hake[d]	17–40	>70	IFQ; some vessels use EM in lieu of 100% observer coverage
At-sea hake	Mothership catcher vessels (MSCVs)	LE permit with MSCV endorsement[a]	Midwater trawl	Pacific hake[d]	8–138[e]	53–460[c]	IFQ; some vessels use EM in lieu of 100% observer coverage
	Catcher–processors (CPs)	LE permit with CP endorsement[a]	Midwater trawl	Pacific hake[d]	82–115	60–570	IFQ
	Tribal	*none*	Midwater trawl	Pacific hake[d]	<38	53–460	IFQ

[a] A.k.a. LE permit. All LE permits are issued by NOAA.
[b] Vessels with a California halibut permit, issued by the state of California, can land CA halibut under California's CA halibut fishery regulations.
[c] *Sebastes* spp.
[d] *Merluccius productus*.
[e] Average values for catcher vessels.

Table 5. 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.

Sector	Subsector	Permit(s)	Gear(s)	Target(s)	Vessel lengths (m)	Depths (m)	Management
Non-nearshore fixed gear	Sablefish endorsed	LE permit (fixed gear endorsement and sablefish quota)[a]	Longlines; pots	Sablefish[c]	7–32	20–1,300	Sablefish tier quotas; 7-month season
	Sablefish non-endorsed (a.k.a. Zero Tier)	LE permit (fixed gear endorsement without sablefish quota)[a]	Longlines; pots	Sablefish[c]; rockfish[d]; flatfish[e]	7–32	20–1,300	Trip limits
	Open access	*none*	Longlines; pots	Sablefish[c]; other groundfish	3–30	20–1,300	Trip limits
IPHC Pacific halibut directed		IPHC Pacific halibut permit[b]	Longlines	Pacific halibut[f]	3–32	40–400	Trip limits; 10-hr fishing periods south of Pt. Chehalis, WA Legal size: >82 cm

[a] A.k.a. LE permit. All LE permits are issued by NOAA.
[b] Issued by the International Pacific Halibut Commission (IPHC).
[c] *Anoplopoma fimbria*.
[d] *Sebastes* spp.
[e] Pleuronectiformes.
[f] *Hippoglossus stenolepis*.

Table 6. 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.

Sector	Permit(s)	Gear(s)	Target(s)	Vessel lengths (m)	Depths (m)	Management
Open access (OA) California halibut	CA halibut permit[a]	Bottom trawl	CA halibut[b]	9–22	10–200	Fish mainly within the CA Halibut Trawl Grounds; minimum mesh sizes; 7-month season
Nearshore fixed gear[c]	CA or OR state nearshore permits and endorsements	Variety of hand lines, pot gear, stick gear, rod and reel	Rockfish[d]; cabezon[e]; greenling[f]	3–15	<100	Federal and state regulations; area closures; 2-month trip limits
Pink shrimp	WA, OR, or CA state pink shrimp permits	Shrimp trawl	Pink shrimp[g]	11–33	60–800	State regulations; bycatch reduction devices; trip limits on groundfish landings
CA ridgeback prawn	Prawn permit[a]	Shrimp or bottom trawl	Golden, spot, ridgeback, or other prawn[h]	9–19	45–700	Oct-May season; trip limits; area restrictions; landing requirements
CA sea cucumber	Sea cucumber trawl permit[a]	Bottom trawl	CA sea cucumbers[i]	9–12	<100	Logbook requirement; area and seasonal closures

[a] Issued by the state of California.
[b] *Paralichthys californicus*.
[c] The state of Washington does not conduct a nearshore fishery.
[d] *Sebastes* spp.
[e] *Scorpaenichthys marmoratus*.
[f] Hexagrammidae.
[g] *Pandalus jordani*.
[h] Includes *Crangon* spp., *Lysmata californica*, *Pandalus clanae*, *P. jordani*, *P. platyceros*, and *Sicyonia ingentis*.
i Parastichopus californicus.

The Fisheries Observation Science Program

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

WCGOP was established in May 2001 by NOAA Fisheries (a.k.a. the National Marine Fisheries Service, NMFS) in accordance with the Code of Federal Regulations (USOFR 1996, 2001). 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.

A-SHOP has conducted observations of the U.S. West Coast at-sea hake fishery since 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. Current A-SHOP program information and documentation on data collection methods can be found in the A-SHOP observer manual (NWFSC 2019a). The at-sea hake fishery has mandatory observer coverage, with each vessel over 38 m carrying two observers. Beginning in 2011, under individual fishing quota (IFQ)/ Co-op Program management, all catcher vessels that deliver catch to motherships are required to carry WCGOP observers or use electronic monitoring equipment.

FOS's goal is to improve estimates of total catch and discard by observing groundfish fisheries along the U.S. West Coast. WCGOP and A-SHOP observe distinct sectors of the groundfish fishery. 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. WCGOP also observes several fisheries that incidentally catch groundfish, including the California halibut trawl and pink shrimp trawl fisheries. A-SHOP observes the fishery that catches and delivers Pacific hake at sea, including nontribal catcher–processor and mothership vessels.

Pacific Halibut Management and Fishery Interaction

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 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 Region (WCR). Pacific halibut catch in Area 2A is divided between tribal and nontribal 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. In 2018, the LE fixed gear sablefish endorsed sector was allowed to retain and land P. halibut north of Point Chehalis, Washington. 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. In all other U.S. West Coast commercial groundfish fishery sectors, P. halibut must be discarded at-sea. However, 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 (TAC) of a fishery, that can be received or held for exclusive use by a person (MSA 2007). The implementation of the IFQ management program in 2011 resulted in changes to the method used for estimating fishing mortality, 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 lat 40°10′N. Pacific halibut caught south of lat 40°10′N are not managed by an IBQ quota, but are reported here under the IFQ fishery.

Data collection and reporting for this fishery are described in Shore-based IFQ Fishery by gear type. 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. Pacific halibut is regularly caught as bycatch in the LE sablefish endorsed fixed gear, LE sablefish nonendorsed fixed gear, and OA fixed gear sectors.

Methods

Data Sources

Data sources for this analysis include onboard observer data (from WCGOP and A-SHOP), landing receipt data (referred to as fish tickets, obtained from PacFIN), and data generated from vessels carrying electronic monitoring (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 (PSMFC). 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 manual (NWFSC 2019b). A-SHOP program information, documentation, and data collection methods can be found in the A-SHOP observer manual (NWFSC 2019a).

The sampling protocol employed by 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[1] 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. 2019). 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 2019) and subsequently divided into various sectors of the groundfish fishery (Somers et al. 2019).

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 fleetwide P. halibut mortality. Methods for in-season IBQ estimation are discussed in Jannot et al. (2020).[2] Results obtained by methods described here resulted in fleetwide estimates of P. halibut mortality that are very close to those reported by the VAS (data not shown to maintain confidentiality).

[1] https://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_processing.cfm
[2] Jannot, J. E., N. Riley, and J. T. McVeigh. 2020. Pacific Halibut Individual Bycatch Quota Calculations for Use in the NOAA West Coast Region Individual Fishing Quota (IFQ) Program: Methods for Estimating Pacific Halibut Discards for In-season Reporting and Special Cases. U.S. Department of Commerce, NOAA Processed Report NMFS-NWFSC-PR-2020-01. https://doi.org/10.25923/dwa2-1568

Table 7. Data collected from P. halibut caught on IFQ vessels using different types of gear. *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.

Gear	Years	Count	Length, Measurement	Viable?
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 sampled portion	actual, all or subset	yes
H&L	2011–16	all in sampled portion	visual, all or subset	no
H&L	2016–present	all in the sample	actual, all or subset	yes

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 7):

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 2019a, 2019b). 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 depend 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 7 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 H&L gear in the IFQ fishery. Visual estimates are in 10 cm increments (55–64 cm, 65–74 cm, etc.).

The crew's cooperation is vital to the observer's sampling success during H&L 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.

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 (Williams and Chen 2003, NWFSC 2019a). 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 (Tables 2 and 3).

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 H&L 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.

Shore-based IFQ fishery Bycatch Estimation

We stratified IFQ P. halibut bycatch data based on sector (shoreside nonhake groundfish, shoreside Pacific hake, at-sea Pacific hake, and LE California halibut) and gear (bottom trawl, midwater trawl, pot, H&L). 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 nonhake groundfish sector, we further stratified using area and depth within each gear type. We maintained area and depth strata that were applied to bottom trawl, H&L, and pot gear in previous reports (see Table 4 of this report for specific strata; 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 (lat 40°10′N) 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 sampled, not sampled, or when 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 ($\hat{W}$) 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:

$$\widehat{W}_{u,s} = \sum_{u} x_{u,s} \times \frac{\sum w_{f,s}}{\sum x_{f,s}} \quad (1)$$

where, for each stratum,

- s = stratum, which includes sector and year and could include area, depth, and/or gear,
- u = unsampled haul,
- f = fully sampled haul,
- x = weight of discarded catch,
- $\hat{W}$ = estimated weight of unsampled P. halibut in the stratum, and
- 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 lat 40°10′N only), IFQM, or IFQFF unsampled categories. Thus, those are the only categories for which P. halibut is estimated. 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. IFQM included all 2018 IFQ managed species (see USOFR 2011 for a listing of IFQ species). North of the lat 40°10′N 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 ($\hat{W}$) 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, or IFQM) in all fully sampled hauls within a stratum. Estimated P. halibut weight was summed across unsampled categories:

$$\widehat{W}_{p,s} = \sum_{y}\left(\sum_{p} x_{p,y,s} \times \frac{\sum w_{f,s}}{\sum x_{f,y,s}}\right) \tag{2}$$

where, for each stratum,

- s = stratum, which includes year and sector, and could include area, depth, and/or gear,
- y = unsampled category (either NIFQ, IFQFF, or IFQM),
- p = partially sampled haul,
- f = fully sampled haul,
- x = weight of discarded catch,
- $\hat{W}$ = estimated weight of unsampled P. halibut in the stratum, and
- 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.

Table 8. Mortality rates used for each of the condition categories for IFQ bottom trawl vessels (Clark et al. 1992).

Condition	Mortality rate
Excellent	0.20
Poor	0.55
Dead	0.90

Table 9. Mortality rates used for each of the condition categories for IFQ pot gear vessels (Williams and Chen 2003).

Condition	Mortality rate
Excellent	0
Poor	1
Dead	1

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 in Appendix B.

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 Tables 8 and 9):

$$DMR_{c,s,j} = m_c \times P_{c,s,j} \tag{3}$$

where

- s = stratum, which could include area, depth, gear, and/or sector,
- c = viability condition (Excellent, Poor, or Dead),
- j = year,
- m = mortality rate,
- P = proportion of sampled P. halibut weight (w), and
- 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:

$$\widehat{F}_{s,j} = \sum_{c} \left(B_{s,j} \times DMR_{s,j} \right) \tag{4}$$

where

- s = stratum, which could include area, depth, gear, and/or sector,
- c = viability condition (Excellent, Poor, or Dead),
- j = year,
- $\hat{F}$ = total estimated discard mortality,
- B = gross estimated discard weight, and
- DMR = discard mortality rate.

Viability data are collected from only a subsample 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 is 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 covary, 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 morality rate of 0.16, 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.

Length Frequencies

The length frequency distribution for P. halibut in the 2011–18 IFQ fishery is provided in Tables 33 and 34. 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 (Appendix B). Occasionally, observers weigh individual fish. Sometimes crew members presort the catch by removing P. halibut and immediately returning 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 H&L gear. Fishers have raised concerns regarding crew safety when landing large P. halibut. In addition, H&L 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 presorting) are almost universal on IFQ H&L vessels. Another case of presorting can occur when halibut are too heavy and/or awkward to weigh in observer baskets. In all cases of presorting, random samples are not available. Therefore, observers visually estimate the length of the halibut in ten-centimeter units (40-cm, 50-cm, 60-cm, etc.), which are later converted to weights using the IPHC length–weight conversion table (Appendix B).

The weighted length frequency distributions of discarded P. halibut for vessels fishing IFQ using bottom trawl or pot gear are provided in Tables 85 and 87 and Jannot et al. (2019).[3] 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

[3] Jannot, J. E., K. E. Richerson, K. A. Somers, and J. McVeigh. 2019. Weighted Length Frequency Distributions for Pacific Halibut in U.S. West Coast Limited Entry and Catch Share Bottom Trawl and Pot Fisheries, 2004–18. U.S. Department of Commerce, NOAA Data Report NMFS-NWFSC-DR-2019-03. https://doi.org/10.25923/5xz2-zy24

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 (Tables 8 and 9), or by 1.0 in the case of midwater trawl, summing these values across viabilities, and rounding 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

WCGOP samples each non-nearshore fixed gear sector through separate random selection processes, with the LE sablefish endorsed season permits receiving the highest level of coverage, then LE sablefish nonendorsed permits, and OA fixed gear the lowest. LE sablefish endorsed vessels that fish outside of the primary season or that have reached their tier quotas 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/gear combination. Two latitudinal strata were applied to the LE sablefish endorsed longline sector (north and south of Pt. Chehalis = lat 46°53′30″N) because previous modeling demonstrated that these strata significantly improved the fit of predicted bycatch amounts to the amounts observed (Heery et al. 2010). Point Chehalis 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 (Tables 47 and 48). Retained weight varies by sector in this fishery and can be either sablefish or all FMP groundfish (except Pacific hake; see Table 46 for type of retained used. For list of FMP groundfish species, see Somers et al. 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 based on a unique vessel and landing date. Any P. halibut caught on fixed gear fish tickets with a majority of nongroundfish landings are either captured in the estimates from the P. halibut directed fishery (Table 66) or nongroundfish fisheries (Table 77).

Fish tickets from the non-nearshore fixed gear sector were partitioned into the three commercial fixed gear sectors (LE sablefish endorsed season, LE sablefish nonendorsed, 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 (LE) or no federal groundfish permit (OA). 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 (Nov–Mar) or made trips within the season after they had reached their tier quota, the fish tickets were placed in the LE sablefish nonendorsed sector. In addition, fish tickets from nonendorsed LE vessels were also placed in the LE sablefish nonendorsed 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 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 (2002–17), we identify P. halibut directed fishery fish tickets using defintions supplied by IPHC. For the current year (2018), fish tickets that included P. halibut landings on or within the two 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 were removed prior to our analysis. This approach may have resulted in the removal of some nondirected 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 (lat 46°53′30″N) 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 coastwide estimates.

The numbers of observed trips, sets, and vessels are summarized for each sector, gear type, and area (where applicable) in Tables 43, 44, and 45. The landed weights of sablefish and FMP groundfish (excluding Pacific hake) are used as a measure for expanding discard from observed trips to the entire fleet (Tables 46 and 47). Observed discard ratios were calculated by sector, gear type, and area, based on the following equation:

$$\widehat{D}_s = \frac{\sum_t d_s}{\sum_t r_s} \times F_s \tag{5}$$

where

- s = stratum, including 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 except Pacific hake recorded on fish tickets in stratum s, and
- $\hat{D}_s$ = discard estimate for stratum s.

For all strata except the LE sablefish nonendorsed 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 nonendorsed 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) were 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 fish tickets by processors 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 Table 47. The discard rate multiplied by the expansion factor yielded an expanded gross P. halibut discard estimate for each stratum (Table 55). 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 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 (Table 46).

Table 10. Mortality rates used for each of the condition categories (m_c) for non-nearshore hook-and-line vessels: *minor*, moderate (*mod*), *severe*, or *dead* (Trumble et al. 2000).

m_c	Rate
m_{minor}	0.035
m_{mod}	0.363
m_{severe}	0.662
m_{dead}	1.000

Discard Mortality Rates

Once an initial gross P. halibut discard weight was estimated, this value was multiplied by a discard mortality rate (Table 55) to generate final discard mortality estimates (Tables 55 and 56, Figures 1 and 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 H&L vessels in the non-nearshore fixed gear sector since 2011. Current methods require observers to collect lengths and viabilities on the first five P. halibut observed in each set on these vessels and to ignore any injuries incurred during landing when assessing viability. For the period 2002–10, we used a single mortality rate for all bycatch (16%) on longline and H&L vessels, which represents an average of DMRs over all years for the Bering Sea/Aleutian region longline fishery (Williams 2008). For the period 2011–18, we used observer field estimates of discarded P. halibut viability on non-nearshore fixed gear vessels fishing longline or H&L gear to estimate mortality of discarded P. halibut (Kaimmer and Trumble 1998). (*Note*: Observers currently do not take viability of P. halibut caught on IFQ H&L 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 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 (Table 52). For the LE sablefish nonendorsed and OA fixed gear sectors, sample sizes were too small to calculate annual rates. Therefore, we calculated a five-year running average of weighted mortality rates for each condition category in these two sectors (Tables 53 and 54). Length measurements associated with each viability record were converted to weights based on the IPHC length–weight table provided in Appendix B.

The proportion of P. halibut sampled weight in a viability category is multiplied by the viability category-specific mortality rate (Table 10, above) according to Equation 3. 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 subsector separately, according to Equation 4.

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 (Figure 7, Tables 57, 58, 59, 60, and 61) and the proportion of sampled P. halibut discard of legal (>82 cm) and sublegal (<82 cm) sizes in non-nearshore fixed gear sectors (Table 62). Most 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 sublegal versus legal P. halibut from visually estimated lengths. Visual estimates were instead summarized in the manner in which they are recorded, with both sublegal- and legal-sized P. halibut falling within the 75–84-cm length bin.

IPHC Pacific Halibut Directed Fishery

In 2017, WCGOP began observing the Pacific halibut directed fishery and estimating fleetwide 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. 2019). Prior to 2017, landings in this fishery were identified using criteria from IPHC and reported in the nongroundfish fisheries not observed by 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 H&L gear. Gross discard and mortality estimates for P. halibut were computed based on the same methods as described above for the non-nearshore H&L fisheries (see Discard Mortality Rates). 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 P. halibut directed fishery (Tables 63, 64, and 66). Because the gear and effort in this fishery are similar to the non-nearshore H&L fisheries, the same mortality rates based on viability (Table 10) were applied to discarded P. halibut in the directed fishery (Table 65). We also present the number of observed vessels, trips, and sets for each opening of the fishery (Figure 8) and the observed physical and visual length frequencies of discarded P. halibut (Tables 67 and 68).

Observed State Fisheries

Pacific halibut bycatch was also observed in the following state-managed fisheries:

- Oregon and California nearshore groundfish fixed gear sectors (Tables 69 and 70).
- Washington, Oregon, and California pink shrimp trawl fisheries (Tables 71 and 72).
- OA California halibut trawl fishery (Table 73).
- California sea cucumber trawl fishery (Table 74).
- California ridgeback prawn trawl fishery (Table 75).

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:

$$\widehat{B} = \frac{\sum_t^b}{\sum_t^r} \times F \tag{6}$$

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, and
- $\hat{B}$ = 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 <50 fth deep. All species included in the nearshore target group, as listed in the WCGOP data processing appendix (NWFSC 2019b), were included in the denominator when calculating bycatch ratios for the nearshore fixed gear sector. Pink shrimp and CA halibut were considered the target species in their respective fisheries. Discard mortality rates are not available for CA 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 (H&L vs. pot). For these reasons, we assumed 100% mortality in the nearshore, pink shrimp, and CA halibut fisheries.

In 2017, WCGOP began placing observers on CA sea cucumber trawl and CA ridgeback prawn trawl vessels. Prior to 2017, landings in these fisheries were included in nongroundfish fisheries not observed by 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 were computed based on Equation 6, 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 ridgeback prawn trawl fishery (Table 75). Confidentiality protections prevent reporting of P. halibut bycatch in the 2018 CA sea cucumber trawl fishery (Table 74).

Exempted Fishing Permits

EFPs are federal permits issued by NOAA Fisheries authorizing vessels to engage in fishing operations that otherwise would be prohibited by regulations (PFMC 2011). 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 EM data supplied to NWFSC Fishery Observation Science Program (FOS) by PSMFC. 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. FOS targets 30% of randomly selected IFQ EM trips for observer coverage for the purposes of scientific observation (e.g., biological sampling). Comparisons 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 Appendix A.

Nongroundfish Fisheries Not Observed by NWFSC

Nongroundfish fisheries that are not observed by FOS occassionally do record some P. halibut bycatch on fish tickets. Data from these fisheries are only available to FOS from PacFIN fish ticket records. We provide a summary of landed P. halibut from these fisheries by year.

Results

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 lat 40°10′N line, with highest concentrations of bycatch north of Pt. Chehalis (Figure 2).

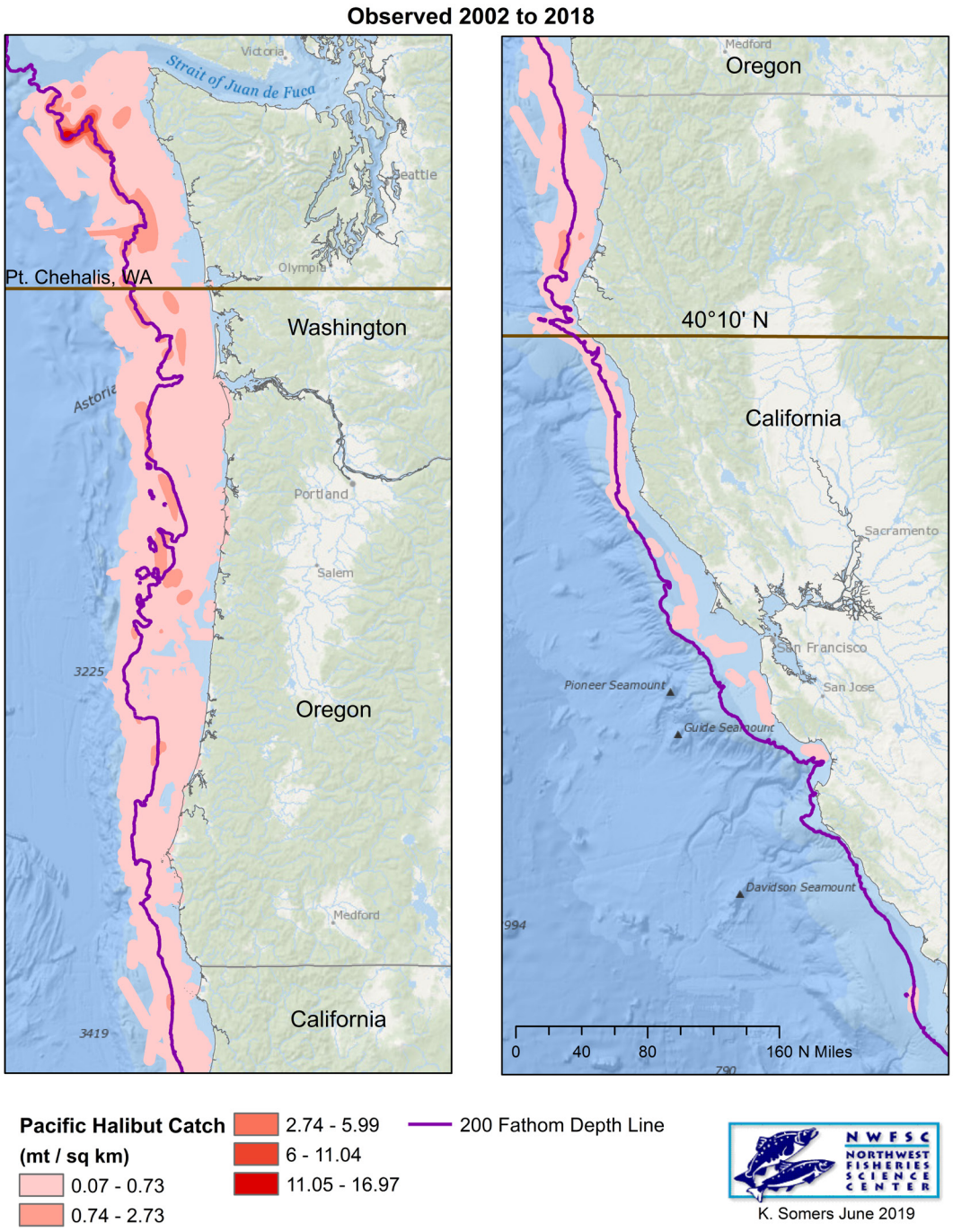

Figure 2. Spatial distribution of Pacific halibut bycatch (mt/km^2) observed by WCGOP (2002–18) off the U.S. West Coast. Gear types observed by WCGOP include bottom trawl, midwater trawl, shrimp trawl, fixed gear hook-and-line, and pot gear. The five catch classifications were defined by excluding any zero values and then applying the Jenks natural breaks classification method. Cells (200 km^2) with less than three 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 2018 strata, 99% or more of the observed IFQ tows or sets were sampled (Tables 11, 12, 13, 14, and 15). IFQ flatfish, IFQ mixed species, and unsorted catch all contributed to unsampled catch (Tables 16 and 17; see NWFSC 2019b for IFQ sampling protocols). The total estimated weight of P. halibut from unsampled tows or sets in 2018 represents a small fraction (0.36 mt, or 0.7%) of the total 2018 IFQ gross discard weight of P. halibut (Tables 16, 17, 18, and 19).

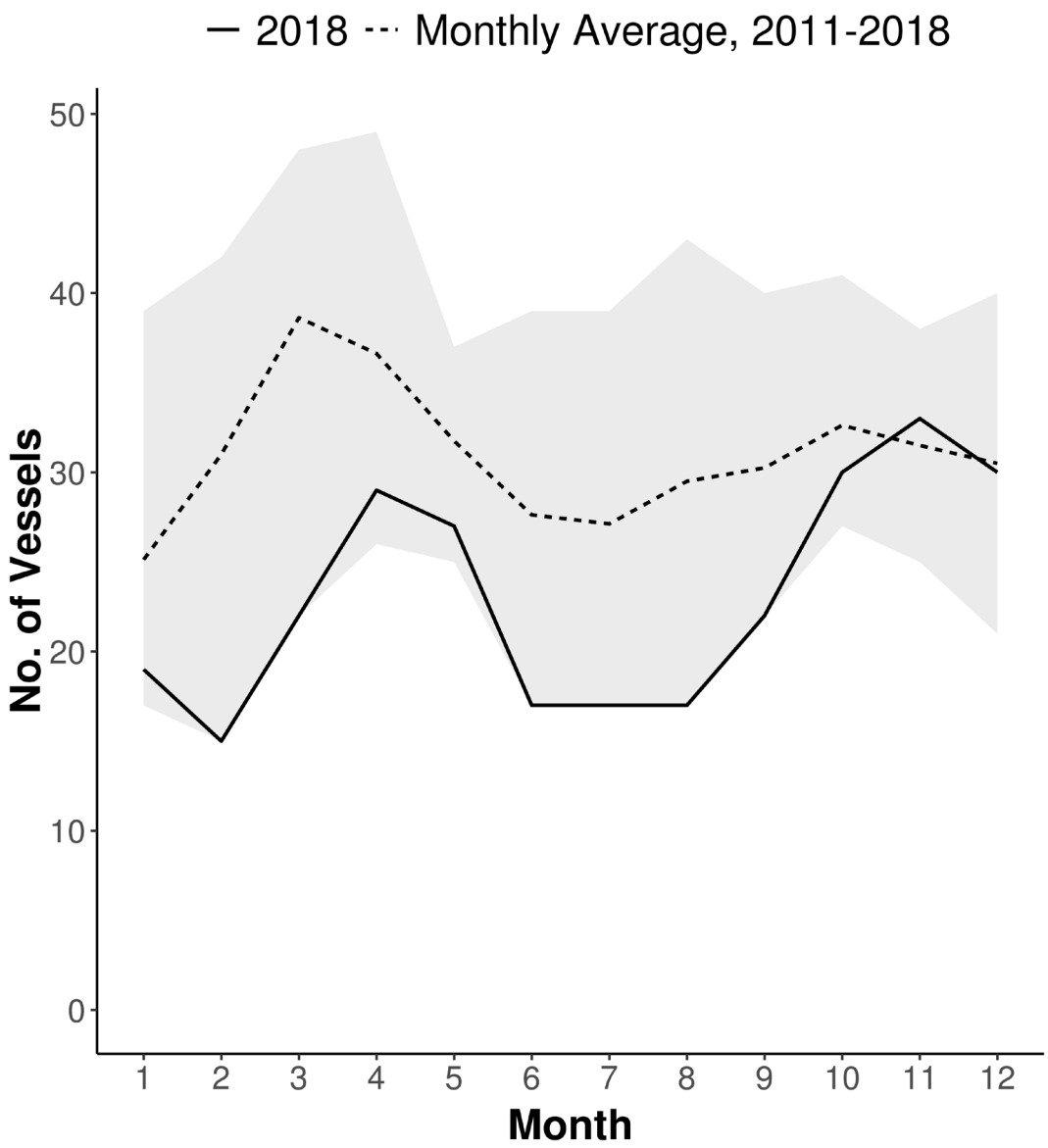

Figure 3. Number of vessels by month for IFQ bottom trawl vessels in 2018 (solid line) and averaged over the 2011–18 period (dotted line). Gray ribbon represents the monthly maximum and minimum across 2011–18. Data from vessels using EM are not included.

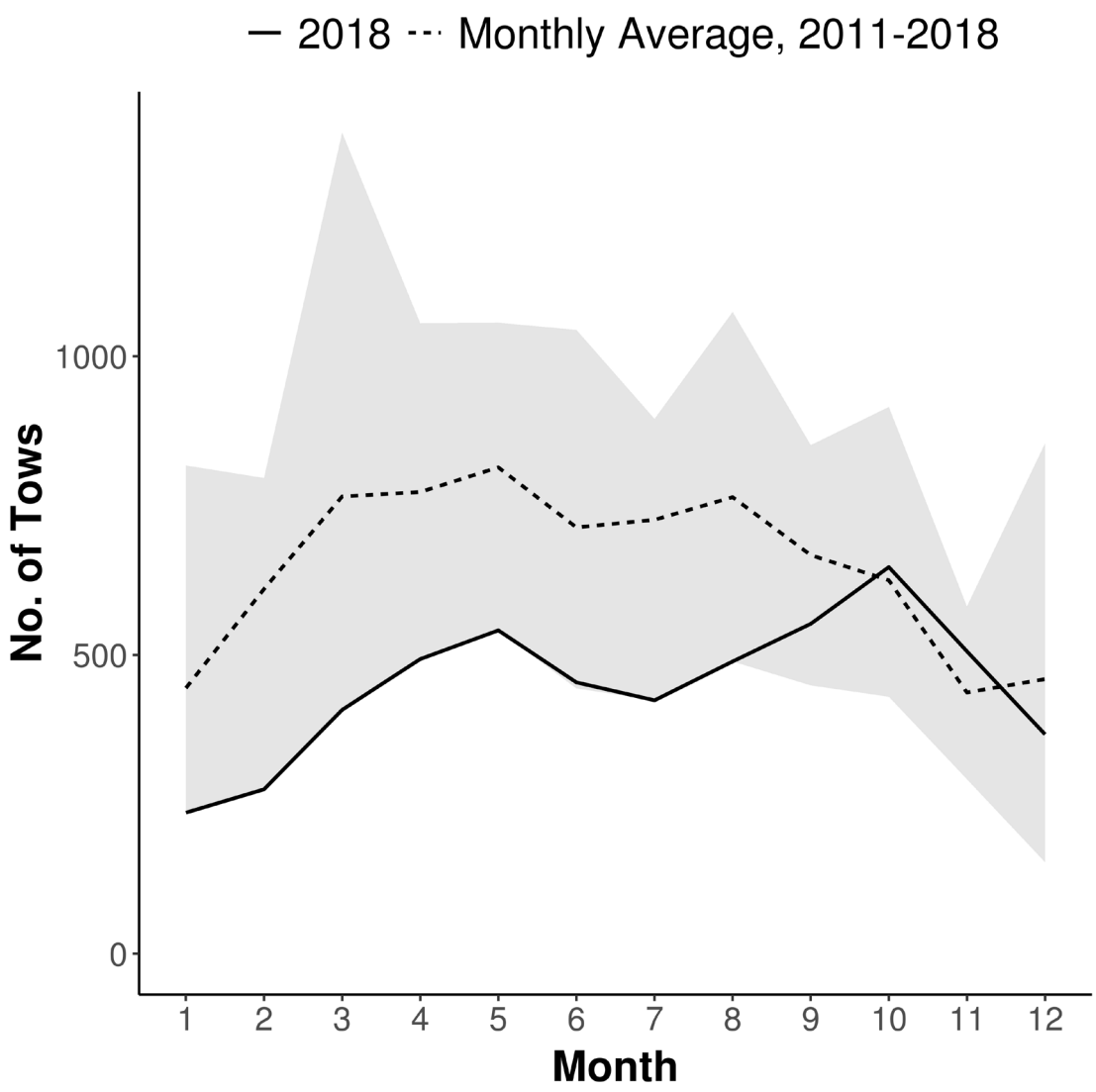

Figure 4. Number of tows by month for IFQ bottom trawl vessels in 2018 (solid line) and averaged over the 2011–18 period (dotted line). Gray ribbon represents the monthly maximum and minimum across 2011–18. Data from vessels using EM are not included.

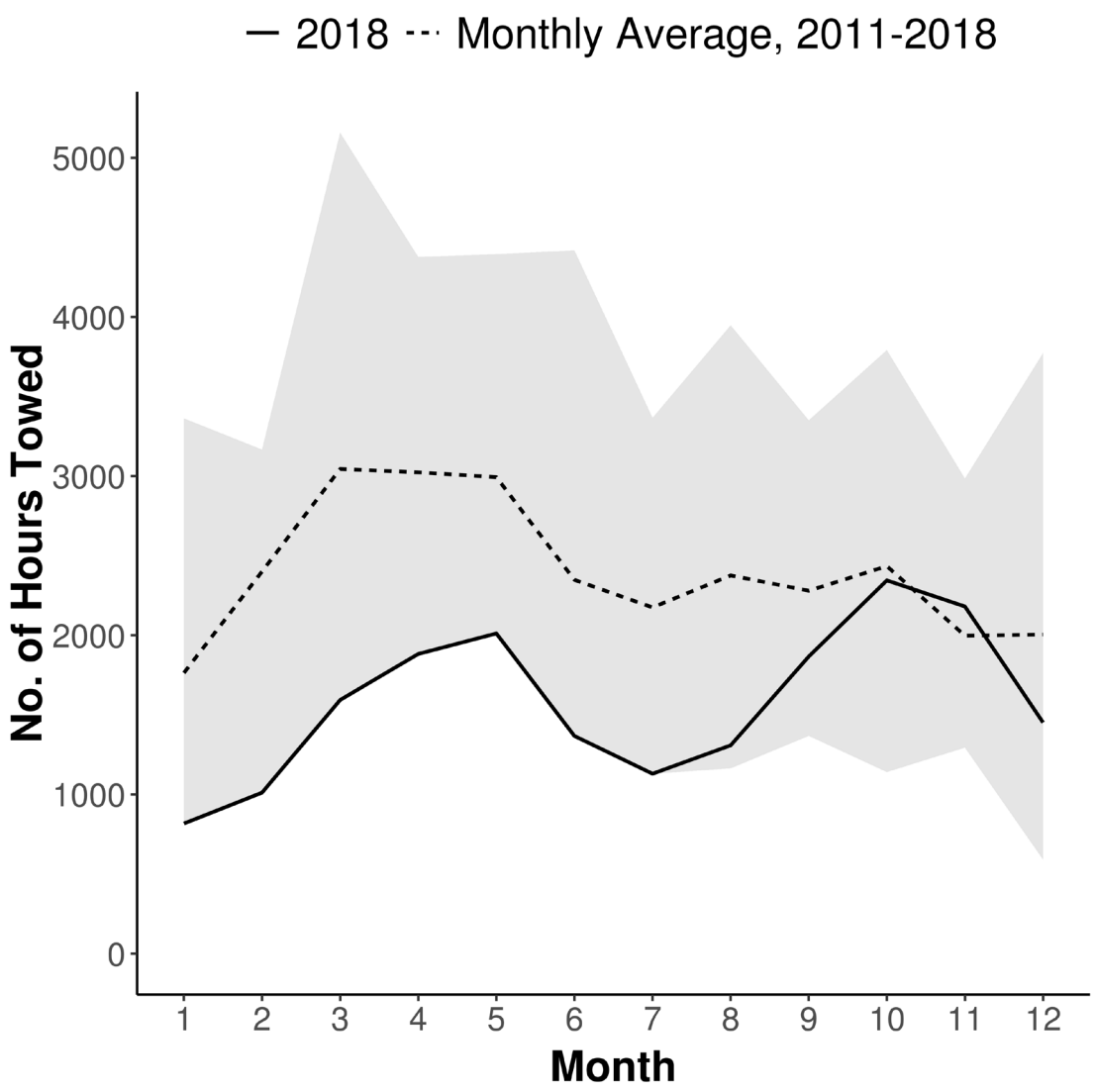

Figure 5. Tow hours by month for IFQ bottom trawl vessels in 2018 (solid line) and averaged over the 2011–18 period (dotted line). Gray ribbon represents the monthly maximum and minimum across 2011–18. Data from vessels using EM are not included.

Gross bycatch estimates and total discard mortality estimates were largest for vessels fishing bottom trawl gear north of the lat 40°10′N management line in depths greater than 60 fth (Table 24). This gear–area–depth stratum accounts for 81% of the 2018 P. halibut discard mortality in the IFQ fishery. The next-largest fraction (5%) of total IFQ discard mortality was found in the same gear–area combination in shallow waters (<60 fth). Together, bottom trawl gear fishing north of the lat 40°10′N management line accounts for 87% of the 2018 P. halibut discard mortality in the IFQ fishery (Table 24).

In terms of viability, the majority of P. halibut on IFQ vessels were classified as either excellent or dead, depending on the stratum (Tables 20, 21, 22, and 23). In 2018, the individuals caught with bottom trawl were evenly split between excellent and dead condition north of lat 40°10′N, with the exception of lat 40°10′N to Pt. Chehalis <60 fth, where a majority of individuals were in excellent condition (Table 20).

Estimated P. halibut discard mortality from all IFQ sectors and gears of the 2018 IFQ fishery is 1.54 mt less than the average for the previous five years (2013–17 mean = 34.19 mt, 2017 = 32.65 mt, including IFQ EM EFP).

The 2018 IFQ estimated P. halibut discard mortality for all gears is 82% less than the estimated discard morality from the 2010 LE bottom trawl fishery (Tables 2 and 78) and 85% less than the average mortality in the LE bottom trawl fishery over the years 2002–10 (220 mt). The management change to catch sharing in 2011 could explain this decrease in P. halibut catch. IBQs for P. halibut might have increased fisher incentives to avoid P. halibut bycatch and thereby changed fisher behavior (i.e., changing fishing grounds, gear, operations, or P. halibut handling).

Estimated bycatch weight of P. halibut from the at-sea hake component of the 2018 IFQ fishery increased slightly from 2017 (2017 = 0.55 mt, 2018 = 0.66; Tables 36, 37, 38, and 78). There was no fishing in the tribal sector. At-sea hake P. halibut length frequencies are given in Table 39.

IFQ Electronic Monitoring EFP

Estimated P. halibut discard mortality from the 2018 IFQ electronic monitoring exempted fishing permit, including fish discarded at the dock, was 5.55 mt from bottom trawl vessels, 0.18 mt from pot vessels, and 1.15 mt from midwater trawl vessels (Tables 40, 41, and 42).

Both IFQ EM bottom trawl and IFQ EM pot vessels had very slightly higher discard mortality rates than non-EM IFQ vessels when using the observer viability method (Tables 81 and 83). However, the observer viability method on IFQ EM bottom trawl vessels appears to give a lower DMR than the time-on-deck model (Table 81). Caution must be used in interpreting the DMRs reported in Appendix A 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 during observer sampling (Tables 80 and 82).

Non-Nearshore Fixed Gear Fishery

The 2018 estimated discard mortality of P. halibut in the longline portion of the LE sablefish endorsed sector decreased by 35% from 2017 (2017 = 38.01 mt, 2018 = 24.55 mt; Table 55) but is still well within the historical range for this fishery (2.94–104.45 mt; Table 55). Compared to 2017, the 2018 observed discard ratio decreased north of Pt. Chehalis (Table 48). Estimated discard of P. halibut from the pot portion of the LE sablefish endorsed sector increased compared to 2017 (2017 = 0.16 mt, 2018 = 0.37 mt; Table 55).

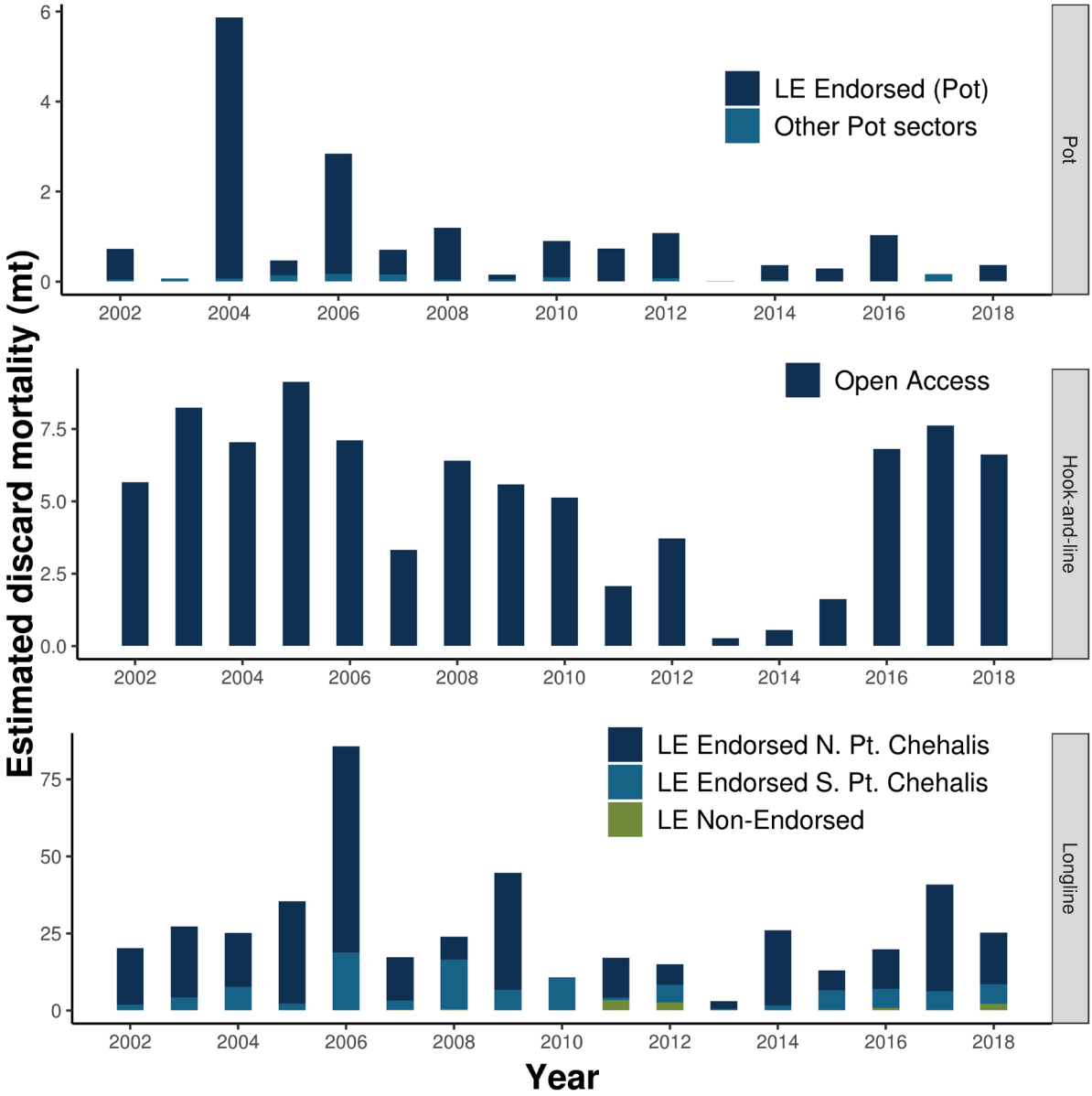

Figure 6. Estimated discard mortality of P. halibut in the non-nearshore fixed gear fishery by sector and year. We apply a fixed average discard rate from 2007–08 data to generate 2002–06 discard estimates for the OA sector, because only a portion of the fishery was observed in 2002–06. *Other Pot sectors*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

Discard of P. halibut among the LE sablefish nonendorsed longline vessels increased during 2018 relative to 2017 (2017 = 0.02 mt, 2018 = 0.61 mt); pot vessels in this sector had a slight decrease in P. halibut bycatch (2017 = 0.01 mt, 2018 < 0.01 mt) and remain a tiny fraction of total P. halibut discard (Table 55). P. halibut bycatch in OA H&L ticked up slightly during 2018 (to 4.31 mt), but pot vessels decreased (2018 = 0.02 mt). Both OA fixed gear sectors still account for only a small portion of total fixed gear bycatch.

Landings of target species decreased by about 400 mt in 2018 for both LE and OA longline and H&L vessels in all non-nearshore sectors (Table 47), despite observed P. halibut encounters and observer coverage being similar to 2017 levels for these vessels (Tables 49 and 44).

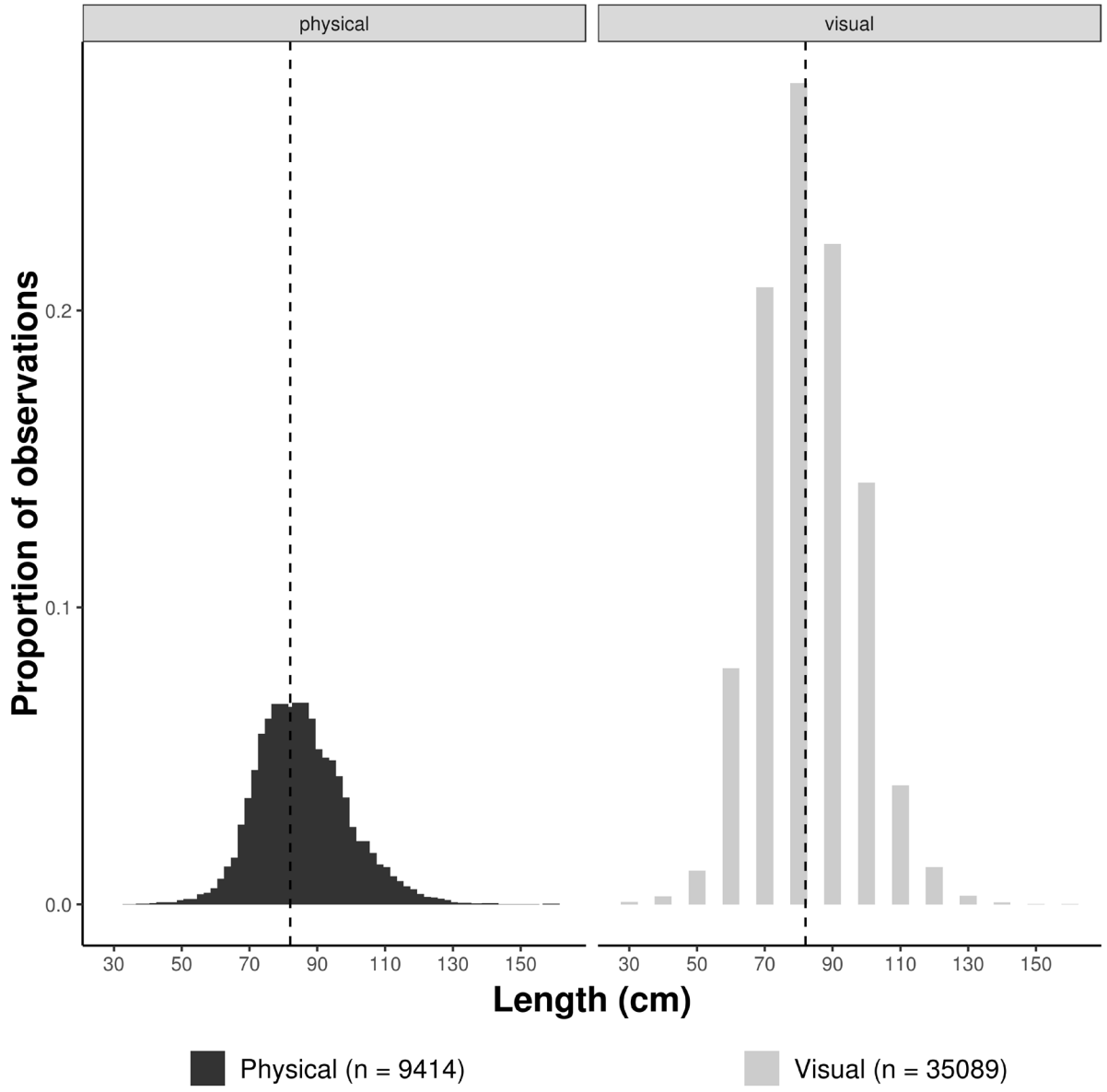

Figure 7. Length frequency distribution of discarded Pacific halibut on WCGOP-observed non-nearshore fixed gear limited entry (LE) and open access (OA) groundfish vessels, Sep 2003–Dec 2018. The majority of P. halibut lengths collected in this fishery were visual estimates (gray bars), which are only estimated in 10-cm bins. The sublegal/legal size cutoff (82 cm) is indicated by a vertical dashed line.

Physical measurements of P. halibut length frequency from the non-nearshore fixed gear sectors can be found in Tables 57, 58, 59, and 60. Visual estimates of length frequencies in the non-nearshore fixed gear sectors can be found in Table 61.

IPHC Pacific Halibut Directed

FOS attained a 26% coverage rate (Table 63) in the second year of covering the IPHC P. halibut directed fishery—a substantially larger fraction than in 2017 (7%). Observer coverage was fairly evenly distributed among the three openings of the fishery in 2018 (Figure 8). The P. halibut discard ratio in this fishery was 0.13, leading to a gross discard weight of 15.1 mt (Table 64). The majority of discarded fish had only minor or moderate injuries (Table 65). Thus, despite the high discard ratio, the estimated total discard mortality after accounting for viability was 2.4 mt. The majority of observed P. halibut discards were less than legal-size (82 cm), although a few were above it (Tables 67 and 68).

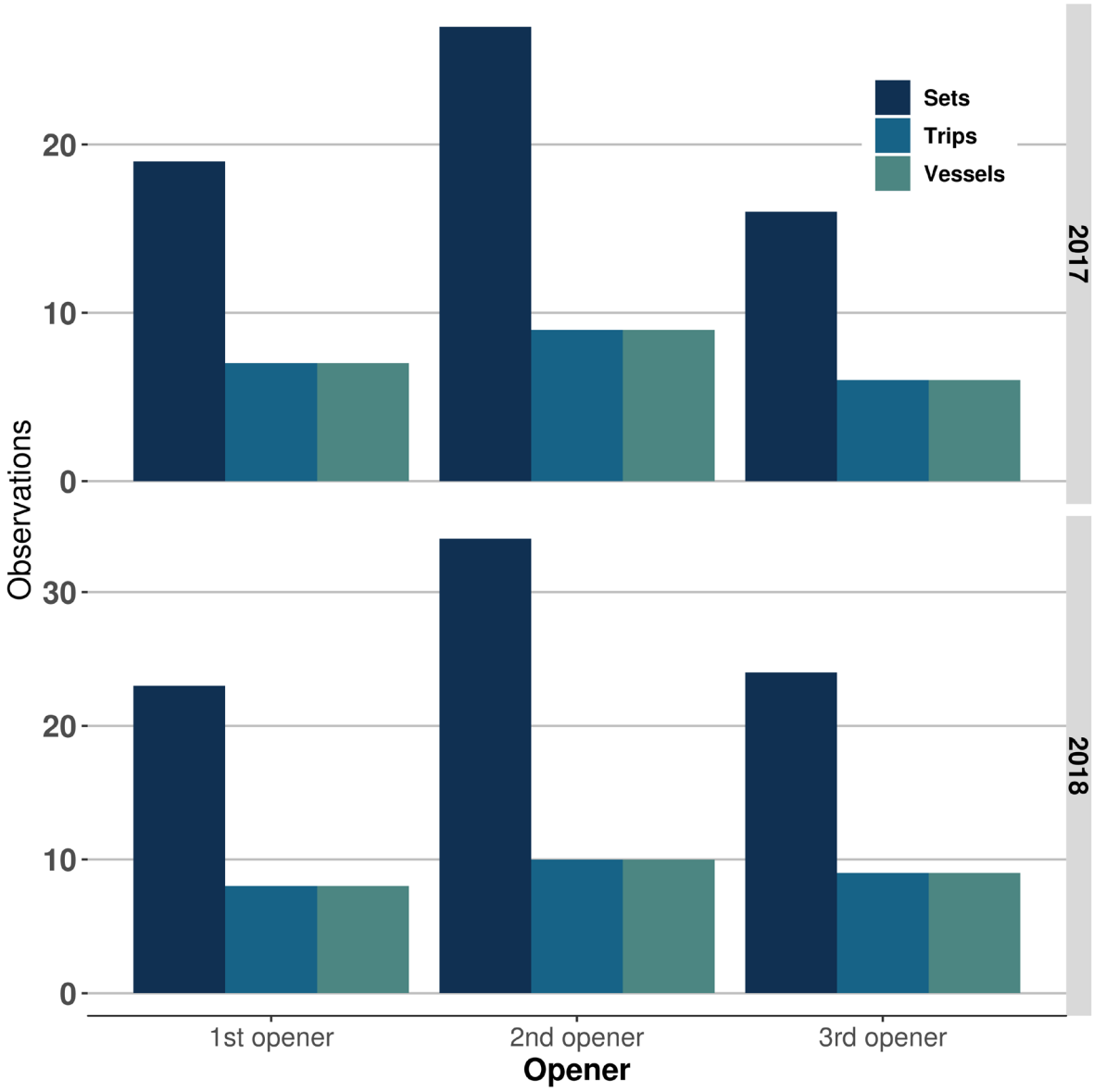

Figure 8. Number of sets, trips, and vessels by opening day for the P. halibut directed fishery.

Observed State Fisheries, EFPs, and Nongroundfish 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 2018 total mortality estimate for P. halibut (Tables 69, 70, 71, 72, and 73). Zero (0) catch of P. halibut was observed in the CA ridgeback prawn fishery (Table 75). Data from the 2018 CA sea cucumber fishery are confidential (Table 74).

Pacific halibut bycatch by year from non-EM EFP vessels has been zero since 2004 (Table 76). Pacific halibut landings from nongroundfish fisheries not observed by FOS were 22.02 mt in 2018 (Table 77).

Summary and Conclusions

IFQ Fishery

Estimated P. halibut discard mortality from the 2018 IFQ non-EM vessels was 25.77 mt and from IFQ EM vessels was 6.88 mt.

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, sample sizes are still very small, complicating interpretation.

P. halibut discard from the at-sea Pacific hake fishery in 2018 (0.66 mt) showed a slight increase relative to 2017 (0.55 mt), but remains below the historical average (2002–17, 1.07 mt).

Non-IFQ Fisheries

The 2018 estimates of P. halibut discard morality in the LE sablefish endorsed sector (24.93 mt) decreased relative to 2017 (38.17 mt), possibly due to decreases in the discard ratio and in effort, but it is not completely clear from available data. The 2018 Pacific halibut mortality estimates on LE sablefish nonendorsed vessels increased for longline gear (0.61 mt) but decreased for pot vessels (<0.01 mt) relative to last year. P. halibut mortality increased relative to 2017 on OA fixed gear H&L (4.31 mt) but decreased on OA pot vessels (0.02 mt) relative to last year. The increase in OA H&L bycatch is the third year in a row of P. halibut bycatch increases for this fishery and gear type.

In the second year of observer coverage in the IPHC P. halibut directed fishery, observer coverage was 26% and evenly distributed across the three openings. The total P. halibut discard mortality after accounting for viability was 2.4 mt.

In the California ridgeback prawn fisheries, zero (0) P. halibut catch was observed.

Estimated P. halibut mortality in all other non-IFQ observed fisheries remained low relative to the IFQ and non-nearshore sectors, and was within the range observed in previous years.

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Appendix A:
IFQ Electronic Monitoring DMR comparison

Pacific Fishery Management Council (PFMC) staff, the NOAA West Coast Region (WCR), and the International Pacific Halibut Commission (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 West Coast Groundfish Observation Program (WCGOP) aims to observe approximately 30% of EM fishing trips. DMRs for EM vessels were calculated and compared using two methods, the observer viability method and the 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 are 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 Viability Analysis.

The time-on-deck model was developed in a collaborative process between the Pacific States Marine Fisheries Commission (PSMFC) and 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, lower mortality rate). The time-on-deck model substitues for a viability assessment on EM vessels when fisheries observers are not present on the vessel to assess viabilities.

The comparison below is for informational purposes only. Due to low sample sizes, the NWFSC Fishery Observation Science Program (FOS) cautions against using these estimates for management purposes. Data from 2015–18 were obtained on pot vessels using EM, and from 2016–18 on bottom trawl vessels using EM. The corresponding non-EM data (i.e., 2015–18 pot and 2016–18 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 share fishery (see Tables 20 and 22).

Appendix B:
IPHC Length–Weight Conversion Table

Length (cm)	Weight (lb)	Length (cm)	Weight (lb)	Length (cm)	Weight (lb)	Length (cm)	Weight (lb)	Length (cm)	Weight (lb)	Length (cm)	Weight (lb)
10	0.02	40	1.43	70	8.77	100	27.87	130	65.17	160	127.71
11	0.02	41	1.59	71	9.19	101	28.77	131	66.82	161	130.32
12	0.02	42	1.68	72	9.61	102	29.70	132	68.48	162	132.96
13	0.04	43	1.81	73	10.05	103	30.67	133	70.17	163	135.65
14	0.04	44	1.94	74	10.49	104	31.64	134	71.89	164	138.36
15	0.07	45	2.09	75	10.98	105	32.63	135	73.66	165	141.12
16	0.07	46	2.25	76	11.44	106	33.64	136	75.44	166	143.90
17	0.09	47	2.43	77	11.95	107	34.68	137	77.25	167	146.72
18	0.11	48	2.58	78	12.46	108	35.74	138	79.08	168	149.54
19	0.13	49	2.76	79	12.99	109	36.84	139	80.95	169	152.49
20	0.15	50	2.95	80	13.51	110	37.94	140	82.87	170	155.45
21	0.18	51	3.15	81	14.07	111	39.07	141	84.79	171	158.42
22	0.20	52	3.35	82	14.64	112	40.21	142	86.75	172	161.44
23	0.24	53	3.57	83	15.23	113	41.38	143	88.76	173	164.51
24	0.26	54	3.79	84	15.83	114	42.59	144	90.79	174	167.60
25	0.31	55	4.01	85	16.45	115	43.81	145	92.84	175	170.75
26	0.35	56	4.25	86	17.09	116	45.06	146	94.93	176	173.92
27	0.40	57	4.52	87	17.75	117	46.32	147	97.05	177	177.14
28	0.46	58	4.76	88	18.41	118	47.62	148	99.21	178	180.40
29	0.51	59	5.05	89	19.09	119	48.94	149	101.39	179	183.71
30	0.57	60	5.31	90	19.80	120	50.29	150	103.62	180	187.06
31	0.62	61	5.62	91	20.53	121	51.65	151	105.87	181	190.46
32	0.71	62	5.93	92	21.25	122	53.07	152	108.16	182	193.87
33	0.77	63	6.24	93	22.02	123	54.48	153	110.50	183	197.36
34	0.84	64	6.57	94	22.80	124	55.93	154	112.83	184	200.86
35	0.93	65	6.90	95	23.59	125	57.41	155	115.24	185	204.43
36	1.01	66	7.25	96	24.41	126	58.91	156	117.66	186	208.03
37	1.10	67	7.61	97	25.24	127	60.43	157	120.13	187	211.67
38	1.21	68	7.98	98	26.08	128	61.99	158	122.62	188	214.71
39	1.32	69	8.38	99	26.96	129	63.56	159	125.16	189	218.50

Length (cm)	Weight (lb)	Length (cm)	Weight (lb)	Length (cm)	Weight (lb)	Length (cm)	Weight (lb)	Length (cm)	Weight (lb)	Length (cm)	Weight (lb)
190	222.89	200	263.17	210	308.25	220	358.38	230	413.91	240	475.09
191	226.70	201	267.46	211	313.03	221	363.69	231	419.76	241	481.55
192	230.56	202	271.79	212	317.86	222	369.05	232	425.69	242	488.05
193	234.48	203	276.17	213	322.73	223	374.45	233	431.66	243	494.60
194	238.45	204	280.60	214	327.67	224	379.92	234	437.68	244	501.24
195	242.44	205	285.10	215	332.65	225	385.45	235	443.76	245	507.92
196	246.50	206	289.62	216	337.70	226	391.03	236	449.91	246	514.66
197	250.60	207	294.21	217	342.79	227	396.67	237	456.13	247	521.48
198	255.74	208	298.84	218	347.93	228	402.36	238	462.39	248	528.36
199	258.93	209	303.51	219	353.13	229	408.09	239	468.72	249	535.28
										250	542.29

Appendix C:
Catch Share Weighted Length Frequencies

Catch composition data from the IFQ fishery for bottom trawl and pot gears were weighted. The frequency within each length bin was weighted based on the following equation:

$$n_{w_l} = n_l \times \frac{W_{s,t}}{\sum_l w_{s,t,l}} \times \frac{\sum_t W_{s,t}}{W_{s,t}} \times \frac{\hat{W}_s}{\sum_t W_{s,t}} = n_l \times \frac{\hat{W}_s}{\sum_l w_{s,t,l}} \quad \text{(C-1)}$$

where

- s = stratum,
- t = tow,
- l = length bin,
- n = number of measured fish,
- w = total weight of fish, as determined through the IPHC length–weight conversion table (Appendix B),
- W = total observed discard weight of Pacific halibut, and
- $\hat{W}$ = estimated total discard weight of P. halibut.

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