

A twenty-year assessment of Mistassini Lake spawning walleye body size

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Introduction

Within the Mistassini Lake region of Eeyou Istchee, the Cree have long depended on the harvesting of fish populations for their subsistence and well-being (Fraser et al. 2006; Marin et al. 2017; Bowles et al. 2022). A greater demand for these fish has occurred in more recent times as both the local human population and the sportfishing tourism industry have expanded (Fraser et al. 2013; Bowles et al. 2020, 2021). Walleye (*Sander vitreus*) is one of the important socio-economic and cultural fish species in Mistassini Lake. It is targeted by both Cree subsistence fishers, and by sport fishers that fish from local Cree operated outfitting camps, the community of Mistissini, and the Albabel-Mistassini-Waconichi Wildlife Reserve (owned and operated by the Cree Nation of Mistissini through the Nibiischii Corporation).

Mistassini Lake is home to several genetically distinct populations within a variety of fish species (e.g. Fraser et al. 2004; Marin et al. 2016), including walleye (Dupont et al. 2007; Bowles et al. 2020). Almost ten years ago, community members expressed concerns regarding increased exploitation pressure on walleye populations within the southern part of the lake. The monitoring efforts of the southern Mistassini Lake walleye populations were put in place following declining trends in body size raised by the CNM and follow-up studies of Bowles et al. (2020, 2021). Specifically, a significant decrease in body size (total length and mass) was documented by both local Indigenous Knowledge (among other concerns) and formal comparisons of body size between 2002/03 and 2015. Subsequent collaborative monitoring efforts were established and implemented in 2016 on a semi-regular basis. Since 2020, monitoring efforts were part of the large-scale *Fostering Indigenous Small-scale fisheries for Health, Economy, and food Security* (FISHES) project. As one of its initiatives, collaborative monitoring of these important walleye populations for local fisheries stewardship by CNM and Nibiischii, are crucial to ensure the sustainable subsistence and recreational walleye fishery in Mistassini Lake, part of Quebec's largest wildlife reserve. The findings discussed below are the life history (i.e., body size) of walleye populations over a twenty-year period (2002 to 2022, approximately three walleye generations) as part of on-going monitoring efforts.

Methods

Fish Sampling

Collaborative walleye sampling has been occurring in Mistassini Lake and its tributaries on a semi-regular basis over the last twenty years. Specifically, fish sampling has occurred in association with several studies and monitoring efforts, including:

- 2002-2003: genetic population structure of sympatric walleye populations (Dupont et al. 2007);
- 2015: initial monitoring of Mistassini Lake walleye following concerns from the community (Marin & Fraser 2016a);
- 2016-2017: monitoring following the adoption of the Walleye Management Plan (Marin & Fraser 2016b; Bowles et al. 2018); and
- 2020-2022: monitoring as a part of the FISHES project.



Photo 1. Collaborative sampling team in 2022.



Photo 2. Measuring a walleye in 2022

As a part of all of these various studies and monitoring efforts, walleye were collaboratively sampled during their spring spawning period. The majority of walleye were captured via angling, however, some walleye were also donated from local fishers using other methods (such as, gillnetting, snagging, snaring and scooping). Fish that were angled were immediately placed in freshwater baths with aerators. Any bycatch species were quickly returned to the river. From each walleye, we collected total and fork length (TL and FL, respectively, ± 1 mm), wet mass (± 50 g), and sex. Walleye were then returned to the water near the location of capture. See Appendix 1 for photos of collaborative sampling over years.

Table S1 (see Appendix 2) contains a summary of the sampling years, rivers, sample sizes, and sampling dates. Due to uneven sample sizes, years were grouped into three time periods to compare body size trends: A = 2002/2003; B = 2015/2016/2017; and C = 2020/2021/2022. Given that the average generation time of walleye in Mistassini Lake is 5-7 years, comparing these time periods reflects between 1 and 3 generations (A vs B ~ 2 generations; B vs C ~ 1 generation; A vs C ~ 3 generations).

Figure 1 provides a spatial and numerical representation of each sampling period per river. Individuals in which sex could not be determined in the field were not retained for future analyses.

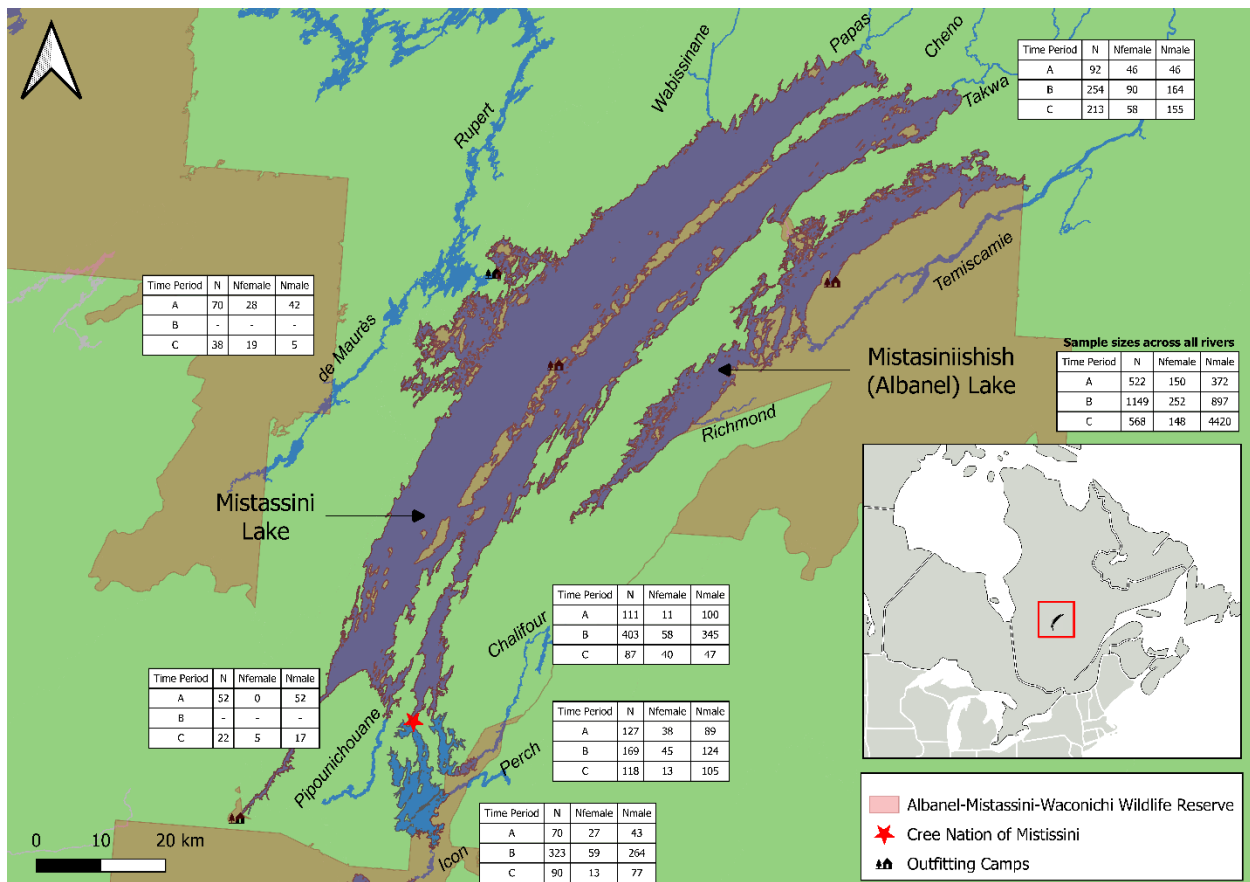


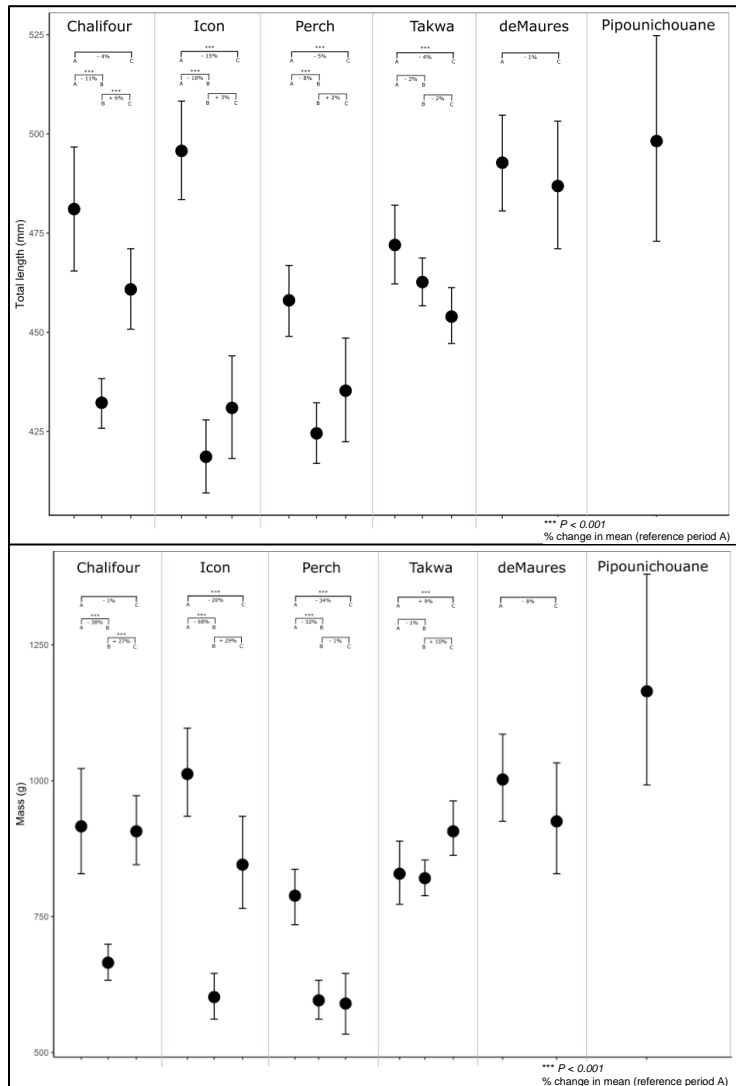
Figure 1. A map showing the location of each sampled river and the total samples available per time period for the analyses.

Data analysis

To determine if and how body size (TL and mass independently) have changed over the twenty-year period, we used linear models in R (R Team 2013). These models allow us to look at each aspect of body size on a per river, sex and time period basis or any combination of these variables. Both TL and mass was log transformed (ln) to meet the requirements of normality in the residuals. To select the best model - that is determining which variables (river, sex and time period and their interactions) best explain any observed changes in body size - we used backward step-wise model selection and *F*-tests. We compared the pairwise least-squares means of each response variable to determine the direction, magnitude, and significance of the change. Significance was detected at an alpha of 0.05 and all multi-comparison *P*-values were adjusted using the false discovery rate (FDR) method for 31 planned (Benjamini & Hochberg 1995). Because we are interested in comparing any body size changes within the same river, and same sex over time, as opposed to between two different rivers or between different sexes between rivers (as this would not track any meaningful changes), we selected the 31 contrasts accordingly.

Results

Overall, the results indicate that both for mass and TL, the three-way interaction between river, sex and time period all contribute significantly to explaining the observed variation in body size among walleye in Mistassini Lake over the last twenty years (Table S2 of appendix). Specifically, both linear regression models were significant (TL, R^2 adj = 0.396, $F_{30,2208} = 49.92$, $p < 0.001$; mass, R^2 adj = 0.399, $F_{30,2208} = 50.52$, $p < 0.001$) and all variables, except one per model, had a significant effect on the response variable (Table S3). A pairwise comparison of the least square means of the interaction terms from each model revealed the direction, magnitude, and significance of the temporal changes in TL and mass.



Both TL and mass show similar trends per river over the last twenty years. Overall, and observed in Figure 2, between the baseline period and subsequent time periods (A vs B and A vs C) we observed a decline in body size in all rivers between 1% (Chalifour mass A vs C) and 68% (Icon mass A vs B). While Takwa observed a decline in TL between A and C by 4%, mass has increased by 9%. Although contemporary (C) body sizes remain smaller than the baseline period (A), it is important to note that there have been several increases since the intermediate time period (B). Notably, an increase in TL in Chalifour, Icon and Perch and in mass for Chalifour, Icon and Takwa. When we examine these results on a per sex basis, see below, we can detect important within river and region nuances.

Figure 2. Least square means TL (above) and mass (lower) between the three time periods for all sampled rivers, which is averaged over sex. Due to lack of samples Pipounichouane is only representative of time period C.

Because walleye exhibit sexual dimorphism (i.e., females tend to be larger in body size compared to males) it is important to look at the different sexes within individual rivers over the twenty years. In general, the results show a stabilizing body size; however, there are nuances within each river and region for both TL and mass. There are specific distinctions that are important to highlight with the aid of Figure 3 (below):

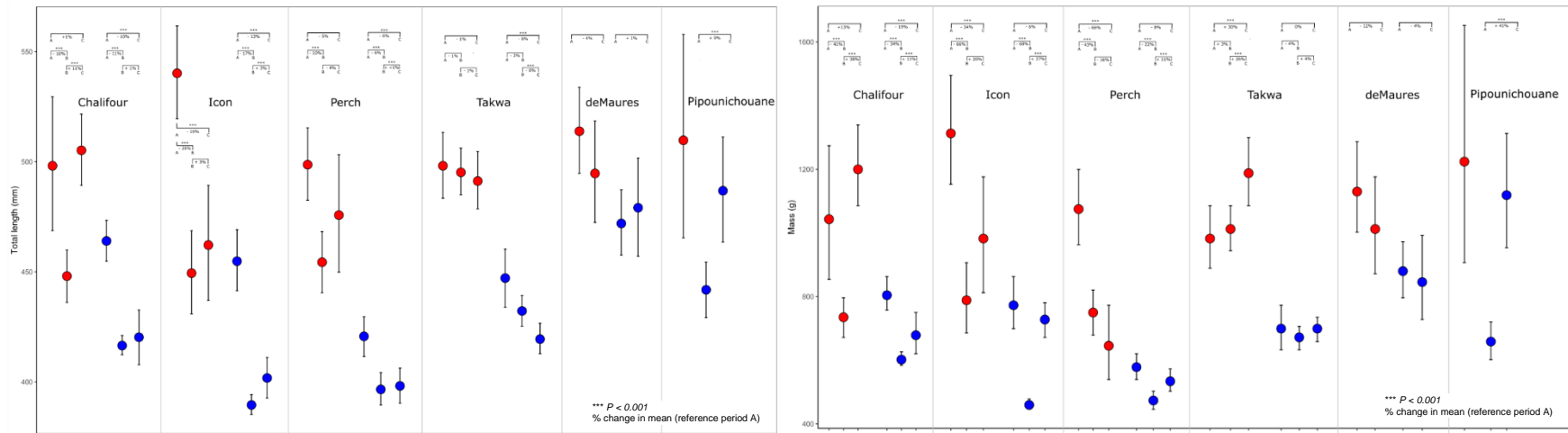


Figure 3. Least squares means of total length (TL), left, and mass, right, for female (red) and male (blue) walleye between the three time periods (A, B and C: going from left to right for each sex within each spawning river). Note: there is no time period B for deMaures (males and females) and Pipounichouane males; and no time period and B for Pipounichouane females due to lack of samples.

- Over the last twenty years (A vs C) the three southern rivers (Chalifour, Icon and Perch) have observed an overall decrease in body size (TL and mass); however, in the most recent years (B vs C), there appears to be a stabilization or slight increase in body size. More specifically:
 - Chalifour River walleye have contemporarily (C) slightly higher (1% TL and 13%) body size compared the baseline period (A), after a significant decrease (10% TL and 41% mass) at the intermediate time period (B). Some of recent increase is driven by some 2022 samples that were donated by a local fisher. These walleye were caught in a gillnet and predominately larger females. For example, in time period C the average female mass was 1200 g; however, removing those donated and gillnetted walleye (31 females and 13 males) lowers the average mass to 963 g. This new average is slightly below the baseline period (A), which was 1043 g, however, the overall trend remains the same.
 - Walleye in Icon River have undergone a significant decrease in body size: 20-68% in time period B and to a lesser, but significant extent in time period C (16-37%). Therefore, walleye have observed a slight, non-significant, increase in body size from B to C (3-20%) but remain lower than historical sizes for both males and females.
 - Perch River have similar trends to Icon: all contemporary (C) walleye remain smaller than historical (A) sizes; however, males (both TL and mass) and females (TL only) show a stabilizing trend (A vs B vs C). Female TL has non-significantly decreased by 5% (A vs C) compared to significantly decreasing 10% (A vs B). Males TL remains significantly lower (6%) since historical sampling (A vs C and A vs B). Female mass has continued to significantly decrease in recent years: 66% lighter in C compared to 43% lighter in B; however male mass has rebounded slightly,

where it is contemporarily (C) non-significantly 8% lower than historical samples (A) compared to the intermediate time period (significant 22%, B).

- The northern river, Takwa, shows a decrease of TL of walleye over the last twenty years for both females (~1%) and significant decrease for males (6%). Mass; however, appears to be more variable and even a significant increase (of 30%) in females and non-significant fluctuation (0-4%) over the last twenty years. This result indicates that fish may be getting smaller in TL but heavier in mass. We speculate that this curious could be spurious in relation to time of sampling, but it merits reassessment in future monitoring efforts.
- deMaures River shows a non-significant decrease in body size (both TL and mass) for females (4-12%) and males (4%) from over the last twenty years (A vs C; except for the TL of males).
- While there are limited samples for Pipounichouane River, we are able to note that when looking at males, we observed a significant increase in body over the last twenty years (A vs C). And, compared to other southern river populations, both male and female walleye from this river are contemporarily quite large. Preliminary analyses of mixed-stock harvests in Mistassini Lake for 2020-2021 using genomics tools indicate that few harvested walleye originate from Pipounichouane River, suggesting that this population might be small in abundance compared to all others in the lake and easily overharvested if targeted in the river in the spring.

As was present in previous years, the sampling over the twenty-year time period displays a sex-bias for more males than females being captured at spawning sites, which is consistent across years (Figure 3). However, as noted above and in previous reports, different sampling techniques also target different sexes and different body sizes. For example, in 2022 a local fisher captured 37 females and 13 males in a gillnet compared to 2 females and 59 males via angling. Walleye females tend to be larger in body size and therefore, gillnets capture more females by increasing the selectivity towards targeting larger fish.

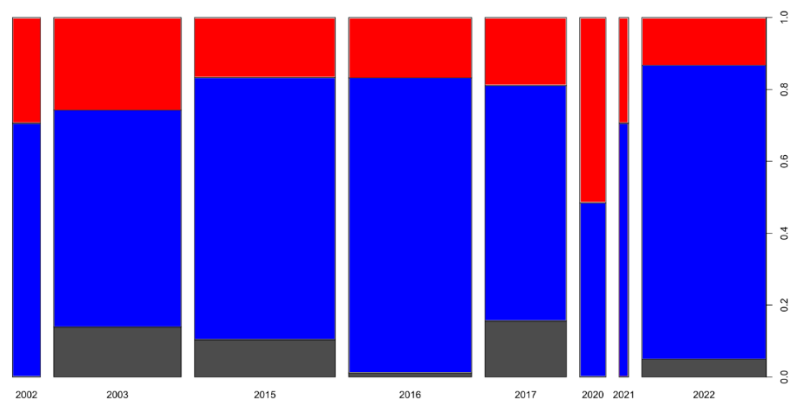


Figure 4. Sampling sex-bias across all rivers for each sampled year: female (red), male (blue), unidentified sex (grey). Individuals were classified as unidentified if they were immature, skip-spawners, or pre-/post-spawning.

Local Management Recommendations

The results above indicate a stabilization in body size in recent years (B vs C); however, body size remains lower than the baseline period (A) in the majority of sampled rivers. Given the average generation time of the walleye in Mistassini Lake (5-7 years), the twenty-year comparison above denotes approximately 3 generations of walleye and the recent stabilization is only representative of approximately 1 generation. While this is encouraging of initial management and subsequent monitoring adopted in 2016, we note that these strategies have not been in full effect

since (mainly due to the covid-10 pandemic), and continued efforts are still highly recommended. Specifically, we recommend that future monitoring include:

- Continued public outreach & education:
 - Inspect and maintain all walleye billboards previously installed. At the time of 2022 sampling all billboards were in good condition except for Perch (north access point near bridge), which has fallen.
 - Advertise (via the radio, pamphlets, and posters) in the community every spring (prior to and during the spawning period) about monitoring and management efforts.
- Ask the public to change three important behaviours with regards to fishing during the spawning period:
 - Permanently reduce the harvest of large number of walleye in the rivers in spring.
 - Reduce the overall number of walleye harvested on the spawning grounds.
 - Refrain from using techniques that size-select for larger walleye (i.e., gillnetting, scooping, snaring and night fishing). These techniques still appeared to be use in at various southern rivers in the 2022 sampling.
- Monitoring of **all** rivers every 3-5 years. It is important that all rivers continue to be monitored for the following reasons:
 - Local fishers expressed concerned, during the 2022 sampling, over decreasing body size in Takwa River in recent years, the most difficult to access spawning river in the region.
 - Observed decreasing trends in body size are not only present in the southern rivers.
 - To ensure accurate comparisons can continue to be made, less sampled rivers (such as deMaures and Pipounichouane) should be part of the monitoring.
- Consider a traditional capture-mark-recapture study to obtain more accurate estimates of population sizes.



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Appendix 1



Photo 4. Field assistant Natalya Assance holding her first walleye in May 2022.



Photo 5. Field assistant Jacob Coon Come holding a large Northern pike in May 2022.



Photo 6. Typical sampling from shore set-up in May 2022.



Photo 7. Natalya Assance and local fishing guide, Norman Neeposh, taking a break while sampling in May 2022.



Photo 8. Jacob Coon Come angling for walleye in May 2022.



Photo 9. Norman Neeposh pulling in a gillnet in May 2022.

Appendix 2

Table S1. Number of samples collected per river, per year and dates of capture.

River	Year	N	N _{female}	N _{male}	N _{unknown}	Dates of capture
Chalifour	2002	43	2	41	0	May 29-30, 2002
	2003	68	9	59	0	May 15-16, 2003
	2015	170	14	117	39	May 20-27, 2015
	2016	163	30	132	1	May 21-24, 2016
	2017	110	14	96	0	May 20-27, 2017
	2020	-	-	-	-	-
	2021	9	3	6	0	May 5, 2021
	2022	87	37	41	9	May 17-20, 2022
Perch	2002	38	1	37	0	May 24-25, 2002
	2003	89	37	52	0	May 11-17, 2003
	2015	61	13	34	14	May 16-30, 2015
	2016	113	32	78	3	May 15-26, 2016
	2017	12	0	12	0	May 23-24, 2017
	2020	-	-	-	-	-
	2021	18	4	14	0	May 1-18, 2021
	2022	101	9	91	1	May 20-21, 2022
Icon	2002	-	-	-	-	May 25-27, 2002
	2003	70	27	43	0	May 7-14, 2003
	2015	114	8	106	0	May 15-20, 2015
	2016	170	13	156	1	May 18-23, 2016
	2017	40	38	2	0	May 19-23, 2017
	2020	-	-	-	-	-
	2021	6	3	3	0	May 17-20, 2021
	2022	87	10	74	3	May 17-20, 2022
Takwa	2002	18	15	3	0	June 7, 2002
	2003	100	31	43	26	June 4, 2003
	2015	166	50	116	0	June 1-2, 2015
	2016	-	-	-	-	-
	2017	134	40	48	46	June 6-7, 2017
	2020	86	40	46	0	June 13-15, 2020
	2021	-	-	-	-	-
	2022	133	18	109	6	June 6-7, 2022
deMaures	2002	25	13	12	0	June 4-6, 2002
	2003	83	15	30	38	May 26-30, 2002
	2015	-	-	-	-	-
	2016	-	-	-	-	-
	2017	-	-	-	-	-
	2020	22	9	13	0	June 23-24, 2022

	2021	-	-	-	-	-
	2022	21	10	6	5	June 7, 2022
Pipounichouane	2002	-	-	-	-	-
	2003	52	0	52	0	May 21-22, 2003
	2015	-	-	-	-	-
	2016	-	-	-	-	-
	2017	-	-	-	-	-
	2020	-	-	-	-	-
	2021	1	0	1	0	May 23, 2021
	2022	22	5	16	1	May 20-21, 2022

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Table S2. Results on model selection for total length (TL) and mass using backward stepwise regressions and *F*-tests. The degrees of freedom (df) reported below are the difference of df between the two models compared.

Model No.	Description [^]	Versus model no.	df	<i>F</i> -value	<i>P</i> -value
log(TL)					
0*	TP + R + S + TP:R + TP:S + R:S + TP:R:S				
1	TP + R + S + TP:R + TP:S + R:S	A	-7	2.482	0.015
log(mass)					
0*	TP + R + S + TP:R + TP:S + R:S + TP:R:S				
1	TP + R + S + TP:R + TP:S + R:S	A	-7	5.323	<0.001

[^]Term abbreviations are as follows: TP = Time period, R = River, S = Sex

*Selected model

Table S3. Analysis of variance table for linear model 0 for each total length (TL) and mass.

Variable(s)	df	<i>F</i> -value	<i>P</i> -value
Response: log(TL)			
Time period	2	182.879	<0.001
River	5	64.127	<0.001
Sex	1	640.446	<0.001
Time period:River	8	14.670	<0.001
Time period:Sex	2	2.654	0.071
River:Sex	5	6.059	<0.001
Time period:River:Sex	7	2.482	0.015
Response: log(mass)			
Time period	2	194.279	<0.001
River	5	67.548	<0.001
Sex	1	571.738	<0.001
Time period:River	8	18.183	<0.001
TimePeriod:Sex	2	1.292	0.275
River:Sex	5	5.379	<0.001
TimePeriod:River:Sex	7	5.326	<0.001