Evaluation of Atlantic salmon (*Salmo salar*) restocking in the Geul River 2017-2021

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Evaluation of Atlantic salmon (*Salmo salar*) restocking in the Geul River 2017-2021	
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CONTENTS

1 INTRODUCTION

Atlantic salmon (*Salmo salar*) are part of the native fish community in Western European river systems. Until the the first half of 20th century, the species occured in Dutch rivers however populations collapsed due to overexploitation, water pollution and fish migration barriers (De Groot 1992; Lenders et al. 2016). However, due to the implementation of international river restoration and salmon reintroduction programmes in the last decades, salmon can once be found again in Dutch rivers. This is also the case for the Geul River, a fast flowing tributary of the Meuse River. There are several historical records of salmon caught in the Geul River, indicating this was a salmon river in the past (figure 1.1).

A

Nieuws uit Valkenburg.

Vischvangst. — Door den bekende visscher werd heden in de Geul een prachtigen zalm gevangen van 6½ kilo gewicht.

B

VALKENBURG.

Vischvangst. — Door den heer Palmen, coiffeur, werden in de Geul gevangen: 3 zalmen, ongeveer 7 pond wegend, en 4 forellen, waarbij er één was van 3 pond, naar het oordeel van den visscher gecroiseerd met een zalm.

Figure 1.1 Historical news articles reporting adult salmon (*Salmo salar*) being caught in the Geul River. A) Limburger courant 11 February 1919 and B) Limburgs dagblad 13 June 1924 (Delpher 2020).

Atlantic salmon is mentioned on Annex II and V of the Habitats Directive (Council of the EU 1992). Restoring a spawning salmon population in the Geul River contributes to the objective of reesteblishement of a sustainable salmon population in the Meuse River. This objective is embedded in the Water Framework Directive goals and in Natura 2000 goals. The catchment area of the Meuse River has been designated as a Habitat Directive area for salmon, with the objective of expanding the population. The designation states that salmon cannot reproduce in the Dutch catchment area of the Meuse River and that the Meuse River is currently only a migration route to upstream abroad spawning grounds (Staatssecretaris van Economische Zaken 2013). However currently, spawning might once again take place in tributaries of the Meuse River which were previously used as spawning grounds, such as the Swalm River, the Ruhr River and the Geul River. In 2014 and 2015, Bureau Natuurbalans - Limes Divergens BV carried out a feasibility study to assess the reesteblishment of salmon in the catchment area of the Geul River. It is concluded that the Geul River offers good potential for this species (Crombaghs et al. 2015). Additionally, an independent and more extensive study was performed by the University of Namur, which confirmed these findings and assigned designated restocking areas (Otjacques et al. 2017).

Now several fish migration barriers have been removed, the water quality has improved considerably in recent years and the related brown trout (*Salmo trutta*) reproduces in the Geul River, it seemed an appropriate moment for the reintroduction of salmon. Therefore, a pilot project was initialized with the release of young salmon in the Dutch Geul River. In the spring of 2017, 24,000 young salmon were released between Bunde and Epen, funded by Sportvisserij Limburg and Ark Natuurontwikkeling. Similarly as in the reintroduction programme in the Ruhr (Belgers & Gubbels 2013), salmon were raised in the Belgian fish hatchery in Erezée. The reintroduced salmon are the offspring of wild salmon caught in the Meuse River near Lixhe.

The evaluation of the 2017 reintroduction was performed by Latli et al. (2017). The authors concluded that restocking the Geul River with salmon in order to regain a viable salmon population in this tributary of the Meuse River is promising, compared to the reference Samson (Bois de Gesves) River in Belgium. Therefore the restocking was continued, resulting in the release of 25,000 young salmon in the spring of 2018, 2019, 2020 and 2021. This was funded by the Province of Limburg, Rijkswaterstaat and Water Authority Limburg (Waterschap Limburg). In order to determine the survival rate and the condition of the young salmon from 2017 until 2021, fish surveys at different reintroduction locations were carried out in September of these years, targeting juvenile salmon (figure 1.2). This report evaluates the reintroduction of salmon in 2018 until 2021 and compares the results with the 2017 evaluation (Latli et al. 2017).

Figure 1.2 Juvenile salmon in caught in the Geul River (photo: P. Lemmers).

2 METHODS

2.1 SAMPLING

During the last week of September in all sampling years, the fish surveys were carried out on four restocking sites (figure 2.1). The fish surveys were carried out using Bretschneider EFGI 650 hand electrofishing equipment and a Rudd, assisted with a person with a 70x55 cm dip net increased the catch efficiency in these fast-flowing streams. Caught salmon were individually measured TL (accuracy 1 mm) and weighed (accuracy 0.1 g).

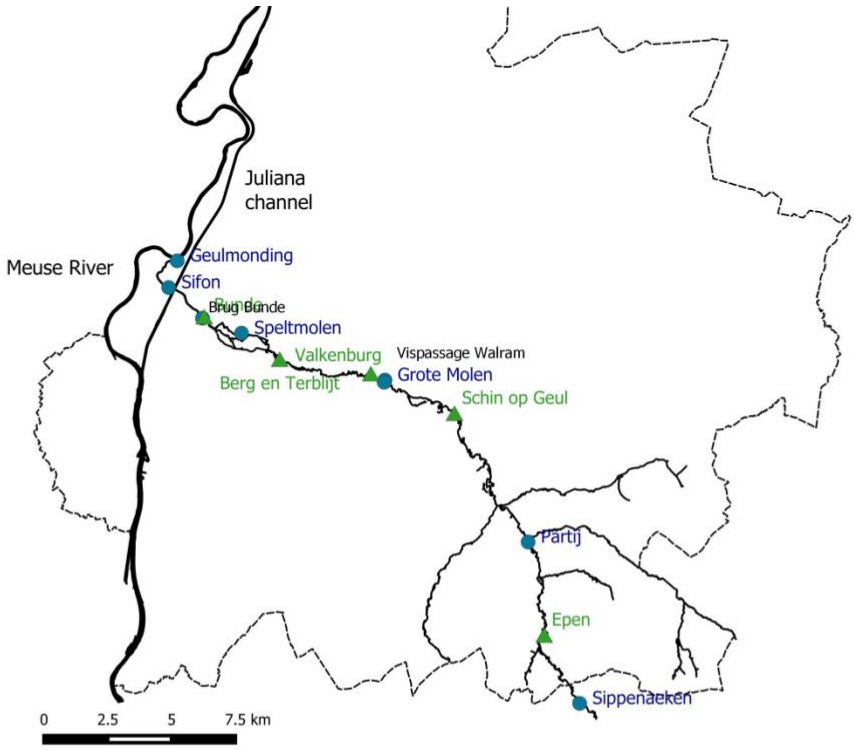

Figure 2.1 Study site located in the Geul River basin. Green triangles indicate the sampling sites. Blue dots indicate the locations of PIT-tag antenna.

Each year, four restocking sites were sampled anually. In 2017, these were Bunde, Valkenburg, Schin op Geul and Epen. However, due to a water pollution event with manure (Lemmers et al. 2018), Epen was not sampled in 2018 and Houthem was sampled instead. No animals were restocked in Epen in 2019 and hence, this site was not sampled in 2019. In 2020 and 2021, all original sites of 2017 were sampled. The number of restocked salmon, as well as the surface area where restocking took place, varied per site (table 2.1). Therefore, the sampling area has been taken into account during sampling.

Table 2.1 Summary of the yearly number of restocked salmon (*Salmo salar*) total stocking area (m^2) and total sampled area (m^2) per sampling site.

Sampling site	Restocked salmon (n)	Total restocking surface area (m^2)	Total sampling surface area (m^2)
Bunde (sector 2B)	2000	4000	1250
Houthem (sector 6)	700	2000	800
Valkenburg (sector 8)	2500	3500	1280
Schin op Geul (sector 11)	2500	5000	3400
Epen (sector 18)	2000	1400	840

2.2 DATA ANALYSIS

For the data analysis, the specific growth rate (% day^{-1}) was calculated. The specific growth rate represents the percentage of growth in weight per day between the restocking and the sampling day (116 days).

SGR = (ln(Weight final) – ln(Weight initial) * 100) / number of days

The Fulton index or condition factor (*K*) is an indication of the fish health and based on the assumption that the weight (g) of the fish is proportional to the cube of its length (cm). This index allows comparing the fitness of fish between sites. A value close to 1 indicates that the population is healthy and well-fed.

K = 100 * (Weigth / $Length^3$)

The data of length and weight meets the assumptions of normality. Arithmetic means between study years were compared using generalized linear models with the use of the program R version 4.0.3 (R Core Team 2020).

Figure 2.2 A first-year salmon being measured after being weighed (photo: P. Lemmers).

3 RESULTS

3.1 QUANTITIES

In total, 1011 juvenile salmon were caught, weighed and measured during all study years (figure 3.1). Most individuals were caught in the year 2017 (n= 379), followed by the 2020 (n= 237), 2019 (n= 192), 2018 (n= 115) and 2021 (n= 88). Proportionally, the highest numbers were caught in Bunde in the most survey years.

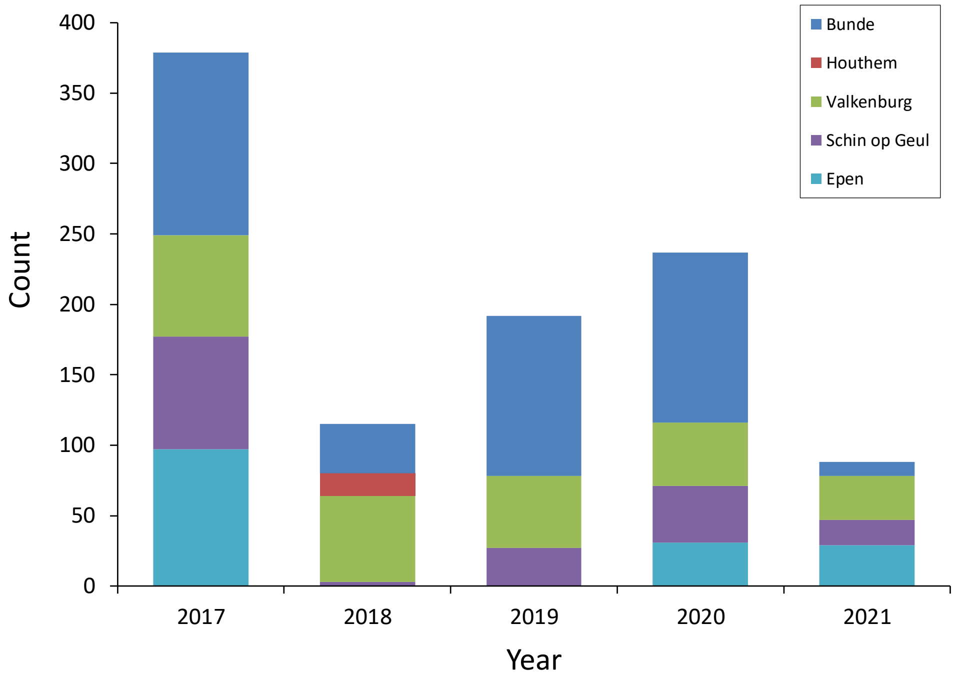

Figure 3.1 Cumulative numbers per study year of caught salmon.

The highest recapture percentage was observed in Bunde during all sampling years with the exemption of 2021 (table 3.2). The lowest recapture percentage of all sampling years was observed in Schin op Geul. In accordance with the highest numbers caught in 2017 (figure 3.1), the highest overall recapture percentage was observed in 2017.

Table 3.2 Summary of the recapture percentages per year and per sampling site. The percentage is corrected for the total number of restocked salmon at the site, the total restocking surface area (m^2) and the total sampling surface area (m^2). n.a. denotes "not assessed".

Sampling site	**Year**				
	2017	**2018**	**2019**	**2020**	**2021**
Bunde	20,8%	5,8%	18,2%	19,4%	1,6%
Houthem	n.a.	5,7%	n.a.	n.a.	n.a.
Valkenburg	7,9%	6,7%	5,1%	4,9%	3,2%
Schin op Geul	4,7%	0,2%	1,4%	2,4%	1,1%
Epen	8,1%	n.a.	n.a.	2,6%	2,6%
mean	10,4%	4,6%	8,3%	7,3%	2,1%

The data presented mainly refers to first-year animals but in a few cases second-year animals were caught. In 2018, in total five second-year old salmon were caught. In 2019, 2020 and 2021 nine, five and four second-year individuals were caught respectively. The largest (235 mm) and heaviest (121,1 g) individual was caught in 2019 in Schin op Geul. It was reported by members of the VBC that these second- old salmon also occasionally were caught by fly-fishing (figure 3.2). In the presented results and analysis, second-year salmon were not included unless otherwise specified.

Figure 3.2 A second-year salmon caught by fly-fishing near Valkenburg in 2018 (photo: L. Huijnen).

3.2 LENGTH-WEIGHT

The smallest individual that was caught was 55 mm and weighted 2,3 g. The lightest individual was 65 mm and weighted 2,2 g. The both largest and heaviest individual, which concerned a two-year old individual, was 235 mm and weighted 121,2 g. The vast majority of the caught salmon measured between 66-128 mm and weighted between 3.9 and 19.1 g (figure 3.3).

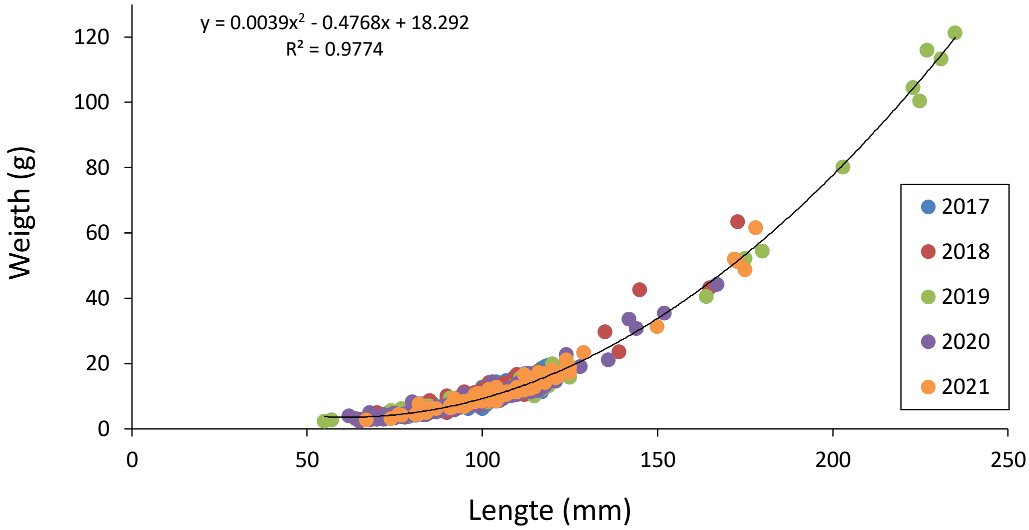

Figure 3.3 Length-weight relation of caught salmon in the Geul river during five study years (n = 1011). A polynomial regression line with corresponding formula and R^2 are also presented. From ≥ 130 mm concern second year individuals.

3.2.1 Length-weight comparisons between years and sites

The arithmetic means of length between sampling sites and years were compared (figure 3.4). In 2017, the individuals were significantly larger than in 2018 (GLM; t= 5.29; p < 0.0001) and 2020 (GLM; t= 4.52; p < 0.0001). The sampling year 2018 had the smallest mean individuals, compared to 2019 (GLM; t= 4.34; p < 0.0001), 2020 (GLM; t= 2.04; p < 0.05) and 2021 (GLM; t= 4.17; p < 0.0001). The year 2019 had significantly smaller individuals than 2020 (GLM; t= 3.05; p < 0.001) but not with 2021. 2020 also had larger individuals than 2021 (GLM; t= 3.00; p < 0.001).
Bunde had significantly smaller individuals than Valkenburg (GLM; t= 13.61; p < 0.0001), Schin op Geul (GLM; t= 10.87; p < 0.0001) and Epen (GLM; t= 5.11; p < 0.0001). Valkenburg had significantly larger individuals than Epen (GLM; t= 5.77; p < 0.0001) but not than Schin op Geul. Similarly, Schin op Geul had larger individuals than Epen (GLM; t= 4.53; p < 0.0001).

The arithmetic means of weight between sampling sites and years were also compared (figure 3.5). Significantly heavier individuals were caught in the sampling year 2017 compared to 2018 (GLM; t= 2.94; p < 0.001) and 2020 (GLM; t= 5.51; p < 0.0001) but with 2019 and 2021. The year 2018 had significantly lighter individuals than 2021 (GLM; t= 2.57; p < 0.05) but not than 2019 and 2020. 2019 had heavier individuals than 2020 (GLM; t= 2.88; p < 0.01) but no differences were observed with 2021. Individuals were lighter in 2020 than in 2021 (GLM; t= 3.89; p < 0.001). The mean weight of individuals in Bunde was significantly lower than in Valkenburg (GLM; t= 12.59; p < 0.0001), Schin op Geul (GLM; t= 10.60; p < 0.0001) and Epen (GLM; t= 4.38; p < 0.0001). Valkenburg had significantly heavier individuals than Epen (GLM; t= 5.66; p < 0.0001) but no differences were observed with Schin op Geul. Schin op Geul also had heavier individuals than Epen (GLM; t= 4.95; p < 0.0001).

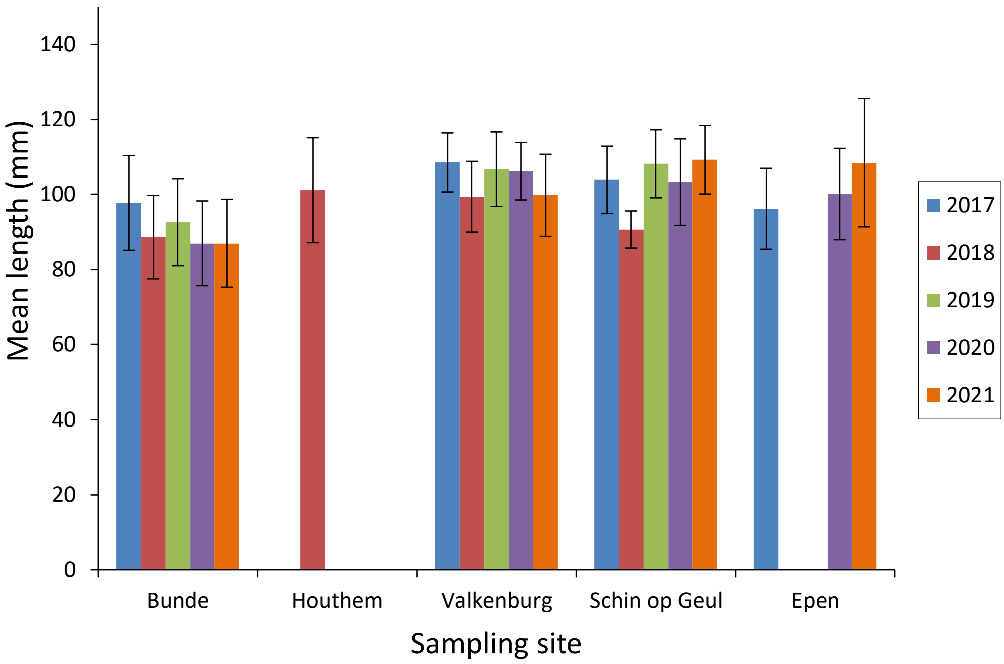

Figure 3.4 Bar graph representation of arithmetic mean TL length (mm) of measured first-year salmon for each sampled site and between years. Error bars represent standard deviations.

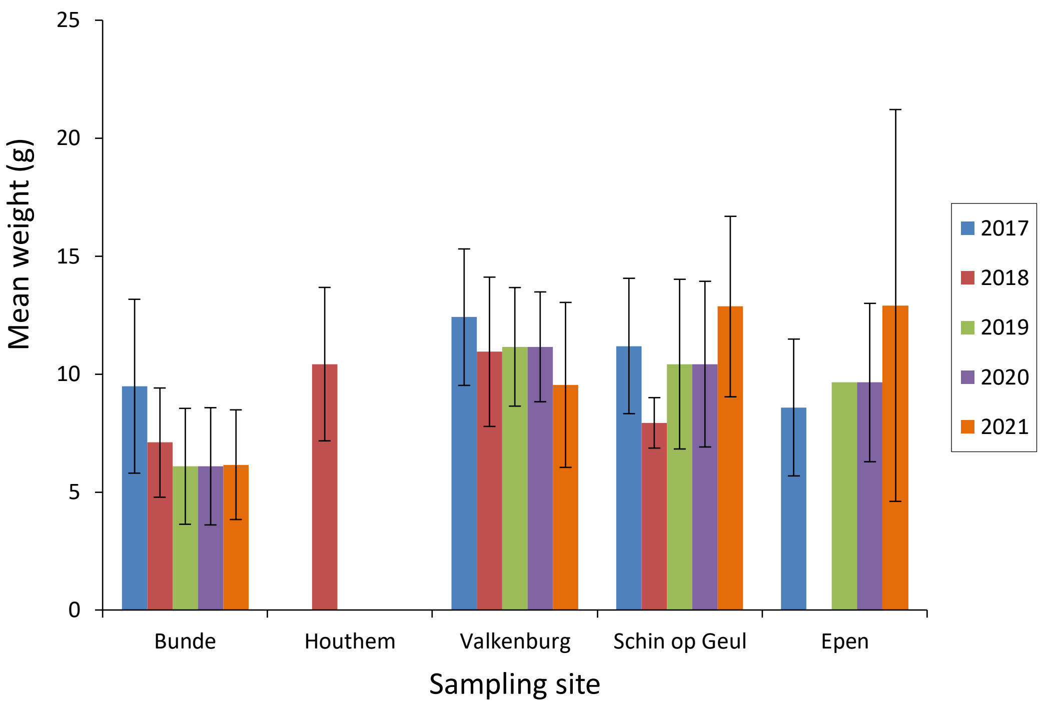

Figure 3.5 Bar graph representation of arithmetic mean weight (g) of weighed first-year salmon for each sampled site and between years. Error bars represent standard deviations.

3.2.2 SGR and Fulton condition factor comparisons

The mean specific growth rate (SGR) of caught during this study was 2,90 % day^{-1}, based on 986 individuals. However, the SGR deviated between years and sampling sites (figure 3.6). The mean SGR was the largest during sampling year 2017 and statistically different compared to 2018 (GLM; t= 3.17; $p < 0.01$) and 2020 (GLM; t= 6.51; $p < 0.0001$) but not to 2019 or 2021. The mean SGR of 2018 did not differ from 2019, 2020 or 2021. Sampling year 2020 had a significant lower SGR than 2019 (GLM; t= 3.81; $p < 0.001$) and 2021 (GLM; t= 3.33; $p < 0.001$).

The comparison between sites showed that Bunde had a significant lower mean SGR than Valkenburg (GLM; t= 14.40; $p < 0.0001$), Schin op Geul (GLM; t= 11.91; $p < 0.0001$) and Epen (GLM; t= 5.12; $p < 0.0001$). Epen had a lower SGR than Valkenburg (GLM; t= 6.37; $p < 0.0001$) and Schin op Geul (GLM; t= 5.39; $p < 0.0001$), no differences between Valkenburg and Schin op Geul were observed.

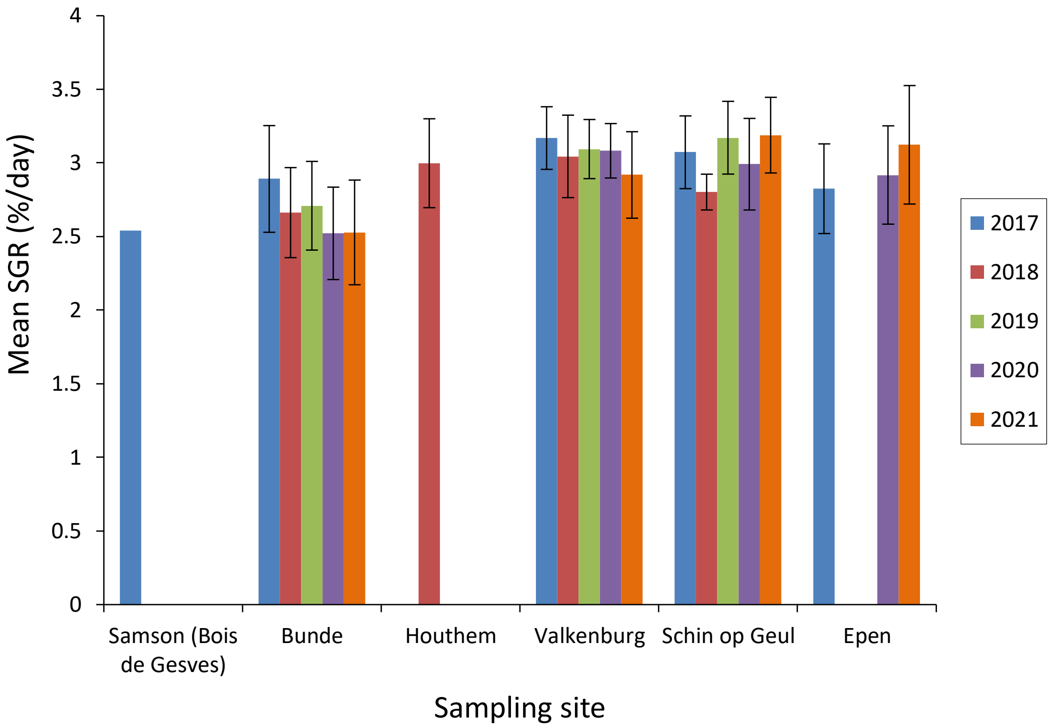

Figure 3.6 Comparison of standard growth rates (SGR) % day^{-1} between each study site per year. The Belgian reference Samson River was also included (provided by Latli et al. 2017). Error bars represent standard deviations. The standard deviation of the Samson River is unknown.

Comparing the Fulton condition factor (*K*) between years showed that there are also differences between sampling years and sites. *K* was significantly higher in 2018 than in 2017 (GLM; t= 6.58; $p < 0.0001$). *K* was higher in 2017 compared to 2019 (GLM; t= 2.60; $p < 0.01$) and 2020 (GLM; t= 4.98; $p < 0.0001$) but no differences were observed with 2021. *K* was also higher in 2018 compared to 2019 (GLM; t= 8.04; $p < 0.0001$), 2020 (GLM; t= 9.65; $p < 0.0001$) and 2021 (GLM; t= 6.66; $p < 0.0001$). And finally, *K* did not differ between 2019 and 2020, 2019 and 2021, nor

between 2020 and 2021. Differences between sampling sites and the Samson River (Belgian reference) could not be tested since the data were not available.
Between sites, *K* was significantly higher in Schin op Geul than in Bunde (GLM; $t = 2.62$; $p < 0.01$) and Epen (GLM; $t = 2.48$; $p < 0.05$). No differences were observed between any of the other sites.

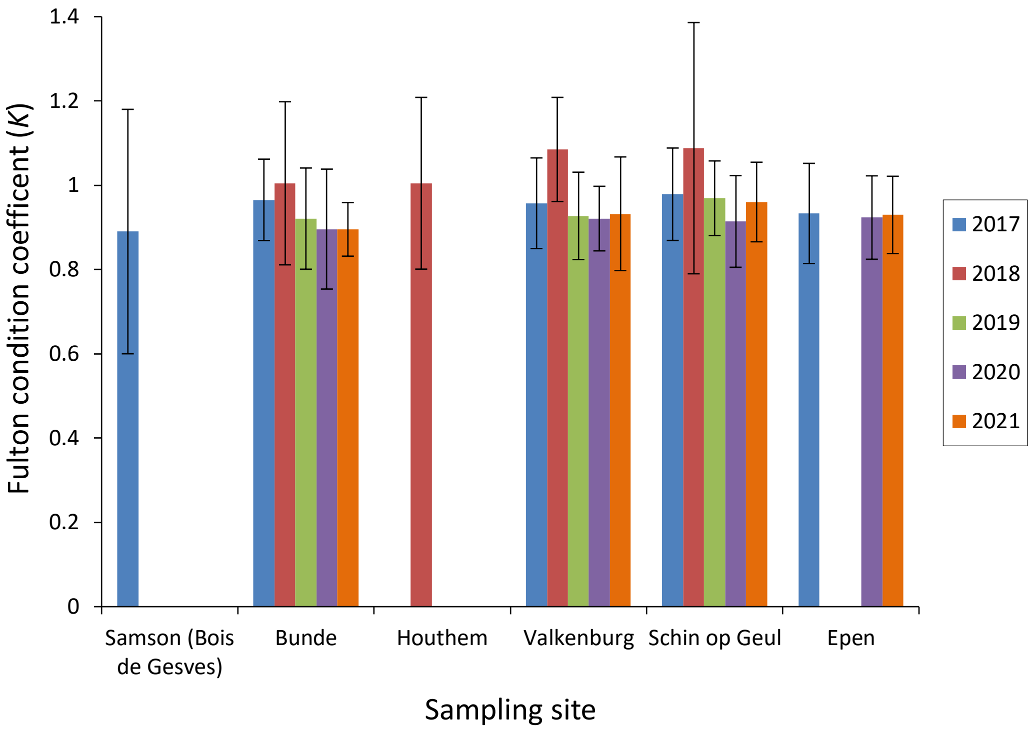

Figure 3.7 Comparison of Fulton condition coefficients (*K*) between each study site per year. The Belgian reference Samson River was also included (provided by Latli et al. 2017). Error bars represent standard deviations.

4 DISCUSSION

4.1 DISCUSSION

In autumn of each sampling year, juvenile salmon are caught on each site where restocking took place in spring. The recapture rate, however, deviates between sampling years and sites despite the same numbers of salmon that have been restocked in spring. The first sampling year 2017 had the highest recapture rate, followed by 2020. The year 2021 had the lowest recapture rate. Possibly high water discharge events and/or relatively warm periods in the summer might affect survival. These events might also affect juvenile salmon dispersion. The summers of 2018 and 2019 were exceptionally warm. In July 2021, there was an extremely high water discharge event for the time of year due to very high rainfall. This may have led to animals being flushed out of the sampling areas. During other fish surveys in de Geul between 2017 and 2021, salmon were occasionally found at sites where no restocking had taken place (unpublished data Natuurbalans), indicating that juvenile salmon disperse from the restocking sites. This means that the recapture rate might be an underestimation of the actual survival. Furthermore, warm/dry and high water discharge events may also affect the length and weight of the juvenile salmon, as significant differences have been observed between years.

The overall mean standard growth rate (SGR) that was determined based on data of 986 caught salmon was 2.90% day^{-1}, exceeds the SGR of 2.54% day^{-1} in the Belgian reference Samson River. Latli et al. (2017) concluded that the SGR in the Geul in 2017 was one of the highest observed during the Meuse Salmon project and is higher than other Belgian rivers. Similarly, the overall mean Fulton condition coefficient of the Geul River was 0.95 which is higher dan the mean Fulton condition coefficient of the Samson River with 0.89. There are slight differences observed between study years and sites in length, weight, SGR and the Fulton condition coefficient *K*. The first restocking year 2017 seemed to be the most successful period in recapture rate and growth rate. However, in 2018 the Fulton condition coefficient *K* was higher compared to other years except 2021. The restocking sites Valkenburg and Schin op Geul harboured the largest and heaviest individuals compared to other sites. Standard growth rates were also higher here compared to the other sites, which might suggests that food availability is better here. However, empirical evidence to support this is lacking.

4.2 CONCLUSION

This evaluation study demonstrated that in general, the Geul River has good rearing grounds for salmon and juveniles are overall in good condition compared to the Belgian reference, although there are differences between the five sampling years and four sites. Juvenile salmon in Schin op Geul showed the highest Fulton condition coefficient *K*. Also, it has been observed that not all salmon migrate to the ocean in their first year as the presence of several two-year old fish has been demonstrated. Continuing the restocking program seems to build upon a solid basis for a durable salmon population in the Geul River. Because adult salmon can be expected to return to spawn, it is advised to remove fish migration barriers that inhibit upstream migration in the Geul River.

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