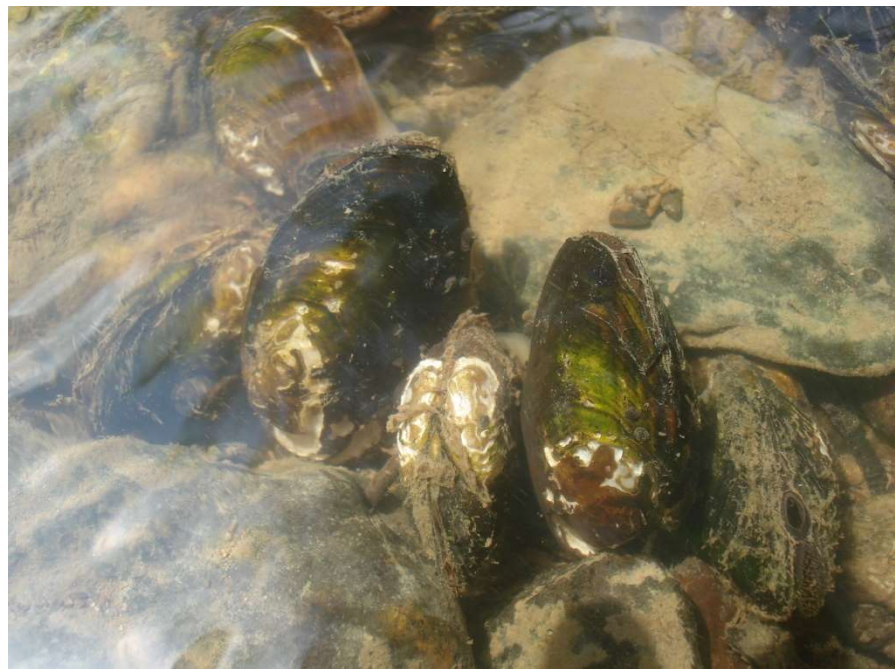


*Restoration of *Unio crassus* rivers in the Luxemburgish Ardennes*

LIFE11 NAT/LU/857



September 1st
2012 – February
28th 2019

Annex

Action D3: Suivi de *Unio crassus* dans son milieu naturel



LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère du Développement durable
et des Infrastructures
Département de l'environnement



LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Agriculture,
de la Viticulture et de la
Protection des consommateurs



Action D3: Suivi de Unio crassus dans son milieu naturel

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1 Monitoring in the River Our and Sauer

The status of the *Unio crassus* population in both rivers (Our and Sauer) was last investigated in the year 2003. In order to gain new information about the population size, age structure and habitat use, the intent of this part was to monitor the population in both rivers.

Table 1: Counted mussels alive and empty shells in the river Our and Sûre

	Our (32 km)	Sauer (20 km)
Prospected [km]	30,5	18,5
Mussels alive [n]	4.563	2.612
Empty shells [n]	1.805	3.545
Proportion alive [%]/ dead [%]	71,6 / 28,4	42,4 / 57,6
Surface of the river bed [m ²]	370.575	190.000
Mean density [ind/m ²]	0,012	0,014

1.1 River Our

The mussel survey in the river Our was finished in the year 2017. From the whole distance of 32km, all 64 (500 meter) sections, which were accessible with the bathyscope, were prospected (in total 30,5 km).

Table 2: Mussel density classes in the river Our

Sections with	Numbers	Distribution [%]
Non accessible	3	5
0-0	3	5
1 - 20	18	28
20 - 40	9	14
40 - 80	10	16
80 - 160	13	20
160 – 420	8	13
Total	64	100

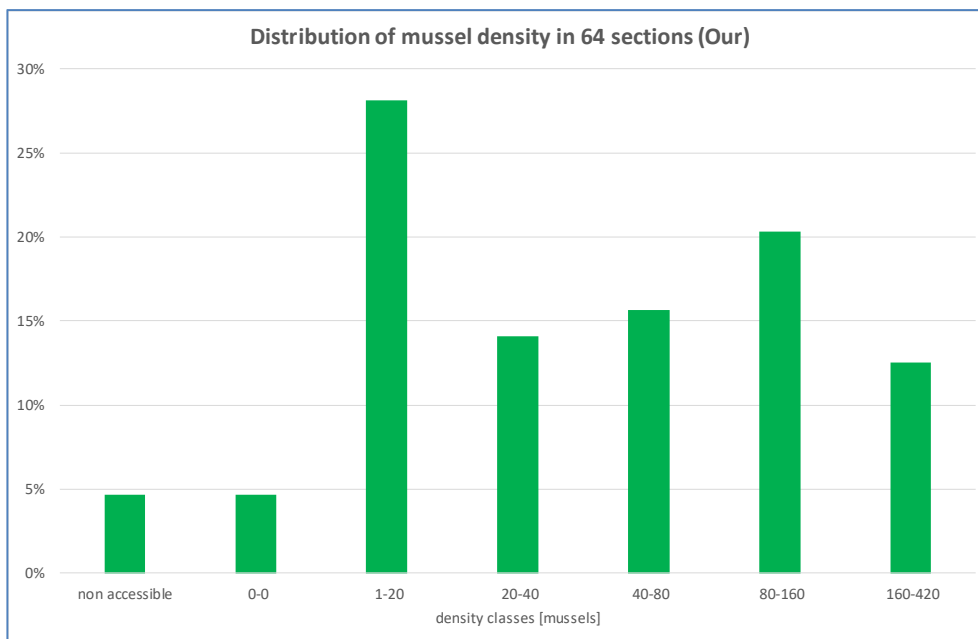


Figure 1: Mussel density classes in the river Our

In about 33% of the sections, more than 80 mussels per sections were found.

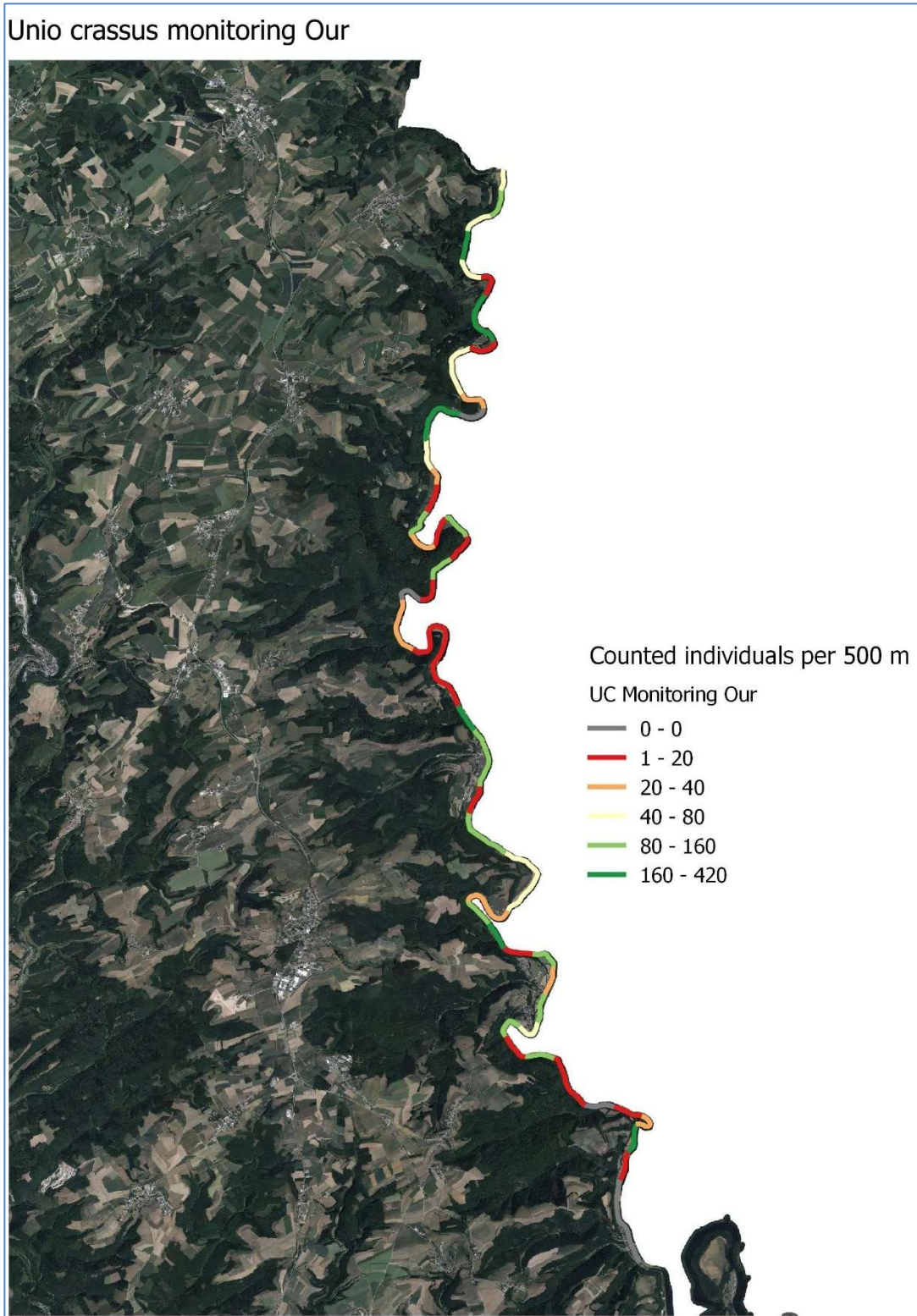


Figure 2: Overview over *Unio crassus* monitoring in the river Our

Figure 2 gives an overview of the monitored river Our and the mussels found. The sections are coloured corresponding to the amount of mussels. In Figure 3, the mussel density around Kalbermillen is shown (as an example). The part above the mill shows a very high density whereas downstream the rebuilt dam less mussels were found.

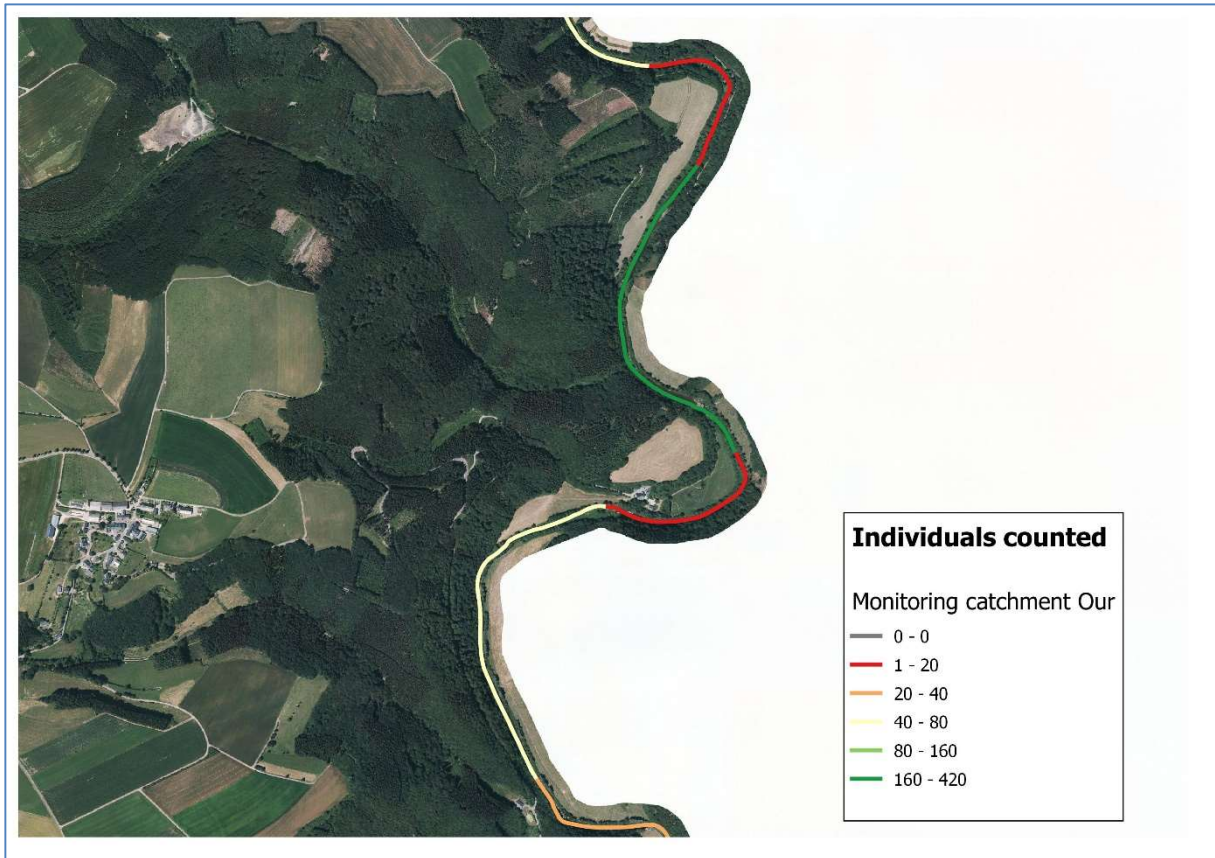


Figure 3: Mussel density at the Kalbermillen

The comparison of the estimated part of rock in each section with the density of mussels shows a negative correlation (see Figure 4). Most of the mussels can be found in section with less rock.

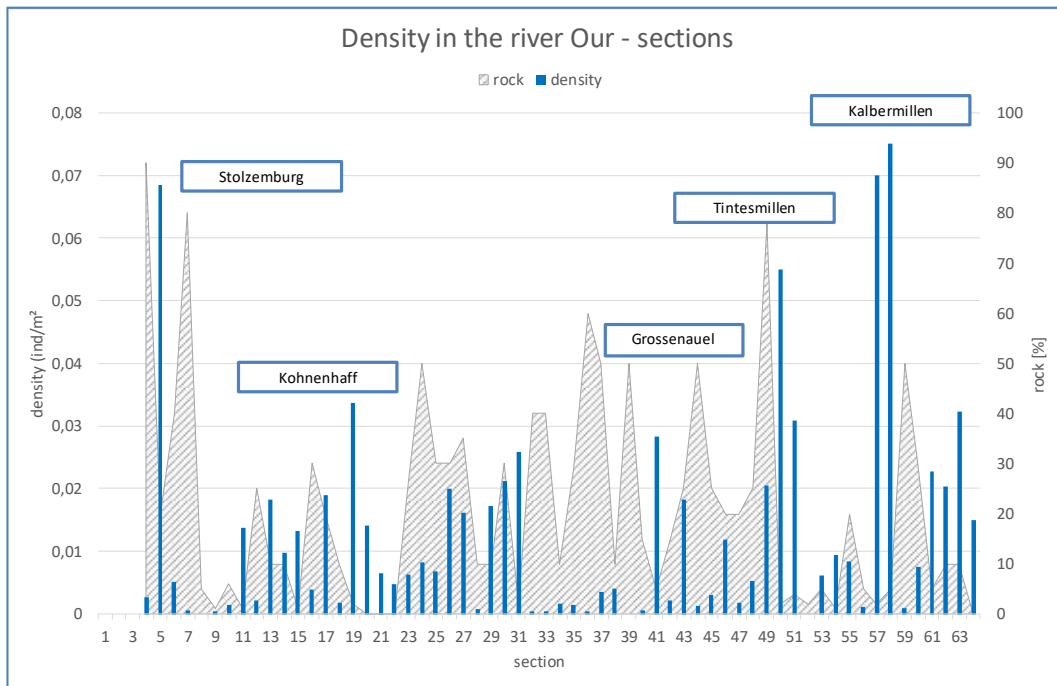


Figure 4: Density of mussels compared to rock in the river Our

1.2 River Sauer

The mussel survey in the river Sauer was finished in the year 2018 – 18,5 km from a total of 20 km were accessible.

Table 3: Mussel density classes in the river Sauer

Sections with	Numbers	Distribution [%]
Non accessible	3	8
0-0	0	0
1 - 20	9	23
20 - 40	8	20
40 - 80	9	23
80 - 160	9	23
160 – 420	2	5
Total	40	100

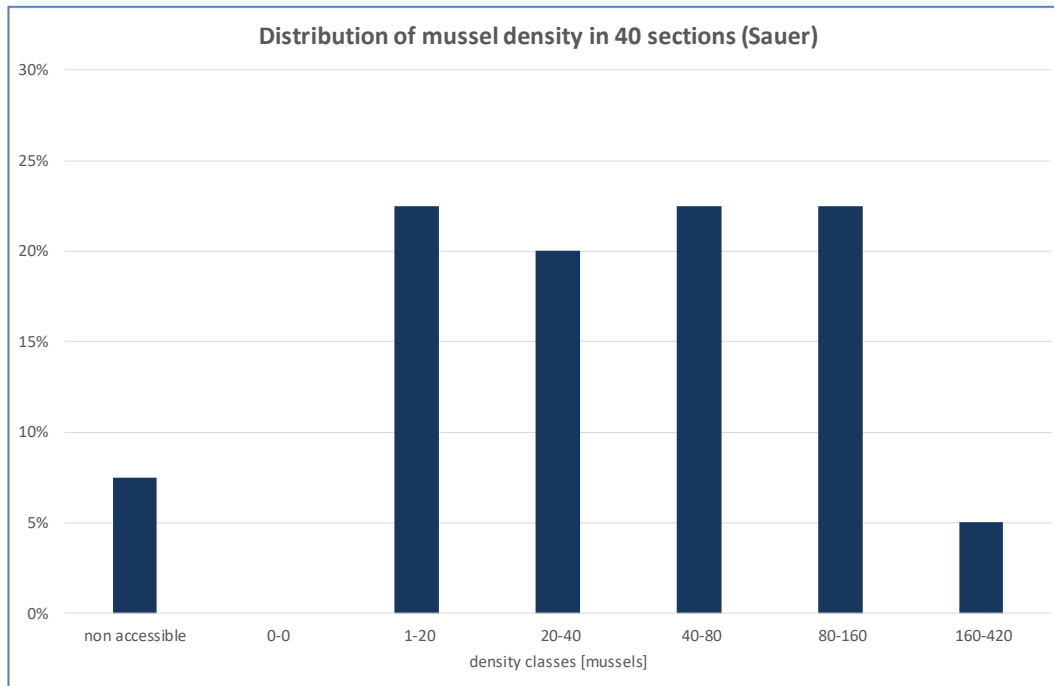


Figure 5: Mussel density classes in the river Sauer

In more than 20% of the sections, more than 80 mussels per sections were found.

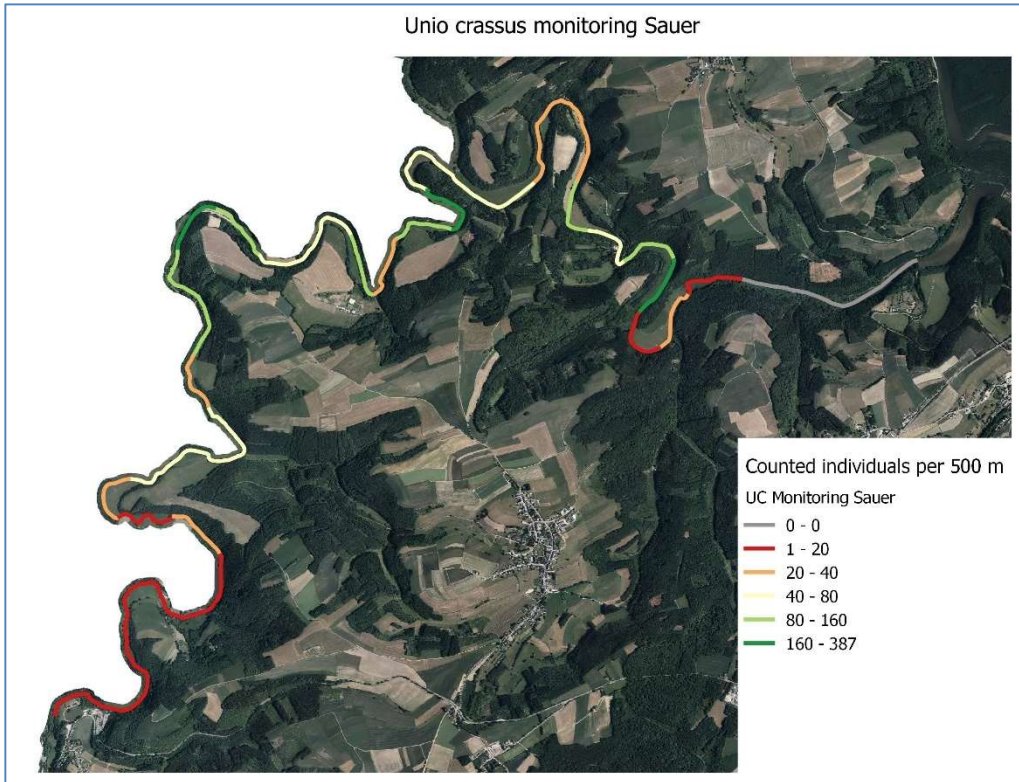


Figure 6: Overview over *Unio crassus* monitoring in the river Sauer

Figure 6 gives an overview over the monitored river Sauer and the found mussels. The sections are coloured corresponding to the amount of mussels.

In Figure 7, the mussel density at Moulin d'Oeil is shown (as an example). The whole area shows a very high density of mussels in the river.

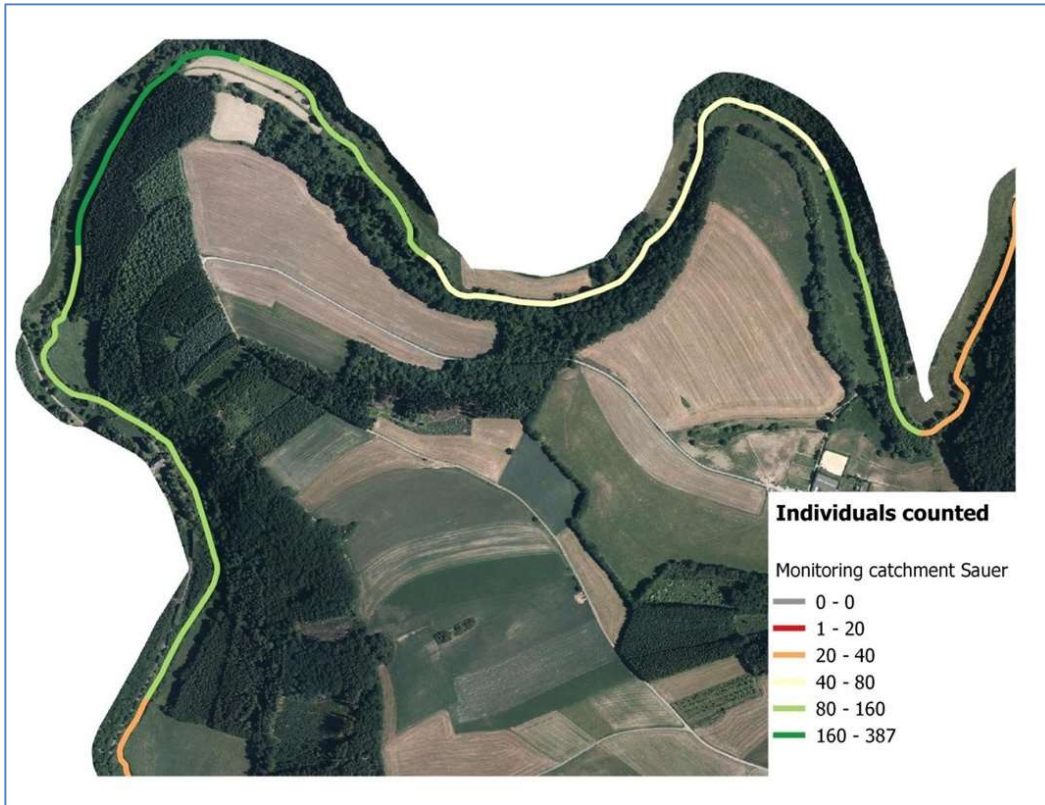


Figure 7: Mussel density at the Moulin d'Oeil

The comparison of the estimated part of rock in each section with the density of mussels shows a negative correlation (see Figure 8). Many mussels can be found in section with less rock.

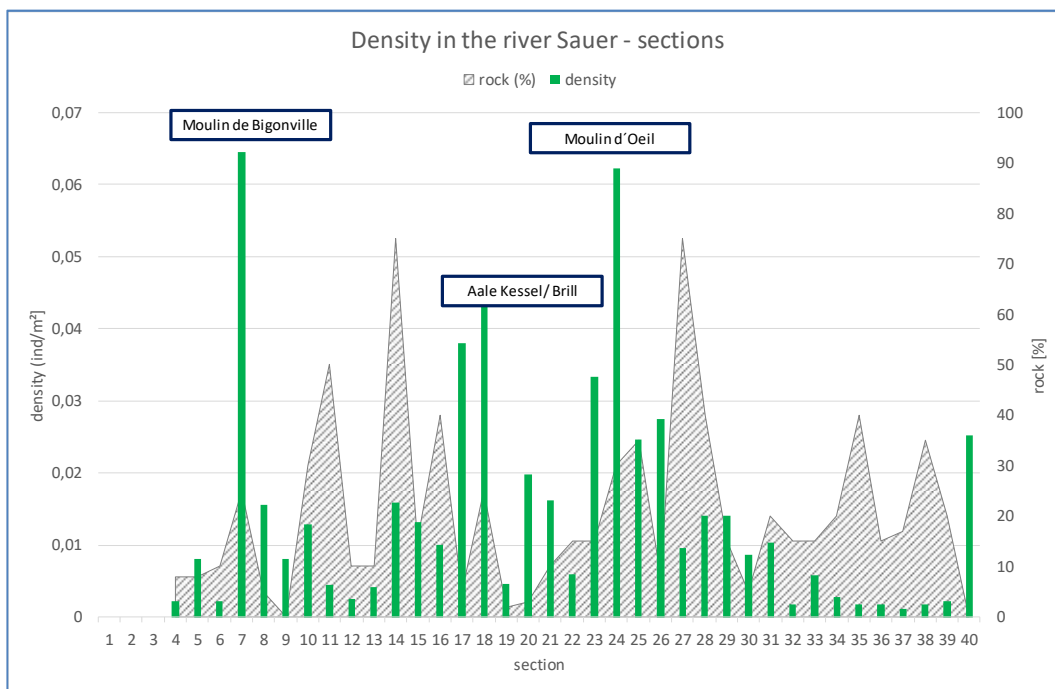


Figure 8: Density of mussels compared to rock in the river Sauer

2 Age structure

Shells from 136 dead *Unio crassus* specimens were collected from a population in river Our (Luxembourg) and from two population in river Sauer (Luxembourg and Belgium). The shells were measured for length, width and height. Thin transverse section were made, coloured and etched. This method is used to see the winter lines.

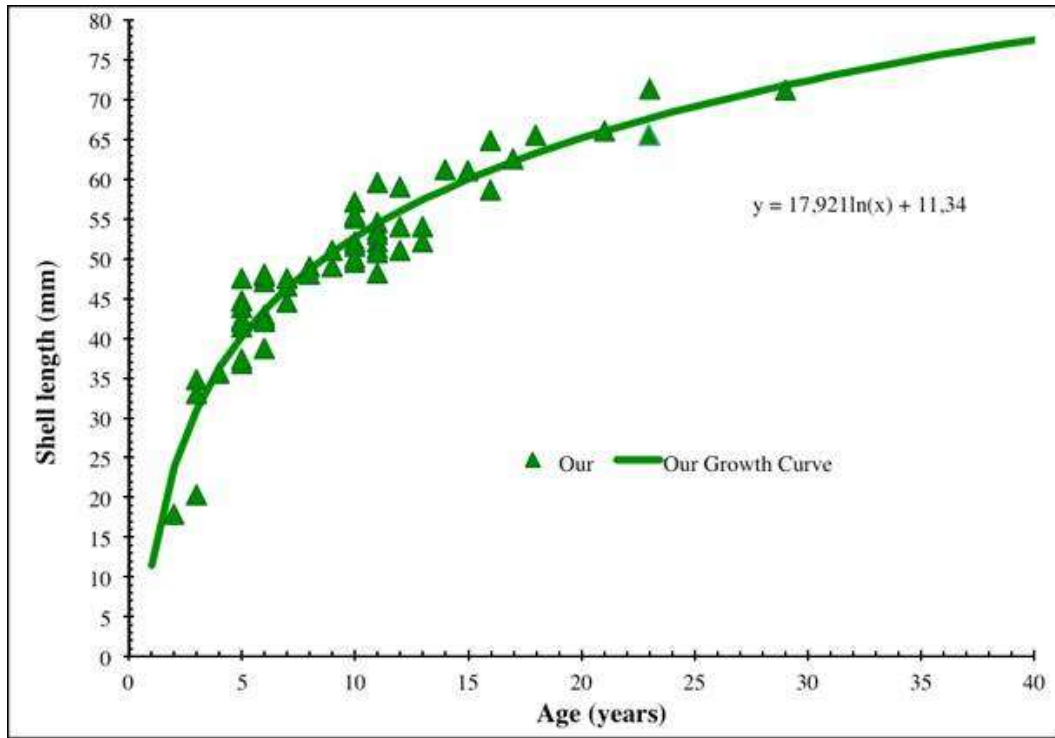


Figure 9: Diagram showing the growth curve for the river Our population calculated by a logarithm

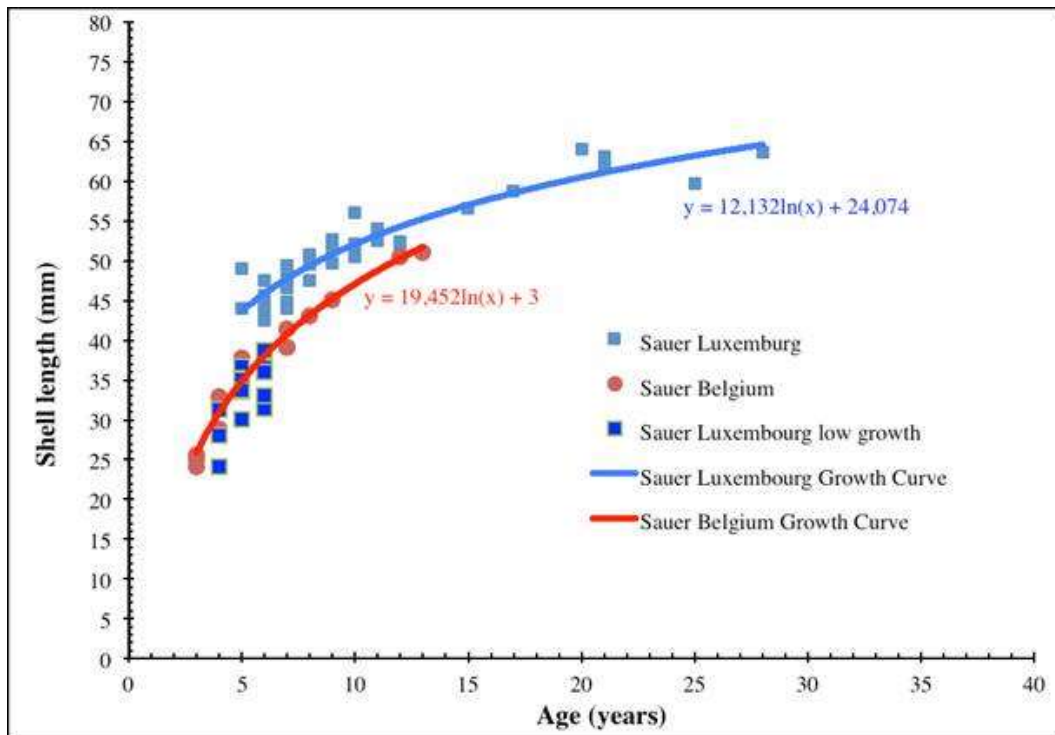


Figure 10: Diagram showing the growth curves for the river Sauer populations calculated by two different logarithms.

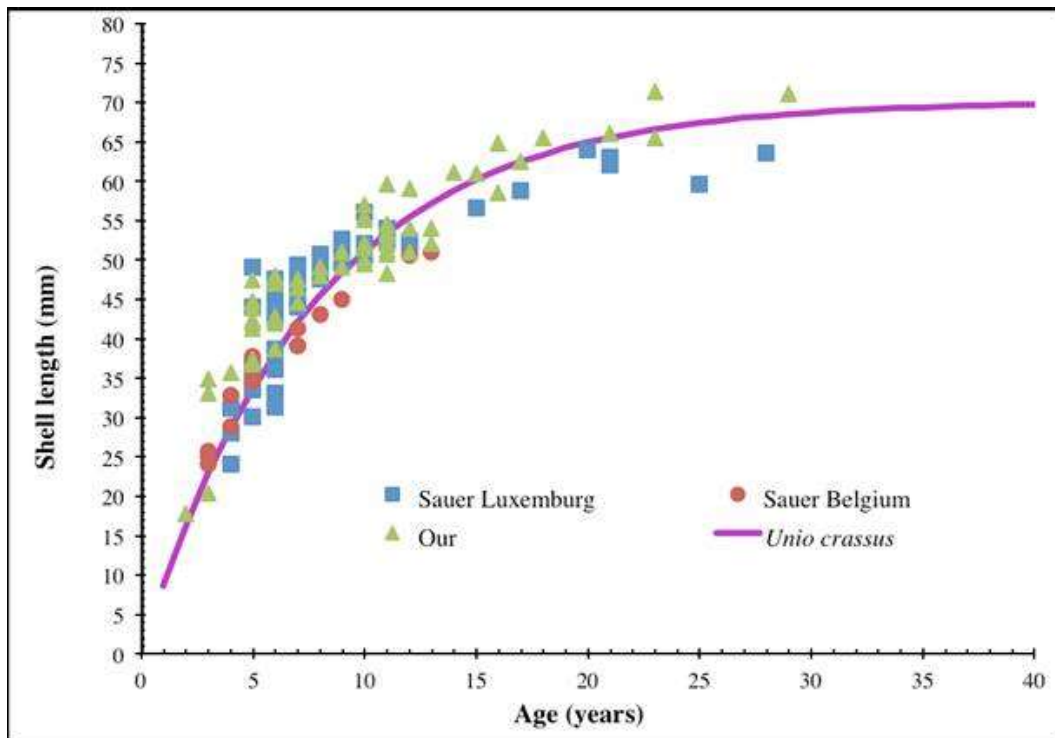


Figure 11: Diagram showing a general growth curve for *U. crassus* in the Luxembourg region

The whole report can be found in D3.

The detailed results of the age determination of the different mussel population in the river Our and Sauer are shown in chapter 3.

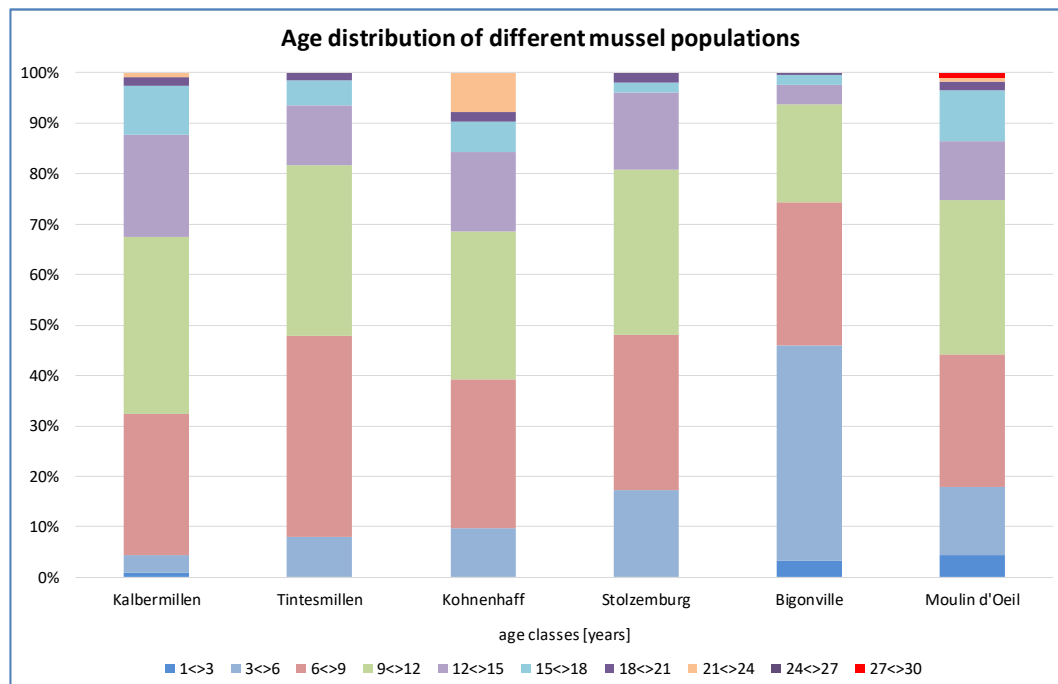


Figure 12: Age structure of the different mussel populations

3 Tagged mussels in the rivers Our and Sauer

Mussels used for breeding and mussels of an area with a high density were tagged and controlled regular.

3.1 River Our

3.1.1 Kalbermillen

3.1.1.1 Overview

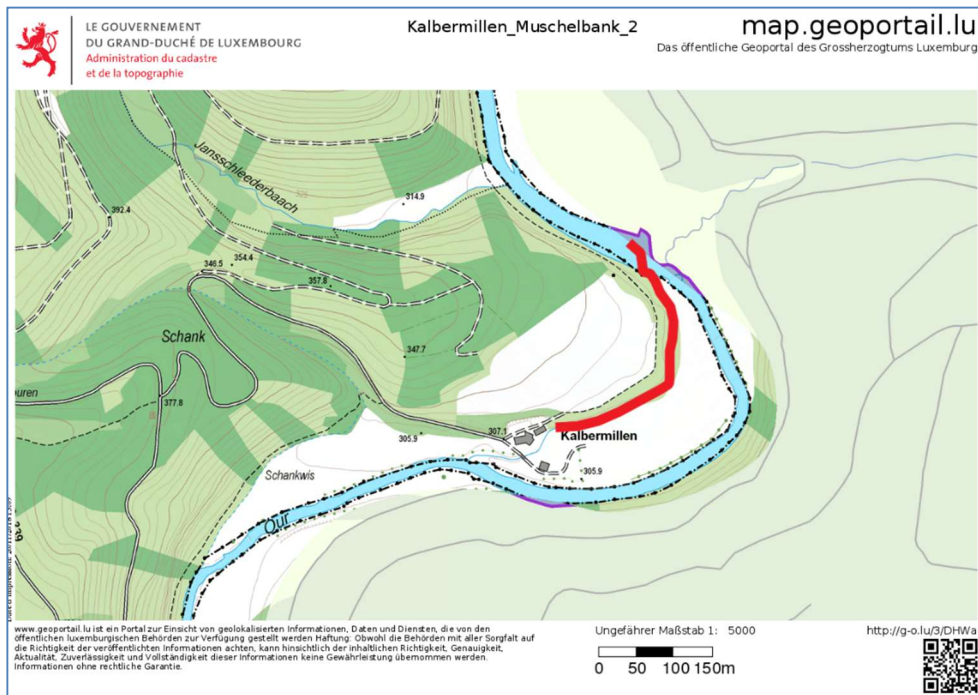


Figure 13: Tagged mussels at Kalbermillen

Table 4: Overview - tagged mussels at Kalbermillen

Numbers	amount	Year	measured	postion
1000 - 1274	275	2013	no	Into the mill stream
1346 - 1459	114	2014	yes	Into the river Our
1460 - 1477	18	2015	no	Into the river Our
Total	407			

Table 5: Barrage at Kalbermillen

<p>2017 - barrage at Kalbermillen – upstream</p>	<p>2017 - barrage at Kalbermillen - downstream</p>
<p>2018 – barrage at Kalbermillen – upstream</p>	<p>2018 – barrage at Kalbermillen - downstream</p>

Table 6: Recovered mussels at Kalbermillen

<p>2013-tagged mussels</p>	<p>2014 – recovered mussels</p>
<p>2016 – recovered mussels</p>	<p>2017 – recovered mussels</p>



3.1.1.2 Results

The mussels were measured and the size distribution is shown in Figure 14.

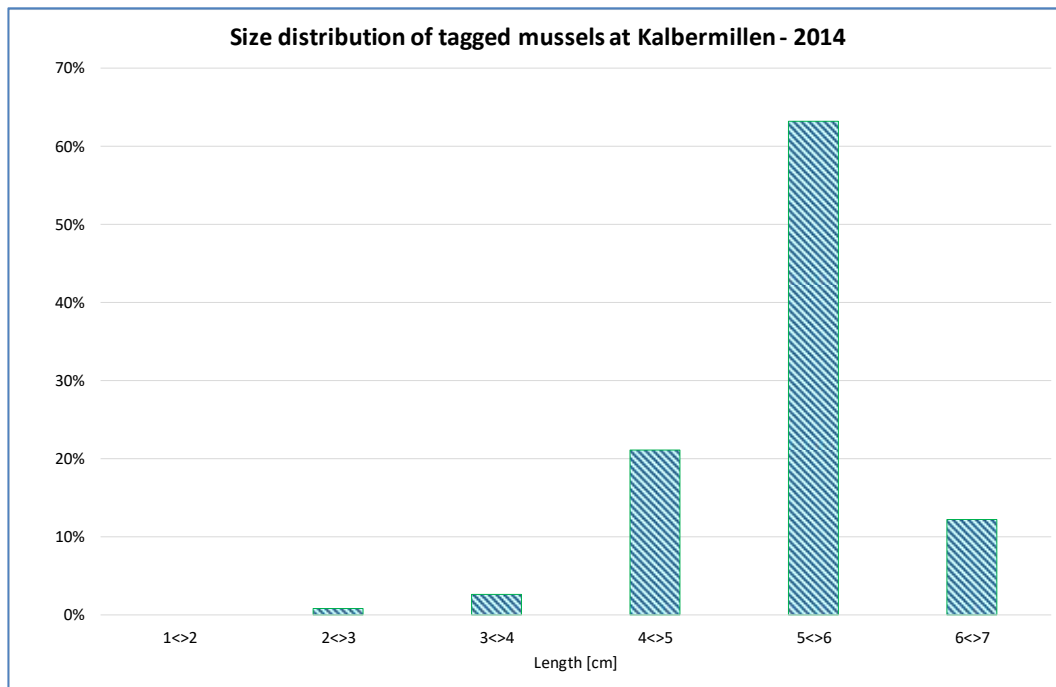


Figure 14: Size distribution of tagged mussels at Kalbermillen

Most of the mussels which were used for breeding had a size between 5 and 6 cm.

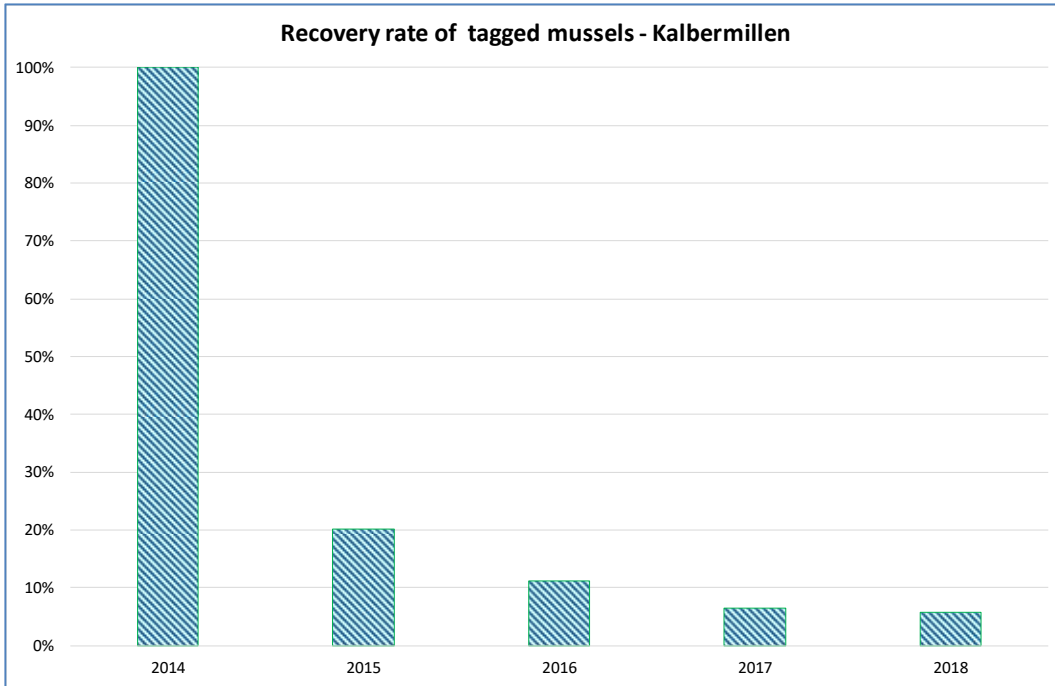


Figure 15: Recovery rate of tagged mussels at Kalbermillen

The recovery rate at this place was very low. The site consists of fine to more coarse sediments and gravel which gives the mussel a good opportunity to bury or to move around. Furthermore a severe flood in summer 2018 carried also some animals downstream. Nevertheless, every year many non-tagged mussels were found. An example is given in Figure 16. Among the non-tagged mussels about 5% of the population had a size <5cm being only 2-5 years old. In this area a natural recruitment is still occurring.

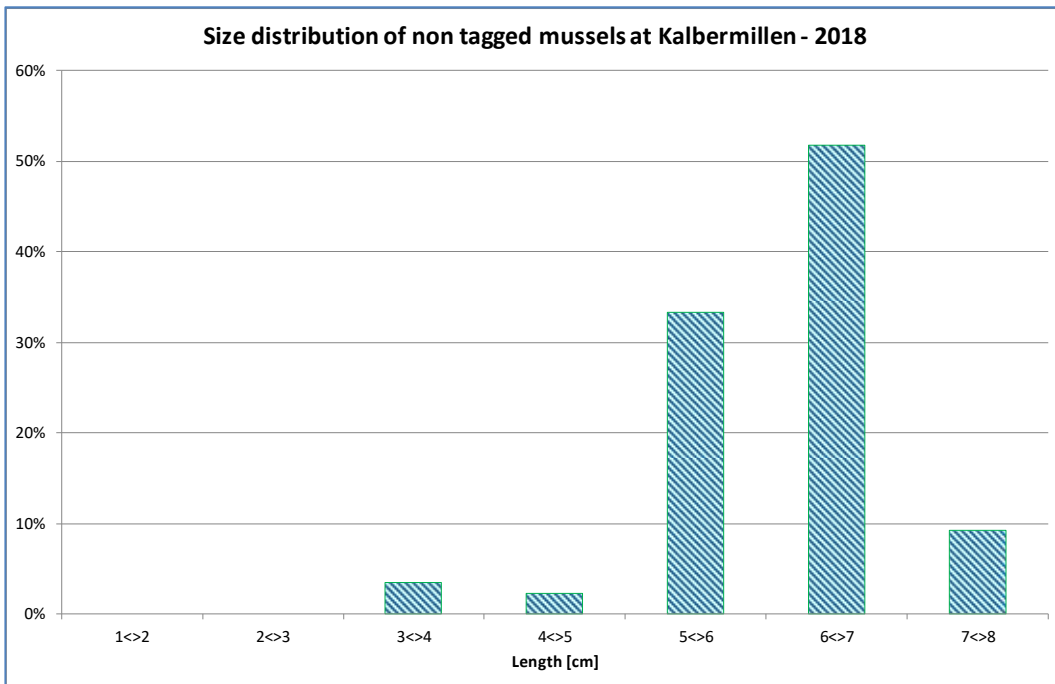


Figure 16: Size distribution of non-tagged mussels at Kalbermillen in 2018

3.1.1.3 Age distribution

The calculation of the age of *Unio crassus* in the river Our was done with the specific formula for the river Our.

$$\text{Length} = 17,921 \ln(\text{age}) + 11,34$$

Equation 1: Growth curve for *Unio crassus* population in river Our

The age was calculated from 114 mussels (length, width and height were measured).

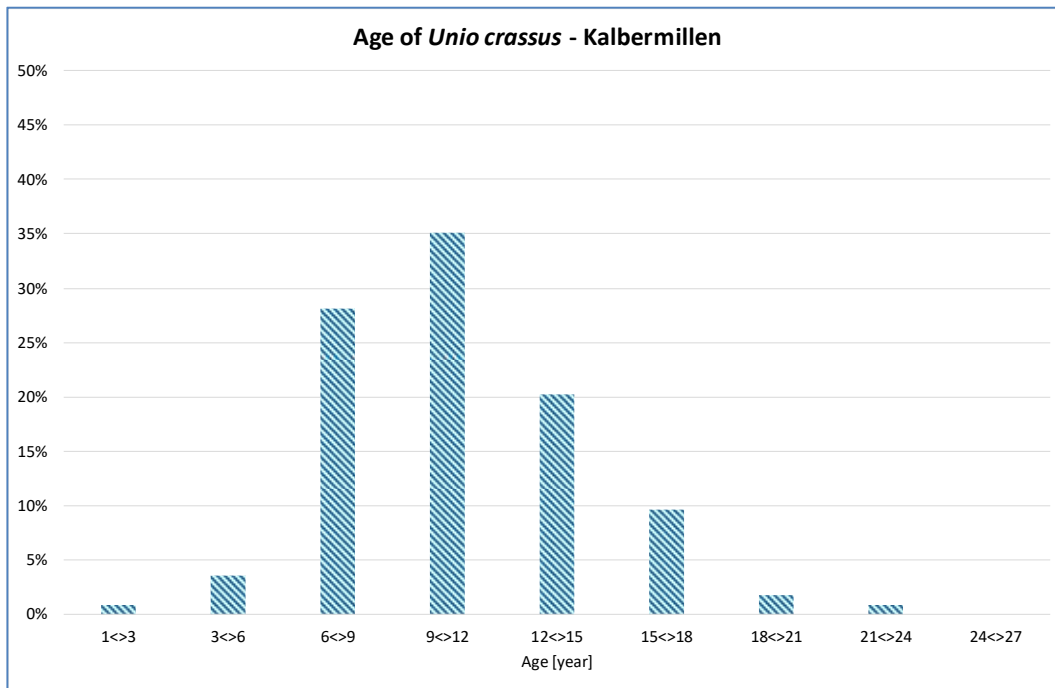


Figure 17: Age distribution of tagged mussels at Kalbermillen

No mussels were older than 25 years. Most of the mussels were younger than 15 years.

3.1.2 Tintesmilen

3.1.2.1 Overview

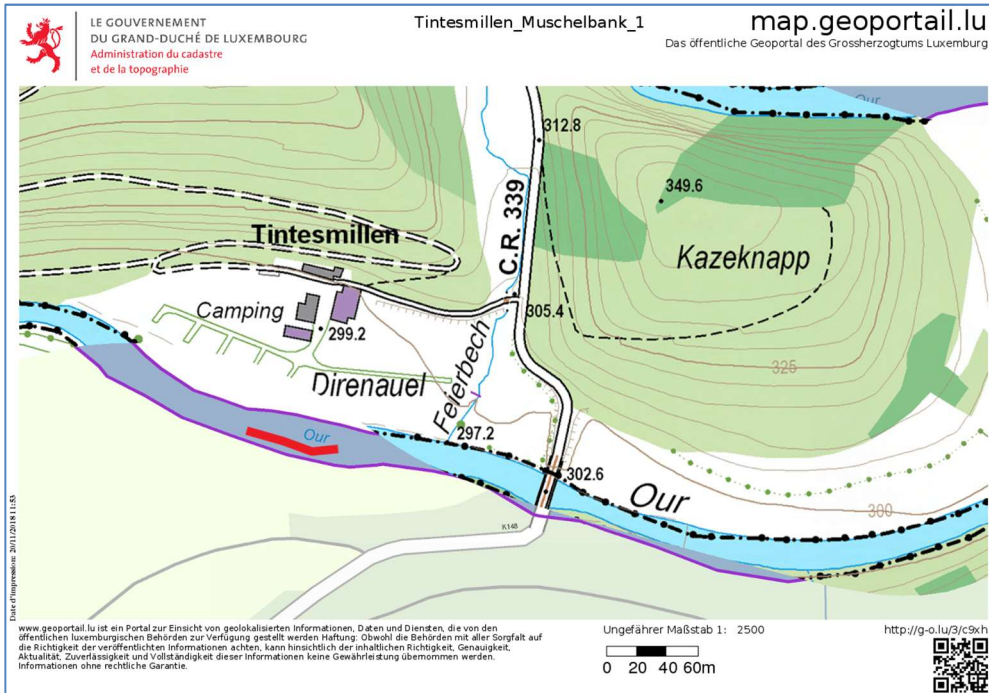


Figure 18: Tagged mussels at Tintesmilen



Figure 19: Recovered mussels at Tintesmilen

Table 7: Overview - tagged mussels at Tintesmilen

Numbers	amount	Year	measured	postion
1478 - 1613	136	2017	yes	in the river Our
Total	136			

3.1.2.2 Results

The mussels were measured and the size distribution is shown in Figure 20.

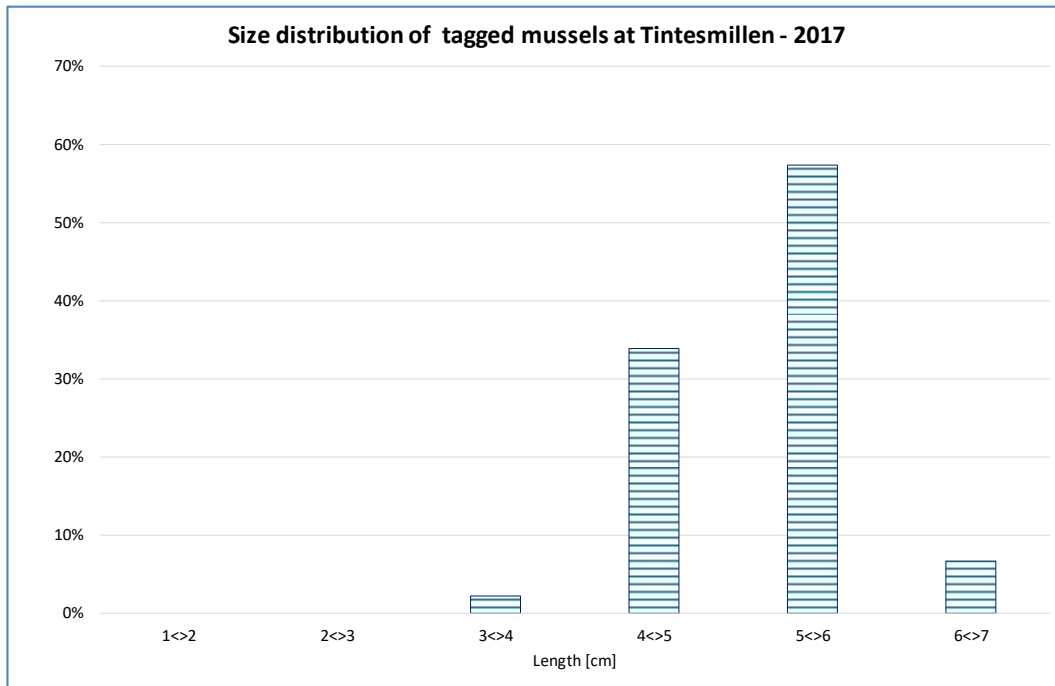


Figure 20: Size distribution of tagged mussels at Tintsmillen

Most of the mussels which were used for reproduction had a size between 5 and 6 cm.

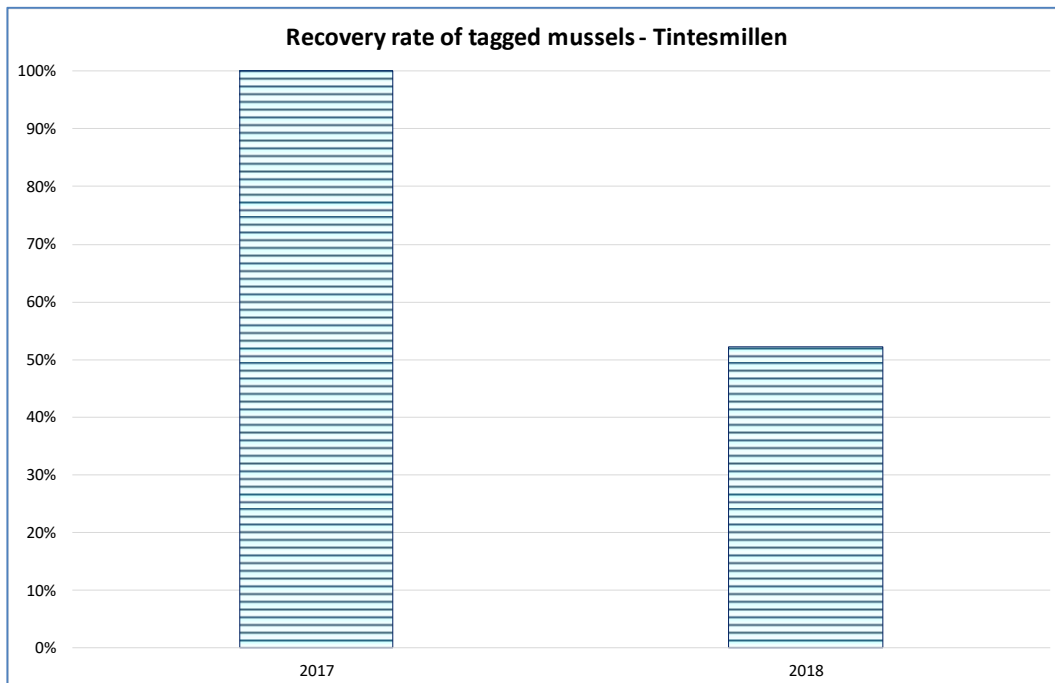


Figure 21: Recovery rate of tagged mussels at Tintsmillen

The recovery rate at Tintsmillen after the first year was with above 50% high (see Figure 21).

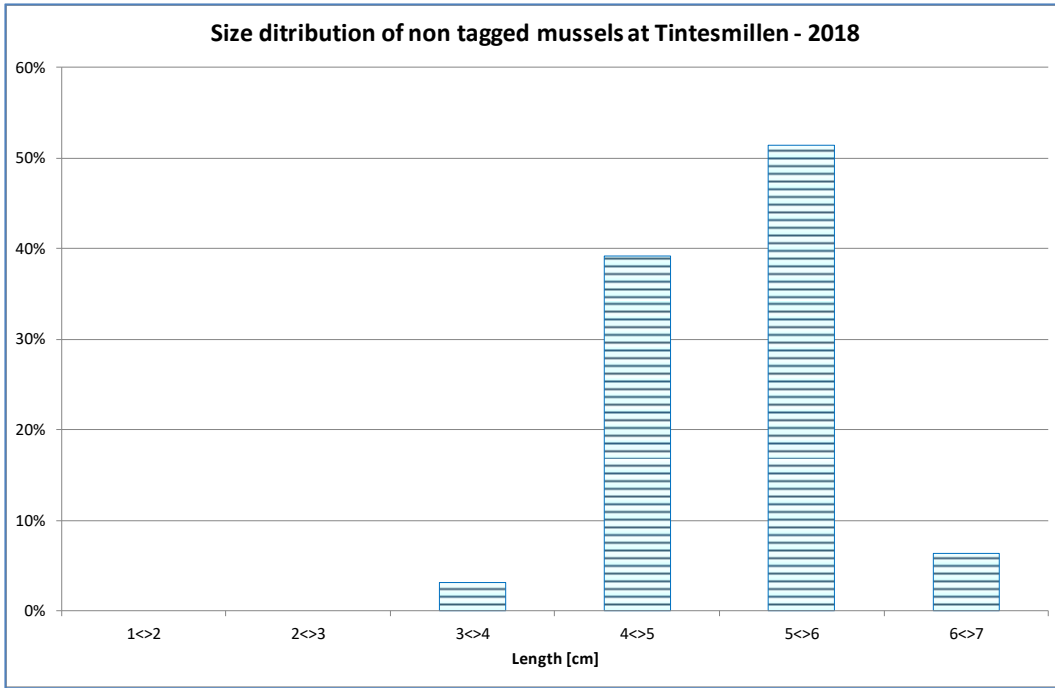


Figure 22: Size ditribution of non-tagged mussels at Tintesmillen

Beside the tagged mussels many non-tagged mussel were found additional.

3.1.2.3 Age distribution

The calculation of the age of *Unio crassus* in the river Our at the site Tintesmillen was done with the specific formula for river Our.

$$\text{Length} = 17,921 \ln(\text{age}) + 11,34$$

Equation 2: Growth curve for *Unio crassus* population in river Our

The age was calculated from 136 mussels (length, width and height were measured).

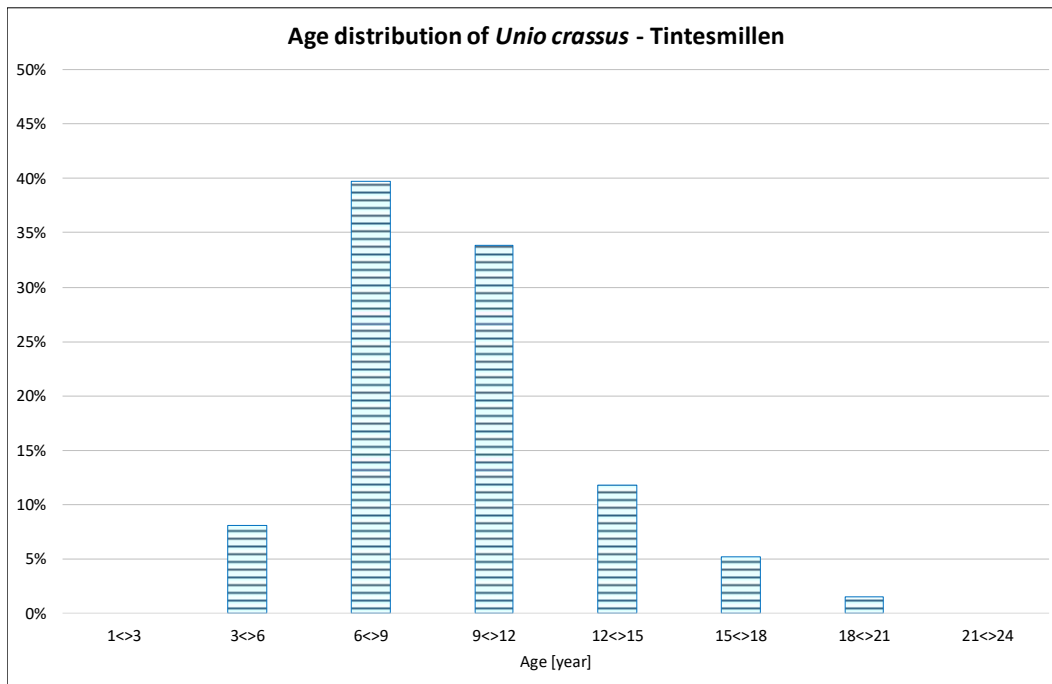


Figure 23: Age distribution of tagged mussels at Tintesmillen

No mussels were older than 21 years. Most of the mussels were younger than 12 years.

3.1.3 Kohnehaff

3.1.3.1 Overview

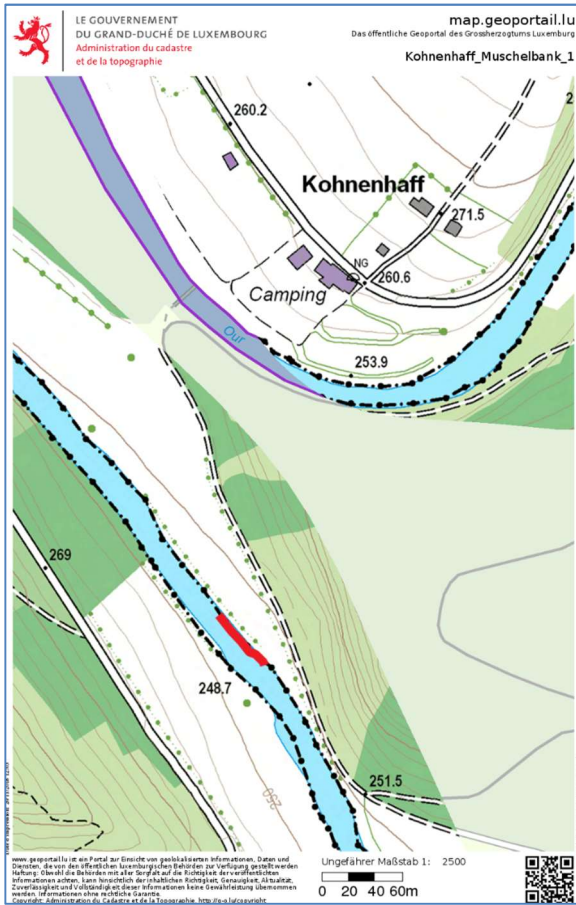


Figure 24: Tagged mussels at Kohnehaff

Table 8: River Our at Kohnehaff

<p>2015 - upstream</p>	<p>2015 – upstream</p>
<p>2017 - upstream</p>	<p>2017- upstream</p>



Table 9: Recovered mussels at Kohnenhaff



Table 10: Overview - tagged mussels at Tintsmillen

Numbers	amount	Year	measured	postion
1275 - 1345	71	2013	yes	in the river Our
Total	71			

3.1.3.2 Results

The mussels were measured and the size distribution is shown in Figure 25.

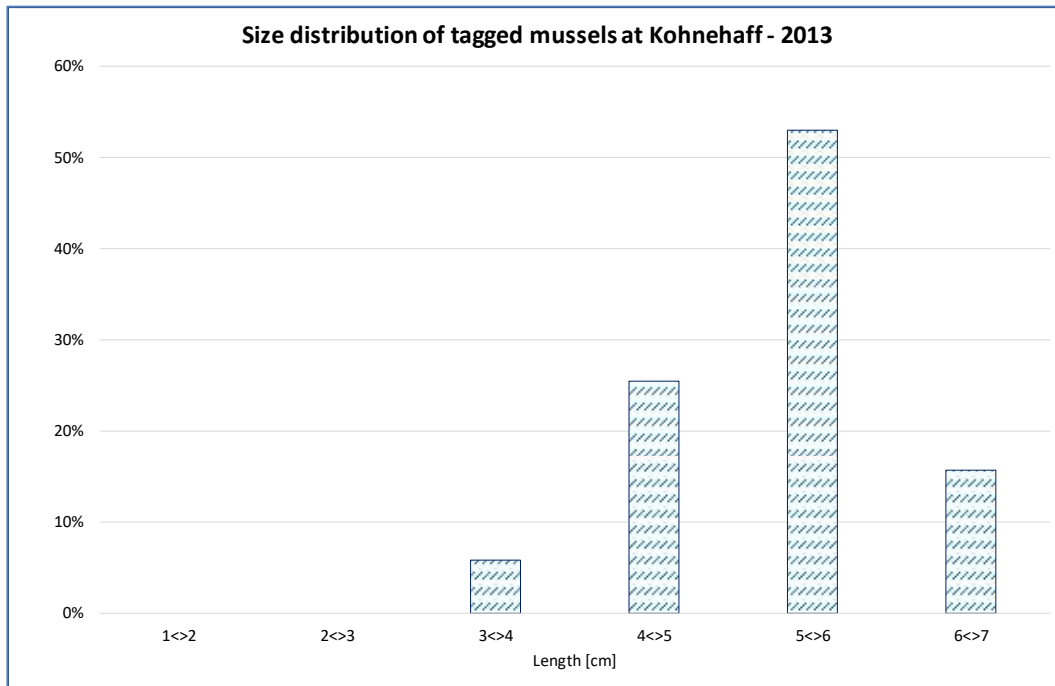


Figure 25: Size distribution of tagged mussels at Kohnehaff

Similar to the other places in the river Our most of the mussels had a size between 5 and 6 cm.

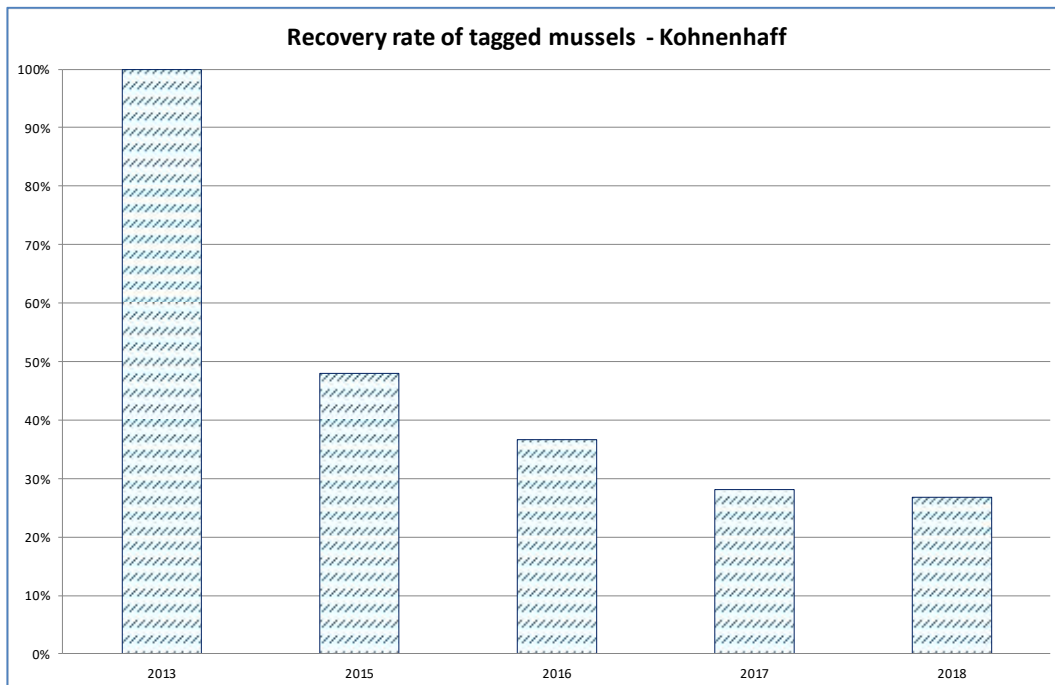


Figure 26: Recovery rate of tagged mussels at Kohnehaff

The recovery rate (see Figure 26) at this site was quite good because the habitat area is restricted.

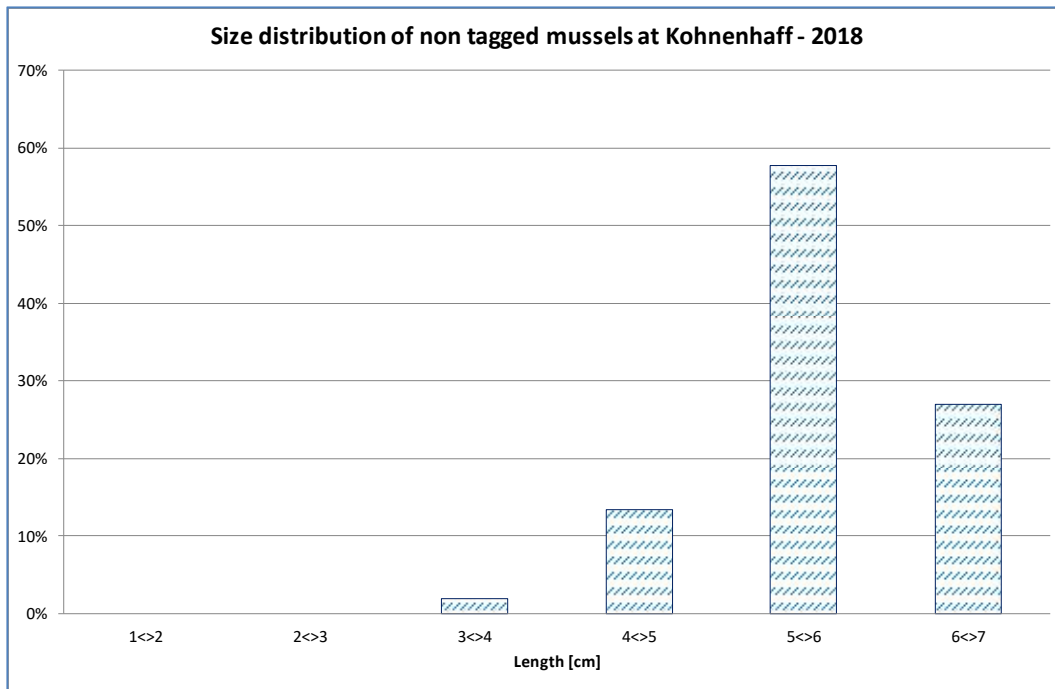


Figure 27: Size distribution of non-tagged mussels at Kohnehaff

Beside tagged mussels a high number of non-tagged mussels were found. The size distribution is similar to the tagged mussels.

3.1.3.3 Age distribution

The calculation of the age of *Unio crassus* in the river Our was done with the specific formula for river Our.

$$\text{Length} = 17,921 \ln(\text{age}) + 11,34$$

Equation 3: Growth curve for *Unio crassus* population in river Our

The age was calculated from 71 mussels (length, width and height were measured).

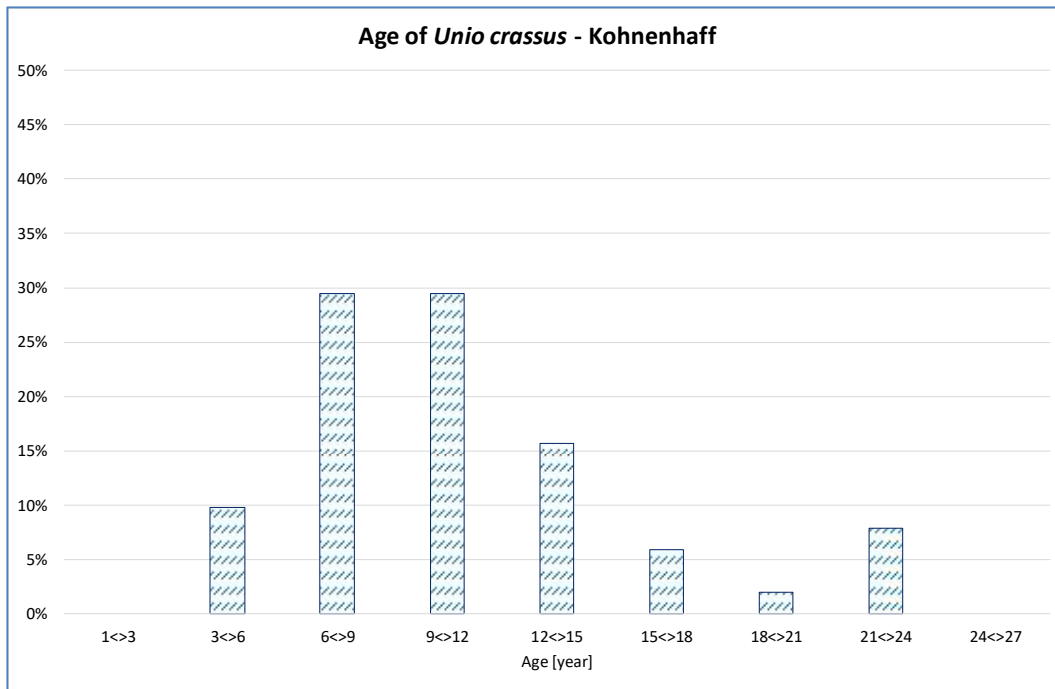


Figure 28: Age distribution of tagged mussels at Kohnenhaff

Most of the mussels were younger than 12 years. At Kohnenhaff some very old mussels were found (up to 24 years).

3.1.4 Stolzenburg

3.1.4.1 Overview

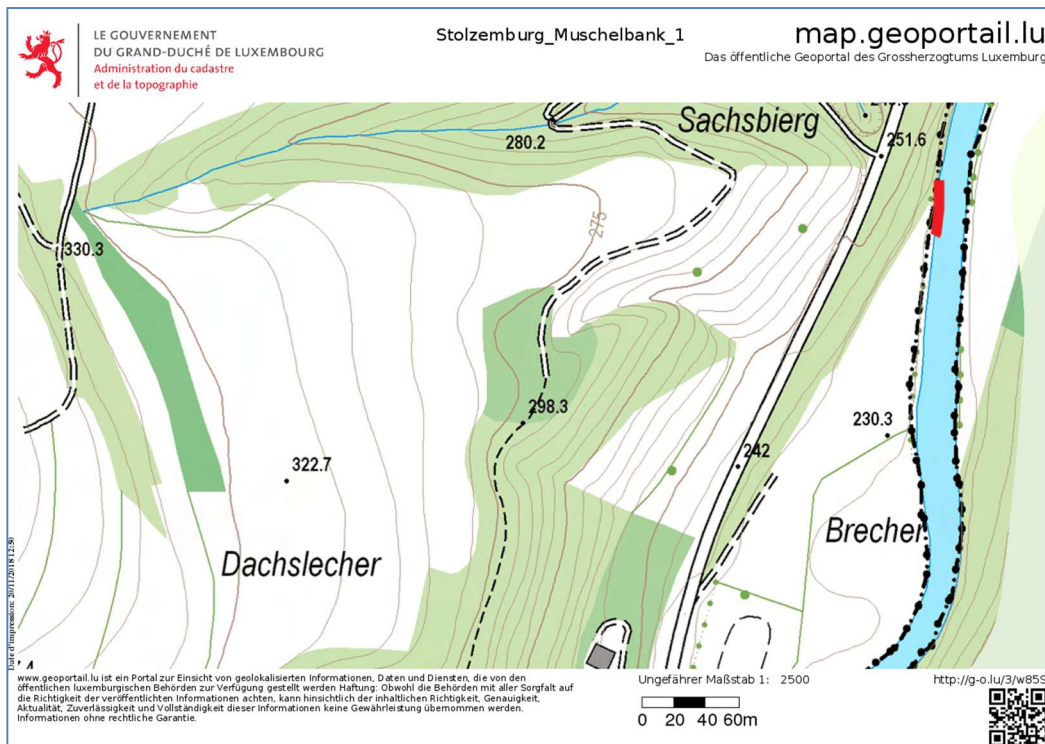
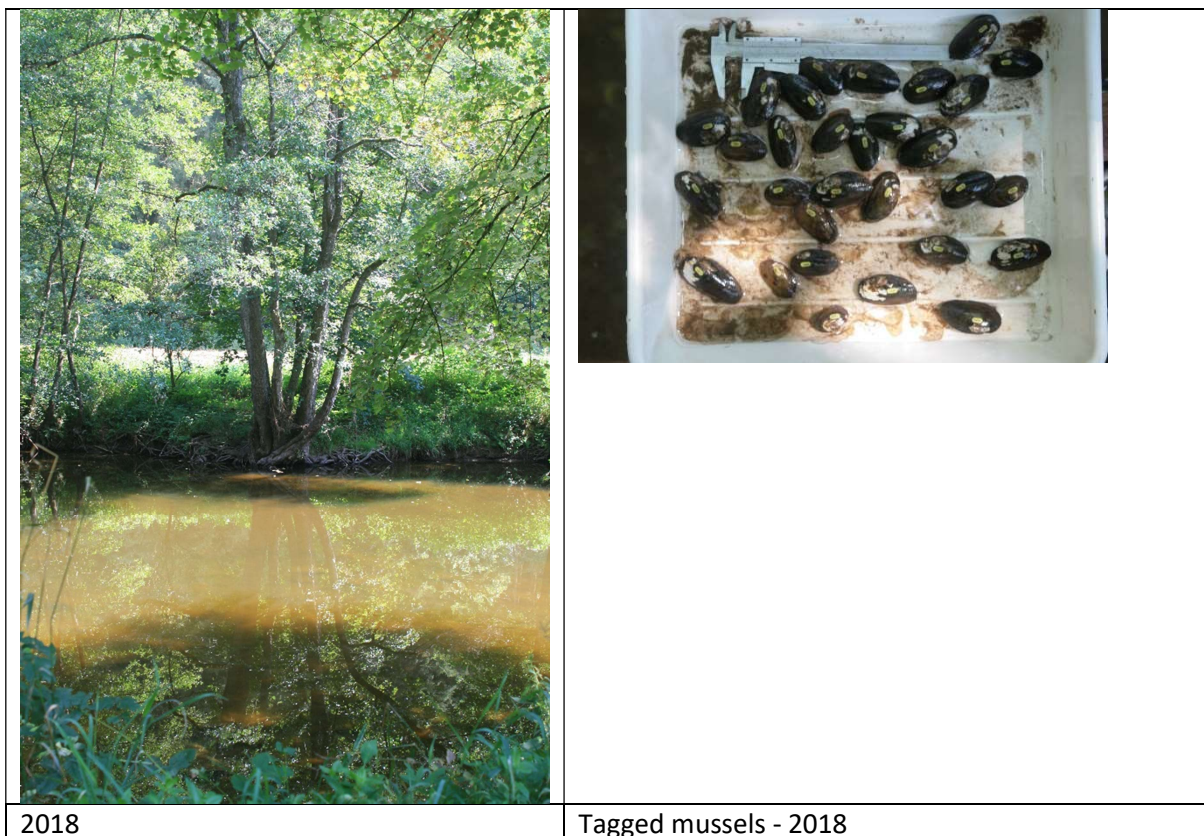


Figure 29: Tagged mussels at Stolzenburg



2018
Figure 30: River Our at Stolzenburg

Tagged mussels - 2018

Table 11: Overview - tagged mussels at Stolzenburg

Numbers	amount	Year	measured	postion
1614 - 1665	52	2018	yes	in the river Our
Total	52			

3.1.4.2 Results

The mussels were measured and the size distribution is shown in Figure 31.

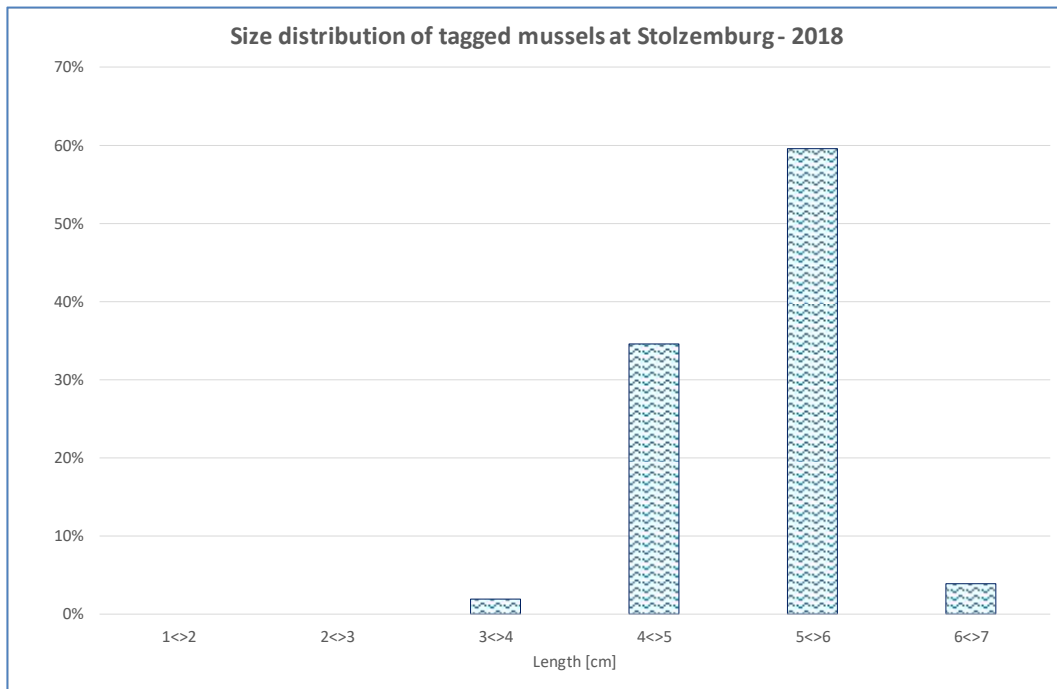


Figure 31: Size distribution of tagged mussels at Stolzenburg

Most of the mussels had a size between 5 and 6 cm. But in this place the percentage of mussels between 4 and 5 cm is higher compared to the other places in the river Our.

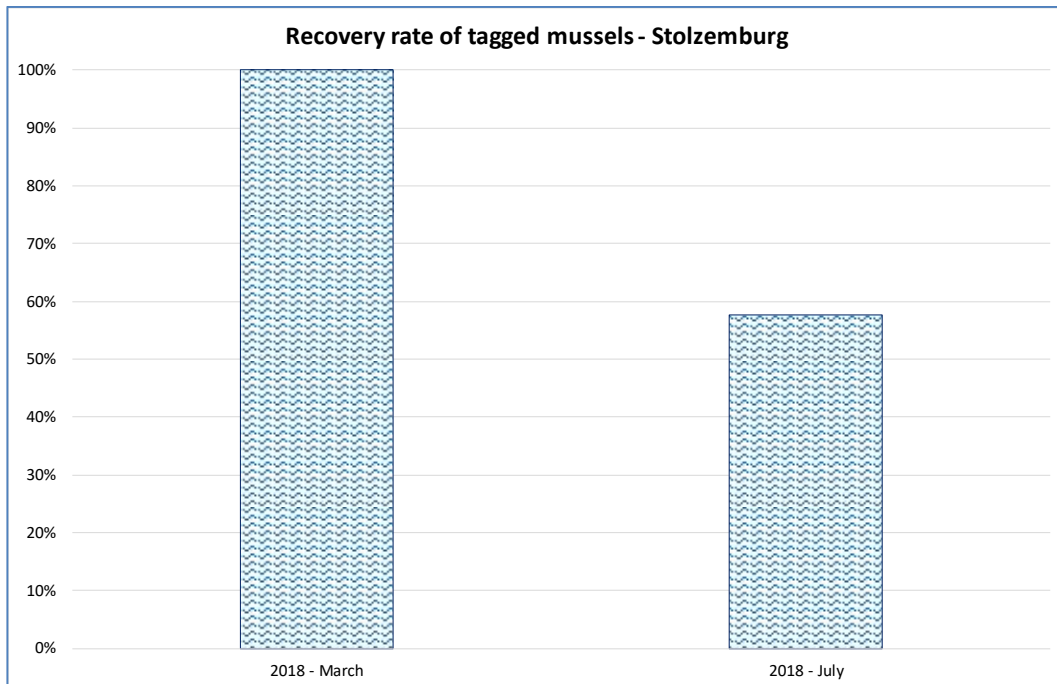


Figure 32: Recovery rate of tagged mussels at Stolzenburg

The recovery rate at this site was with almost 60% high. This is probably because there was only a short amount of time (4 months) between tagging and refinding. The mussels had less time to disperse and the following years will show if the recovery rate at this site stays high.

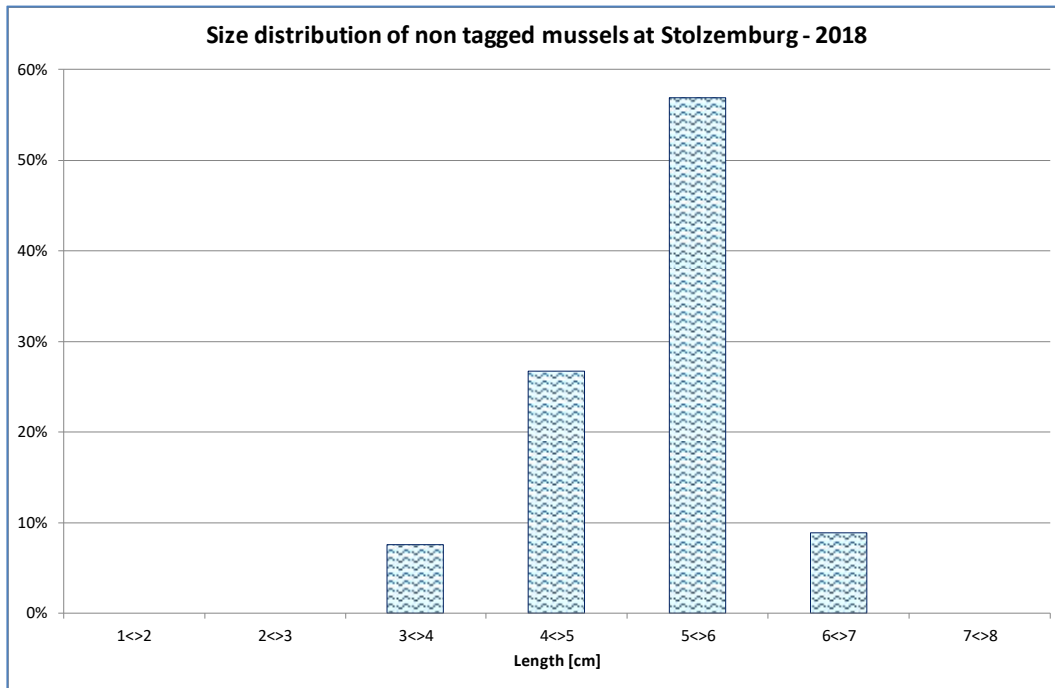


Figure 33: Size distribution of non-tagged mussels at Stolzenburg

Beside tagged mussels, a high number of non-tagged mussels were found. The size distribution is similar to the tagged mussels.

3.1.4.3 Age distribution

The calculation of the age of *Unio crassus* in the river Our was done with the specific formula for river Our.

$$\text{Length} = 17,921 \ln(\text{age}) + 11,34$$

Equation 4: Growth curve for *Unio crassus* population in river Our

The age was calculated from 52 mussels (length, width and height were measured).

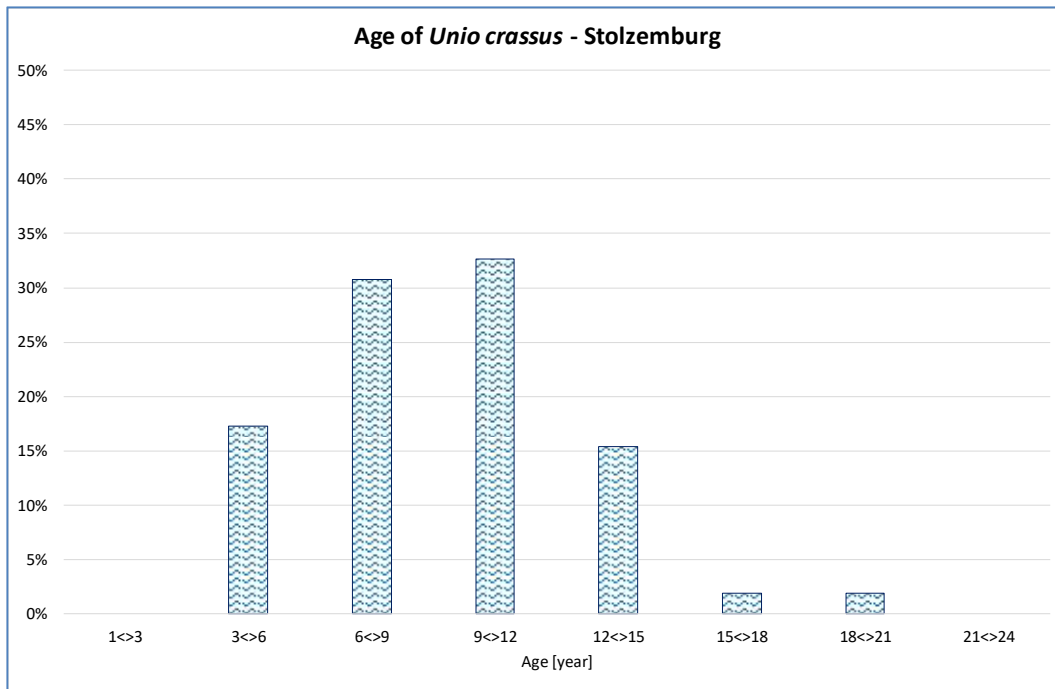


Figure 34: Age distribution of tagged mussels at Stolzenburg

Most of the mussels were younger than 12 years. No mussels were older than 21 years.

3.2 River Sauer

3.2.1 Bigonville

3.2.1.1 Overview

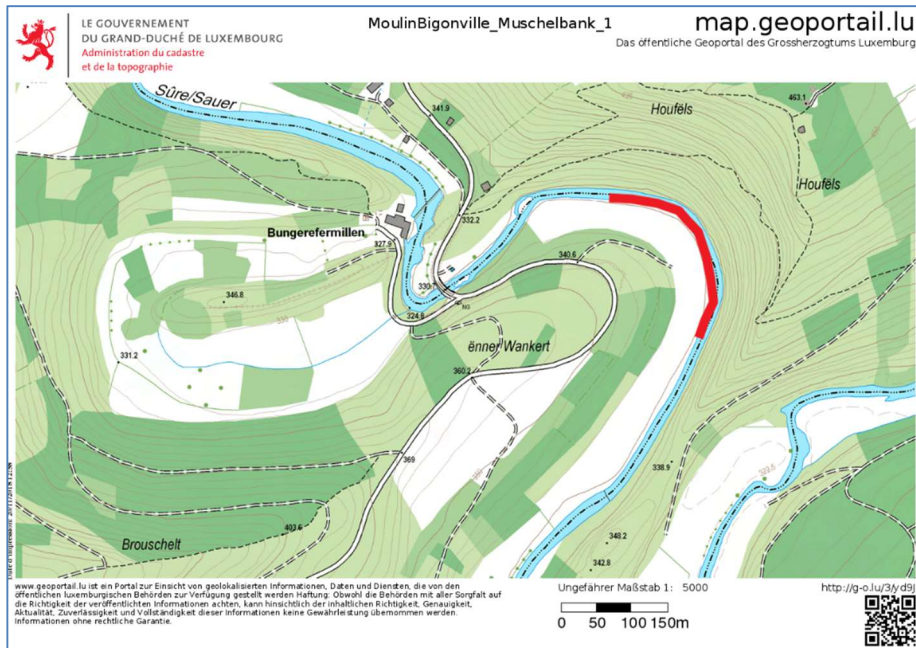


Figure 35: Tagged mussels at Moulin de Bigonville

Table 12: Overview - tagged mussels at Moulin de Bigonville

Numbers	amount	Year	measured	postion
50 - 109	60	2014	yes	in the river Sauer
110 -218	109	2014	yes	in the river Sauer
219 - 259	41	2015	yes	in the river Sauer
371 - 402	32	2017	yes	in the river Sauer
Total	242			

Table 13: River Sauer at Moulin de Bigonville

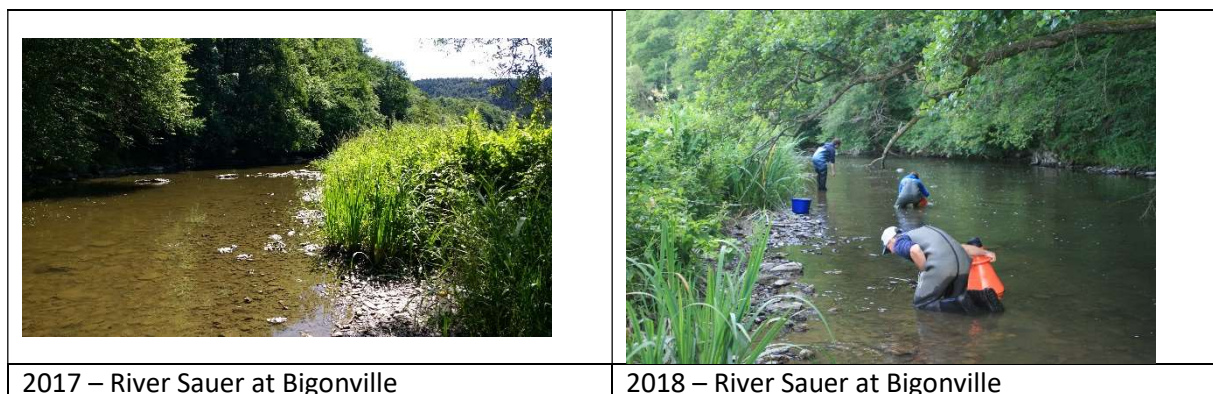






Table 14: Recovered mussels at Bigonville

	
2014-tagged mussels	2015 – recovered mussels
	
2016 – recovered mussels	2017 – recovered mussels
	
2018 – recovered mussels and non tagged mussels	

3.2.1.2 Results

The mussels were measured and the size distribution is shown in Figure 36.

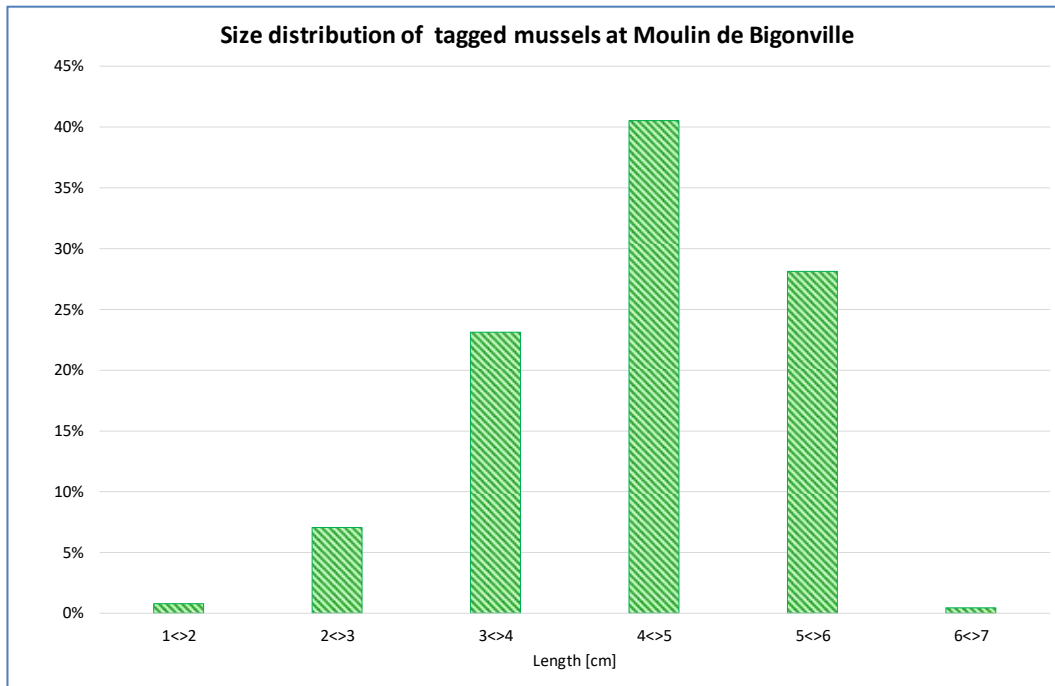


Figure 36: Size distribution of tagged mussels at Bigonville

Most of the mussels were between 4 and 5 cm.

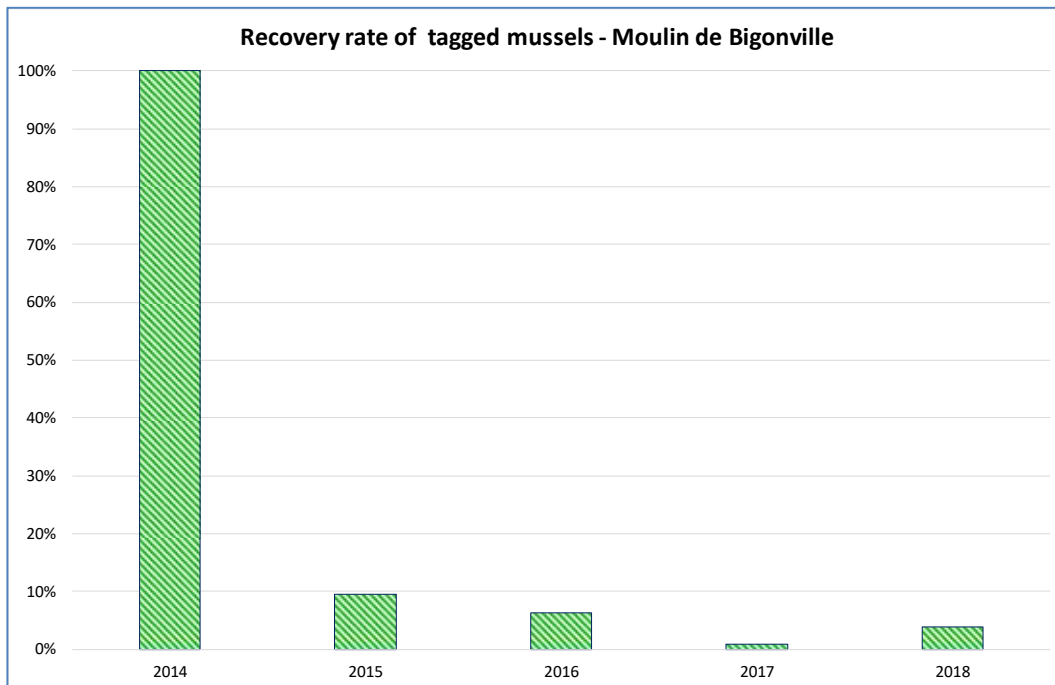


Figure 37: Recovery rate of tagged mussels at Bigonville

The recovery rate at Moulin de Bigonville was very low from the beginning on. This is caused by the hydropeaking of the mill upstream. The mussels probably moved more into the middle part of the river, buried themselves or disappeared.

3.2.1.3 Age distribution

The calculation of the age of *Unio crassus* in the river Sauer was done with two specific formula for river Sauer.

$$\text{Length} = 12,132 \ln(\text{age}) + 24,074$$

Equation 5: Growth curve for *Unio crassus* population in river Sauer bigger than 4 cm

$$\text{Length} = 19,452 \ln(\text{age}) + 3$$

Equation 6: Growth curve for *Unio crassus* population in river Sauer smaller than 4 cm

The age was calculated from 52 mussels (length, width and height were measured).

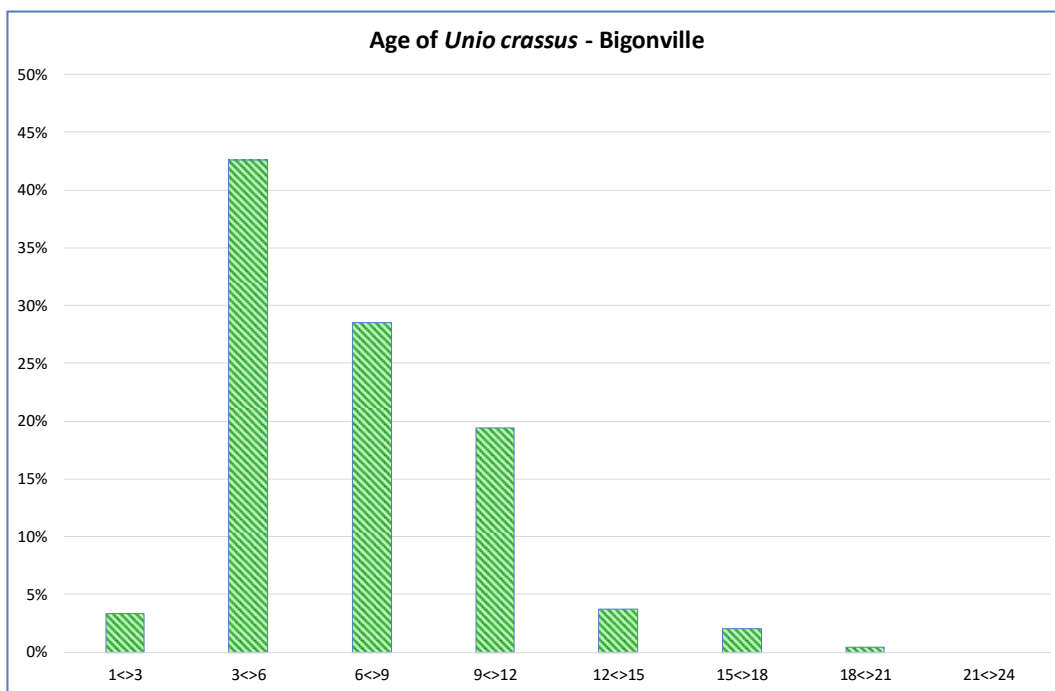


Figure 38: Age distribution of tagged mussels at Bigonville

More than 40% were between 3 and 6 years old and less than 10% are older than 12 years. No mussels were older than 21 years.

3.2.2 Moulin d'Oeil

3.2.2.1 Overview

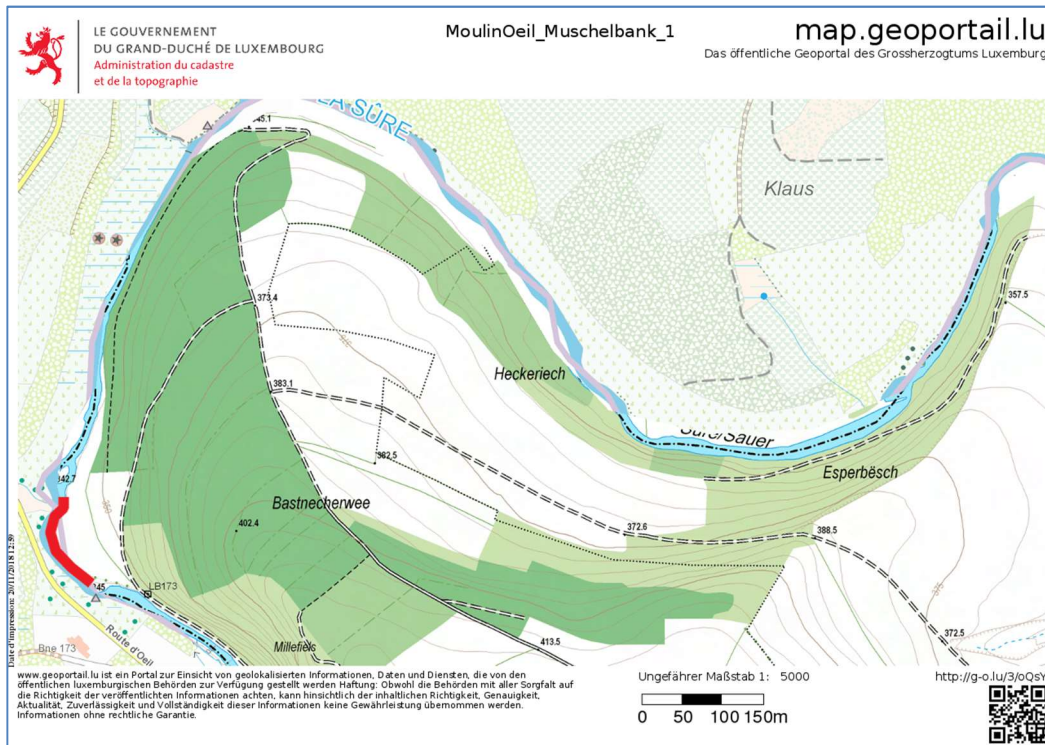


Figure 39: Tagged mussels at Moulin d'Oeil

Table 15: Overview - tagged mussels at Moulin d'Oeil

Numbers	amount	Year	measured	postion
001 - 049	50	2013	yes	in the river Sauer
260 - 370	111	2017	yes	in the river Sauer
403 - 459	57	2017	yes	in the river Sauer
Total	218			

Table 16: Sauer at Moulin d'Oeil

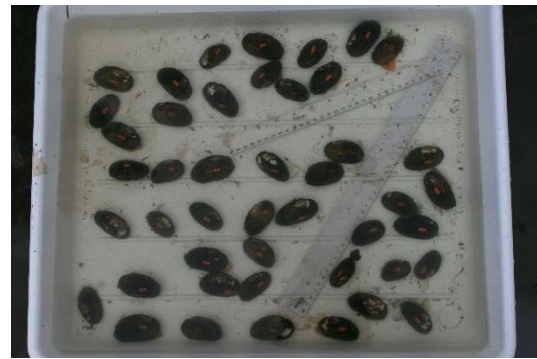


2018 – River Sauer at Moulin d'Oeil

Table 17: Recovered mussels at Moulin d'Oeil



2013-tagged mussels



2018 – recovered mussels

3.2.2.2 Results

The mussels were measured and the size distribution is shown in Figure 40.

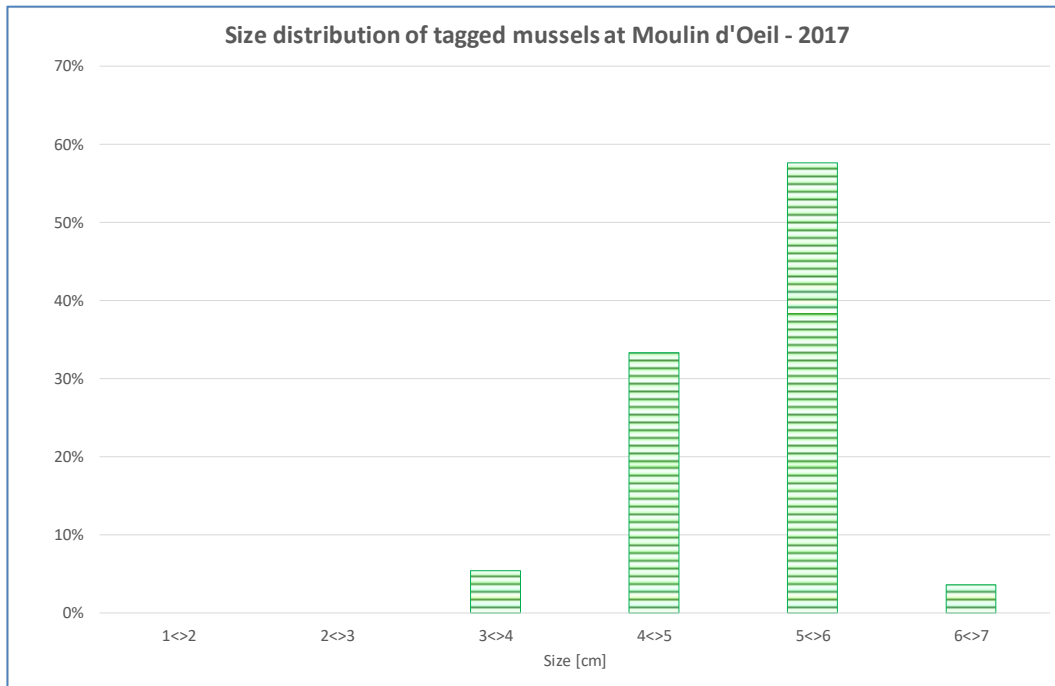


Figure 40: Size distribution of tagged mussels at Moulin d'Oeil

Most of the mussels which were used for culture were between 5 and 6 cm in size.

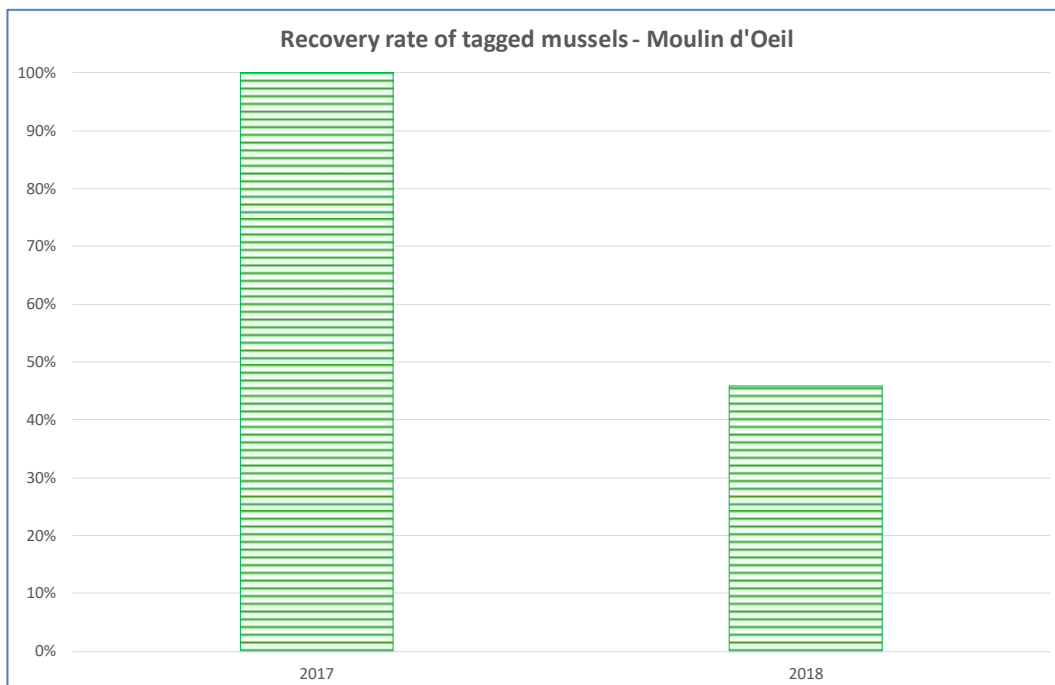


Figure 41: Recovery rate of tagged mussels at Moulin d'Oeil

The recovery rate is about 50% after one year.

3.2.2.3 Age distribution

The calculation of the age of *Unio crassus* in the river Sauer was done with two specific formula for river Sauer.

$$\text{Length} = 12,132 \ln(\text{age}) + 24,074$$

Equation 7: Growth curve for *Unio crassus* population in river Sauer bigger than 4 cm

$$\text{Length} = 19,452 \ln(\text{age}) + 3$$

Equation 8: Growth curve for *Unio crassus* population in river Sauer smaller than 4 cm

The age was calculated from 111 mussels (length, width and height were measured).

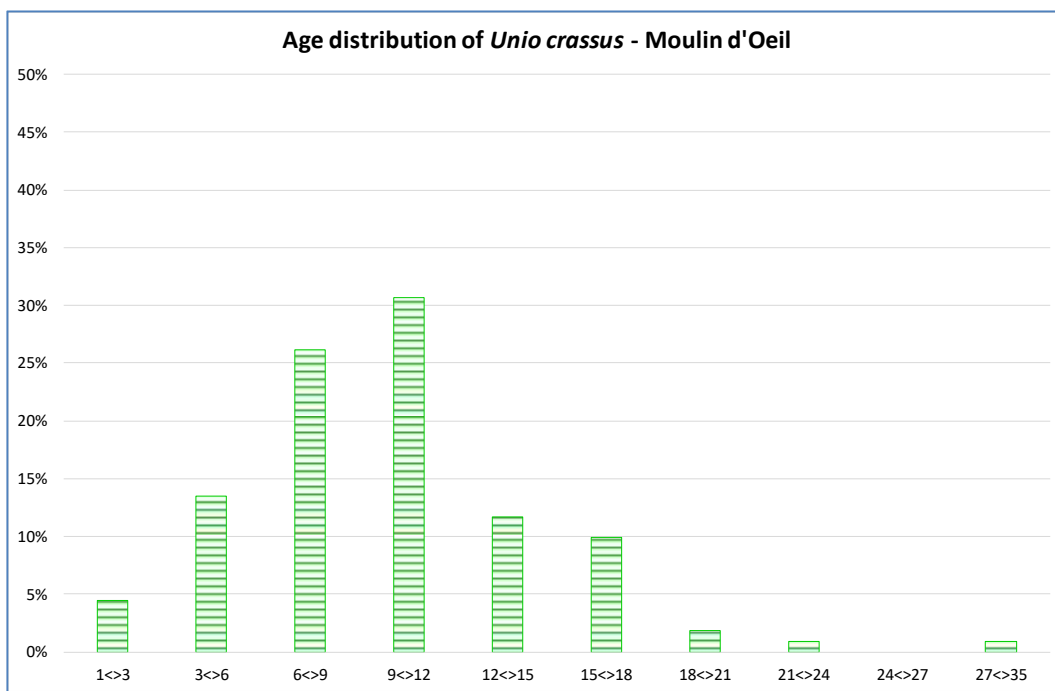


Figure 42: Age distribution of tagged mussels at Moulin d'Oeil

More than 50% were younger than 12 years. One very old mussel was found (34 years).

4 Sediment analysis

4.1 Methods

Sediment was collected in the mussel habitat in the vicinity of the tagged mussels. Six different places were analysed. Sediment was taken out with a box sized 2 litre volume. The sediment was sieved (> 2 mm, $> 630\mu\text{m}$, $> 63\mu\text{m}$ and $< 63\mu\text{m}$), dried and weighted. The results of the different places and years are shown below.

4.2 Overview

All mussel habitats show similar sediment size distribution in the riverbed. The fraction > 2 mm was the heaviest fraction in the collected sediment of the mussel habitats – except Moulin d’Oeil where a lot of sand could be found. No differences are seen in the part of the fraction $< 63\mu\text{m}$.

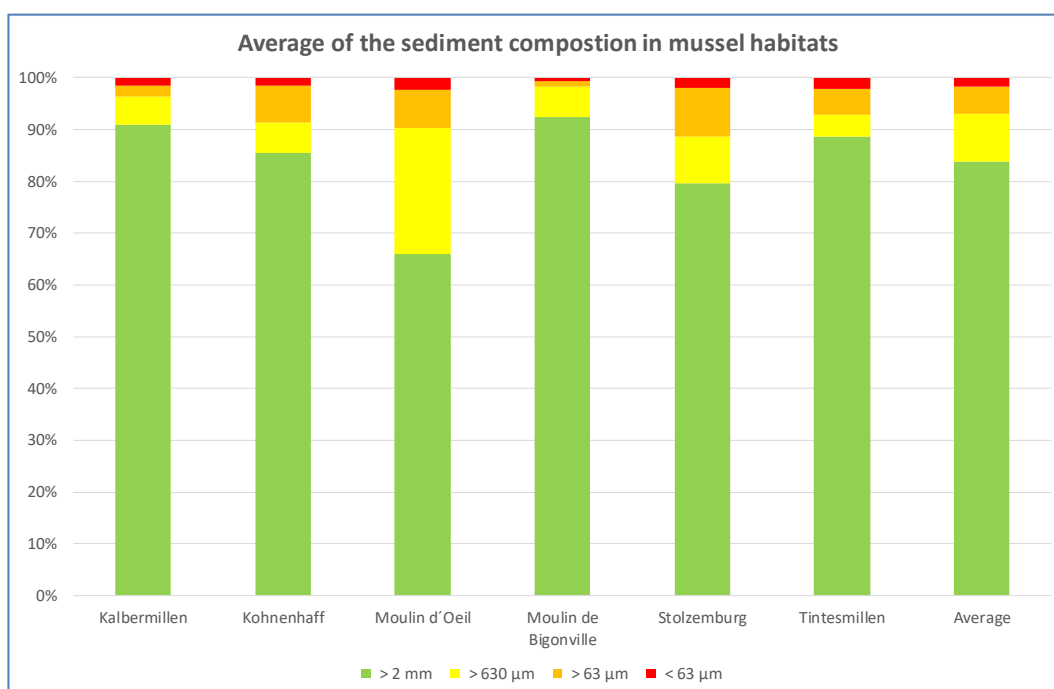


Figure 43: Sediment analysis of different mussels habitat – average of all samples

The details of the distribution are shown in Table 18.

Table 18: Sediment analysis of different mussels habitat – average of all samples

Place	> 2 mm	> 630 μm	> 63 μm	< 63 μm
Kalbermillen	91%	6%	2%	2%
Tintesmillen	89%	4%	5%	2%
Kohnenhaff	86%	6%	7%	2%
Stolzemburg	80%	9%	9%	2%
Moulin de Bigonville	92%	6%	1%	1%
Moulin d’Oeil	66%	24%	7%	2%
Average	84%	9%	5%	2%

4.3 Results

4.3.1 Kalbermillen

Sediment was collect and analysed 4 times during the project time. The distribution is shown in Table 19 and Figure 44. The heaviest fraction was bigger 2 mm.

Table 19: Sediment analysis of Kalbermillen mussels habitat

Date	> 2 mm	> 630 µm	> 63 µm	< 63 µm	Sum	> 2 mm	> 630 µm	> 63 µm	< 63 µm
2014 ¹	2,5 g	3,1 g	70,1 g	92,8 g	168,4 g	1%	2%	42%	55%
2016	2195,3 g	55,0 g	31,5 g	21,1 g	2303,0 g	95%	2%	1%	1%
2017	1941,9 g	52,3 g	54,7 g	40,5 g	2089,4 g	93%	3%	3%	2%
2018	2787,0 g	393,0 g	73,1 g	55,1 g	3308,2 g	84%	12%	2%	2%
Average	2308,1 g	166,7 g	53,1 g	38,9 g	2566,8 g	91%	6%	2%	2%

¹ – first sediment sampling which was done incorrect, data are not used for the average calculation

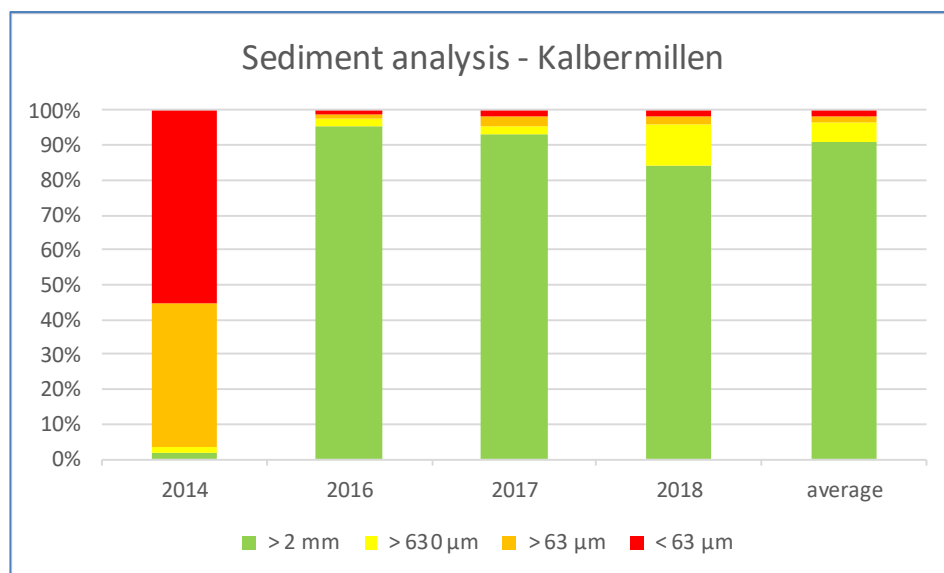


Figure 44: Sediment analysis of Kalbermillen mussels habitat

4.3.2 Tintsmillen

Sediment was collected and analysed 2 times during the project. The distribution is shown in Table 20 and Figure 44. The heaviest fraction was bigger 2 mm. In 2018 the fraction of > 630 µm increased. This shows the heterogenous size distribution in a mussel habitat.

Table 20: Sediment analysis of Tintsmillen mussels habitat

Date	> 2 mm	> 630 µm	> 63 µm	< 63 µm	Sum	> 2 mm	> 630 µm	> 63 µm	< 63 µm
2017	1669,1 g	22,5 g	62,4 g	28,4 g	1782,4 g	94%	1%	3%	2%
2018	2301,3 g	197,3 g	176,8 g	80,1 g	2755,3 g	84%	7%	6%	3%
Average	1985,2 g	109,9 g	119,6 g	54,2 g	2268,9 g	89%	4%	5%	2%

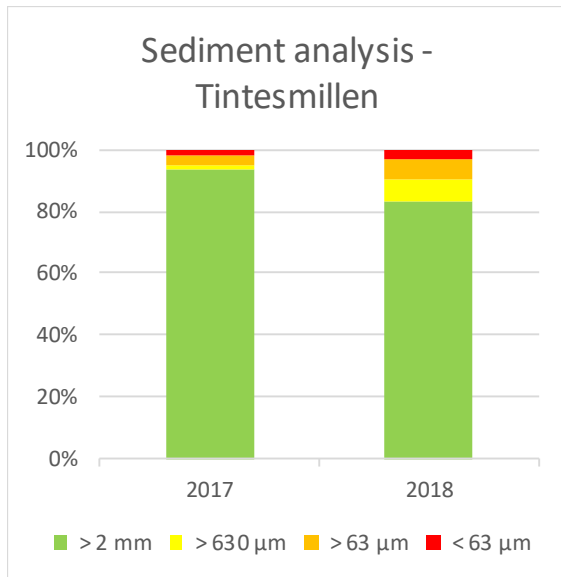


Figure 45: Sediment analysis of Tintesmilleren mussels habitat

4.3.3 Kohnehaff

Sediment analyses were done 5 times during the project time and the size distribution changed slightly during the years. In general the fraction distribution is similar to the other places.

Table 21: Sediment analysis of Kohnehaff mussels habitat

Date	> 2 mm	> 630 µm	> 63 µm	< 63 µm	Sum	> 2 mm	> 630 µm	> 63 µm	< 63 µm
2014	803,5 g	101,4 g	205,9 g	43,2 g	1153,9 g	70%	9%	18%	4%
2015	2289,4 g	126,8 g	184,6 g	30,6 g	2631,4 g	87%	5%	7%	1%
2016	1607,1 g	37,4 g	18,3 g	4,2 g	1667,0 g	96%	2%	1%	0%
2017	2503,1 g	206,6 g	183,2 g	46,0 g	2938,9 g	85%	7%	6%	2%
2018	2856,7 g	194,8 g	113,3 g	27,8 g	3192,6 g	89%	6%	4%	1%
Average	2012,0 g	133,4 g	141,1 g	30,4 g	2316,8 g	86%	6%	7%	2%

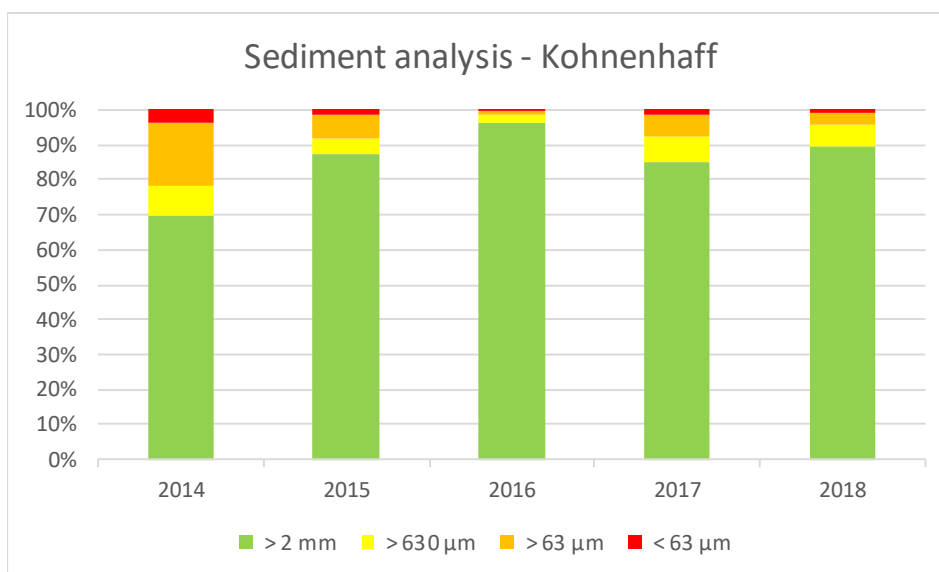


Figure 46: Sediment analysis of Kohnehaff mussels habitat

4.3.4 Stolzemburg

The place called Stolzemburg was analysed only once in the project time. The first mussels were tagged in March 2018.

Table 22: Sediment analysis of Stolzemburg mussels habitat

Date	> 2 mm	> 630 µm	> 63 µm	< 63 µm	Sum	> 2 mm	> 630 µm	> 63 µm	< 63 µm
2018	2232,7 g	249,4 g	265,0 g	54,9 g	2801,9 g	80%	9%	9%	2%

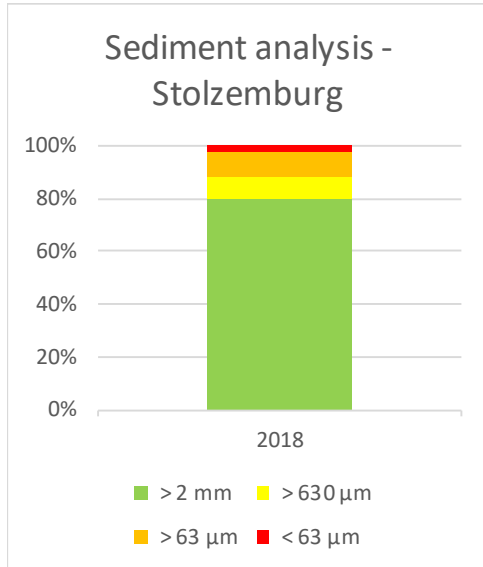


Figure 47: Sediment analysis of Stolzemburg mussels habitat

4.3.5 Moulin de Bigonville

Sediment analyses were done 4 times during the project time and the size distribution changed slightly during the years. In general, the fraction distribution is similar to the other places in Our and Sauer.

Table 23: Sediment analysis of Moulin de Bigonville mussels habitat

Date	> 2 mm	> 630 µm	> 63 µm	< 63 µm	Sum	> 2 mm	> 630 µm	> 63 µm	< 63 µm
2014	1628,3 g	89,1 g	14,1 g	12,1 g	1743,6 g	93%	5%	1%	1%
2016	1949,5 g	198,5 g	22,6 g	9,5 g	2180,2 g	89%	9%	1%	0%
2017	1655,1 g	39,9 g	6,5 g	10,8 g	1712,2 g	97%	2%	0%	1%
2018	2767,0 g	192,6 g	61,6 g	38,8 g	3059,9 g	90%	6%	2%	1%
Average	2000,0 g	130,0 g	26,2 g	17,8 g	2174,0 g	92%	6%	1%	1%

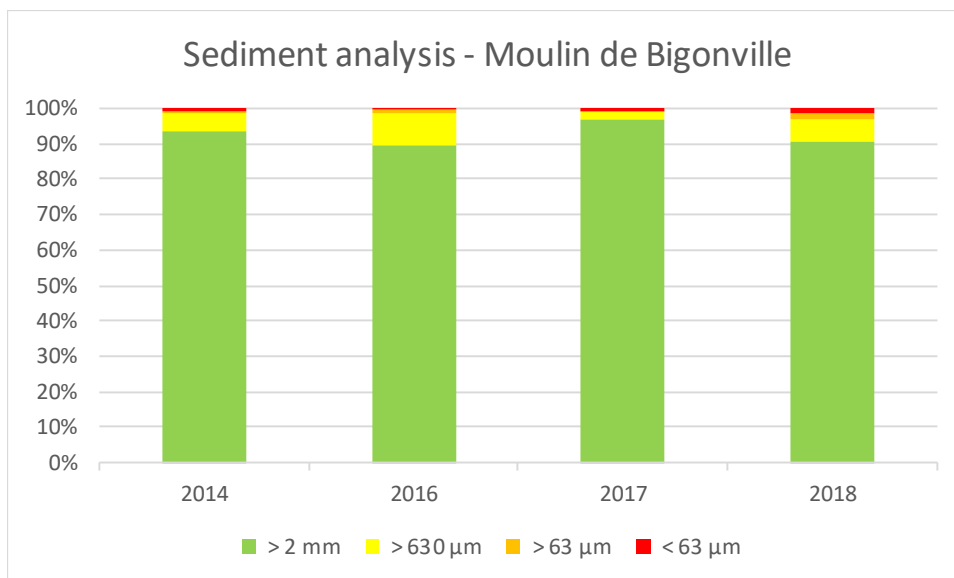


Figure 48: Sediment analysis of Moulin de Bigonville - mussels habitat

4.3.6 Moulin d’Oeil

The place called Moulin d’Oeil has been analysed twice in the project time. The first mussels were tagged in August 2013. The fractions of > 2 mm and > 630µm have a bigger part than the sediments from other mussels habitats. In this part of the river Sauer a lot of sand is deposited.

Table 24: Sediment analysis of Moulin d’Oeil mussels habitat

Date	> 2 mm	> 630 µm	> 63 µm	< 63 µm	Sum	> 2 mm	> 630 µm	> 63 µm	< 63 µm
2017	1505,1 g	757,8 g	151,6 g	59,0 g	2473,5 g	61%	31%	6%	2%
2018	1646,2 g	417,3 g	191,4 g	58,0 g	2312,9 g	71%	18%	8%	3%
Average	1575,7 g	587,6 g	171,5 g	58,5 g	2393,2 g	66%	24%	7%	2%

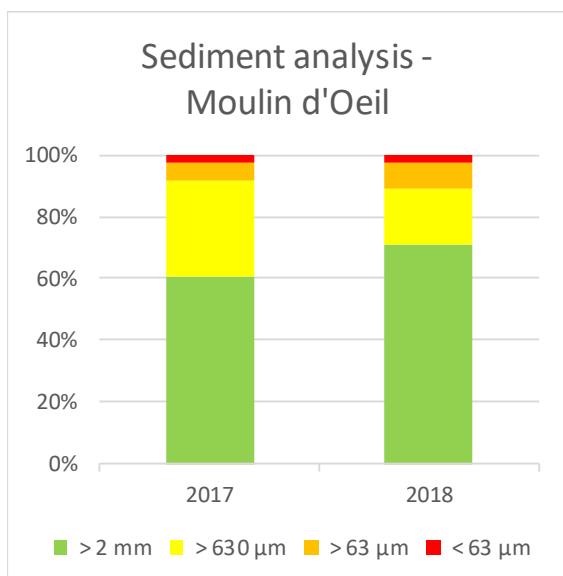


Figure 49: Sediment analysis of Moulin d’Oeil mussels habitat

5 Fertility

The fertility control always occurred during the collection of the adult mussel for the breeding process (see Table 25) or, if this was too early, later at the breeding facility. By slightly opening the shell with a special designed forceps, the gills of the mussels become visible. Seeing swollen and beige-orange coloured gills indicates that already developing eggs have been deposited in the mantle of the mussel. The fertility was never checked on all collected animals in the respective years, but only on a few animals to minimize the stress to the mussels. It was possible to collect glochidia in every year of the project runtime.

Table 25: Date and number of transferred adult mussels from both river to the rearing facility

	2013	2014	2015	2016	2017	2018
Date/period - Our taken	2012	04.04.	22.04.	08.04.	05.04.	06.04-10.04.
Date - Our back	18.07.	24.06.	18.07.	10.08.	25.08.	2019
Number - Our taken	100	50	63	81	141	84
Number - Our back	95	47	47	70	135	82
Date/period- Sauer taken	22.04.- 29.04.	21.03.	24.04.	12.04.- 02.05.	07.04.	09.04.- 18.04.
Date - Sauer back	11.07.	02.07.	15.07.	10.08.	09.08.	11.07.
Number - Sauer taken	50	65	36	60	120	67
Number - Sauer back	55	59	34	48	109	55

The presence of naturally infested fish in both streams (see D2) also indicates, that the mussels are still fertile and produce larvae in the wild. For both rivers, it was always possible to collect enough adult mussels. For the river Our, in total 519 mussels were collected in the 6 years, from which 476 could be returned. There was a loss of 8% of the mussels at the mill, which is acceptable. In the river Sauer in total 398 animals were collected and 360 could be returned. The survival rate of the adult mussels from the river Sauer was 90,5%. All mussels were normally collected in April.

6 Survival rate of the juvenile mussels

The rearing procedure shown in Figure 50 gives the survival rates observed during the last years in the respective steps. In every step, there is a loss of mussels.

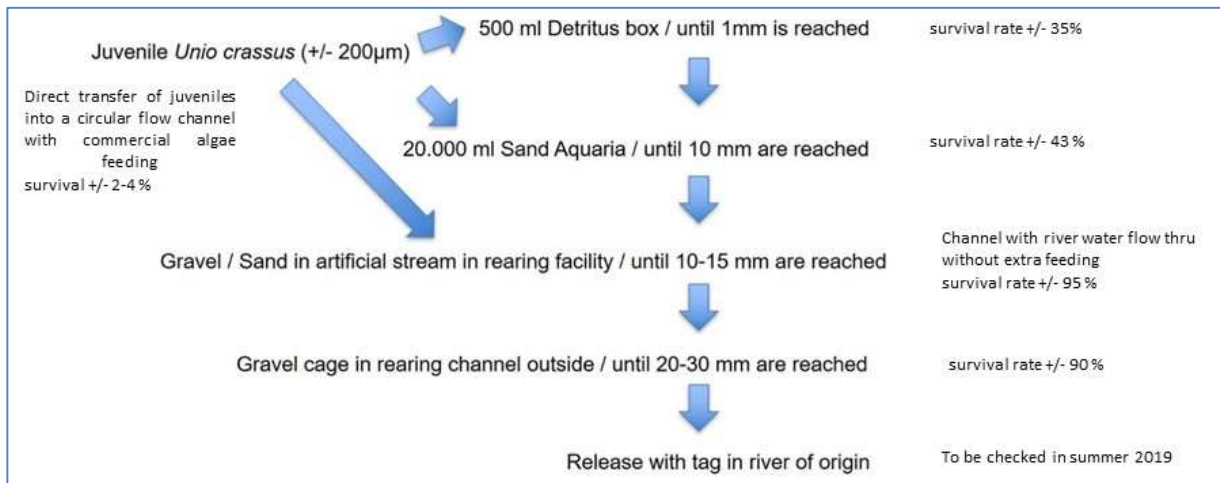


Figure 50: Rearing procedure with the survival rates in the respective steps

Applying the following procedure: freshly dropped mussels → detritus Box → sand aquaria → river water flow thru channel → outside channel → release, we get a total survival of 12-15%. This is acceptable and allowed us to produce +/- 1000 mussels per stream /year. Unfortunately, the less time-consuming method putting high numbers of freshly dropped mussels directly in a circular flow channel with commercial algae feeding had only a low survival rate of 2-4%. This had not direct impact on the project, as this method was not foreseen from the beginning. However once optimized, and as we were mostly able to collect >5000 juvenile mussels, this method could help to release much more mussels to the streams to strengthen the population.

In 2014 first *Unio crassus* were released in gravel cages in the rearing channel at the mill of Kalborn. Also in the following years, 2015, 2016, 2017 and 2018 we continued releasing mussels with gravel cages in the rearing channel. As these are the mussels, which will normally be released in the following year and as these mussels are already in contact with their natural environment (river water) without extra feeding we carefully followed the development of these animals. Figure 51 shows the results obtained from all cages checked in June 2018. These entire mussels were released in 2018. 11 new cages were filled with 1266 mussels (555 Our & 711 Sauer) between June and July 2018. Overall 85% of the mussels had survived, which is a positive development. An average growth of 250% was obtained after 4 years (from 14mm to 36 mm) which we also evaluated as good. The slight increase in survival over time is due to the fact, that every year a higher number of new mussels was added with new cages, which showed a better survival, and thus the overall survival increased.

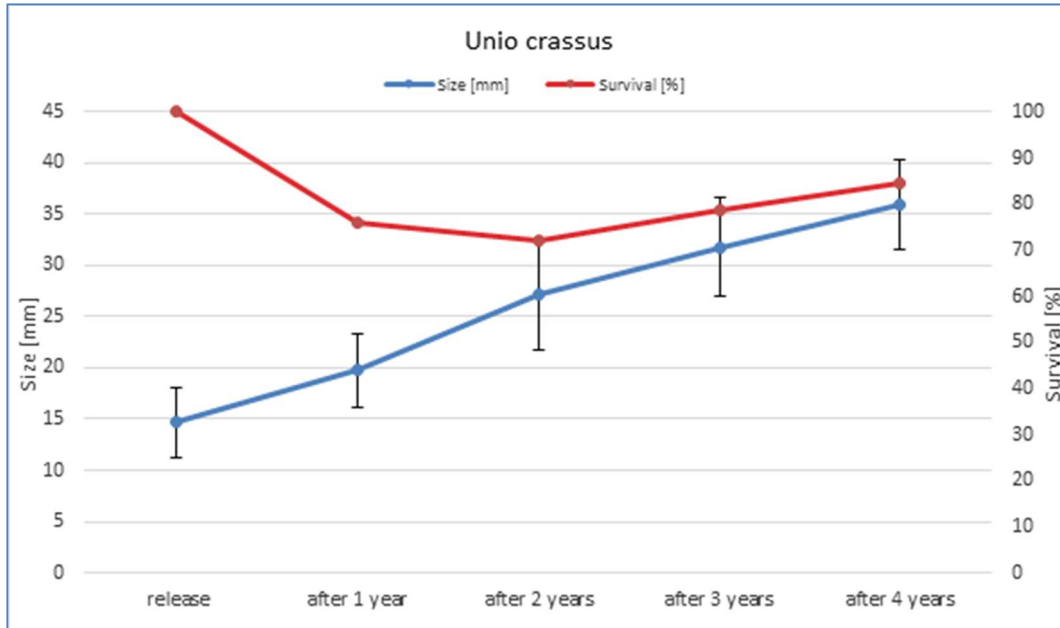


Figure 51: Survival and growth of the mussels released in gravel cages