STATE OF WASHINGTON
DEPARTMENT OF FISH AND WILDLIFE

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TO: **Puget Sound Dungeness Crab Fishery Managers**

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SUBJECT: Updates to Puget Sound Dungeness Crab Catch Record Card data processing for generation of recreational catch estimates

Executive Summary

Overview

- Each year, the Washington Department of Fish and Wildlife (WDFW) estimates Dungeness crab harvest in Puget Sound using Catch Record Cards (CRCs). Harvest estimates based on Dungeness crab CRCs are generated by WDFW's CRC data team.
- Harvest estimates from past years (2011-2022) were found to exclude out of season harvest (pre-season and post-season) reported on summer and winter CRCs. Furthermore, the bias correction, which is used to estimate Dungeness crab harvest from recreational harvesters that did not report their CRC, has been applied incorrectly.

The issue and how it was found

- Analysis of reported summer and winter 2022 Dungeness crab CRCs revealed a discrepancy between harvest estimates made by WDFW's CRC unit and staff from the Puget Sound crustacean team. This analysis revealed certain categories of reported CRC data were being excluded from the final catch estimate and the bias correction was being applied incorrectly.

What was changed

- To ensure all catch is accounted for, Puget Sound crustacean staff have developed a new catch accounting methodology to verify the CRC unit is accounting for all catch reported on summer and winter CRCs.

Moving forward

- Updated CRC data processing rules will be used for all CRC based catch estimates.
- The Puget Sound Crustacean Team will process the data and verify estimates to ensure accuracy in the data and calculations before use in harvest management.

- WDFW is working on developing an electronic catch reporting system that will generate recreational catch estimates in real-time for improved timeliness of catch reports and harvest management. New methods will be developed for this process.

Background

Each year, the Washington Department of Fish and Wildlife (WDFW) generates estimates of Dungeness crab harvest in Puget Sound using catch reported on Catch Record Cards (CRCs), the same catch reporting tool that is required for anglers harvesting Salmon, Steelhead, sturgeon, and Halibut in Washington waters. The Puget Sound Crab endorsement and CRC was first introduced in 2000 but it wasn't until 2007 that a dedicated Puget Sound Crab CRC was issued and the catch data from these CRCs used to generate recreational catch estimates.

Currently, anglers wishing to harvest Dungeness crab in any Puget Sound Marine Area must record all harvested crabs on a CRC. Information associated with each successful trip is recorded on the CRC including the Marine Area where the harvest occurred, the month and day of harvest, and the total crabs retained. Following the end of the season, successful crabbers must then submit their CRCs to the Department either via mail or through an online reporting system within a defined reporting period. Any crabbers that do not return their cards within the reporting period are considered a non-respondent and are assessed a $10 penalty on their next purchase of a crab endorsement. Summer CRC returns have ranged from 36% to 55% since 2011.

Non-Response Bias

Data from the reported CRCs are used to estimate total recreational catch each season. Because only half of the CRCs issued each season are returned to the Department, the current methods expand the reported catch to all the issued CRCs then applies a 'bias correction factor' to account for the lower catch rates in the non-respondent population. The non-response bias correction model is generated from a correlation between the CRC return rate in a season and the ratio of estimates derived from reported CRCs *and* a telephone survey of non-respondents to the fully expanded CRC-only estimate.

The current bias correction model is derived from data collected through telephone surveys conducted from 2007 to 2010 to estimate total catch from the non-respondent population. A random sub-sample of crabbers from the non-respondent group was drawn each season to acquire catch information. Catch per angler was then estimated for each Marine Area and expanded to produce a total catch estimate for the non-respondent group. These data, in addition the harvest estimates from the CRC reports, were used to generate the non-response bias correction model.

Data Reporting and Processing

All the reported CRC data is received by the WDFW CRC Unit through the internet reporting tool or, in the case of mail-in cards, entered manually. It is common for catch data recorded on Dungeness crab CRCs to contain errors such as catch reported from coastal Marine Areas, catch reported without a month and/or Marine Area, as well as harvest reported out of season or in closed areas.

All CRC data are managed and processed by WDFW's CRC Unit. The current methods that are applied to filter and process the data are the same as when the methods were first developed in 2011.

Details about the assumptions

Since the current CRC catch estimation methods were developed, WDFW staff assumed that all catch reported on summer and winter CRCs was being included in the catch estimate and the bias correction value, calculated from the bias correction model based on the return rate of CRCs, was being calculated and applied equally to each area and month after apportionment of unknowns. Harvest estimates of Dungeness crab from CRCs have always been conducted solely by the WDFW CRC Unit using the statistical software SAS. As a result, there has been minimal review of the catch estimation methods and no updates to the SAS code used to produce the estimate since 2011.

Timeline of preliminary and final estimates

Following the closure of the recreational crab fishery each season, the WDFW licensing unit opens online crab harvest reporting. For the summer season, online reporting opens the day following the closure (typically Labor Day) and remains open through October 1. The winter reporting period typically opens January 1 and lasts through February 1. September is an active time of fishery planning for State and Tribal commercial fisheries and the winter recreational fishery. Crustacean team staff begin requesting preliminary estimates of summer recreational harvest from the WDFW data team as early as mid-September, which are based solely on internet reports. While not final, these preliminary, internet-based reports are often used in making fishery management decisions. Once the internet reporting period closes, the remaining paper CRCs are manually entered, and final recreational estimates are available and ready for distribution. Summer estimates are typically complete in October and winter estimates complete in March.

During the 2022 crab season, WDFW committed to using estimates which incorporate the telephone survey data for the 2022-2023 harvest period (description below). Throughout the season, estimates that were produced using the traditional CRC methods were considered as 'preliminary'. Due to the length of time it takes to conduct the telephone surveys and process the data, final recreational (revised) harvest estimates were distributed in June 2023, much later than in a typical year.

2023 Data Update

Responsive Management survey – repeating past methods

In 2022, WDFW partnered with the survey research firm, Responsive Management, to repeat the previous telephone survey of non-respondents. The goal of this work was to compare the results of the 2022 survey to data produced from the 2007-2011 surveys. The intent was to also use the information to update the current non-response bias correction factor correlation model and generate recreational catch estimates for the 2022-2023 harvest season. The methods that were applied in the telephone survey were identical to those that were for the 2007 – 2011 surveys. Once all data entry was complete (both internet and paper CRC reports), non-respondents were selected to contact for catch information. The primary difference from the original study was that participants could be contacted via email and text message, in addition to phone, to increase participation in the survey.

Identification of data discrepancies

In the spring of 2023, Puget Sound crustacean team staff were working to produce harvest estimates using the CRC catch reports and telephone survey data from Responsive Management for the 2022-2023 harvest season.

Examining summaries of the number of reported crabs from summer and winter 2022 Catch Record Cards revealed a discrepancy between estimates made from the WDFW crustacean team and estimates from the WDFW CRC Unit. This analysis indicated certain categories of reported CRC data was being excluded from the catch estimate (i.e., catch reported in June prior to the PS fishery opening). The WDFW crustacean team has always assumed that all CRC reports are included in the estimates and that bias correction was being applied uniformly, as a single value to the reported CRC data for a given year. These assumptions were incorrect, as a significant portion of harvest reported out of season was being excluded from the catch estimate and further data analysis revealed that a differential bias correction value was being applied based on the area and month the CRC data was reported from. It remains unclear why this was occurring.

In response to these findings, WDFW crustacean team staff revised the data processing to include all the records reported on CRCs and to apply the bias correction model uniformly. Some other changes were made (described below), which resulted in a substantial difference in the overall catch estimated with the revised data processing rules. Additionally, WDFW staff recalculated the annual harvest totals using the new data processing methods and compared them to what was generated from the WDFW CRC unit from 2011 – 2022. This comparison revealed some differences in total estimated crabs ranging from -37,680 crabs to +40,790 crabs (Table 1). These differences are a result of total number of crabs included in the estimate and how the bias correction was applied. Overall, small changes in the bias correction resulted in large changes to the total catch estimate.

On April 14, 2023, WDFW staff distributed an email which showed a comparison of telephone survey-based estimates and the traditional CRC-based estimates. It was after this email was sent that the issues with the data processing were found and addressed. WDFW staff met with tribal co-managers on May 2, 2023, then again on June 7, 2023, to describe and present the changes to the methods and the impact on the overall harvest numbers.

Summary of Previous and Updated Data Processing Rules

2011 – 2021 Data Processing Rules

<u>Catch Reported on a Summer CRC:</u>

- All catch reported from Marine Areas 1-3 (coastal areas) is removed from the catch estimate. All catch from Marine Area 4 is included in the catch estimate, regardless of whether the reported catch occurred on the west or east side of the Bonilla-Tatoosh line.
- All catch reported from June is removed from the catch estimate unless the fishery was open in June during a given year.
- Since 2017, all catch reported prior to June (January-May) has been included in the catch estimate and categorized as an unknown for month. Prior to 2017, catch reported during the period January-May was removed.
- All catch reported during the open summer recreational season (typically July 1 – Labor Day) is included in the catch estimate.
- Since 2017, all catch that occurred in September (after Labor Day) and reported on a summer card is removed except for Marine Area 7 (Region 1). *Catch from Marine Area 7(the only area that is typically open during this time period) is moved to the winter estimate for that same year.*
- All catch reported without a month and/or Marine Area is included in the catch estimate. This catch is categorized as an unknown for month and/or Marine Area.

- The expansion factor and bias correction is applied to all reported catch to account for non-reported CRC's. A differential bias correction is being applied to data partitioned by month and Marine Area instead of a single bias correction value (Table 2).
- All catch categorized as unknown (January-May, unknown marine area, and unknown month) is then apportioned to the appropriate in-season month (July, August, or September [on or prior to Labor Day]) based on catch proportions by month for each marine area.
- Catch from Marine Area 9 (Region 2W) is split into 25C and non-25C. Catch from 25C is added to the catch estimate for Marine Area 12 (Region 5).

Catch Reported on a Winter CRC:

- All catch reported from Marine Areas 1-3 (coastal areas) is removed.
- All catch that occurred on or prior to Labor Day and reported on a winter card is removed.
- All catch reported during the open winter recreational season (September [after Labor Day], October, November, and December) are included.
- All catch reported without a month and/or Marine Area is included in the catch estimate. This catch is categorized as an unknown for month and/or Marine Area.
- The expansion factor and bias correction is applied to all reported catch to account for non-reported CRC's. A differential bias correction is being applied to data partitioned by month and Marine Area instead of a single bias correction value.
- All catch categorized into 'unknown' (unknown marine area and unknown date) is apportioned to the appropriate in-season month (September [after Labor Day], October, November, or December) based on catch proportions by month for each marine area.
- Catch from Marine Area 9 (Region 2W) is split into 25C and non-25C. Catch from 25C is added to the catch estimate for Marine Area 12 (Region 5).

2022 Updated Processing Rules

Catch Reported on a Summer CRC:

- All catch reported from Marine Areas 1-3 (coastal areas) is removed. All catch from Marine Area 4 is included in the catch estimate, regardless of whether the reported catch occurred on the west or east side of the Bonilla-Tatoosh line.
- All catch reported prior to July 1 (January-June) is included in the catch estimate (Table 3).
- All catch reported during the open summer recreational season (typically July 1 – Labor Day) is included in the catch estimate (Table 3).
- All catch that occurred in September (after Labor Day) and reported on a summer card is included in the summer catch estimate for all Marine Areas (Table 3). *Catch from Marine Area 7 (Region 1) is not moved to the winter estimate for that same year.*
- All catch reported without a month and/or Marine Area is included in the catch estimate. This catch is categorized as an unknown (Table 3).
- All out of season catch (January-June and September [after Labor Day]) and catch reported without a known Marine Area and/or month is then apportioned to the appropriate in-season month (July, August, or September [on or prior to Labor Day]) based on catch proportions by month for each marine area (Table 4).
- Catch from Marine Area 9 (Region 2W) is split into 25C and non-25C. *Catch from 25C is added to the estimate for Marine Area 12 (Region 5) after applying the bias correction.*

- The expansion factor and bias correction is applied to all reported catch to account for non-reported CRC's. A single bias correction value is applied consistently to all reported CRC data to produce the final catch estimate (Table 5; Table 6).

Catch Reported on a Winter CRC:

- All catch reported from Marine Areas 1-3 (coastal areas) is removed.
- All catch that occurred on or prior to Labor Day and reported on a winter card is included in the catch estimate.
- All catch reported during the open winter recreational season (September [after Labor Day], October, November, and December) is included in the catch estimate.
- All catch reported without a month and/or Marine Area is included in the catch estimate. This catch is categorized as an unknown for month and/or Marine Area.
- All catch categorized into 'unknown' (prewinter season catch, unknown Marine Area, and unknown month) is apportioned to the appropriate in-season month (September [after Labor Day], October, November, or December) based on catch proportions by month for each marine area.
- Catch from Marine Area 9 (Region 2W) is split into 25C and non-25C. *Catch from 25C is added to the estimate for Marine Area 12 (Region 5) after applying the bias correction.*
- The expansion factor and bias correction is applied to all reported catch to account for non-reported CRC's. A single bias correction value is applied consistently to all reported CRC data to produce the final catch estimate.

Moving forward

On June 29, 2023, a policy co-manager meeting was held to discuss crab catch accounting issues broadly, but agreement was reached on using revised data processing rules for all CRC-based harvest estimates and to apply an updated bias correction model that incorporates results from the 2022 telephone survey in generating the 2023-2024 catch estimates. It was acknowledged that recreational catch reporting needs continued improvement in accuracy, precision, and timeliness.

Following the review and update of CRC data processing methods in 2022, the WDFW Crustacean Team will validate and process all CRC data used in generating the recreational catch estimates each season. The team will aim to make data, processing code, and summary reports available to co-managers. The CRC data team will continue to manage all reported CRC data, including managing the online reporting system and manual entry of submitted paper CRCs.

In fall of 2023, the WDFW Crustacean team will initiate a project to update the current non-response bias correction model with data from the 2022 Responsive Management telephone survey. Additionally, WDFW will be looking for resources to conduct additional phone surveys for ongoing improvement to the model.

Within the next 5 years the Department expects to launch a mobile electronic CRC application which will allow CRC holders to report data electronically in real-time from a mobile device. This new tool is expected to address many of the current challenges surrounding reporting compliance and timely availability of catch data. The methodology used to generate catch estimates with the new platform will differ greatly from the current approach and may take several take years to refine before full scale adoption. The WDFW Crustacean team, and other units, will be engaging with co-managers to provide updates on the development of the e-CRC application, roll-out plans and proposed catch estimation methods using the new data stream.

Data Tables

Table 1: Table showing comparison of bias corrected crab harvest estimates using the revised data processing rules and the original data processing rules and using the same data. A negative value indicates the original methods produces a higher estimate relative to the revised methods. A positive total indicates the original methods produces a lower estimate relative to the revised methods. Since 2017, the original methods moved all catch reported on a summer card that occurred in Marine Area 7 in September (after Labor Day) to the winter estimate, resulting in a lower estimate produced by the revised method for winter. Since 2017, catch reported on a summer card in Marine Area 7 in September (after Labor Day) has ranged from 8,372 to 15,208 pounds.

Difference in Harvest Estimates (Revised - Original)						
	Summer		**Winter**		**Annual Total**	
Year	**Crabs**	**Pounds**	**Crabs**	**Pounds**	**Crabs**	**Pounds**
2011	4,697	8,455	-4,100	-7,379	597	1,076
2012	-952	-1,716	-319	-573	-1,271	-2,289
2013	-5,260	-9,467	-589	-1,062	-5,849	-10,529
2014	-6,264	-11,274	-1,101	-1,982	-7,365	-13,256
2015	-8,482	-15,268	-644	-1,158	-9,126	-16,426
2016	-35,861	-64,550	-1,819	-3,277	-37,680	-67,827
2017	4,567	8,220	-3,324	-5,983	1,243	2,237
2018	3,862	6,952	-2,394	-4,309	1,468	2,643
2019	2,309	4,156	-3,010	-5,419	-701	-1,263
2020	3,310	5,957	-2,975	-5,356	335	601
2021	9,673	17,411	-4,752	-8,552	4,921	8,859
2022	42,844	77,120	-2,054	-3,698	40,790	73,422

Table 2: Individual bias correction values applied to reported CRC catch data in 2016 by Marina Area and month using the old processing rules. The bias correction values for summer 2016 were back calculated using the following equation: $B = H_T / (H_R * [N_T / N_R])$, where B is the bias correction, H_T is the total harvest including non-reported CRCs, H_R is the total harvest from reported CRCs, N_T is the total CRCs issued, and N_R is the total CRCs returned. The expansion factor (N_T / N_R) for the summer 2016 reporting period is 1.903. The correct bias correction value (B) for the summer 2016 reporting period is 0.689.

Marine Area	June	July	August	Sept 1-5
4	0.694	0.694	0.741	0.690
5	0.694	0.693	0.746	0.694
6		0.695	0.745	0.695
7		0.695	0.744	0.695
8-1		0.695	0.744	0.695
8-2		0.695	0.743	0.695
9 (non-25C)		0.695	0.743	0.695
9 (25C)	0.694	0.695	0.695	0.695
10		0.700	0.759	0.699
11		0.695	0.744	0.695
12	0.694	0.695	0.785	0.695
13	0.694	0.694	0.744	0.694

Table 3: Census data from reported summer 2022 Catch Record Cards using the updated processing rules. Pre-June catch includes all catch reported from January through May 2022. Marine Area 7 is the only area open in September after Labor Day. Unk is Unknown.

Marine Area	Pre-June	June	July	August	Sept 1-5	Post Labor Day	Unk	Total Crab	Pounds (lbs.)
4	12	33	114	196	21	16	0	392	706
5	2	11	978	354	80	33	0	1,458	2,624
6	15	285	33,229	13,368	3,201	321	0	50,419	90,754
7	44	276	67,385	83,422	21,430	8,449	0	181,006	325,811
8	0	0	295	140	33	0	0	468	842
8-1	12	214	58,213	27,985	6,677	318	0	93,419	168,154
8-2	31	230	60,154	32,965	7,675	434	10	101,499	182,698
9	7	117	22,515	12,142	3,720	232	0	38,733	69,719
10	0	50	5,667	3,985	932	41	0	10,675	19,215
11	10	11	4,467	3,142	46	34	0	7,710	13,878
12	5	34	10,226	4,527	1,434	85	0	16,311	29,360
13	0	0	46	48	0	5	0	99	178
Unk	0	0	7	0	0	0	12	19	34
Total	138	1,261	263,296	182,274	45,249	9,968	22	502,208	903,974

Table 4: Census data for reported summer 2022 Catch Record Cards after apportioning out of season harvest and harvest reported without a Marine Area and/or month to the appropriate Marine Area and month based on catch proportions using the updated processing rules. Note Marine Area 9 (Region 2W) is split into 25C and non-25C.

Marine Area	July	August	Sept 1-5	Total Crab	Pounds (lbs.)
4	135	232	25	392	706
5	1,010	366	83	1,459	2,626
6	33,644	13,535	3,241	50,420	90,756
7	70,821	87,676	22,523	181,020	325,836
8-1	58,700	28,213	6,732	93,645	168,561
8-2	60,725	33,272	7,746	101,743	183,137
9 (non-25C)	16,361	8,824	2,704	27,888	50,199
9 (25C)	6,363	3,431	1,051	10,846	19,522
10	5,716	4,019	940	10,675	19,215
11	4,499	3,165	46	7,710	13,878
12	10,304	4,562	1,445	16,311	29,360
13	48	51	0	99	178
Total	268,326	187,346	46,536	502,208	90,3974

Table 5: The bias correction value applied to reported CRC catch data in summer 2022 for each Marina Area by date category using the updated processing rules. The bias correction value is calculated using the following bias correction factor model: $Y = -0.50(X)^2 + 1.39(X) + 0.097$, where Y is the bias correction factor and X is the response rate of reported CRCs. The correct bias correction value (Y) for the summer 2022 reporting period is 0.593 and the response rate (X) of returned CRCs is 0.42.

Marine Area	July	August	Sept 1-5
4	0.593	0.593	0.593
5	0.593	0.593	0.593
6	0.593	0.593	0.593
7	0.593	0.593	0.593
8-1	0.593	0.593	0.593
8-2	0.593	0.593	0.593
9 (non-25C)	0.593	0.593	0.593
9 (25C)	0.593	0.593	0.593
10	0.593	0.593	0.593
11	0.593	0.593	0.593
12	0.593	0.593	0.593
13	0.593	0.593	0.593

Table 6: Total recreational harvest estimates for summer 2022 by area, including non-reported CRCs corrected for bias using the updates processing rules. Total recreational harvest is calculated using the following equation: $H_T = H_R * (N_T / N_R) * B$, where B is the bias correction, H_T is the total harvest including non-reported CRCs, H_R is the total harvest from reported CRCs, N_T is the total CRCs issued, and N_R is the total CRCs returned. The bias correction value (B) for the summer 2022 reporting period is 0.593. The expansion factor (N_T / N_R) for the summer 2022 reporting period is 2.375

Marine Area	July	August	Sept 1-5	Total Crab	Pounds (lbs.)
4	190	327	35	552	994
5	1,424	516	117	2,057	3,703
6	47,436	19,083	4,570	71,089	127,960
7	99,853	123,617	31,756	255,226	459,407
8-1	82,763	39,778	9,492	132,033	237,659
8-2	85,618	46,911	10,921	143,450	258,210
9 (non-25C)	23,068	12,441	3,812	39,321	70,778
9 (25C)	8,971	4,837	1,482	15,290	27,522
10	8,059	5,667	1,325	15,051	27,092
11	6,343	4,462	65	10,870	19,566
12	14,528	6,432	2,037	22,997	41,395
13	68	72	0	140	252
Total	378,321	264,143	65,612	708,076	1,274,538