Pacific Halibut Bycatch in IPHC Area 2A in the 2007 Groundfish Trawl Fishery

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ABSTRACT

This report updates the estimates of Pacific halibut bycatch and mortality in the limited-entry groundfish bottom trawl fishery through the calendar year 2007. The estimates of halibut bycatch and mortality in the bottom trawl fishery are based upon the method developed in the report for 1999 (Wallace, 2000). The current report uses halibut bycatch rates observed for the 2007 calendar year by the West Coast Groundfish Observer Program (WCGOP). These rates are stratified by season, depth, latitude, and amount of arrowtooth flounder catch, and then multiplied by the amount of 2007 trawl effort in each stratum determined from Oregon and Washington trawl logbooks. Estimated halibut bycatch and mortality from other gear types has not been updated for 2007. Using the same average rate of discard mortality rate (50%) that has been used in recent reports, estimated mortality of Pacific halibut in the 2007 bottom trawl fishery is 175,133 lb net weight, of which 111,326 lb (64%) is legal-sized. These amounts are 48% and 56% lower than the corresponding estimates for the 2006 trawl fishery. We also present here an option which uses mortality estimates that are based on WCGOP observations of the viability of discarded halibut during the 2004-2007 bottom trawl fisheries. For 2004-2006, these observations, in conjunction with the corresponding survival rates used by the International Pacific Halibut Commission (IPHC), result in net mortality estimates that are 25-30% higher than those obtained using the fixed 50% mortality rate. For 2007, estimated halibut mortality using the observer viability data is estimated to be 273,657 lb, which is 56% higher than the amount estimated using the fixed 50% mortality rate. As in past reports, forecast of bycatch for the current year (2008) or future years is not attempted.

GROUNDFISH FISHERY BACKGROUND

Pacific halibut is a "prohibited species" for trawl gear on the west coast, therefore all halibut that is caught must be discarded. Even though there is no economic incentive to catch halibut, changes in the groundfish fishery and its management affect not only the amount of groundfish fishing effort, but also its geographic and temporal distribution. Since halibut bycatch rates vary among time and area strata, changes in the amount and distribution of effort will alter the amount of halibut bycatch that is estimated for the trawl fleet. Here we briefly describe the management changes that occurred in 2007.

In early 2007, review of the most recent observer data revealed higher rates of canary bycatch shoreward of the Rockfish Conservation Area (RCA) in the area north of 40°10' N. lat. with selective flatfish gear than had been expected. In response, the Pacific Fishery Management Council divided the northern area into seven latitudinal sub-areas, for purposes of specifying RCA boundaries. Most notably, the sub-areas north of 48°10' N. lat. and between 43°20.83' and 42°40.50' N. lat. were closed from the shore out to 150 or 200 fm from April through September. In general, the shoreward RCA boundaries in these sub-areas in other months and in other sub-areas throughout the year were set at 75 fm, as they had been throughout 2006. Seaward RCA boundaries were shallower (150 fm) north of 45°03.83' N. lat. in 2007 than they were in 2006 (200-250 fm) from April through August. During the remainder of the year, and in the region between 40°10' and 45°03.83' N. lat., seaward RCA boundaries were similar to those in 2006. The extended shoreward closure throughout much of 2007 along the far north Washington coast and the southern Oregon coast contributed to reductions of roughly 75% and 45% in the hours trawled shoreward of the RCA in those areas, respectively, compared to 2006. From the standpoint of halibut bycatch, reduced shoreward effort off northern Washington is particularly important, since halibut bycatch rates in that area/depth are typically among the highest on the US west coast. For the entire area north of 40°10' N. lat., trawl hours decreased by 45% (8,995 hours) shoreward of the RCA and increased by 36% (8,266 hours) seaward of it.

2007 BYCATCH ESTIMATES

Analysis of 2007 bycatch data from the West Coast Groundfish Observer Program

The WCGOP provided data for the complete calendar year of 2007 for this analysis. There were 1,752 bottom trawl tows between 48.667 and 40.667 degrees N. latitude included in this study (Figure 1). An estimated net total weight of 86,058 lb of halibut was caught in those tows. Seventy-five percent of these weights are estimated by using the Pacific halibut length-weight relationship (IPHC, personal communication), 18% reflect weighed fish, 5% are from visual estimates, and the remaining 2% are from other methods. The length frequencies of the halibut measured in the 2007 observer data are given in Table 1.

For all of the limited-entry groundfish bottom trawl activity, methods similar to those in Pikitch (1998) were used to analyze the observer data and identify appropriate strata for bycatch estimation. These strata are season (Jan-Aug and Sept-Dec), depth (0-75, 75-150 150-250, 250-700 fm), area (four latitudinal ranges) and catch of arrowtooth flounder (0-20 lb/hour and >20

lb/hour). Numbers of observed tows and trawl hours, halibut catch rates, and the proportions of legal-sized halibut (>81 cm) are summarized for each of these strata in Table 2.

Bottom Trawl Effort from Logbooks

Trawl logbook data for 2007 were obtained from PacFIN. Since ODFW does not collect logbook data for 100 percent of the trawl deliveries during a typical year, Oregon logbook effort (hours towed) was expanded using fish tickets on a port and month basis. This approach was used in order to avoid any potential bias created by unequal collection of logbooks in the three major ports (Astoria, Newport, and Coos Bay). WDFW's "extrapolated and expanded" trawl effort was used for Washington trips, which is calculated by the agency to account for less than 100 percent of logbook submissions.

Logbook trawl effort (hours) for Oregon was expanded to that entire fleet using the ratio of total groundfish catch reported on fish tickets divided by logbook groundfish catch, for each port and month. These expansion ratios were applied to the tow effort (hours) to arrive at the expanded effort for Oregon's trawl fleet. The stratification scheme identified through analysis of observer data was then applied to the expanded logbook effort observations. Total fleet effort for each stratum in 2007 is reported in Table 2. A comparison of trawl effort in 2006 and 2007, with depth strata compressed to two categories for tows conducted shallower and deeper than 150 fm, is presented in Table 3.

Viability Analyses

In prior years' reports, a fixed percentage (50%) of the entire estimated weight of discarded halibut has been assumed to survive being caught and discarded (Gregg Williams, IPHC, personal communication). Since 2004, WCGOP observers have collected viability data on discarded Pacific halibut, using the same condition key developed by the IPHC for use by observers in North Pacific fisheries. Observations of several external fish characteristics are used to assign each fish that is evaluated to one of three categories: Dead, Poor, or Excellent (Williams and Chen 2004). We therefore present analyses of discard survival: one based on the fixed percentage and a second option for discussion utilizing the observer viability data.

Pacific halibut pose unique challenges for observer sampling. When a trawl net is dumped on deck, most vessels will scan the catch for Pacific halibut and immediately return them to sea, which is termed "presorting". Vessels presort halibut to increase the likelihood of survival of the discarded fish. In addition to the need to quickly return halibut to, in order to promote survival, halibut are often too heavy and/or too awkward to weigh in observer baskets. Therefore, in most circumstances 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. Observers also have the option of measuring a halibut and then converting to weight using the IPHC length/weight conversion table or actually weighing the individual, but these rarely occur. Regardless of the sampling methodology used, the total weight of discarded Pacific halibut is estimated for all sampled tows.

There are two types of biological data collected on halibut: length and viability. Viability is determined using IPHC dichotomous keys, which use physical characteristics to indicate whether the individual is "dead", "poor", or "excellent". Table 4 summarizes viability data provided by WCGOP observers in the LE bottom trawl fishery from 2004 to 2007. During this period, the percentage of halibut weight with viability assessments has ranged from 16% to 24%.

The top row of Table 4 reports the mortality rates assigned to each of the condition categories by the IPHC (Williams and Chen 2004). Note that only 90% of the fish assigned to the "Dead" category are assumed to die following release. The percentage of halibut assigned to the Dead category nearly always increases with depth, as the percentage assigned to the Excellent category diminishes. The weighted average mortality rate for each year and depth interval is reported in the last column of Table 4, and was calculated by summing the product of each category's mortality rate and the proportion of weight assigned to it.

Table 5 reports the average mortality rate, average tow hours and average tow catch in each depth stratum and year from observer data. Tow hours and tow catch were used as factors in two simple regressions in order to evaluate their relationship with mortality rates. Results of these regressions are presented in Table 6. Regardless of whether actual or log-transformed values for stratum tow duration and catch per tow are used, they account for at least 75% of the variability in stratum mortality rates. These are, however, very rudimentary models that serve primarily to confirm that the viability assessments are consistent with our expectations that longer tow times and more crowded nets will tend to reduce the condition of fish that are caught.

Figure 2 shows the actual and predicted mortality rates, from the regression using transformed independent variables. Although predictions for 10 of the 16 strata are within 5% of the observed mortality rates, there is a clear year effect (i.e. all rates from 2005 are over-estimated and all from 2007 are under-estimated). This indicates that other factors are affecting fish condition, as assessed by observers. These could include water and air temperatures, fish size, or the proportion of rockfish (and their damaging spines) in the catch. Tow duration and catch amounts may also have differential effects depending on fish size or depth, and above some threshold, increases in either factor are likely to have diminishing marginal effects upon fish condition. Future exploration of these relationships may help to clarify the extent to which the condition of discarded halibut is influenced by fishing practices, environmental conditions, and stock dynamics, such as large recruitment events.

Method of Estimating Pacific Halibut Bycatch

Amounts of halibut bycatch in each stratum are estimated by multiplying total (expanded) stratum effort (tow hours) by the stratum halibut bycatch rate (pounds/tow hour). These amounts are then multiplied by the stratum average mortality rates (either the fixed 50% rate, or the appropriate rate based on observer viability assessment from Table 4) to estimated total halibut mortality. Estimates of bycatch and discard morality for the entire bottom trawl fleet are then obtained by summing values across strata. If there is logbook effort within a stratum, but no observed tows, the 2007 coast-wide average bycatch rate (14.35 kg per hour) is used. This value

is calculated as the unweighted average of the stratum means. Preliminary work done in 2001 using a sophisticated approach of imputing missing data showed little difference on the calculated total bycatch, between using the unweighted average of the stratum means and the imputed values.

Results

The estimated total amount of discarded halibut fell by nearly 50% between 2006 and 2007, to the lowest value in the past decade (211.8 mt, Table 7). A key factor in this change was the 45% reduction in trawl effort in depths less than 150 fm (Table 6), where halibut bycatch rates are generally higher. The effect of this reduction was enhanced by the closure, for much of the year, of the northern-most shoreward areas, where halibut bycatch rates tend to be higher than the remainder of the coast. The estimated mortality ratio of 4.2 pounds of halibut per tow hour is also the lowest of all years presented. Two methods were used to estimate the amount of mortality arising from these discards. Table 7 reports results, for 2007 and prior years, using the fixed mortality rate of 50% that has been used in recent annual reports. Because a fixed rate is applied, the estimate of 2007 halibut mortality (175.1 mt) is also nearly 50% lower than in 2006. For amounts of total bycatch/discard, total mortality, and legal-sized mortality, 95% confidence limits are reported in parentheses below the point estimates for years 2004-2007. Confidence limits should be viewed as minimum estimates, since trawl effort is assumed known without error.

The proportion of legal-sized halibut (> 81cm) is estimated from the length frequencies of halibut measured in the observer data (Table 1). All measurements of fish lengths are converted to fish weight based on a length-weight relationship for Pacific halibut, and the proportion of discard that is of legal size (by weight) is computed for each stratum (Table 2). The average legal-sized proportion (calculated as the unweighted average of the stratum means) is used when no other estimate was available. During preparation of this report, an error was identified in the programming used to estimate the proportion of mortality comprised by legal-sized halibut for the years 2004-2006. Correcting that problem resulted in significantly lower proportions of mortality that were of legal size than were previously reported for those years. The reduction in these proportions ranges from 20% in 2004 to 47% in 2006. Since 2004, the corrected annual percentages of legal-sized mortality range from 56% in 2004 to 40% in 2006. The percentage in 2007 (48%) is slightly higher than the 4-year average (47%).

Table 8 reports the same quantities as Table 7 for 2004 through 2007, but with halibut mortality estimated using observer assessment of fish viability according to the same condition key developed by the IPHC. The annual amounts of total and legal-sized mortality are higher, in each year, when fish viability is used to determine average mortality rates (Figure 3), though yearly rank order remain the same for both. The viability-based estimates are within 7% of the fixed-rate estimates in 2004 and 2006, however they are nearly 50% higher in 2007. The reduction in total mortality between 2006 and 2007 (26%) is not as large as that estimated using the fixed mortality rate, due primarily to the substantial increase in the proportions of fish caught shallower than 250 fm that were assigned to the “Dead” category (Table 3). Table 9 summarizes the average length of observed halibut, by year and depth interval, with the proportions of total mortality from legal-sized fish from both models.

In preliminary review of this analysis by the IPHC, a question was raised regarding the application of the viability category mortality rates, which were compiled based on numbers of fish, to fleet weight estimates within each stratum. We believe that the manner in which our calculations have been performed is mathematically equivalent to expanding the numbers in each category to the stratum level and then applying mortality assumptions and converting to weight. However, we are developing additional programming to compute mortalities using this latter approach.

Finally, Table 10 summarizes available halibut mortality estimates by fishery from 1977 through 2007. Bycatch mortality estimates for 1977-1997 are included from Williams et al. 1998. Limited Entry groundfish bottom trawl estimates are presented for 2004 through 2007, using both the 50% mortality rate method and the mortality rates based on observed viability data.

It is not possible to make a forecast for the 2008 fishery given lack of a methodology to project the distribution of effort among model strata prior to the complete availability of a year's logbook data.

REFERENCES

Pikitch, E.K., Wallace, J.R., Babcock, E.A., Erickson, D.L., Saelens, M., and Oddsson, G. (1998) Pacific halibut bycatch in the Washington, Oregon, and California groundfish and shrimp trawl fisheries. North American Journal of Fisheries Management. Volume 18, pp. 569-586.

Wallace, J.R. (2000) Unpublished report. Pacific halibut discard in the EDCP Observer Program. June 2000. 18 pg.

Williams, G. H. and D. Chen (2004). Pacific Halibut Discard Mortality Rates in the 1990-2002 Alaskan Groundfish Fisheries, With Recommendations For Monitoring in 2004-2006. Int. Pac. Halibut Comm., online report available at: http://www.iphc.washington.edu/halcom/research/bycatch/2004dmrrep.pdf.

Williams, G. H., G. Stauffer, H. Weeks, M. Saelens, J. Scordino, D. Bodenmiller, and T. Northup (1998). Pacific halibut bycatch in Area 2A: Bycatch rates and current estimates of bycatch mortality. Int. Pac. Halibut Comm. Rep. of Assess. and Res. Activ. 1998: 269-282.

Table 1. Length frequencies for Pacific halibut collected by the West Coast Groundfish Observer Program during 2007. (The upper limits on the length intervals are inclusive, the lower limits are not.)

Length Interval (cm)	Length Freq.	Percent Length Freq.
25-30	0	0.00
30-35	0	0.00
35-40	0	0.00
40-45	0	0.00
45-50	0	0.00
50-55	6	0.33
55-60	62	3.41
60-65	232	12.75
65-70	342	18.80
70-75	324	17.81
75-80	253	13.91
80-85	170	9.35
85-90	135	7.42
90-95	102	5.61
95-100	88	4.84
100-105	37	2.03
105-110	37	2.03
110-115	16	0.88
115-120	6	0.33
120-125	2	0.11
125-130	2	0.11
130-135	1	0.05
135-140	2	0.11
140-145	1	0.05
145-150	1	0.05
150-155	0	0.00
155-160	0	0.00
160-165	0	0.00
165-170	0	0.00
170-175	0	0.00
175-180	0	0.00
180-185	0	0.00
Total	1819	100

Table 2. Numbers of observed tows and Pacific halibut catch rates by strata, observed in the 2007 LE groundfish bottom trawl fishery by the West Coast Groundfish Observer Program, with overall fleet trawl effort from Oregon and Washington logbook data. The last two columns, from 2006, are for comparison purposes. (The upper limits are inclusive for all intervals; the lower limits are not.)

SEASON: JANUARY - AUGUST

Arrowtooth Catch (lb/h)	Latitude	Depth (Fathoms)	Number of Observed Tows	Number of Tows with ≥ 1 Halibut	Wgt. (kg., rnd) Halibut per Hour	Trawl Effort (hours) from OR & WA	Proportion Legal by Weight	Number of Observed Tows **2006**	Wgt. (kg., rnd) Halibut per Hour **2006**
≤ 20	40.667 - 42.667	0 - 75	0	0		329.53		0	
		75 - 150	0	0		0.00		0	
		150 - 250	17	12	6.06	473.37	0.70	9	3.84
		250 - 700	24	1	0.04	1497.76	1.00	50	0.07
	42.667 - 46.667	0 - 75	161	92	8.92	3891.90	0.14	402	10.59
		75 - 150	6	2	1.55	66.99	1.00	62	7.90
		150 - 250	102	23	1.17	3118.54	0.70	71	1.83
		250 - 700	219	7	0.04	5215.63	0.39	137	0.14
	46.667 - 47.667	0 - 75	144	80	9.28	2265.87	0.13	155	10.73
		75 - 150	0	0		16.72		4	1.89
		150 - 250	19	10	9.67	343.63	0.87	6	1.63
		250 - 700	17	2	0.06	1002.33	0.00	27	0.25
	47.667 - 48.667	0 - 75	15	12	25.68	514.89	0.37	146	36.88
		75 - 150	0	0		51.80		18	22.33
		150 - 250	35	15	13.45	284.21	1.00	24	5.16
		250 - 700	51	9	0.66	1019.73	1.00	34	0.18
> 20	40.667 - 42.667	0 - 75	0	0		0.00		0	
		75 - 150	0	0		0.00		0	
		150 - 250	1	*	*	*		0	
		250 - 700	6	2	0.29	59.73	0.61	3	0.00
	42.667 - 46.667	0 - 75	63	43	15.85	782.96	0.27	144	12.82
		75 - 150	1	*	*	*	*	83	13.63
		150 - 250	129	87	7.43	3143.69	0.50	164	3.17
		250 - 700	105	51	5.92	1936.14	0.62	61	1.62
	46.667 - 47.667	0 - 75	22	22	10.43	332.36	0.25	38	11.25
		75 - 150	2	*	*	*		9	12.32
		150 - 250	35	26	15.62	518.92	0.65	15	5.57
		250 - 700	3	1	3.84	274.31		4	0.48
	47.667 - 48.667	0 - 75	2	*	*	*	*	54	51.79
		75 - 150	0	0		32.32		36	44.26
		150 - 250	58	38	15.86	810.61	0.76	21	27.57
		250 - 700	35	22	23.28	386.65	0.90	22	8.83

Table 2. Continued.

SEASON: SEPTEMBER - DECEMBER

Arrowtooth Catch (lb/h)	Latitude	Depth (Fathoms)	Number of Observed Tows	Number of Tows with ≥ 1 Halibut	Wgt. (kg., rnd) Halibut per Hour	Trawl Effort (hours) from OR & WA	Proportion Legal by Weight	Number of Observed Tows **2006**	Wgt. (kg., rnd) Halibut per Hour 2006
≤ 20	40.667 - 42.667	0 - 75	10	3	1.39	29.81	0.60	0	
		75 - 150	0	0		0.00		0	
		150 - 250	9	7	5.20	369.95	0.92	5	1.25
		250 - 700	12	2	0.26	659.08	0.42	8	0.91
	42.667 - 46.667	0 - 75	88	23	1.36	1388.50	0.41	123	0.36
		75 - 150	0	0		18.07		4	0.00
		150 - 250	24	9	2.84	1377.71	0.77	8	5.03
		250 - 700	97	4	0.13	2938.72	0.00	69	0.11
	46.667 - 47.667	0 - 75	15	4	2.27	424.63	0.00	12	0.23
		75 - 150	0	0		3.10		0	
		150 - 250	6	4	7.78	83.47	0.91	1	0.00
		250 - 700	8	1	0.33	230.49	0.65	1	0.97
	47.667 - 48.667	0 - 75	30	13	3.54	244.94	0.48	41	61.49
		75 - 150	0	0		0.00		6	75.05
		150 - 250	3	3	8.26	136.21	1.00	0	
		250 - 700	14	2	0.59	614.17	1.00	6	0.81
> 20	40.667 - 42.667	0 - 75	0	0		0.00		0	
		75 - 150	0	0		0.00		0	
		150 - 250	0	0		114.75		0	
		250 - 700	3	0		68.29		1	1.73
	42.667 - 46.667	0 - 75	21	7	0.88	215.09	0.45	76	0.74
		75 - 150	0	0		19.57		10	0.49
		150 - 250	87	43	5.84	2571.13	0.70	67	9.11
		250 - 700	39	7	1.22	1110.78	0.80	39	0.42
	46.667 - 47.667	0 - 75	0	0		58.63		7	0.59
		75 - 150	0	0		0.00		0	
		150 - 250	5	3	4.27	145.04		1	4.36
		250 - 700	3	1	0.34	108.34	1.00	0	
	47.667 - 48.667	0 - 75	2	*	*	*	*	6	226.20
		75 - 150	0	0		2.24		25	0.71
		150 - 250	3	2	8.87	175.74	1.00	8	28.96
		250 - 700	1	*		*		4	3.14

Table 3. Trawl effort (hours) in the 2006 and 2007 Limited Entry groundfish bottom trawl fisheries off Oregon and Washington.

Arrowtooth Catch (lb/h)	Latitude	Depth (fathoms)	Trawl effort (hours)		% change from 2006 to 2007
			2006	2007	
≤ 20	40.667 - 42.667	0 - 150	351	359	2%
		150 - 700	2273	3000	32%
	42.667 - 46.667	0 - 150	7087	5365	-24%
		150 - 700	8694	12651	46%
	46.667 - 47.667	0 - 150	2700	2710	0%
		150 - 700	1124	1660	48%
	47.667 - 48.667	0 - 150	2456	812	-67%
		150 - 700	2134	2054	-4%
	Total	0 - 150	12595	9247	-27%
		150 - 700	14225	19365	36%
		All depths	26820	28612	7%
> 20	40.667 - 42.667	0 - 150	5	0	-100%
		150 - 700	263	334	27%
	42.667 - 46.667	0 - 150	4761	1101	-77%
		150 - 700	6657	8762	32%
	46.667 - 47.667	0 - 150	1225	428	-65%
		150 - 700	511	1047	105%
	47.667 - 48.667	0 - 150	1245	61	-95%
		150 - 700	1116	1531	37%
	Total	0 - 150	7236	1589	-78%
		150 - 700	8547	11673	37%
		All depths	15783	13262	-16%
Total	Total	0 - 150	19831	10836	-45%
		150 - 700	22772	31038	36%
		All depths	42602	41874	-2%

Table 4. Annual amounts and percentages of observed Pacific halibut discard assigned to each viability condition category, for four depth strata during the 2004-2007 Limited Entry groundfish bottom trawl fisheries.

	Total weight of observed halibut (lb)	Weight of discards (lb) by fish viability category				% of total lb with viabillity assessment	Percent of samples where fish viability was assessed			weighted average mortality rate
		Unknown	Dead	Poor	Excellent		Dead	Poor	Excellent	
Mortality rate applied to discards in category			90%	55%	20%		90%	55%	20%	
2004										
0+ thru 75 fm	73,196	63,579	2,238	2,449	4,930	13%	23%	25%	51%	0.452
75+ thru 150 fm	18,598	17,397	566	351	284	6%	47%	29%	24%	0.632
150+ thru 250 fm	53,218	39,731	8,256	2,808	2,422	25%	61%	21%	18%	0.701
250+ thru 700 fm	19,496	17,018	1,849	214	416	13%	75%	9%	17%	0.752
All depths	**164,508**	**137,724**	**12,909**	**5,823**	**8,051**	**16%**				
2005										
0+ thru 75 fm	99,455	79,715	8,402	4,639	6,699	20%	43%	24%	34%	0.580
75+ thru 150 fm	75,722	60,948	5,530	4,689	4,555	20%	37%	32%	31%	0.573
150+ thru 250 fm	36,130	20,817	9,637	2,751	2,925	42%	63%	18%	19%	0.703
250+ thru 700 fm	10,302	6,523	2,275	893	611	37%	60%	24%	16%	0.704
All depths	**221,609**	**168,003**	**25,844**	**12,972**	**14,790**	**24%**				
2006										
0+ thru 75 fm	104,680	92,552	4,022	2,156	5,950	12%	33%	18%	49%	0.494
75+ thru 150 fm	21,674	20,317	704	240	413	6%	52%	18%	30%	0.625
150+ thru 250 fm	22,067	16,140	3,970	734	1,223	27%	67%	12%	21%	0.712
250+ thru 700 fm	4,522	2,022	2,005	195	300	55%	80%	8%	12%	0.789
All depths	**152,943**	**131,031**	**10,702**	**3,325**	**7,885**	**14%**				
2007										
0+ thru 75 fm	32,217	26,020	3,973	548	1,676	19%	64%	9%	27%	0.680
75+ thru 150 fm	156	103	36	0	17	34%	68%	0%	32%	0.673
150+ thru 250 fm	37,806	26,831	8,690	919	1,366	29%	79%	8%	12%	0.784
250+ thru 700 fm	15,909	14,137	1,388	233	151	11%	78%	13%	9%	0.794
All depths	**86,088**	**67,092**	**14,087**	**1,700**	**3,209**	**22%**				
All years and depths		**940,608**	**112,999**	**45,940**	**64,662**	**19%**				

Table 5. Pacific halibut discard mortality rates, average tow duration, and average tow catch of all species from WCGOP observed Limited Entry bottom trawl tows north of 40.667° N. lat. by year and depth interval from 2004-2007.

	Depth (fm)			
	0+ thru 75	75+ thru 150	150+ thru 250	250+ thru 700
2004				
Average mortality rate	0.452	0.632	0.701	0.752
Average tow hours	1.89	2.39	3.97	5.62
Average tow catch (lb)	1,984	3,747	5,101	4,886
2005				
Average mortality rate	0.580	0.573	0.703	0.704
Average tow hours	2.42	2.21	4.88	6.29
Average tow catch (lb)	3,072	4,580	4,915	4,993
2006				
Average mortality rate	0.494	0.625	0.712	0.789
Average tow hours	2.55	2.42	4.36	5.83
Average tow catch (lb)	2,279	4,066	5,062	5,306
2007				
Average mortality rate	0.680	0.673	0.784	0.794
Average tow hours	2.71	2.71	4.49	6.16
Average tow catch (lb)	2,701	4,188	5,505	4,867

Table 6. Results of Ordinary Least Squares Regression, with year-depth stratum average mortality rate as the dependent variable.

		Explanatory variables	
		Untransformed	Log-transformed
Adjusted R Square		0.749	0.789
Intercept	coefficient	0.36301	-0.70730
	p-value	*0.00001*	*0.11705*
Stratum avg. tow duration	coefficient	0.02721	0.12315
	p-value	*0.04379*	*0.01172*
Stratum avg. catch/tow lbs	coefficient	0.00005	0.14675
	p-value	*0.01559*	*0.01968*

Table 7. Halibut bycatch and mortality in the Oregon and Washington Limited Entry bottom trawl fisheries for groundfish off the west coast, **using a 50% rate of mortality for discards**. Estimates from 2002-2007 are based on observations by the West Coast Groundfish Observer Program. All estimates in this table (except the seventh and last column) are derived from a sum over strata cells; see the text for details. The 95% confidence limits, based on the variability in discard of halibut per trawl hour, are given in parentheses. Note that the trawl effort is assumed known without error; hence these confidence limits are a minimum estimate.

Year	Trawl Effort (hours)	Estimated Halibut Bycatch (numbers)	Estimated Halibut Bycatch (kg, round)	Estimated Halibut Bycatch (lb, net)	Estimated Total Halibut Mortality (lb, net)	Est. Mortal-ity (lb) per Trawl Hour	Estimate d Legal-Sized Halibut Mortality (lb, net)	Estimated Legal-Sized divided by Total Halibut Mortality
1998	92,294	164,961	1,259,374	2,082,690	1,041,345	11.3	691,755	0.6643
1999	81,420	147,995	1,144,236	1,892,280	946,140	11.6	638,091	0.6744
2000	70,363	122,234	944,120	1,561,338	780,669	11.1	523,097	0.6701
2001	67,199	124,969	962,348	1,591,482	795,741	11.8	532,912	0.6697
2002	52,168	NA	618,913	1,023,527	511,764	9.8	286,221	0.5593
2003	58,339	NA	558,544	923,693	461,847	7.9	366,745	0.7941
2004	37,495	NA	296,225 (192k-464k)	489,882 (317k-768k)	244,941 (158k-384k)	6.5	136,691 (87k-220k)	0.5581
2005	39,377	NA	432,806 (255k-655k)	715,752 (421k-1,084k)	357,876 (210k-542k)	9.1	152,264 (87k-236k)	0.4254
2006	42,602	NA	403,194 (163k-688k)	666,782 (269k-1,137k)	333,391 (134k-569k)	7.8	134,394 (57k-251k)	0.4031
2007	41,874	NA	211,801 (95k- 349k)	350,266 (157k-577k)	175,133 (78k-288k)	4.2	84,036 (31k-146k)	0.4798

Notes: Halibut bycatch by the California bottom trawl fishery is not included. Proportion of legal-sized mortality (>81 cm) is estimated from length frequencies of fish measured by the West Coast Groundfish Observer Program. 1 kg, round = 1.65375 pounds, net weight.

Table 8. Halibut bycatch and mortality in the Oregon and Washington LE bottom trawl fisheries for groundfish off the west coast, **using rates of discard mortality derived from observer assessment of fish viability**. All estimates in this table (except the seventh and last column) are derived from a sum over strata cells; see the text for details. The 95% confidence limits, based on the variability in discard of halibut per trawl hour, are given in parentheses. Note that the trawl effort is assumed known without error; hence these confidence limits are a minimum estimate.

Year	Trawl Effort (hours)	Estimated Halibut Bycatch (kg, round)	Estimated Halibut Bycatch (lb, net)	Estimated Total Halibut Mortality (lb, net)	Mortality (lb) per Trawl Hour	Halibut Bycatch Mortality divided by Halibut Bycatch	Est. Legal-sized Halibut Mortality (lb, net)	Legal-sized divided by Total Halibut Mortality
2004	37,495	296,225 (192k-464k)	489,882 (317k-768k)	260,590 (169k-423k)	6.9	0.5319	153,804 (98k-254k)	0.5902
2005	39,377	432,806 (255k-655k)	715,752 (421k-1,084k)	417,863 (246k-635k)	10.6	0.5838	178,218 (102k-278k)	0.4265
2006	42,602	403,194 (163k-688k)	666,782 (269k-1,137k)	345,648 (139k-593k)	8.1	0.5184	158,570 (59k-281k)	0.4587
2007	41,874	211,801 (95k- 349k)	350,266 (157k-577k)	257,338 (1115k-425k)	6.1	0.7347	127,677 (48k-222k)	0.4961

Notes: Halibut bycatch by the California bottom trawl fishery is not included. Proportion of legal-sized mortality (>81 cm) is estimated from length frequencies of fish measured by the West Coast Groundfish Observer Program. 1 kg, round = 1.65375 pounds, net weight.

Table 9. Average length (cm) of Pacific halibut observed in the west coast bottom trawl fishery by year and depth interval from 2004-2007.

Year	Depth interval (fm)					Proportion of legal-sized Total Halibut Mortality from	
	0+ thru 75	75+ thru 150	150+ thru 250	250+ thru 700	All Depths	Table 7	(Table 8)
2004	75.60	82.13	84.72	87.71	80.59	0.5581	(0.5902)
2005	73.34	76.58	81.64	88.48	76.36	0.4254	(0.4265)
2006	72.25	77.34	79.78	88.48	74.38	0.4031	(0.4587)
2007	70.03	78.50	82.06	81.79	77.42	0.4798	(0.4961)

Note: The proportion of mortality which is of legal size from Table 7 is estimated using a constant 50% rate of mortality, whereas Table 8 proportions utilize observer assessments of fish viability.

Table 10. Summary of total estimated bycatch mortality of Pacific halibut, in thousands of pounds, net weight, by fishery in 2A. Bycatch mortality estimates for 1977-1997 are reported from Table 3 in Williams, et al. 1998.

Year	Foreign, JV & Catcher-Proc.	Groundfish Trawls	Shrimp Trawls	Hook & Line	TOTAL
1977	3	308	82	16	409
1978	2	308	82	16	408
1979	1	308	82	16	407
1980	1	308	82	16	407
1981	Trace	308	82	16	406
1982	Trace	308	82	16	406
1983	1	308	82	16	407
1984	Trace	308	82	16	406
1985	Trace	308	82	16	406
1986	1	308	82	16	407
1987	1	308	82	16	407
1988	1	308	82	16	407
1989	2	308	82	16	408
1990	2	308	82	16	408
1991	2	308	82	16	408
1992	0	385	43	16	444
1993	0	385	43	16	444
1994	0	385	43	16	444
1995	0	548	50	16	614
1996	0	548	50	16	614
1997	0	548	50	16	614
1998	0	1,041	25	---	---
1999	---	946	---	---	---
2000	---	781	---	---	---
2001	---	796	---	---	---
2002	---	512	---	---	---
2003	---	462	---	---	---
2004	---	245 (261)	---	---	---
2005	---	358 (418)	---	---	---
2006	---	333 (346)	---	---	---
2007	---	175 (257)	---	---	---

Note: Bycatch mortality by groundfish trawls in 1998-2007 does not include fisheries off California. Bycatch mortality by shrimp trawls in 1998 does not include fisheries off California and Washington. 2004-2007 groundfish trawl estimates are given based on a 50% mortality rate and (based on observed fish viability).

Table 11. Summary of estimated mortality of legal-sized Pacific halibut, in thousands of pounds, net weight, by fishery in Area 2A. The bycatch mortality estimate for legal-sized halibut for 2005 is from this report. (Sums across fisheries may not equal the TOTAL due to rounding.)

Year	Foreign, JV & Catcher-Proc.	Groundfish Trawls	Shrimp Trawls	Hook & Line	TOTAL
1977	2	191	51	10	254
1978	1	191	51	10	253
1979	0.6	191	51	10	252
1980	0.6	191	51	10	252
1981	Trace	191	51	10	252
1982	Trace	191	51	10	252
1983	0.6	191	51	10	252
1984	Trace	191	51	10	252
1985	Trace	191	51	10	252
1986	0.6	191	51	10	252
1987	0.6	191	51	10	252
1988	0.6	191	51	10	252
1989	1	191	51	10	253
1990	1	191	51	10	253
1991	1	191	51	10	253
1992	0	239	27	10	275
1993	0	239	27	10	275
1994	0	239	27	10	275
1995	0	340	31	10	381
1996	0	340	31	10	381
1997	0	340	31	10	381
1998	0	692	16	---	---
1999	---	638	---	---	---
2000	---	523	---	---	---
2001	---	533	---	---	---
2002	---	286	---	---	---
2003	---	367	---	---	---
2004	---	137 (154)	---	---	---
2005	---	152 (178)	---	---	---
2006	---	134 (159)	---	---	---
2007	---	84 (128)	---	---	---

Note: Bycatch mortality by groundfish trawls in 1998-2004 does not include fisheries off California. Bycatch mortality by shrimp trawls in 1998 does not include fisheries off California and Washington. 2004-2007 groundfish trawl estimates are given based on a 50% mortality rate and (based on observed fish viability).

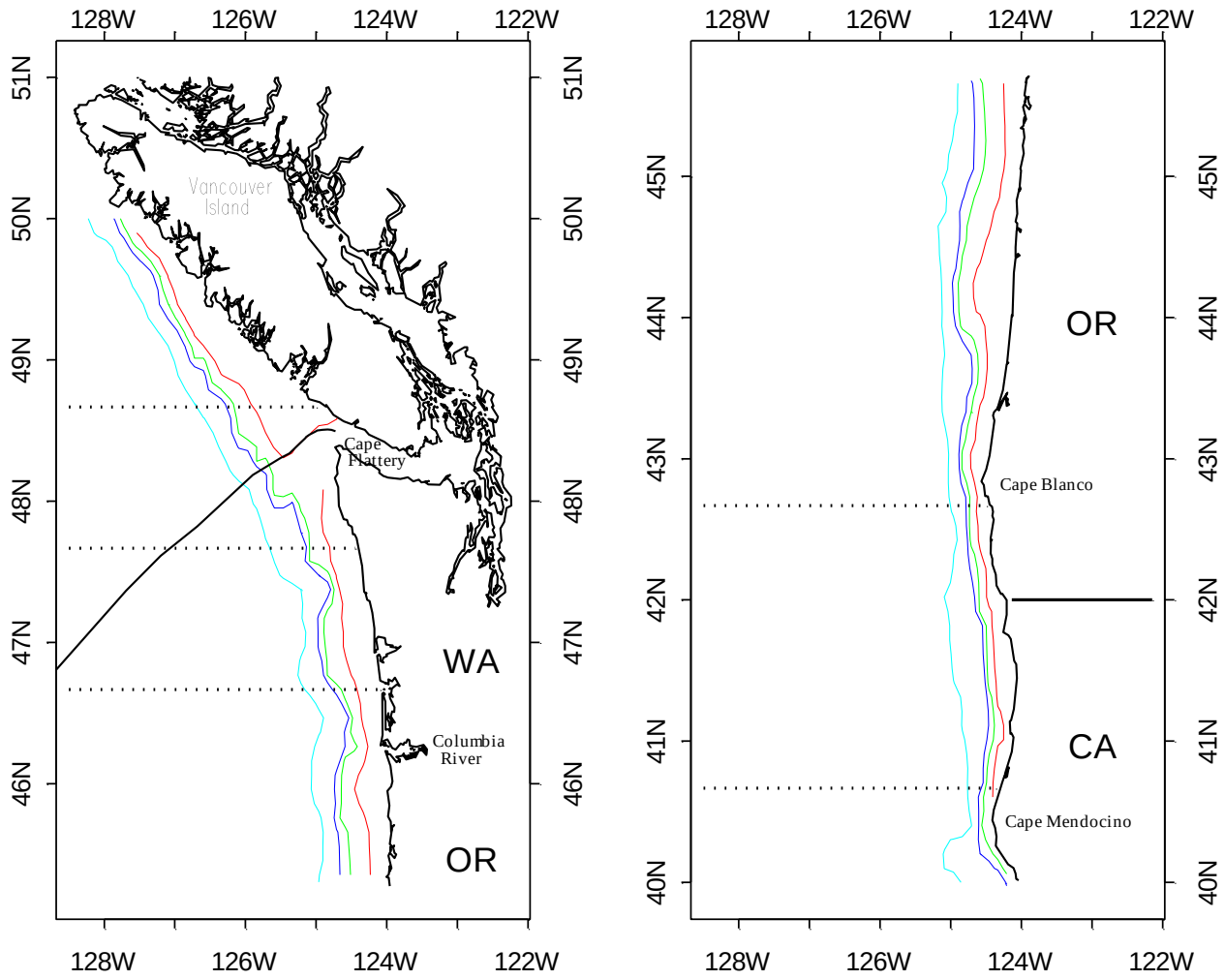

Figure 1. A map of IPHC area 2A with the latitudinal strata demarcated by dotted lines. In the most northerly strata only the area east of the EEZ line is covered by this report. Depth contours are plotted for 75, 150, 250, and 700 fathoms.

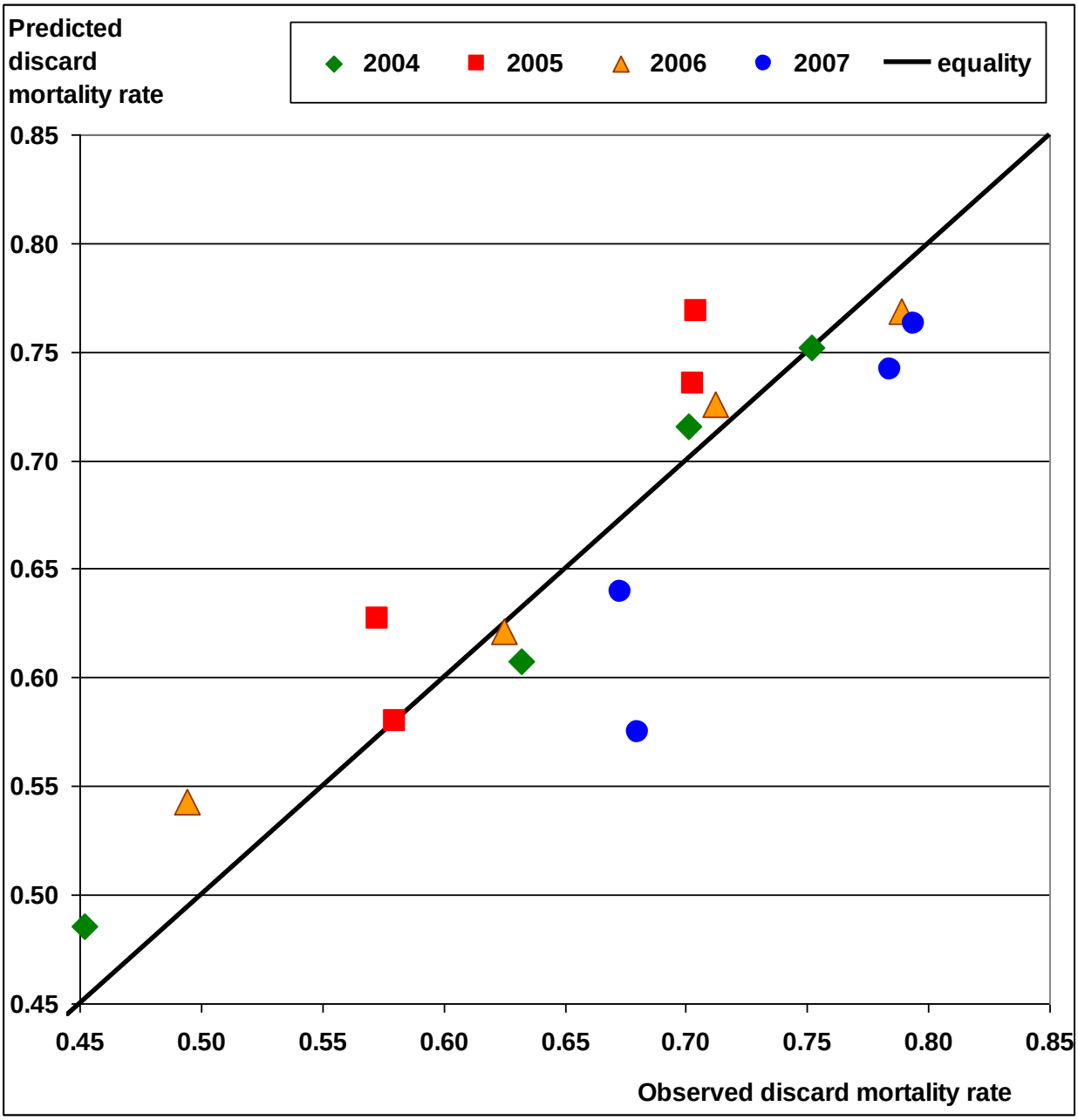

Figure 2. Observed and predicted average stratum discard mortality rates for Pacific halibut, based on the regression results reported in Table 5, using log-transformed average tow duration and average total catch per tow as explanatory variables.

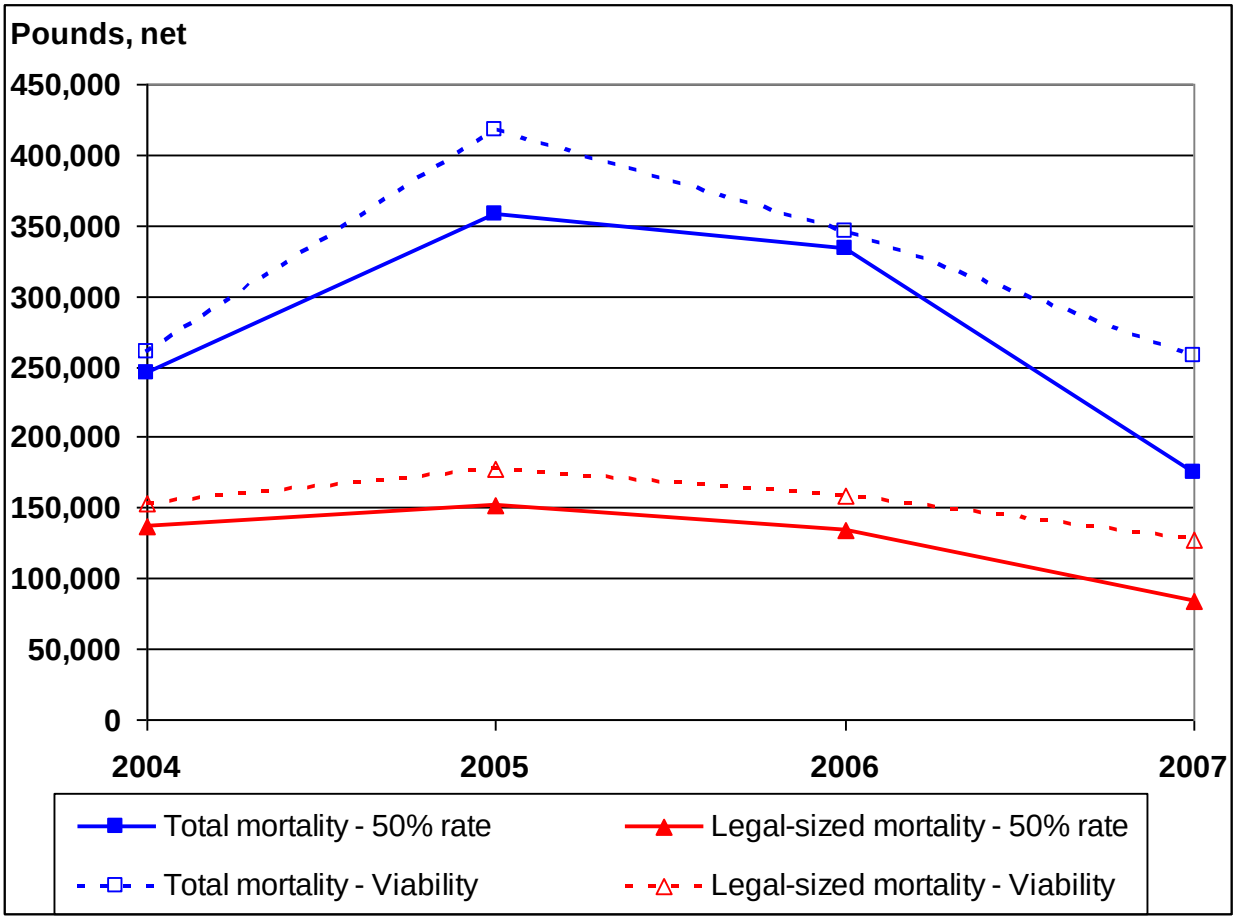

Figure 3. Comparison of estimated amounts of total and legal-sized discard mortality of Pacific halibut in the Limited Entry bottom trawl fishery using a 50% mortality rate and rates based on viability evaluation by at-sea observers from 2004-2007.