Estimating Proportion of Large Salmon on Harry's River, Newfoundland Using a DIDSON Acoustic Camera

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by

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ABSTRACT

Veinott, G. and Caines, D. 2016. Estimating Proportion of Large Salmon on Harry's River, Newfoundland Using a DIDSON Acoustic Camera. Can. Manuscr. Rep. Fish. Aquat. Sci. 3100: iii + 11 p.

A DIDSON (Dual-Frequency Identification Sonar) acoustic camera has been used to enumerate upstream migrating Atlantic Salmon in Harry's River, Newfoundland since 2011. Operated in high frequency mode, acoustic images were used to estimate the length of individual salmon to determine the proportion of large (≥ 63 cm) fish in the annual spawning migration. The proportion of large salmon is a critical factor in determining the status of the stocks. The variability in length of individual fish based on three measurements per fish averaged approximately ± 6 cm at the 95% confidence interval and ± 3 cm at the 80% confidence interval. A mean DIDSON length of ≥ 69 cm used as the cutoff for a large salmon produced good agreement between the proportion of large salmon based on DIDSON measurements, salmon trapped and measured, and historical records and is therefore recommended for use in future assessments.

RÉSUMÉ

Veinott, G. and Caines, D. 2016. Estimation de la proportion de grands saumons dans la rivière Harry's, à Terre-Neuve-et-Labrador, à l'aide d'une caméra acoustique DIDSON. Can. Manuscr. Rep. Fish. Aquat. Sci. 3100: iii + 11 p.

Une caméra acoustique DIDSON (sonar d'identification à double fréquence) dénombre depuis 2011 la remontée du saumon de l'Atlantique dans la rivière Harry's, à Terre-Neuve-et-Labrador. Exploitée en mode haute fréquence, la caméra produit des images acoustiques qui ont servi à estimer la longueur de chaque saumon dans le but d'établir la proportion des poissons de grande taille (≥ 63 cm) dans la migration de reproduction annuelle. La proportion de grands saumons est essentielle pour connaître l'état des stocks. La variabilité de la longueur de chaque poisson d'après trois mesures par poisson est en moyenne de ± 6 cm à un intervalle de confiance de 95 % et de ± 3 cm à un intervalle de confiance de 80 %. Pour caractériser les grands saumons, une longueur moyenne d'au moins 69 cm obtenue par caméra DIDSON a été choisie. La proportion de grands saumons obtenue par caméra DIDSON avec ce chiffre concorde avec le nombre de saumons piégés et mesurés ainsi qu'avec les données d'archives. Il est donc recommandé de l'utiliser dans les évaluations futures.

INTRODUCTION

Mature adult Atlantic Salmon (*Salmo salar*) return from overwintering in the open ocean to their home rivers throughout Newfoundland and Labrador (NL), Canada each spring. Most of the salmon returning are categorized as “small” (<63 cm) and are commonly referred to as grilse. Large salmon (≥63 cm), on the other hand, consist of grilse that are spawning for a second or third time or salmon that have spent two or more winters at sea (2SW or MSW salmon) before returning to their home waters.

To assess the status of the salmon stocks in NL, the Department of Fisheries and Oceans (DFO) count the number of salmon returning to a selection of rivers each year (Fig. 1) and convert the numbers to eggs deposited per square meter of available fluvial and lacustrine habitat (O’Connell and Dempson 1995; O’Connell et al. 1997). Rivers that meet their designated egg deposition targets are assumed to be supporting sustainable salmon populations. In order to convert numbers of upstream migrating salmon to eggs requires knowledge of the proportion of the run that is female, mean fecundity, and the proportion of the run comprised of large fish because large salmon produce more eggs than small salmon (Veinott and Cochrane 2011).

At most salmon enumeration facilities in NL, the proportion of large salmon in the annual run is determined by either trapping and measuring a sub-sample of the run or by capturing video images of the migrating fish and converting video lengths to actual lengths. However, on Harry’s River, located on the south west coast of Newfoundland, a DIDSON (Dual-Frequency Identification Sonar, Sound Metrics Corporation) acoustic camera is used to count upstream migrating fish. The DIDSON (Fig. 2) emits multiple sonar beams which under ideal conditions can produce near video quality images. However, environmental conditions are rarely ideal so determining lengths of fish using the DIDSON images can be challenging. The purpose of this report is to evaluate the length data that has been produced by the DIDSON under standard field operating conditions to determine the degree of uncertainty in the measurements, to compare DIDSON derived length measurements to historical trap and video length measurements, and to recommend a length cut-off value to separate large from small salmon when using DIDSON length data in stock assessments.

METHODS

STUDY SITE

Harry’s River (48^{o} 30’ 45”N, 58^{o} 25’ 00”W) is located on the south west coast of the island of Newfoundland and drains into St. Georges Bay (Fig. 1). The basin area is 815.85 km^2 and the total length of the main river is 70.5 km. The main stem of the river is mostly rubble and boulder with some gravel patches (Porter et al. 1974). In 2003, a fish counting fence and trap of the type described by Anderson and McDonald (1978) was installed near the head of tide (Fig. 3) and operated for three years (2003-2005). The counting fence covered the entire width of the river and migrating salmon were trapped, counted, and then released up-stream. In 2005, a second fence and trap of the same type was installed near the community of Gallants approximately 25 km upstream, which operated until 2010. In 2006, a video camera was installed at the Gallants site and migrating salmon were videotaped as they passed through a tunnel in the fence. A trap was also operated at Gallants at the same time and both the video equipment and trap operated until 2010. In 2011, a partial fish counting fence and two DIDSON sonar units were installed at approximately river km 3 and were still in operation at the end of the 2015 salmon run. The partial counting fence corralled fish through an opening in the fence of approximately 30 m. One DIDSON operated in low-frequency long-range mode and covered the area of the river from 10 m to 30 m from shore. The second DIDSON operated in high-frequency short-range mode and covered the river from 3-10 m off shore. Salmon were counted based on the sonar images produced by the DIDSON. In 2012, the opening in the partial counting fence was narrowed to approximately 10 m and the long-range DIDSON (low-frequency) was used as an auxiliary counter in the event of a failure of the short-range unit or a fence washout. In 2013, a partial fence and trap was re-installed at the Gallant's location for one week in July for the purpose of collecting lengths, weights and scale samples on a portion of the salmon run. In 2014, a partial fence and trap was installed again at the Gallant's location for the collection of biological data, which operated for the entire field season (June-August).

LENGTH MEASUREMENTS

During the years when traps operated, salmon were measured from the tip of the nose to the fork of the tail using a measuring board (Fig. 4). Salmon were laid on their right side on the board and the fork length recorded to the nearest mm. For fish that were videotaped, the proportion of large salmon that passed through the tunnel was determined based on video recordings. The camera and monitor were calibrated by inserting a 63 cm board in the tunnel through which the fish swam, then transferring the length of the board to the monitor's screen. Video tapes were reviewed daily and the number of salmon equal to or larger than 63 cm was recorded. The tunnel was 30 cm wide so no correction was made for the distance the salmon would be from the camera lens.

DIDSON length measurements were taken from stored sonar images captured on the short-range DIDSON only. However, it is not possible to distinguish between different salmonid species using a DIDSON. Therefore, protocols were in place to eliminate trout (*Salvelinus fontinalis*) and Atlantic salmon parr from the analyses. Based on historical sampling from Harry's River (unpublished data, this lab) upstream migrating adult Atlantic Salmon were assumed to be greater than 40 cm. Any fish measuring less than 40 cm was assumed to be a trout or parr and was not included in the analysis. Starting with the first salmon of the run the length of every fifth salmon was measured three times using the DIDSON software. On a still sonar image of a fish the operator first placed the computer's cursor at the fork of the tail then at the nose and recorded the calculated DIDSON length to the nearest 0.1 cm. The sonar file was then advanced several frames and a second measurement taken. This was repeated for the third measurement. The mean, standard deviation, 95% and 80% confidence intervals (CI) were calculated for each fish based on the three measurements. In 2012 and June of 2013, every fifth fish was only measured once. In 2013, the short-range DIDSON failed part way through the field season and only 80 fish were measured three times.

RESULTS AND DISCUSSION

In all years the mean lengths of salmon estimated from the DIDSON software were normally distributed (Fig. 5) (Kolmogorov-Smirnov $p<0.01$) despite being slightly positively skewed. The positive skew created slightly larger means compared to the median value (Table 1). The confidence intervals around length measurements of individual fish are shown in Fig. 6. As can be seen from these figures, there is considerable variability in these values, but the average 80% CI is approximately 3 cm and for the 95% CI the average is approximately 6 cm. If a 6 cm margin of error is applied to the criterion for large salmon, the required length of a large salmon would increase to ≥69cm. A 69 cm cut-off for large salmon based on the DIDSON measurements compares well with other measurement methods. For example, between 2003 and 2010 the percentage of large-sized fish in the Harry's River run varied between 10% and 20% regardless of the measuring method (Fig. 7). From 2011 to 2014, the percentage of large salmon varied between 12 and 21 based on length estimates from the DIDSON (69cm cut-off). In 2013, the percentage of large salmon was outside this range based on trap data (34.5% large) and much higher than that estimated by the DIDSON (21% large). However, in 2013 the trap at Gallants was only operated for one week as a pilot project and may not be representative of the entire run. In 2014, the trap at Gallants was operated for the full season and the trap and the DIDSON were in good agreement and once again produced estimates of the percentage of large salmon in the 10% to 20% range (Fig. 7).

Other studies that measured fish lengths using DIDSON technology reported better accuracy when fish were oriented perpendicular to the sonar beams (Tušer et al. 2014; Hightower et al. 2013). This occurs naturally with upstream migrating fish and the DIDSON aligned perpendicular to the current, which was the case on Harry's River. However, several studies reported reduced accuracy on larger fish (Tušer et al. 2014; Hightower et al. 2013; Burwen et al. 2010; Cronkite et al. 2006). For example, Bruwen et al. (2010) had good overall agreement between known lengths of Chinook Salmon (*Oncorhynchus tshawytscha*) and DIDSON length estimates (their $R^2 = 0.90$; n=18) using tethered fish, but reported a negative bias for all fish longer than 17 cm with residuals of ± 8 cm. Tušer et al. (2014) found that the girth of large fish could produce a sonar "shadow" resulting in the underestimation of total length, while

Cronkite et al. (2006) found that DIDSON lengths averaged 1.3 cm longer for Sockeye Salmon (*Oncorhynchus nerka*). Hightower et al. (2013) reported over and under estimates of DIDSON lengths when compared to known lengths of white perch (*Morone Americana*) and Atlantic Sturgeon (*Acipenser oxyrhynchus oxyrhynchus*), respectively.

Given that there appears to be species and size-specific biases in DIDSON measurements, it would seem prudent to assume there is also a bias in the measurements obtained on Harry's River. Obviously as the length used to define a "large" salmon increases, the percentage of salmon in the large category declines, however, the confidence that the fish is ≥ 63 cm increases (Table 2). A precautionary approach would dictate using a high degree of confidence. Fisheries managers can chose a cut-off length for large salmon based on their risk tolerance, but choosing ≥ 63 cm from the DIDSON files would result in the highest percentages of large salmon ever observed on Harry's River (compare Table 2 to Fig 7). Even a cut-off length of ≥ 66 cm would produce higher than average percentages of large fish. It is recommended therefore, that future assessments use a cut-off of ≥ 69 cm for large Atlantic Salmon when length estimates are taken from a DIDSON acoustic camera.

CONCLUSIONS

When using a DIDSON acoustic camera to estimate the lengths of individual Atlantic Salmon migrating upstream in Harry's River, considerable variability was observed. The variability in length of individual fish based on three measurements per fish averaged approximately ± 6 cm at the 95% confidence interval and ± 3 cm at the 80% confidence interval. A mean DIDSON length of ≥ 69 cm as the cutoff for a large salmon produced good agreement between the proportion of large salmon based on the DIDSON measurements and salmon trapped and measured, and is therefore recommended for use in future assessments.

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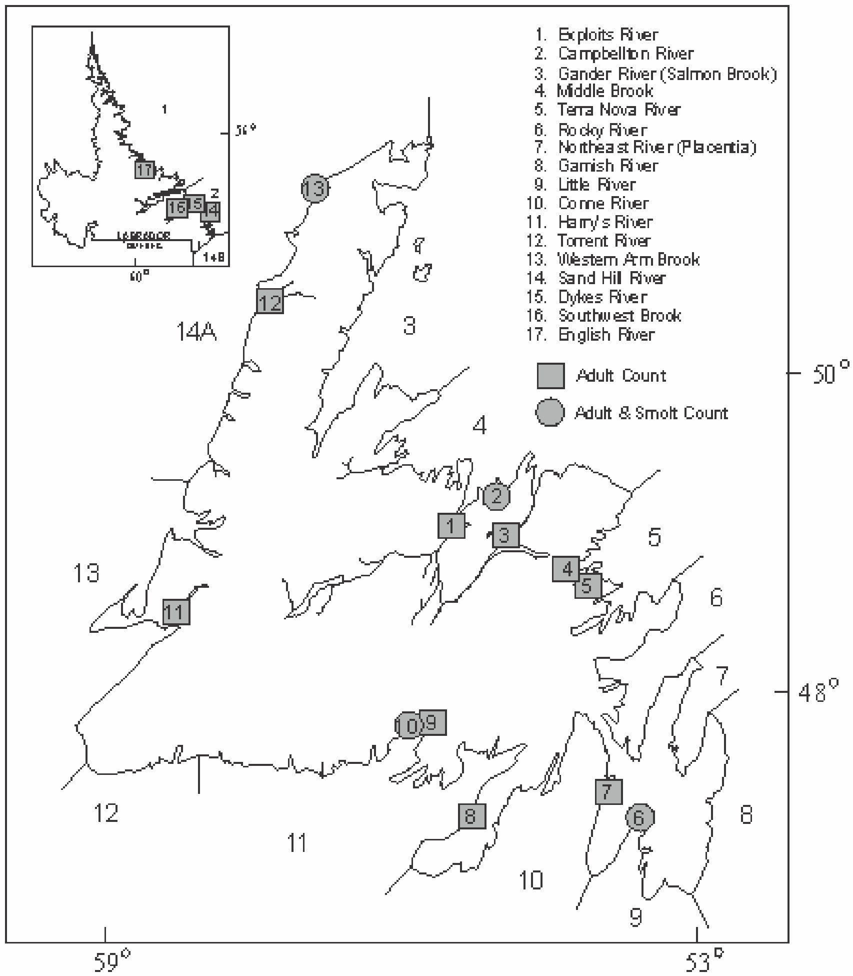

Figure 1. Map of Newfoundland and Labrador showing locations of salmon enumeration sites in 2015. Numbers in coastal waters between solid lines identify Salmon Fishing Areas (SFA). Harry's River is in SFA 13.

Figure 2. Image of a DIDSON 300 Sound Metrics sonar unit of the type used on Harry's River. (Photo credit: Sound Metrics Corp. http://www.soundmetrics.com/ with permission).

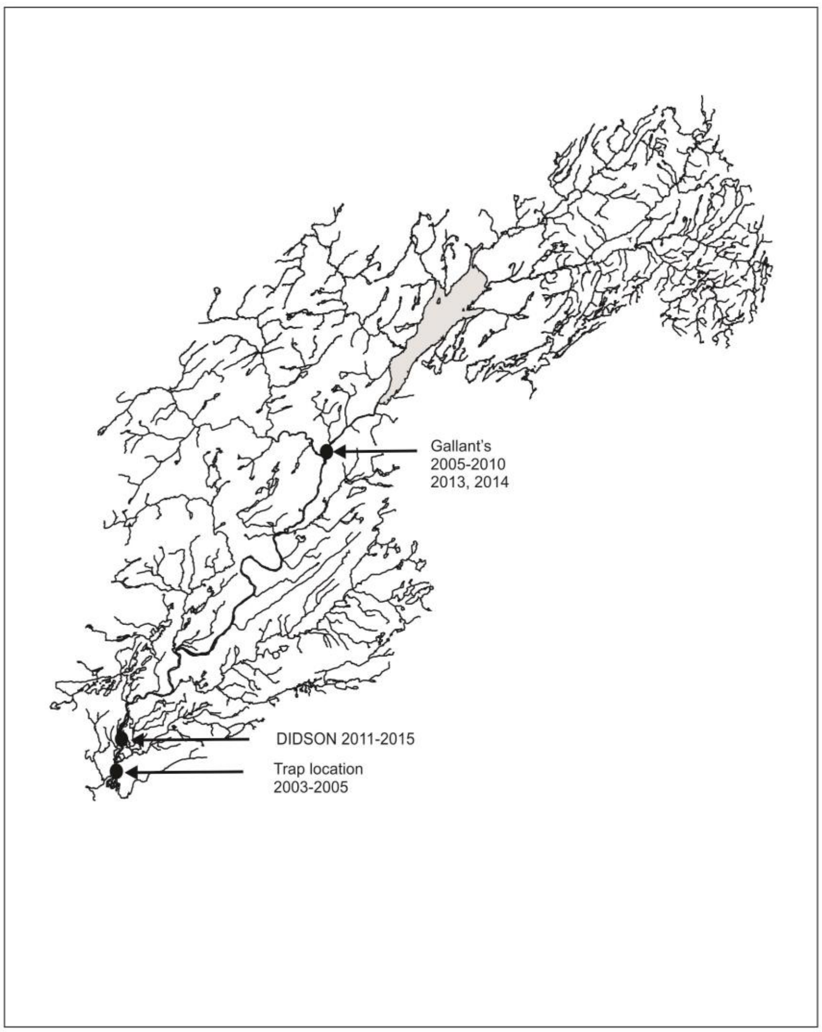

Figure 3. Map of Harry's River watershed showing locations and dates of salmon enumeration facilities from 2003 to 2014.

Figure 4. Image of an Atlantic Salmon on a measuring board. (Photo credit: Steve Duffy)

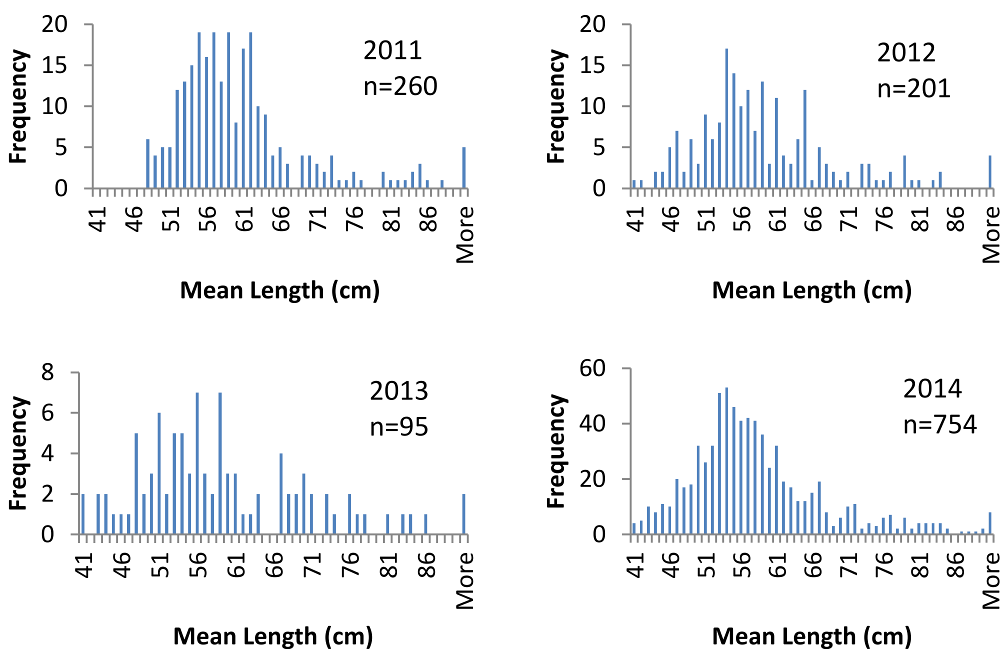

Figure 5. Frequency distributions of mean length of Atlantic Salmon acquired from repeated measurements (n=3) of DIDSON sonar images for 2011 to 2014.

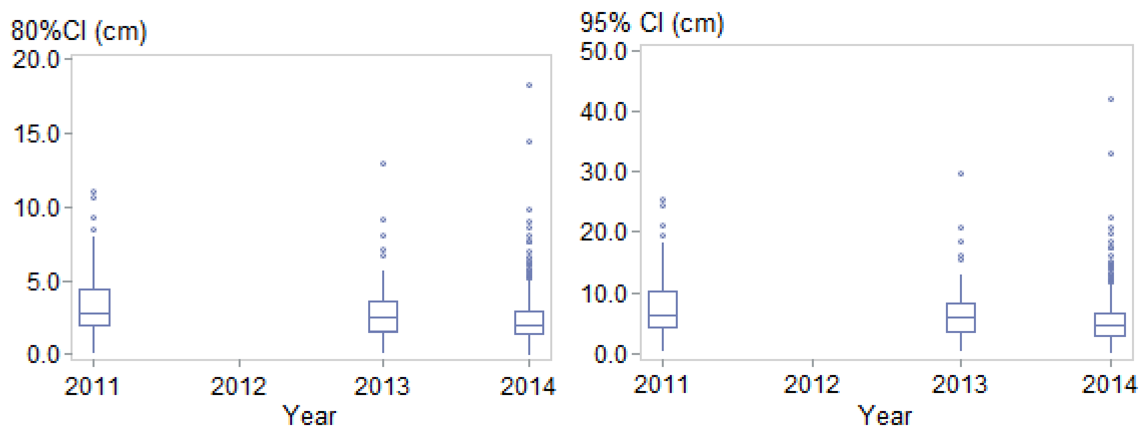

Figure 6. Box plots of the 80% and 95% confidence intervals calculated from repeated measurements (n=3) of individual Atlantic Salmon on DIDSON sonar images. Box shows median value, 25^{th} and 75^{th} percentiles. Whiskers are 1.5 X interquartile range. Circles are measurements falling outside the interquartile range.

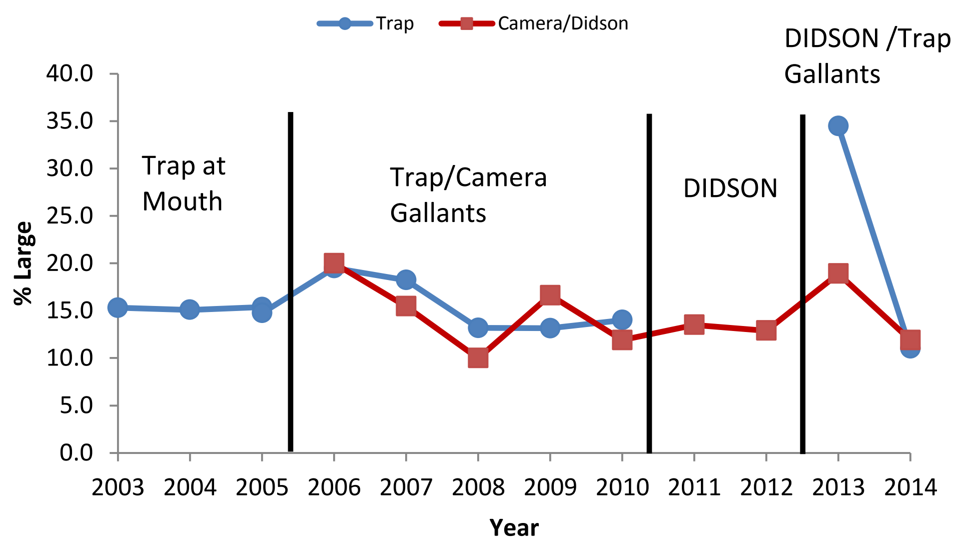

Figure 7. Trends in the percentage of large Atlantic Salmon in the annual upstream migration on Harry's River. Length estimates are based on trapped and measured fish (blue line solid circles); videotape images of fish (camera), or DIDSON sonar images of fish (red line solid squares). The trapped and videotaped fish define a large salmon as ≥ 63 cm whereas, the lengths from the DIDSON sonar images defined a large salmon as ≥ 69 cm. Vertical bars indicate time frame when each method was in use.

Table 1. Mean, median and mode fork lengths of Atlantic Salmon in the annual upstream migration on Harry's River estimated from DIDSON sonar images from 2011 to 2014. N= total number of salmon measured.

Year	Mean	Median	Mode	N
2011	60.2	58.3	61.8	260
2012	58.8	56.7	53.1	201
2013	57.5	55.5	50.2	80
2014	57.8	55.8	52.8	754

Table 2. Percent of large Atlantic Salmon in the annual upstream migration on Harry's River estimated from DIDSON sonar images from 2011 to 2014 based on using a ≥ 63 cm criterion to define large salmon, a ≥ 66 cm (80% confidence interval) criterion and a ≥ 69 cm (95% confidence interval) criterion.

Year	≥ 63 cm	≥ 66 cm	≥ 69 cm
2011	23.1	16.2	13.5
2012	27.4	17.9	12.9
2013	29.5	27.4	18.9
2014	21.1	15.9	11.9