2022-23 Sea-Run Salmon Harvest

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Document Control			
Version	**Updated**	**Updated By**	**Changes**
1.1	28 June 2023	H. Sanders Garrick	Original Document
1.2	04 July 2023	H. Sanders Garrick	Addition of CSI graphs, minor formatting updates
1.3	31 July 2023	H. Sanders Garrick	Addition of river reach results Fixed an in-text error caught by E. Craig, and changed graphs to reflect change
1.4	11 Sept 2023	E. Craig	Addition of section 4.7 and corresponding updates to other text

1. Executive Summary

During the 2022-23 sea-run salmon season, anglers harvested an estimated 1,115 salmon in the North Canterbury and Central South Island regions of Fish & Game.

The majority of harvest occurred on the Rakaia River, but more than 85% of reported harvest occurred within the 4 major sea-run salmon fisheries: the Rakaia, Rangitata, Waimakariri, and Waitaki rivers.

Approximately 61% of estimated harvest occurred on rivers in the North Canterbury region while ~39% of estimated harvest occurred on rivers in the Central South Island.

Relative to the 2021-22 season, estimated harvest decreased for the Rakaia, Rangitata, and Waitaki rivers, but increased for the Waimakariri.

The majority of reported salmon harvest occurred in March, but timing of harvest varied by river.

The average length of harvested salmon was 67cm, smaller on average than those reported during the 2021-22 season.

2. Introduction

Fish & Game manages sea-run salmon in the North Canterbury and Central South Island regions using a seasonal bag limit. Anglers who purchase a licence to fish salmon receive a bag limit card, which they are required to fill out immediately upon harvest of a salmon. Details listed on the card include the date and location of harvest, the sex and length of the fish, and fin clip status. The information gathered during this survey is used to assess the health of the sea-run salmon fishery in the central eastern portion of the South Island of New Zealand, and help guide management actions in accordance with the adaptive management plan (Webb & Terry 2020).

3. Methods

In 2023, anglers were asked to return their bag limit card by 7 May, following the close of the sea-run salmon season on 1 May. Bag limit cards could be returned via online form, email, post,

or in person at either the Central South Island or North Canterbury offices. Anglers who did not harvest any salmon were asked to indicate on their card whether they went fishing for sea-run salmon. Fish & Game accepted entries until 15 May to allow time for postal delivery.

On 15 May, anglers who had not voluntarily submitted their bag limit cards were identified as potential phone survey participants, and a subset was selected using a random stratified sampling method. Using previous harvest survey data, we identified anglers who are known to have harvested at least one salmon between the 2018-19 and 2021-22 fishing seasons. These anglers constituted the “known success” stratum, while all remaining anglers were classified to the “no known success” stratum, or anglers with no recorded salmon harvest since the 2018-19 season. We used the sample function in program R (R Core Team 2022) to randomly select 200 anglers from the known success stratum and 1,800 anglers from the no known success stratum, with the goal of collecting 100 and 900 surveys, respectively. Phone surveys were conducted between 15 May and 2 June 2023.

We compared harvest between anglers who returned their bag cards voluntarily and those who were surveyed during phone interviews using a generalized linear model with a Poisson distribution. Similarly, we compared harvest between anglers with known success and anglers with no known success using a generalized linear model with a Poisson distribution. We used results of these models to determine whether data from multiple survey strata should be combined or remain separate while calculating harvest estimates.

Harvest from voluntary returns was not extrapolated to any non-respondents, as the mean harvest of those who returned their bag cards voluntarily was substantially different from those who did not. Additionally, harvest was substantially different between the two phone survey strata. Thus, all strata were maintained while calculating harvest estimates.

An estimate of harvest was calculated by extrapolating the mean harvest/active angler across each stratum according to the formula:

$$H_i = T_i \times P_i \times \bar{Y}_i$$

In which, for stratum i, H represents estimated harvest, T represents the total number of anglers, P represents the participation rate (i.e., the proportion of licenced anglers who actively fished), and $\bar{Y}$ represents the mean harvest per angler.

We extrapolated these results to 404 anglers in the known success stratum and 8,944 anglers in the no known success stratum to produce an estimated harvest for each stratum. Estimated harvest was calculated for all non-respondents by calculating the weighted total mean from the phone survey strata according to the formula:

$$\hat{Y} = \sum F_i \bar{Y}_i$$

In which $\hat{Y}$ represents the weighted mean and, for stratum i, F represents the proportion of total respondents and $\bar{Y}$ represents the mean (Arnold et al. 2023).

Total variance was calculated from the phone survey data according to the formula:

$$S_{\hat{Y}}^2 = \frac{1}{N-1}\left(\sum (N_i - 1)S_i^2 + \sum N_i\left(\bar{Y}_i - \hat{Y}\right)^2\right)$$

In which variance of the weighted mean, $\hat{Y}$, is represented by $S_{\hat{Y}}^2$, S_i^2 represents variance for stratum i, $\bar{Y}_i$ represents mean harvest of stratum i, and N and N_i represent the total and stratum sample sizes (Arnold et al. 2023).

A 95% confidence interval was calculated around the harvest estimate for each stratum and total harvest according to the formula:

$$Z_{\alpha} \times \sqrt{\frac{S_{\hat{Y}}^2}{N}}$$

In which Z is the z-score for a confidence interval of a given value of α: 1.96 for a 95% confidence interval. Total harvest was calculated as the sum of harvest reported from voluntary returns and the total estimate from phone interviews.

We assessed the distribution of harvest dates across all anglers who reported valid harvest dates, and across the 4 major sea-run salmon fisheries (Rakaia, Rangitata, Waimakariri, and Waitaki) for anglers who also reported valid location of harvest.

We assessed the average length of harvested salmon across all anglers who reported valid lengths, and across the 4 major sea-run salmon fisheries for anglers who also reported valid location of harvest. We used a simple linear model to evaluate the relationship between length and river catchment.

4. Results

4.1 Voluntary Card Returns

Before the 15 May cut off, we received 3,645 valid bag card returns. Of those, 44.0% reported that they did not fish for sea run salmon during the 2022-23 season. Forty percent (1,492 anglers) reported that they fished for sea run salmon but did not harvest any fish. Only 551 anglers (15.1%) reported that they harvested salmon (Figure 1).

4.2 Phone Surveys

We surveyed 1003 anglers in total: 102 anglers from the known success stratum and 901 from the no known success stratum. Due to surveyor error, 2 entries were incomplete and were thus removed from the final dataset. One additional angler who was surveyed was a family member of randomly selected survey participant but was not included in the random sample and was thus removed from the final dataset. Of the remaining 1000 anglers, 630 (63.0%) did not go fishing, 321 (32.1%) went fishing but did not harvest salmon, and 49 (4.9%) successfully harvested salmon (Figure 1). Only 16 anglers (1.6%) reported successfully harvesting their limit of 2 salmon. The mean number of salmon harvested by those who went fishing was 0.18 fish/angler (± 0.025).

Mean salmon harvest amongst anglers who returned their bag cards voluntarily had a mean harvest rate of 0.33 fish/angler (± 0.014), 5 times the mean harvest of those who were surveyed during phone interviews. The two groups were statistically distinct ($F_{1, 3041} = 149$, $p < 0.001$; Figure 2), therefore we did not extrapolate data from voluntary returns to non-respondents. Mean salmon harvest amongst anglers with known success was 0.40 fish/angler (± 0.067),

nearly 15 times the mean salmon harvest amongst anglers with no known success who harvested, on average, 0.027 fish/angler (± 0.0066). The two strata were statistically distinct ($F_{1, 998} = 161$, $p < 0.001$; Figure 3).

Amongst anglers with known success, 71.6% of those surveyed actively participated in the 2022-23 salmon season, with an average harvest of 0.56 fish/active angler (± 0.087). Amongst anglers with no known success, 33.1% of those surveyed actively participated in the 2022-23 salmon season, with an average harvest of 0.08 fish/active angler (± 0.019).

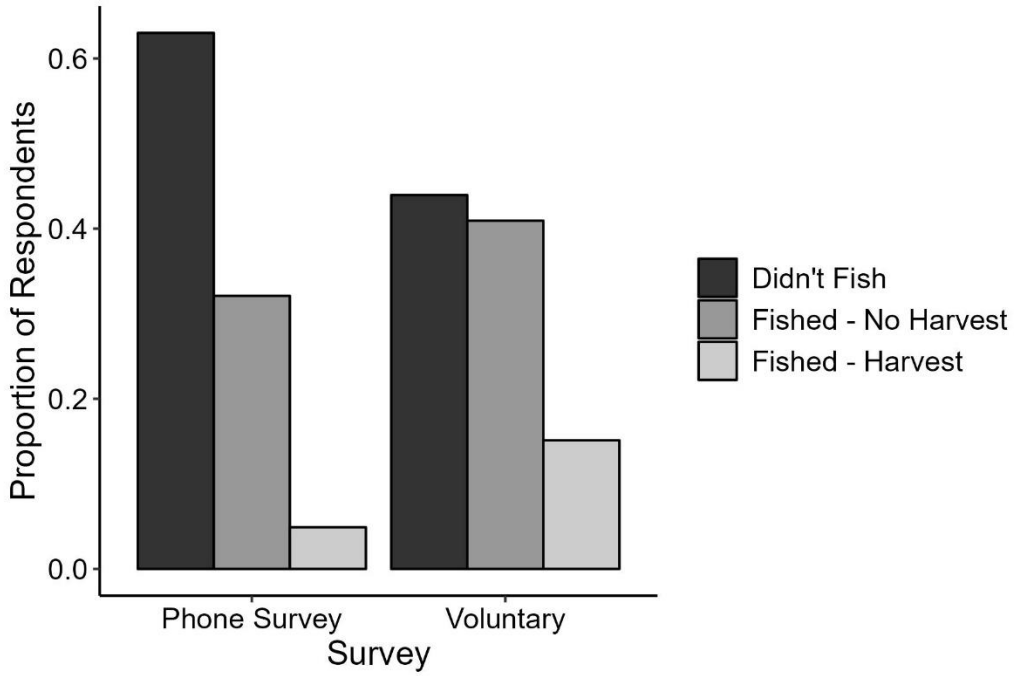

Figure 1. The proportion of respondents who didn't fish, fished but didn't harvest, and both fished for and harvested sea run salmon in the North Canterbury and Central South Island regions of Fish & Game by survey type during the 2022-23 season.

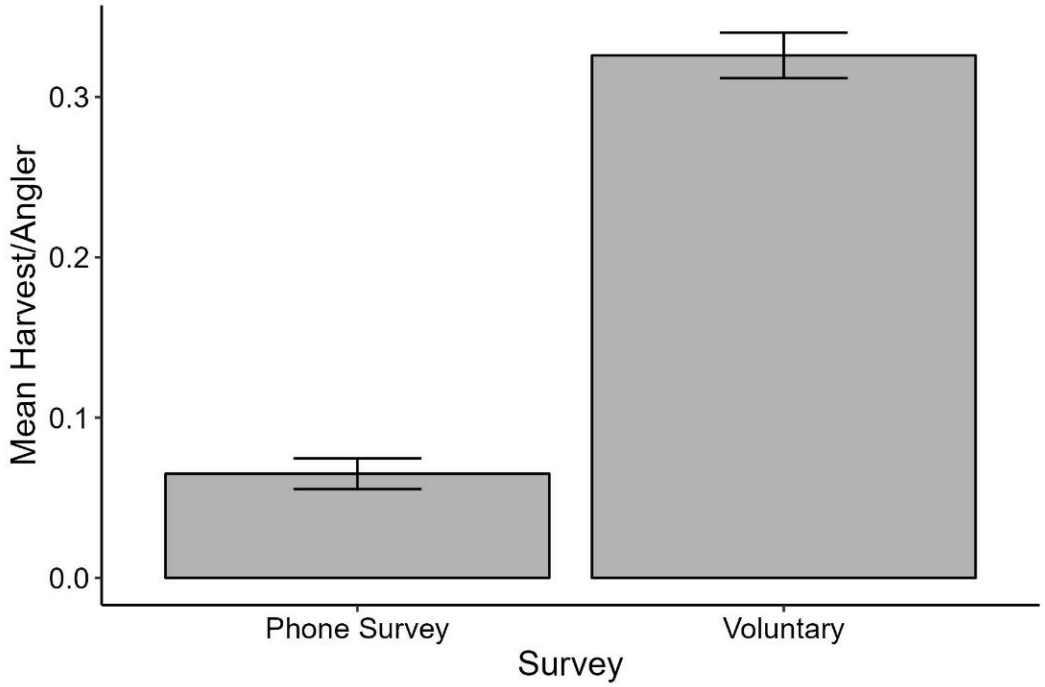

Figure 2. Mean harvest of sea run salmon by survey type for anglers in the North Canterbury and Central South Island regions of Fish & Game during the 2022-23 season. Error bars represent standard error.

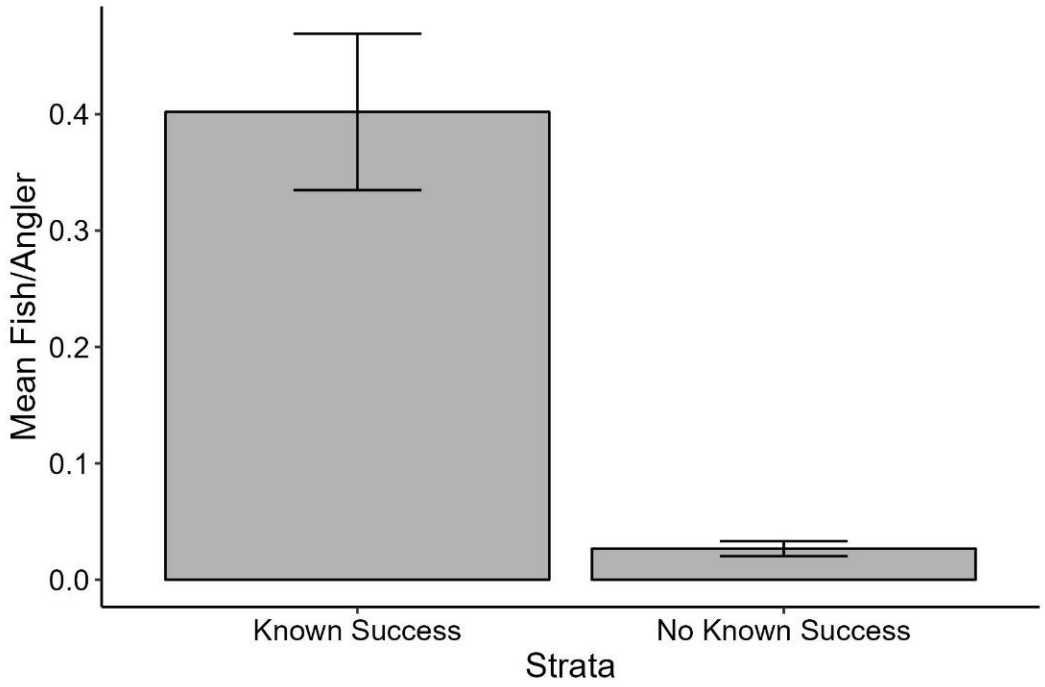

Figure 3. Mean harvest of sea run salmon by phone survey stratum for anglers in the North Canterbury and Central South Island regions of Fish & Game during the 2022-23 season. Error bars represent standard error.

4.3 Estimated Harvest

Voluntary respondents reported a total harvest of 666 salmon. Estimated harvest was 162.4 (± 49.4) salmon for the known harvest stratum and 239.0 (± 110.7) salmon for the no known harvest stratum. Total estimated harvest was 1,115.1 (± 89.6) salmon (Figure 4).

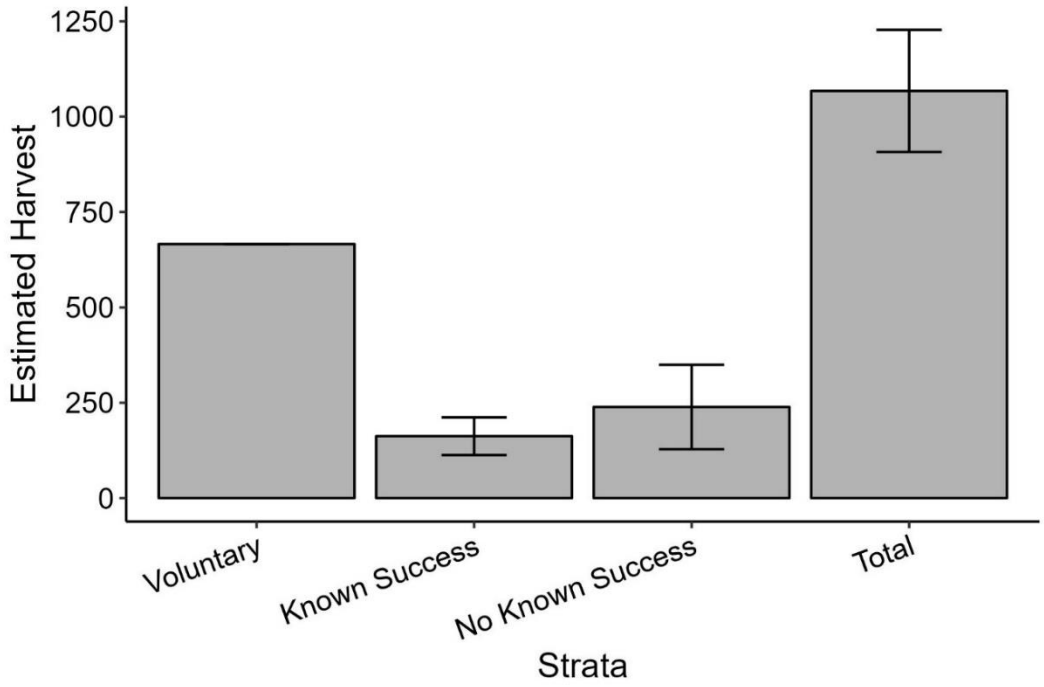

Figure 4. The estimated salmon harvest and 95% confidence interval on the estimate for each survey stratum, North Canterbury and Central South Island regions of Fish & Game, 2022-23 season.

Eight of the salmon harvested were not subject to the sea-run salmon harvest restrictions, as they were either harvested outside the regulated regions or were harvested from the canals. An additional 8 salmon reported did not include valid information on the location of harvest. Of the remaining salmon harvested, more than 87% were harvested from the Rakaia, Rangitata, Waimakariri, and Waitaki rivers (Table 1). Angler effort was greatest on the Waimakariri, followed by the Rakaia, Rangitata, and Waitaki, respectively.

Harvest varied substantially by river, both within and between survey strata (Figure 5). Total estimated harvest was greatest for the Rakaia (299.3 ± 67.6 salmon), followed by the Waimakariri (245.8 ± 65.0 salmon), the Waitaki (195.2 ± 54.0 salmon), and the Rangitata (161.1 ± 36.8 salmon). Estimated harvest on each of the 4 major rivers has decreased relative to the 2021-22 season, with the exception of the Waimakariri which increased by 59 fish (31.7%; Figures 6-10).

Table 1. The reported harvest, estimated harvest (with 95% confidence interval), and reported number of active anglers by survey stratum for the 2022-23 sea-run salmon season in North Canterbury and Central South Island Regions of Fish & Game, broken down by each of the 4 major sea-run salmon fisheries.

Reported Harvest					
	All Rivers	Rakaia	Rangitata	Waimakariri	Waitaki
Voluntary	666	203	109	138	121
Known Success	41	11	9	7	7
No Known Success	24	5	2	7	4
Total	731	219	120	152	132

Estimated Harvest					
	All Rivers	Rakaia	Rangitata	Waimakariri	Waitaki
Known Success	162 ± 49.4	44 ± 26.7	36 ± 20.3	28 ± 21	28 ± 18
No Known Success	239 ± 110.7	51 ± 27	20 ± 27	70 ± 57	40 ± 47
Total	1,115 ± 89.6	299 ± 67.6	161 ± 36.8	245 ± 65.0	195 ± 54.0

Active Anglers Surveyed					
	All Rivers	Rakaia	Rangitata	Waimakariri	Waitaki
Voluntary	2,043	568	109	138	121
Known Success	73	34	9	7	7
No Known Success	297	73	2	7	4
Total	2,413	675	120	152	132

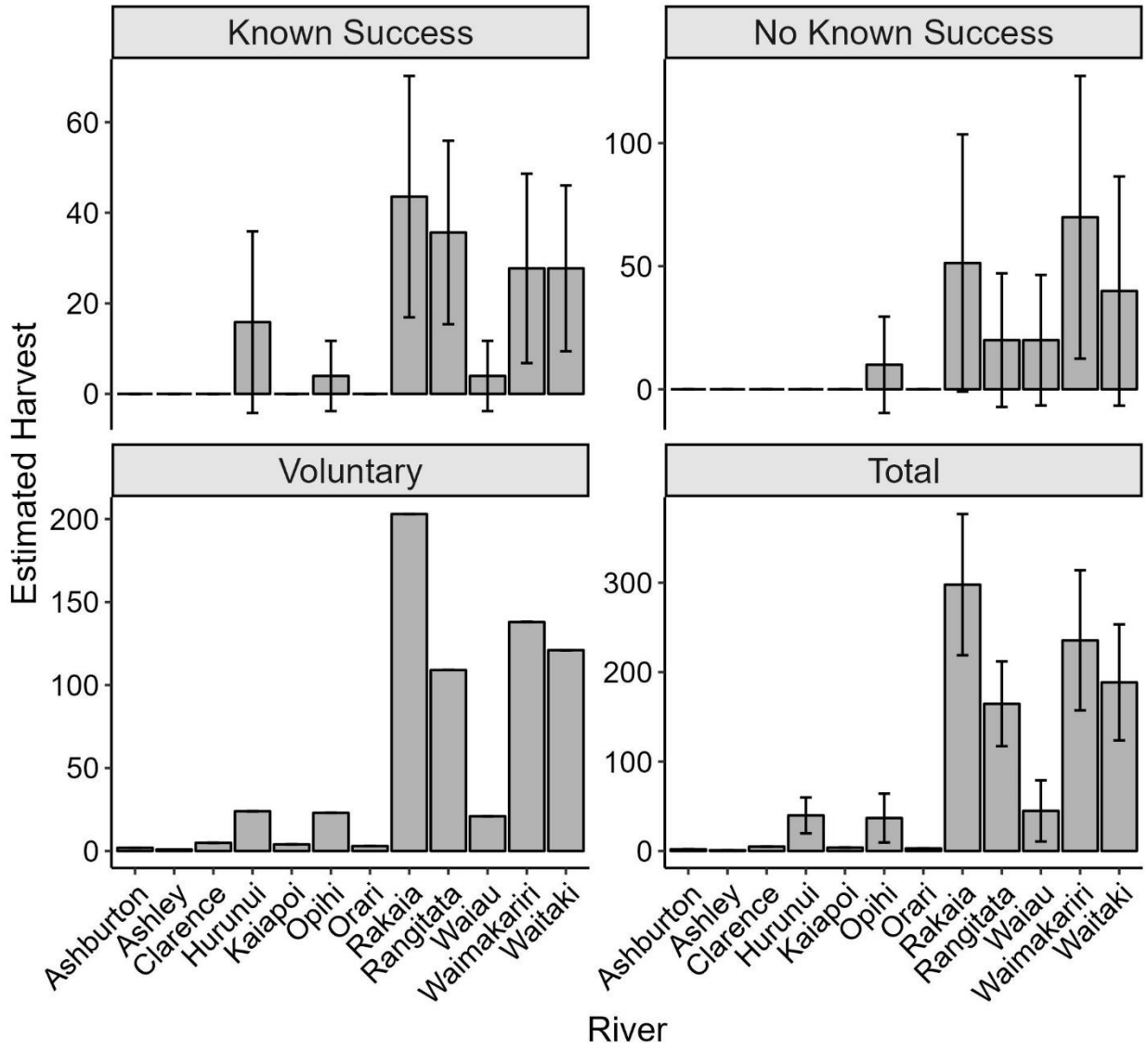

Figure 5. Estimated sea-run salmon harvest in the North Canterbury and Central South Island regions of Fish & Game during the 2022-23 fishing season by river for each survey stratum.

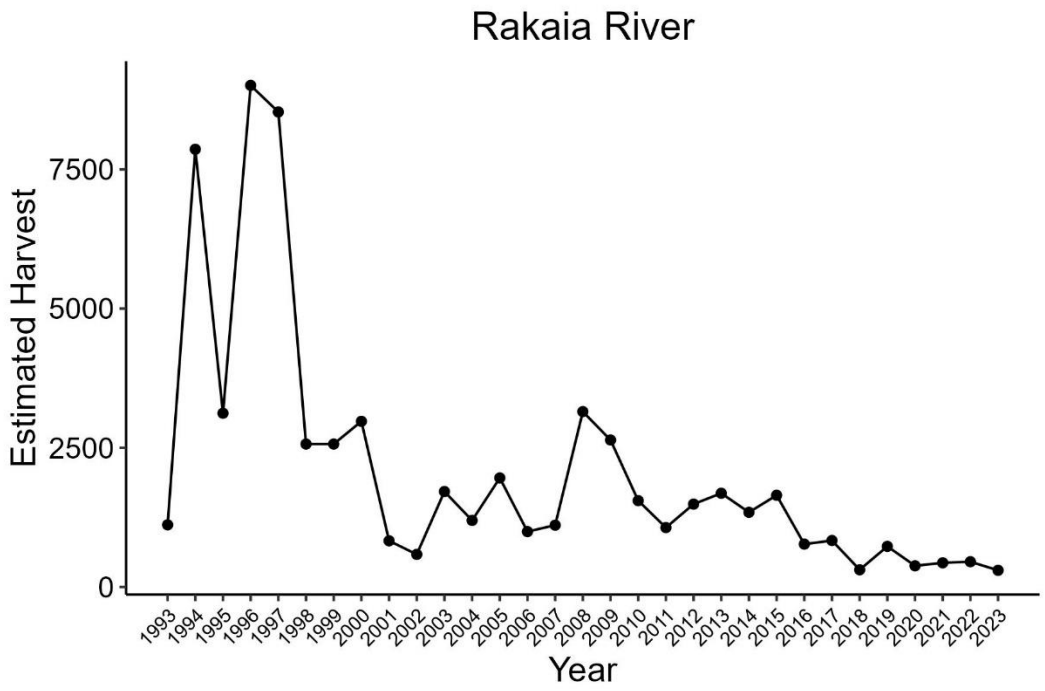

Figure 6. Estimated sea-run salmon harvest in the Rakaia River Catchment, 1993-2023.

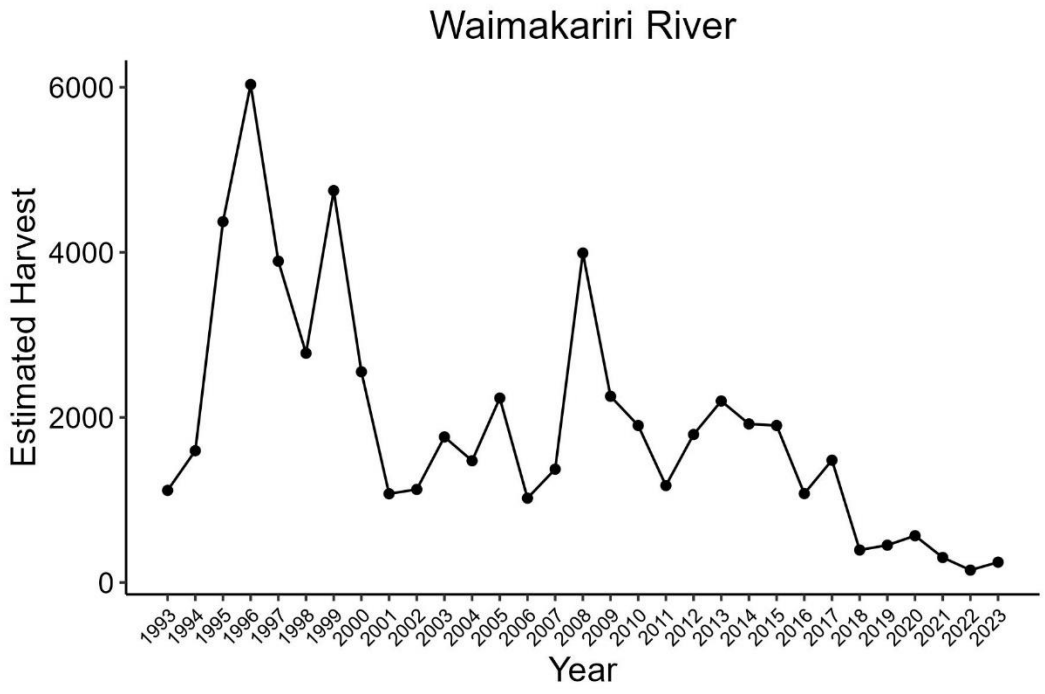

Figure 7. Estimated sea-run salmon harvest in the Waimakariri River Catchment, 1993-2023.

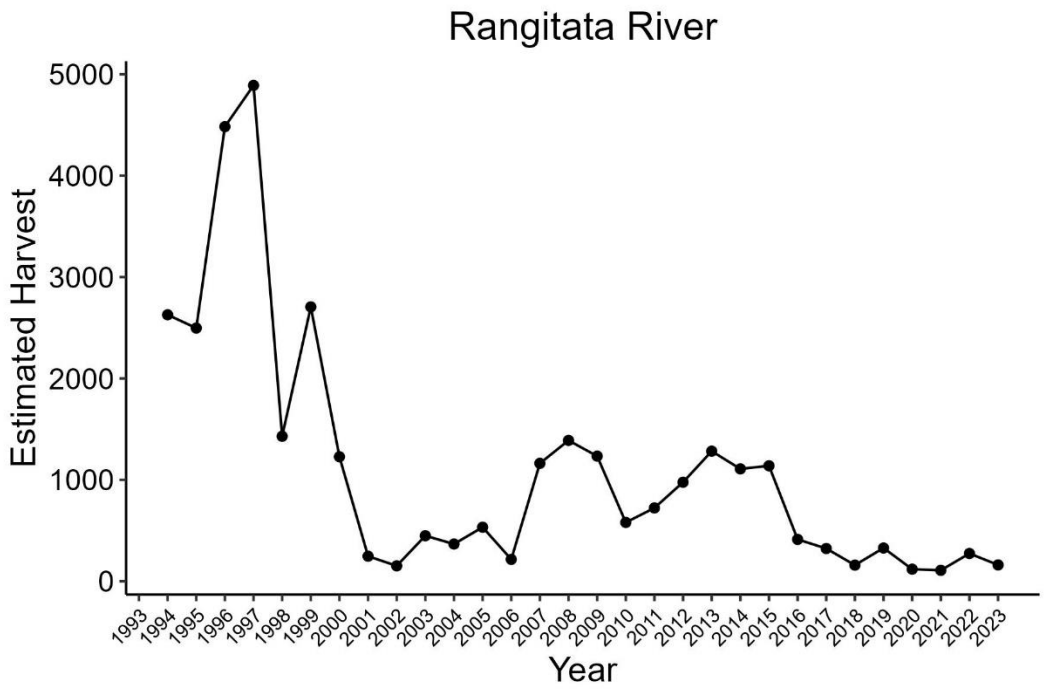

Figure 8. Estimated sea-run salmon harvest in the Rangitata River Catchment, 1993-2023.

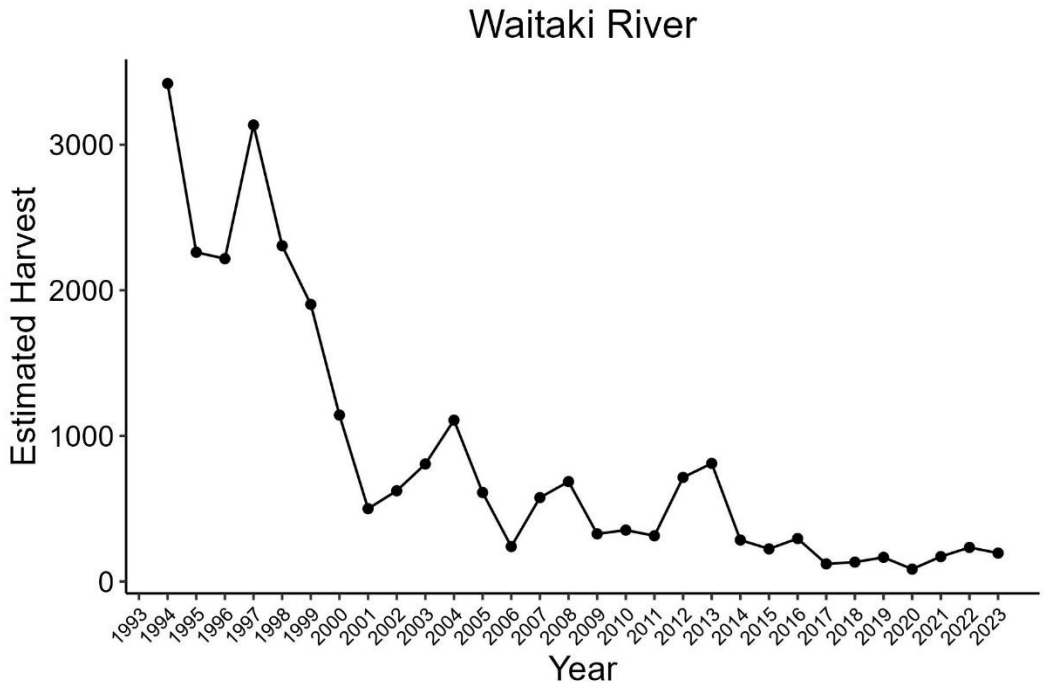

Figure 9. Estimated sea-run salmon harvest in the Waitaki River Catchment, 1993-2023.

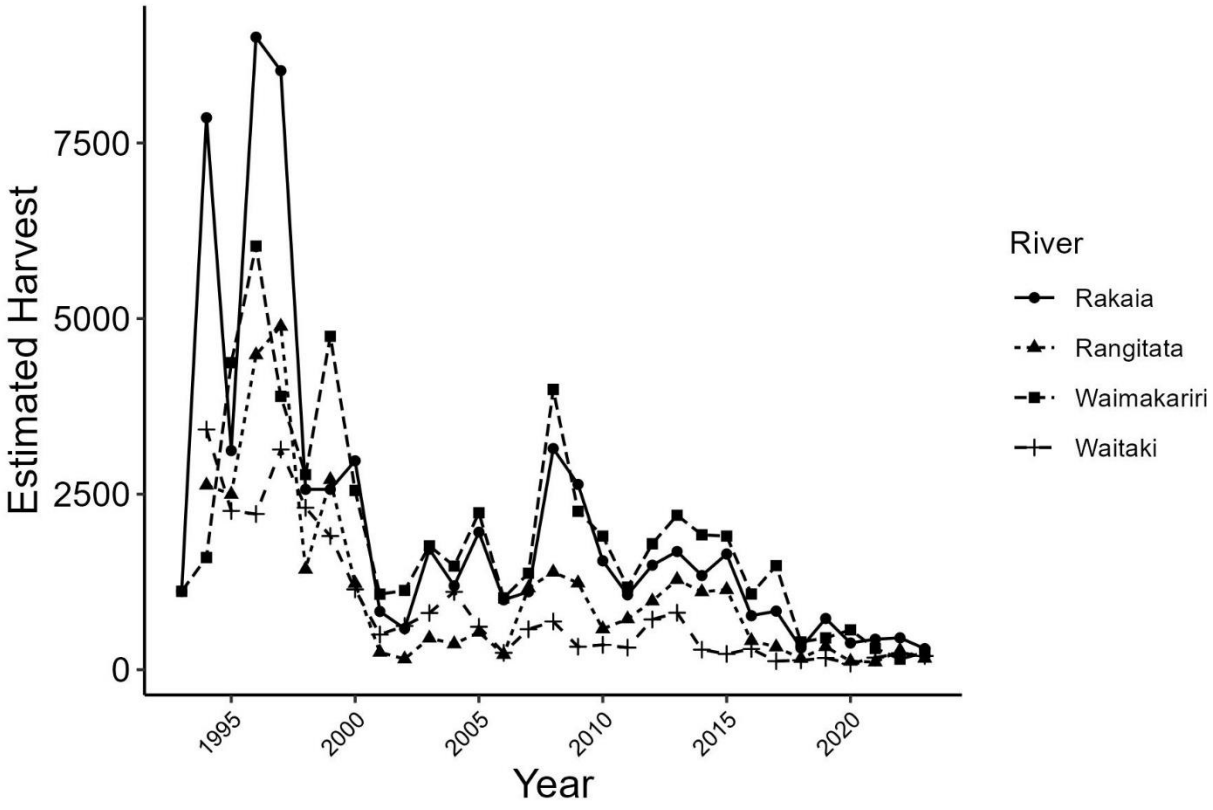

Figure 10. Estimated sea-run salmon harvest across the 4 major salmon fisheries in the North Canterbury and Central South Island regions of Fish & Game, 1993-2023.

4.4 Date of Harvest

The majority of salmon were harvested during March (28.0%), followed by February (23.8%), and April (21.1%). Less than 10% of reported harvest occurred before the first of the year (Figure 11). Timing of harvest varied by river (Figure 12). In the Rakaia catchment, harvest was equal in January and February, with 60% of total reported catch occurring within this 2-month span. In the Rangitata catchment, harvest was equal in February and March, with 54% of total reported catch occurring within these 2 months. Harvest in the Waimakariri catchment peaked in March at 35% of total reported catch. Nearly all of the reported catch in the Waitaki catchment occurred during March and April, with 64% of reported catch occurring in April.

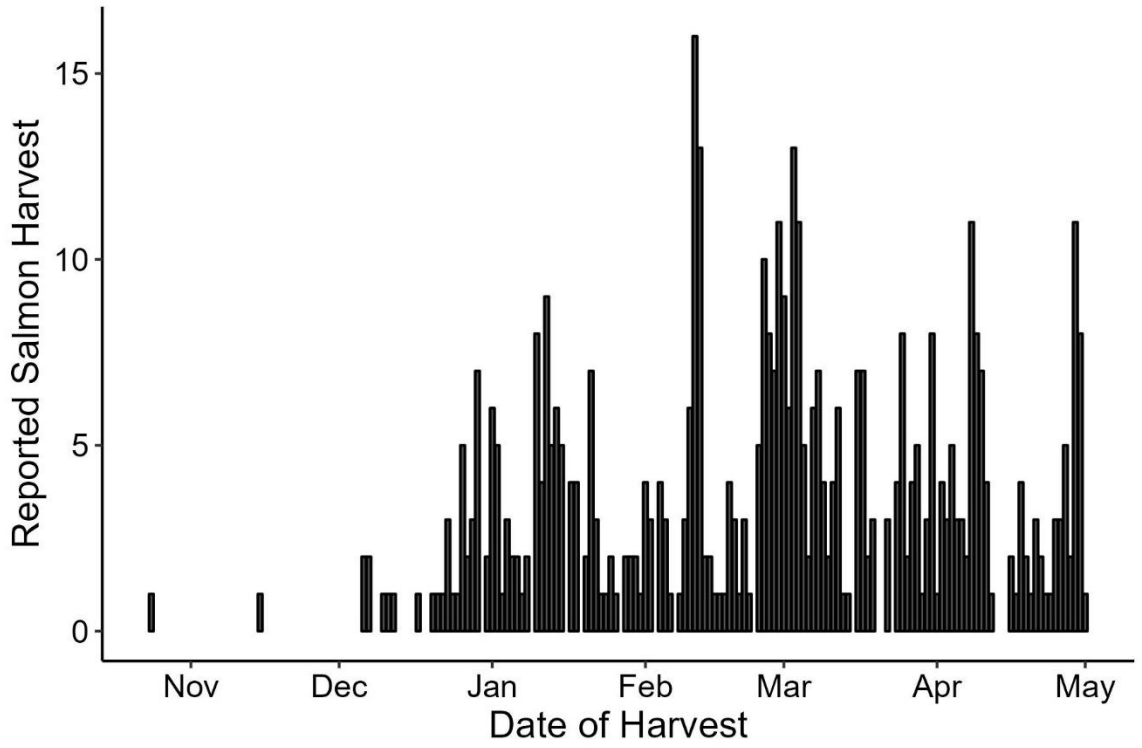

Figure 11. Date of harvest for all sea-run salmon harvested during the 2022-23 fishing season in North Canterbury and Central South Island Regions of Fish & Game, as reported by anglers.

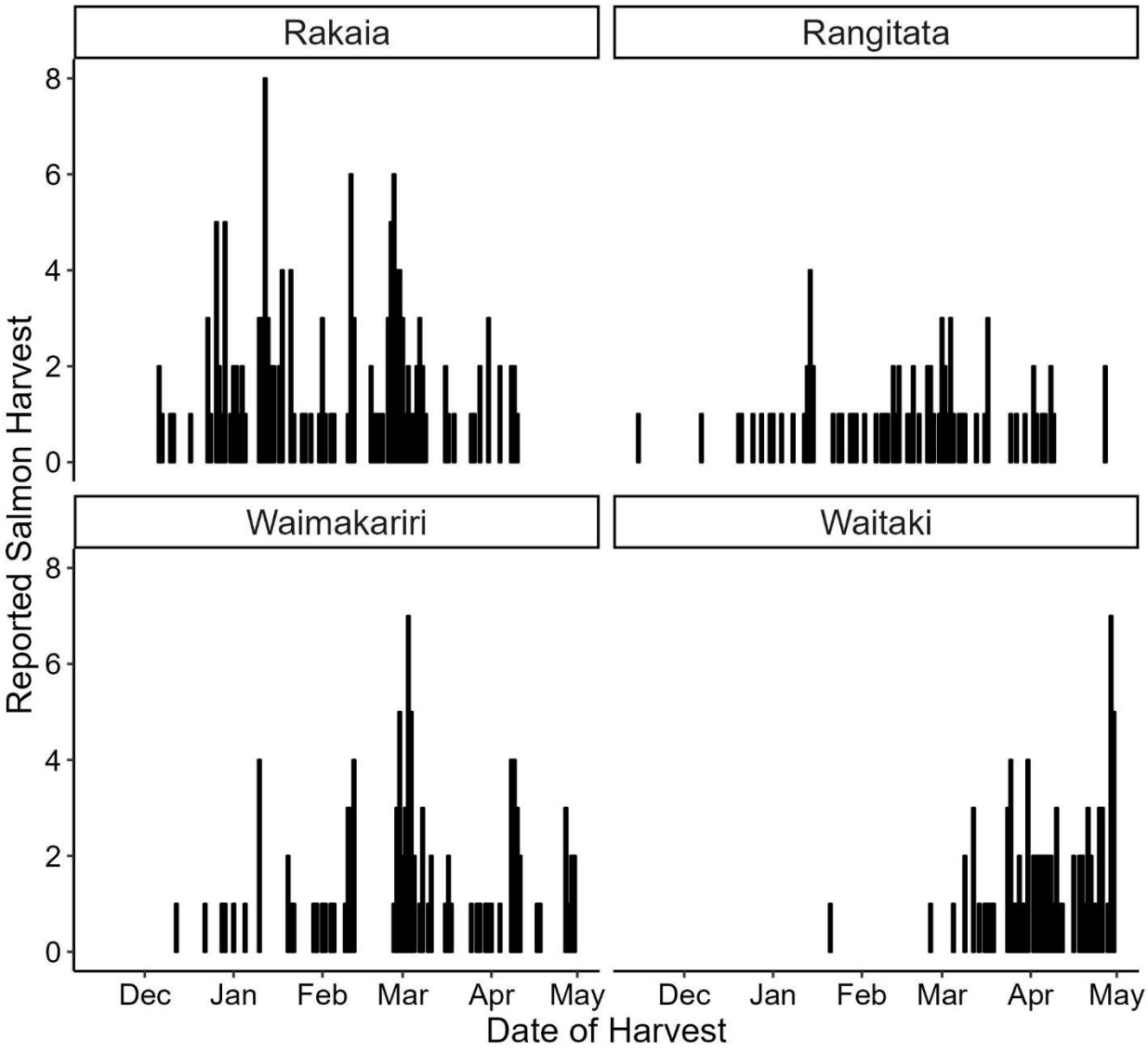

Figure 12. Date of harvest for sea-run salmon harvested during the 2022-23 fishing season on the 4 major sea-run salmon fisheries in North Canterbury and Central South Island Regions of Fish & Game, as reported by anglers.

4.5 Spatial Distribution of Catch

A valid river reach of catch was reported for 622 harvested salmon. The majority of rivers had the highest reported harvest at the mouth or lower reach. The exception was the Waiau, which had higher reported harvest in the upper and middle reaches (Table 2).

Table 2. Percent of reported sea-run salmon harvest by reach for 7 major salmon fisheries in the North Canterbury and Central South Island regions of Fish & Game during the 2022-23 season, as reported by anglers.

North Canterbury

River	Reach	Description	Harvest (%)
Hurunui	1	Mouth and tidal reaches	60.7
	2	Above tidal reaches to SH1	17.9
	3	SH1 to Mandamus confluence	10.7
	4	Above Mandamus confluence	10.7
Rakaia	1	Mouth and tidal reaches	40.1
	2	Above tidal reaches to SH1	22.4
	3	SH1 to gorge bridge	24.5
	4	Above gorge bridge	13.0
Waiau Uwha	1	Mouth and tidal reaches	11.8
	2	Above tidal reaches to SH1	5.9
	3	SH1 to Hanmer Bridge	47.1
	4	Above Hanmer Bridge	35.2
Waimakariri	1	Mouth and tidal reaches	23.9
	2	Above tidal reaches to SH1	45.7
	3	SH1 to gorge bridge	15.2
	4	Above gorge bridge	15.2

Central South Island

River	Reach	Description	Harvest (%)
Opihi	1	Mouth and lagoon	81.8
	2	Above lagoon to Temuka Junction	9.1
	3	Above Temuka Junction	9.1
Rangitata	1	Mouth and lagoon	54.7
	2	Above lagoon to SH1	17.9
	3	SH1 to Arundel Bridge	12.3
	4	Arundel to bottom of gorge	2.8
	5	Gorge and above	12.3
Waitaki	1	Mouth and lagoon	16.3
	2	Above lagoon to SH1	46.4
	3	SH1 to Stonewall	30.9
	4	Above Stonewall	6.4

4.6 Size of Salmon

The size of salmon harvested varied between rivers (Table 3). On average, the size of salmon harvested was similar between the Rakaia and Waimakariri rivers, highest on the Rangitata, and lowest on the Waitaki ($F_{3, 544} = 9.7$, $p < 0.001$). For each river, the average length of harvested salmon was lower than the reported average length from the 2021-22 season.

Table 3. Mean, maximum, and 1st-3rd quartile length (cm) of sea-run salmon harvested during the 2022-23 fishing season in North Canterbury and Central South Island Regions of Fish & Game, as reported by anglers. Values are provided for all fish reported, and by river for the 4 major sea-run salmon fisheries.

Length (cm)	All Rivers	Rakaia	Rangitata	Waimakariri	Waitaki
N	640	192	103	141	112
Mean	67.1	68.2	70.8	67.0	63.1
Maximum	96.0	93.0	96.0	90.0	82.0
Most Common	61 - 74	62-75	65-76	63-72	60-71

4.7 Fin Clips

Reported fin clips varied between rivers and between regions (Table 4). Frequency of fin clipped fish was highest on the Rangitata River, where the McKinnon's Creek hatchery is located. Anecdotal reports from anglers also suggested that fin clipped salmon were caught and released on the Waiau Uwha River.

Table 4. Frequency of fin clipped salmon harvested during the 2022-23 fishing season in North Canterbury and Central South Island Regions of Fish & Game, as reported by anglers. Values are provided from all fish reported, only for rivers where fin clipped fish were reported.

	Kaiapoi	Opihi	Orari	Rakaia	Rangitata	Waimakariri	Waitaki
Voluntary	1	5	1	5	23	2	6
Survey	0	1	0	0	1	1	1
Total	1	6	1	5	24	3	7

5. Discussion

This year, the size of the confidence interval around the total estimate is relatively small, 8% of the total estimate. This was achieved due to the high proportion of voluntary responses. At the 15 May deadline, it was estimated that 27.2% of all licence holders submitted their bag cards voluntarily (before the removal of invalid responses and duplicates). This is complimented by

the fact that people who voluntarily submit their bag card information are more likely to have successfully harvested salmon than those who do not. From this perspective, the campaign to encourage licence holders to turn in their bag cards before the deadline was a great success and should be repeated in future years.

Both estimated harvest and the size of harvest have declined relative to the 2021-22 season. This is likely related to the warmer than normal ocean temperatures over the past year, resulting in suboptimal living conditions for ocean dwelling salmonids. However, it is also important to note that one goal of implementing the 2 salmon seasonal bag limit was to reduce harvest relative to the size of the run. Thus, it will be crucial to evaluate estimated harvest in relation to run size before drawing any conclusions.

We caution against using the size estimates presented in this report to draw conclusions about the true size or age structure of the salmon population, as bag limits encourage catch and release fishing. It is likely that many anglers release smaller salmon, biasing the size estimates to be larger than what is present in the river. Similarly, date of harvest is likely skewed late to provide longer fishing opportunities for anglers. Thus, both of these metrics should be regarded carefully. Reports of fin clips should also be used with caution when estimating harvest of hatchery-origin fish as this data relies on anglers correctly identifying such fish. There has been minimal education for salmon anglers on how to identify a fin clipped fish; those new to salmon angling or those who have not been previously involved with fin-clipping may not be aware of the practice.

In addition to biasing salmon size and the timing of harvest, catch and release fishing encouraged by the seasonal bag limit may reduce harvest relative to predictions developed before the introduction of the bag. Specifically, while many anglers delay harvesting their second fish in order to prolong their season, some forego harvesting a second salmon in order to fish up until the last day of season. Therefore, predictions of harvest under a bag limit developed using data collected before the introduction of a seasonal bag are likely conservative estimates.

Salmon suffer negative physiological impacts from handling and exposure to higher ambient temperatures that can lead to death even when the fish are released. Estimates of mortality caused by catch and release fishing vary by fish treatment and environmental factors, but are typically ~5-10% (Raby et al. 2015; Dye and Borden 2018). While Fish & Game has taken measures to improve fish treatment during catch and release fishing, it will be critical to develop methods to assess catch and release fishing in order to adequately estimate angling related mortality not accounted for in the harvest estimate. Staff in North Canterbury and Central South Island are currently evaluating the efficacy of including questions on catch and release in the salmon harvest survey.

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