1987

Biological Conservation **42** (1987) 115–132

The Unionid Mussels (*Mollusca, Bivalvia*) of the Belgian Upper River Meuse: An Assessment of the Impact of Hydraulic Works on the River Water Self-purification

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(Received 19 September 1986; revised version accepted 13 April 1987)

ABSTRACT

In September 1983, the nine weirs regulating the flow of the River Meuse between Givet (France) and Namur (Belgium) were kept fully open for technical purposes. The water level therefore dropped, allowing the sampling of benthic organisms and the mapping of the different kinds of banks. For each bank type, the density of unionid mussels was measured. Silt and fine gravel bottoms are the preferred habitats of these mussels. In these natural habitats, the mean biomass is estimated at more than 1·8 tonnes ha^{-1}. *In pebbles this value is near 1 tonne* ha^{-1} *whereas in the stony blocks and on rocky bars it falls to 165 kg* ha^{-1}. *Man-made banks are poor biotopes: 297 kg mussels* ha^{-1} *on old stoneworks and only 65 kg* ha^{-1} *on recent ones.*

When the filtration rate is considered, it can be shown that, at the time this study was undertaken, the unionid mussels living on the Meuse banks filtered more than 300 litres water s^{-1}. *This rate will drop to 27 litres* s^{-1} *within only a few years if the designed hydraulic works are carried out.*

This study emphasises the negative effects of these works on the self-purification capacity of the river.

INTRODUCTION

The Unionidae are known to make up more than 90% of the biomass of benthic invertebrates of some lakes and rivers (Ökland, 1963; Negus, 1966),

Biol. Conserv. 0006-3207/87/$03·50 © Elsevier Applied Science Publishers Ltd, England, 1987. Printed in Great Britain

to increase the mineralisation of organic matter in suspension (the respiration/assimilation ratio being higher than 0·9 according to Tudorancea & Florescu, 1968 and Tudorancea, 1972) as well as the sedimentation of fine particles (Stanczykowska *et al.*, 1976). Due to their great filtering capacity, they are important in the natural purification of water (De Bruin & Davids, 1970; Lewandowski & Stanczykowska, 1975). It is generally agreed (Wolff, 1968; Cvancara, 1972; Harman, 1972; Salmon & Green, 1983) that the type of substrate largely accounts for the density of these freshwater molluscs. However, the factors determining the choice of habitat of the different species remain unclear.

The purpose of the present work was first to identify these factors in the case of the River Meuse and secondly to investigate the effects of hydraulic works on the self-purification process of the river.

STUDY AREA

The River Meuse extends 46·5 km between the towns of Givet (France) and Namur (Belgium), the difference in level being 20 m (average slope: 0·43‰). The river width is about 100 m at Givet and 125 m at Namur. Its average annual rate of flow is 180 $m^3 s^{-1}$ at Ampsin, i.e. 35 km downstream from the area studied (IRM, 1983*a*). Descy *et al.* (1981) have shown that the biological quality of the Belgian upper River Meuse water, which is rich in calcium, is still quite good. Yet slight organic pollution can be observed (O_2 saturation: 90 to 100%; 0·1 to 0·25 ppm of phosphorus) and also some zinc pollution. In addition, the river receives radioactive effluents from the Chooz nuclear power-station.

The river banks can be subdivided into natural substrates on the one hand—rocks, areas of stony blocks (>25 cm), pebbles (>2 cm), and fine sediment (mud, sand and gravel)— and into reinforcement works on the other—open stone pitching, ripraps, gabions, or stone pitching covered with concrete, embankment walls.

MATERIAL AND METHODS

The usual sampling techniques for the study of benthic communities (bottom or grab dredges) are not very satisfactory for such large animals as unionid mussels. Moreover, direct methods (hand picking or scuba-diving) are often impracticable because the waters are too turbid or too deep.

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Of particular interest in the case of our study is the fact that the nine weirs regulating the flow of the River Meuse between Givet and Namur are put out of service for three weeks every three years, during which time the water level drops by 2 to 2·5 m. This situation facilitates the study of benthic macro-invertebrates, although observations have to be made in the shortest time possible since some predators such as the grey heron *Ardea cinerea* L., the black-headed gull *Larus ridibundus* L. or the musk rat *Ondatra zibethicus* L. take advantage of the conditions, as do onlookers and children who collect animals. Finally, some animals may move towards the water or bury themselves in the sediment. In 1983, the temporary putting out of service of the weirs started on 11 September and ended on 2 October. Our sampling was limited to 12, 13, 14 and 17 September.

In spite of this favourable situation we did not succeed in sampling the mussel populations in areas of the river which remained submerged, although a comparison between exposed and submerged areas would have been helpful. However, water turbidity, current speed and stream depth remained so great in these areas that sampling would have been inefficient. Our results are consequently limited to the exposed parts of the river bed.

Substrate distribution and area estimation

The surface covered by each substrate was calculated as follows:

(a) The distribution of each substrate was observed in the field and transferred onto 1:25 000 maps allowing for the presence of two facies: the banks as such and that part of the river bottom not covered by water.
(b) On the maps, the length occupied by each substrate was subsequently measured by means of a curvimeter, for each of the two facies.
(c) The surface covered by each substrate was calculated multiplying the length measured in (b) with the average width of the uncovered area, the latter having been estimated for each type of substrate and each facies as a function of the river profile.

Density and length frequency distribution of the mussels

Our samples were collected over some 89 quadrats of 1 m^2 distributed along the river (Fig. 1) in different types of environment. The sampling sites were chosen according to ease of access and the different environmental conditions. At each site the position of each quadrat was determined at random by throwing, with the eyes closed, a wooden frame of 1 m sides. Each square was dug out with a fork (2 cm between the pins), the mussels were

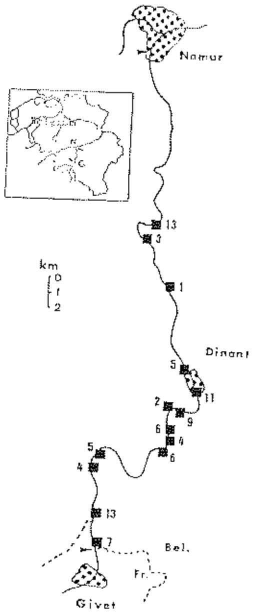

Fig. 1. Map of the study area showing the distribution of the sampling sites. The number of samples taken at each site is indicated.

identified to species according to Adam (1960), counted and measured with a caliper rule (0·1 mm accuracy).

Habitat choice

For each of the 89 1 m^2 quadrats, we estimated the value of 14 parameters (Table 1) directly *in the field*, and then attempted to relate these variables to the density of unionid molluscs and some other invertebrates. We used the MULTM reciprocal averaging program (Lebart *et al.*, 1977), because it works on contingency tables, and can therefore take account of qualitative variables, not easily done using other factorial methods. The advantage of this procedure is that the user is able to analyse the behaviour of the 'illustrative' variables in an environment defined with the 'active' variables. For further discussion of this question, see Benzecri *et al.* (1980).

Assessment of the biomass and of the filtration capacity of the mussels

It is possible to estimate the filtration power of individual mussels from their fresh weight (including the valves (Alimov, 1969) and the fresh weight with its length (Tudorancea & Gruia, 1968; Lewandowski & Stanczykowska, 1975; Ghent *et al.*, 1978; Petit, 1978; Huebner, 1982).

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TABLE 1

Study of the Habitat Requirement of Unionid Mussels: Parameters and Classes Used in the Reciprocal Averaging Analysis

Parameters	*Classes*			
	1	*2*	*3*	*4*
Substrate				
Mud, sand	absence	presence		
Reduced mud (anaerobic decomposition)	absence	presence		
Branches	absence	presence		
Gravels	absence	presence		
Pebbles	absence	presence		
Rocks, stony blocks, concrete	absence	presence		
Slope (%)	0 to 20	21 to 50	>50	
Depth (cm)	0 to 60	61 to 100	101 to 150	>150
Distance from the bank (m)	0 to 2	2 to 5	>5	
Flow speed	high	moderate	slow	
Aquatic vegetation	absence	presence		
Navigation	absence	presence		
Organic effluents	absence	individual sewage	village	town
Bank type	natural	semi-natural	man-made	
Fauna				
Anodonta piscinalis < 60 mm	absence	1 to 10 m^{-2}	$>10\,m^{-2}$	
Anodonta piscinalis > 60 mm	absence	presence		
Pseudanodonta elongata	absence	presence		
Unio pictorum > 60 mm	absence	presence		
Unio pictorum < 60 mm	absence	presence		
Unio crassus	absence	presence		
Dreissena polymorpha	absence	presence		
Viviparus viviparus	absence	presence		
Orconectes limosus	absence	presence		

The fresh weight of each individual we collected was calculated from several weight–length relationships as follows:

Anodonta piscinalis Nills: The following equation was computed from original data of 54 mussels taken from the River Meuse, wiped dry, measured to the nearest 0·1 mm and then weighed to the nearest 0·1 g.

$$\text{Log}\,W = 3{\cdot}255 \log L - 4{\cdot}533 \quad (r = 0{\cdot}994)$$

This equation was also used as a basis for the calculations for *Pseudanodonta elongata* Holandre, since no published data for this species were found.

Unio pictorum (L.): the weight–length relationship in Petit (1978), for the same population was used:

$$\text{Log}\,W = 2{\cdot}730 \log L — 3{\cdot}648 \quad (n = 53;\ r = 0{\cdot}995)$$

Unio crassus Philipsson: Since our material was too limited and no published data were found in the literature on the fresh weight–length relationship for this species, we applied an equation characterising a *U. tumidus* Philipsson population since this species is similar to *U. crassus*.

$\text{Log } W = 2{\cdot}3086 \log L - 2{\cdot}745$ (Lewandowski & Stanczykowska, 1975)

In these equations, the weight (W) is expressed in grams and the length (L) in millimetres. Given the weight of an individual, it is possible to compute its filtration capacity as follows:

$V = 84{\cdot}14\ W^{0{\cdot}49}$ where V, the filtration capacity, is given in millilitres h^{-1} (Alimov, 1969).

In this way, we obtained a biomass and a filtration value for each quadrat sampled; average values were then calculated for each habitat type.

Impact of the bank reinforcement works

The impact of reinforcement works done on large rivers is not easy to determine accurately; we have, however, attempted to make a comparison on the one hand of the present situation with that which existed before reinforcement work was carried out, and, on the other, what might happen if the upper River Meuse were to be completely 'modernised'.

The present filtration capacity of the mussels living on the banks and the exposed part of the river bed was estimated from the area covered by each substrate and the average filtered volume per square metre of substrate.

To compute the 'past' filtration capacity, we assumed that before man's intervention the different types of natural banks and bottoms (rocks, mud beaches, pebbles, blocks, etc.) exist in the proportions in which they can still be found today in undisturbed areas. We calculated the surface occupied by each type of environment and then the total filtration capacity, in the same way as for the present situation.

As regards what might happen in the near future, we assumed that the proportion of different types of banks of the River Meuse that will be completely 'modernised' will be the same as exists along the man-made banks between the French border and Namur.

Impact of the temporary stoppage on bivalve populations

Bivalves move with difficulty. Any prolonged drying-out of the river bed must therefore affect their populations. After the three weeks' stoppage, we visited some sites in order to estimate mussel mortality. We counted

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individuals, alive and dead, along a shaded and a sunny path. During the period studied the rainfall was very low: 30·4 mm (IRM, 1983*b*).

RESULTS

Estimation of the area of each habitat

The results are shown in Table 2. The total area above water during stoppage was about 64·2 ha, i.e. 12·3% of the surface usually occupied by the river. It can also be seen that barely 30% of the river banks are at present not reinforced by man-made works.

Habitat choice

The eigen values corresponding to the five factorial axes obtained by the reciprocal averaging represent, in increasing order of the axes, 13·3%, 11·8%, 8·5%, 7·7% and 7·1% of the total variability of the data. The following interpretation mainly concerns the first two axes, the rest serving to provide useful complementary indications or to qualify the conclusions drawn (Fig. 2). It can be seen that in the upper right square the sampling points are characterised by a slight slope and depth, a fine substrate (mud, sand, gravel), natural banks and undisturbed by the lighter traffic (waves). These last two variables are redundant insofar as the river branches that are not open to navigation are less 'improved' than others, and exhibit the highest densities of unionid mussels. On the other hand, the samples present in the lower left square are the richest in *Dreissena polymorpha* (Pallas), *Viviparus viviparus*

TABLE 2
Assessment for Each Habitat Type of the Total Area left out of Water during Temporary Stoppage

	Habitat type	*Bank*		*Bottom*	
		Length (m)	*Width (m)*	*Length (m)*	*Width (m)*
A	Mud, sand, fine gravel	24 950	2·3	11 687·5	7·0
B	Pebbles	3 812·5	2·0	43 250	6·0
C	Rocks, stony blocks, gabions, ripraps	5 862·5	3·0	13 300	3·0
D	Old open stone pitching	21 800	0·75	6 812·5	2·25
E	Walls, stone pitching covered by concrete	41 825	2·25	23 200	2·25

(L.) and *Orconectes limosus* (Rafinesque). Their slope and depth are average to steep, the substrate rough (blocks of stone, rocks) and the banks man-made, though not completely covered with concrete.

The third axis seems to indicate that the unionid mussels are also abundant in sites of average depth (100 to 150 cm) even if the slope is quite steep (20 to 25%) provided the quality of the substrate remains adequate: mud, sand, fine gravel. It also points to the scarcity of the fauna on the upper part of man-made banks with a steep slope. The fifth axis shows that small *Anodonta piscinalis* (less than 60 mm) are most abundant in shallow waters (between 60 and 100 cm).

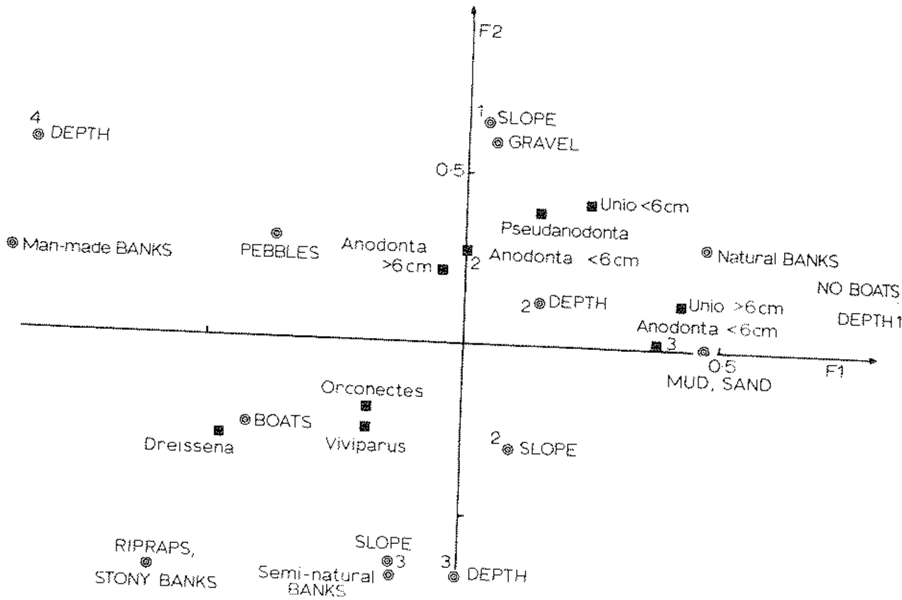

Fig. 2. Simplified representation of the reciprocal averaging results showing the plan of the two first components. ■: illustrative variables (animals); ◎: main variables (habitat parameters). When a value appears near a variable name, it refers to the class of this variable (see Table 1) (for full explanation, see text).

The behaviour of some variables cannot be explained: this is due to the fact that they do not often occur in the sampling: the presence of *U. crassus* (7 occurrences), that of hydrophytes or helophytes (9 occurrences) or of a substrate rich in reduced organic matter (13 occurrences). The influence of the amount of organic pollution in the river remains unclear. Reciprocal averaging shows that the unionid mussels may not be very sensitive to this factor; however, our attempt at expressing the level of this pollution (Table 1) is too approximative.

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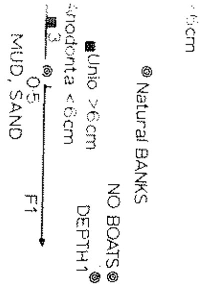

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TABLE 3

Density and Biomass of Unionid Mussels for Each Habitat Type of the Belgian Upper River Meuse

	Habitat	*Number of samples*		*U. pictorum*		*U. crassus*		*A. piscinalis*		*P. elongata*		*Total biomass*
				d	*B*	*d*	*B*	*d*	*B*	*d*	*B*	
A	Mud, sand, fine gravel	47	m	3·60	35·4	0·19	3·6	13·43	143·4	0·89	6·0	188·4
			s	4·21	55·3	0·90	18·6	18·38	203·2	2·48	14·2	
B	Pebbles	21	m	0·86	10·3	0·19	2·0	5·24	87·7	0·43	2·9	102·9
			s	1·28	18·6	0·51	5·0	5·72	124·4	0·93	8·2	
C	Rocks, stony blocks, ripraps	9	m	—	—	—	—	0·89	16·5	—	—	16·5
			s	—	—	—	—	1·36	30·6	—	—	
D	Old open stone pitching	6	m	1·00	27·3	—	—	0·33	2·4	—	—	29·7
			s	2·45	66·8	—	—	0·82	5·8	—	—	
E	Walls, stone pitching covered by concrete	6	m	0·17	0·6	—	—	0·67	5·9	—	—	6·5
			s	0·41	1·5	—	—	1·03	11·6	—	—	

d = density (individuals m^{-2}).
B = biomass (g m^{-2}).
m = mean.
s = standard deviation.

Density

In the light of the above results, which stress the great importance of the substrate to unionid mussels, we estimated the density of these animals in the main types of habitat encountered along the upper River Meuse (Table 3).

The variances of these densities are, in all cases, markedly greater than the means, indicating that these species have an aggregative distribution pattern (Fig. 3), a point also confirmed by Tudorancea & Gruia, 1968, Burla *et al.* (1974) as well as Petit (1978). Although the use of an arithmetic mean in our calculations is not necessarily very accurate, since the distribution of samples is not normal. Petit (1978) has shown that if based on large quadrats (1 or 4 m^2), the values calculated are very close (at least for *A. piscinalis* and *U. pictorum*) to those computed after adjustment to an heterogeneous aggregative distribution model (Gérard,, 1970). Our results will thus be used as they appear in Table 3.

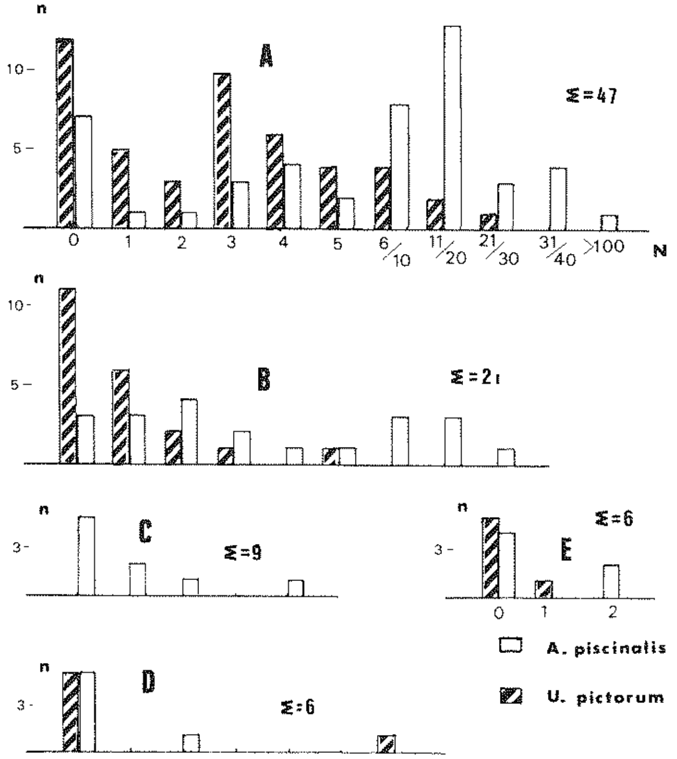

Fig. 3. Sample size frequency distribution of two mussel species over five bank types. A: mud, sand, fine gravel; B: pebbles; C: rocks, stony blocks, ripraps; D: old open stone pitching; E: concrete walls, stone pitching covered by concrete; N: sample size (number of mussels/sample); n: number of samples; $\sum$: total number of samples.

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TABLE 4

Filtration Capacity of Unionid Mussels for Each Habitat Type of the Belgian Upper River Meuse

	Habitat		*Filtration capacity (litres m^{-2} h^{-1})*				
			U. pictorum	*U. crassus*	*A. piscinalis*	*P. elongata*	*Total*
A	Mud, sand, fine gravel	m	0·795	0·064	3·244	0·147	4·250
		s	1·066	0·322	4·338	0·349	
B	Pebbles	m	0·202	0·049	1·511	0·078	1·840
		s	0·309	0·123	1·633	0·193	
C	Rocks, stony blocks, ripraps	m	—	—	0·301	—	0·301
		s	—	—	0·512	—	
D	Old open stone pitching	m	0·419	—	0·073	—	0·492
		s	1·027	—	0·180	—	
E	Walls, stone pitching covered by concrete	m	0·027	—	0·144	—	0·171
		s	0·066	—	0·240	—	

m = mean.
s = standard deviation.

Biomass

The high value of the mussel biomass in the natural habitats (nearly 2 tonnes h^{-1} in the muddy areas and 1 tonne ha^{-1} in the pebbles) (Table 3) contrasts with the very low one on the man-made banks (65 to 297 kg ha^{-1} according to type).

Filtration capacity

Table 4 presents an estimation of the filtration capacity of unionid mussels for each habitat type along the River Meuse. Since the density and biomass of the mussels are much greater in natural habitats than on artificial substrates, it is not surprising to see that the same is true when the flow of filtered water is taken into account.

TABLE 5

Assessment of the Filtration Capacity of the Whole Unionid Population in Three Situations
(Area out of water during temporary stoppage only)

	Habitat	*Estimated filtration capacity (litres $m^{-2}h^{-1}$)*	*Past 'undisturbed' situation ($m^3 h^{-1}$)*	*Present situation ($m^3 h^{-1}$)*	*Future 'improved' situation ($m^3 h^{-1}$)*
A	Mud, sand, fine gravel	4·250	1 348·4	591·6	—
B	Pebbles	1·840	778·0	491·4	—
C	Rocks, stony blocks, ripraps	0·301	14·6	17·3	17·4
D	Old open stone pitching	0·492	—	15·6	33·3
E	Walls, stone pitching covered by concrete	0·171	—	24·9	48·5
Total filtration	$m^3 h^{-1}$		2 141·0	1 140·8	99·2
	litres s^{-1}		594·7	316·9	27·5

Table 5 shows that the present situation, although not excellent, is relatively satisfactory when compared with the former. It should be remembered that two-thirds of the river banks are 'improved' (Table 2), but despite this, the filtration capacity has not been reduced to half its 'original' level. It can also be clearly seen that the so called proposed 'improvement' works will involve a sharp drop in capacity of more than 90%! This is to be expected since 95% of the current filtration is ensured by the mussels living in the natural habitats of the river.

Impact of the temporary stoppage on the mussel populations

Along the two transects followed, we observed a total mortality among *A. piscinalis* and *D. polymorpha*. In the case of *U. pictorum*, a 26% mortality rate

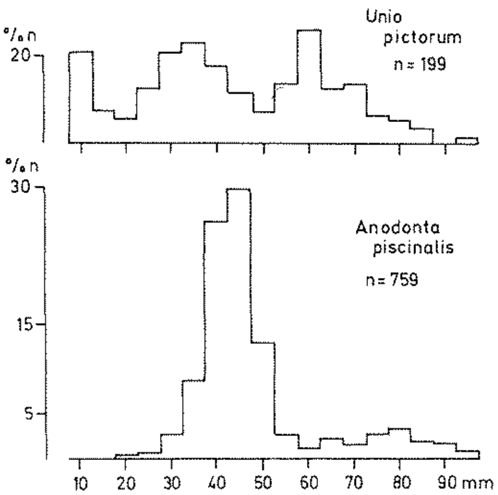

Fig. 4. Length frequency distribution of *U. pictorum* and *A. piscinalis* in the River Meuse in September 1983.

(n = 50) was noted in the shady site and 50% (n = 50) in the sunny site (significant difference at $\alpha = 0{\cdot}02$ level). The better survival rate of *Unio* can probably be explained by their having thicker valves. These very high mortality rates imply a rapid turnover of the population and explain why the proportion of small, i.e. young, individuals is so great, particularly in *A. piscinalis* (Fig. 4).

DISCUSSION

In large rivers, the study of living populations is made difficult not only by the depth and turbidity but also by navigation and the lack of adequate sampling techniques.

Due to the very particular circumstances the benthic organisms of the upper River Meuse were directly accessible in good conditions for observation. The results given here are, however, limited as they only concern the river banks and the exposed part of the bed, i.e. about 12% of the whole river bed area. It would be very hazardous to extrapolate our results to the whole river since sound information on the quality of the continually submerged part of the river bed or about the mussels living there is not available. The unionid distribution pattern is depth-dependent and their maximum density in shallow waters has been precisely recorded (Burla, 1972; Cvancara, 1972; Lewandowski & Stanczykowska, 1975; Ghent *et al.*, 1978; Brönmark & Malmqvist, 1982; Salmon & Green, 1983).

Methodology

To what extent are our results reliable?

(1) The 89 m^2 sampled is small compared with the total surface exposed, but it was not possible to obtain many more samples as we had to gather as much data as available in the shortest time possible.

(2) The calculation of the surfaces is made on the basis of a map on a scale of 1:25 000 and a rough evaluation of the mean width of the different types of substrate.

(3) We computed the biomass of *U. crassus* and of *P. elongata* by means of equations characterising other mussel species. Their biomass and filtration capacity estimations are consequently somewhat inaccurate. Since these two species are infrequent in the population (during this study, 51 individuals only of *P. elongata* and 13 of *U. crassus* were found, whereas 199 *U. pictorum* and 759 *A. piscinalis* were taken), this relative inaccuracy cannot, however, greatly alter our conclusions.

(4) It is difficult to calculate the filtration capacity of a population very accurately. Among bivalves, indeed, the filtration rate varies as a function of a great number of factors such as pH, temperature, turbidity and viscosity of the water, the stream velocity or the concentration and quality of the seston (Morton, 1971; Walne, 1972; Stanczykowska *et al.*, 1976). However, it appears that the major source of variation is to be found in the size of the individuals (Morton, 1971; Walne, 1972).

Although the data which form the basis of this study appear to be weak and our method rather rudimentary, we think our results are of value. They are the only data available relative to the River Meuse and are similar to those of other authors (see below). Moreover, our conclusions on the impact of the reinforcement works are based on a comparison of three situations.

Biomass

The richest environments both in species and individuals were the natural habitats where the substrate is fine. In muddy areas, the total biomass of unionid mussels amounted to 1884 kg ha^{-1}, comparable to the results of Ökland (1963): 2593 kg ha^{-1} in a eutrophic lake in Norway; those of Negus (1966) in the Thames: 2921 kg ha^{-1}; and those of Tudorancea & Florescu (1968) and Tudorancea (1972) for shallow lakes in Rumania: 1204 kg ha^{-1} for the former, and 751 and 1191 kg ha^{-1} in the two lakes studied by the latter. The situation observed in the upper River Meuse can thus be considered to be normal. In addition, the richness of the areas with fine gravel and pebbles—1029 kg ha^{-1}—and the very bad quality of man-made banks should be noted.

Importance of the present filtration capacity

The amount of water filtered by the populations of unionid mussels living on the banks and exposed part of the river bed may seem unimportant as it only corresponds to 1/568th of the average annual rate of the river flow measured at Ampsin. Unionid mussels filter a quantity of water equal to that filtered by a purification station for more than 150 000 equivalent-inhabitants (180 litres of water filtered per inhabitant per day, Lemaire & Lemaire, 1975). The water filtered by the mussels is of better quality than that received by effluent purification stations, and the mussels have real advantages in comparison with such installations: of the particles they 'catch', they deposit those they do not consume, agglutinating them in mucus (pseudofaeces). Part of the ingested particles is assimilated and converted to 90–95% water and carbon dioxide (Tudorancea & Florescu, 1968); the other is evacuated as faeces enriched in bacteria and is in turn used up by other invertebrates as prime quality food (Stanczykowska, 1975). Thus they speed up sedimentation and mineralisation of organic matter in suspension, without any investment or running cost. Economically, it is thus particularly worthwhile to maintain high densities.

Impact of the reinforcement works

In order to assess the impact of hydraulic works on the river self-purification process, we assumed that the proportion of different types of banks of the 'modernised' river would be the same as that existing at present. In fact, the hypothesis is very optimistic for the old open stone pitchings, which provide shelter for the greatest number of animals, are being progressively covered with concrete. Moreover, downstream from Namur, the bank 'improvement' is most often characterised by the construction of concrete walls, often vertical—real deserts without life.

The situation is thus likely to become even worse than predicted by our extrapolations. Indeed, the young unionid mussels prefer shallow areas, which disappear completely when improvement works are undertaken.

Influence of the temporary stoppage on bivalve populations

The acceleration of the turn-over rate of the populations becomes quite obvious in the case of *A. piscinalis* when its length frequency distribution is compared with that of other populations. Tudorancea (1972) and Lewandowski & Stanczykowska (1975) have shown that the mode of the age-frequency distribution of their *A. piscinalis* population was 5 years in two cases, 4 years in another. These 4- and 5-year-old mussels were, respectively, about 50 and 60 mm long. They can be still larger (Ökland, 1963; Negus, 1966).

The main part of the Meuse *Anodonta* population would thus comprise individuals that are not older than 3 years. When the habitat has dried out due to the stoppage, recolonisation can be ensured by migration or reproduction of individuals which remain.

Observations made in November 1984 show the rapidity of the colonisation process. One year after the end of our study, the stretch of river at Anseremme-Dinant was drained again to permit the construction of a landing stage. At Neffe (Fig. 1, first station upstream from Dinant) in September 1983, 27 *A. piscinalis*, 2 *U. pictorum*, 6 *U. crassus* and one *P. elongata* were recorded in 5 quadrats of 1 m^2, i.e. 7·2 individuals m^{-2}. In November 1984, on a surface of 26 m^2, we counted 82 *A. piscinalis*, of which only 4 were greater than 50 mm, 16 *U. pictorum* and 5 *U. crassus*, i.e. a density of 3·96 mussels m^{-2}, more than half the density found in 1983.

CONCLUSIONS

(1) The highest densities of unionid mussels can be observed in areas with fine substrates (mud, sand and fine gravels), the slope and depth of which are slight, preferably in reaches which are not open to navigation or in places protected from the river navigation, i.e. where the banks have not yet been 'modernised'. Inversely, the environments with rough substrate or the completely artificial ones are very poor in unionid mussels.

(2) The modernisation works undertaken today by the Public Works Department are disastrous for the aquatic life. We have calculated that the filtering capacity of the population of unionid mussels living in the exposed area between Givet and Namur is at present 317 litres s^{-1} whereas it would have been about 595 litres s^{-1} before the bank reinforcement works. If these were to be done along the whole course of the river, the filtering capacity would not be more than 27 litres s^{-1} at its best.

(3) The drying of a part of the river bed due to the temporary putting out of use of the river causes a very high mortality among bivalves, namely among the species with a thin shell (*A. piscinalis*, *D. polymorpha*). However, the repopulation of the environment is quite rapid and happens mainly through young individuals.

In short, this study clearly points to the negative impact of the 'modernisation' works of the river. The subsequent disastrous impoverishment of the populations of benthic macroinvertebrates is combined with an important decrease in the self-purification capability of the river.

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ACKNOWLEDGEMENTS

We are specially indebted to Mrs G. Hallet-Van Roost for her helpful technical assistance in the field. We are also grateful to Mr Th. MacQuiston and to Mr H. Blyth for the revision of the English language, and to Prof. J. Cl. Ruwet, Dr J. Cl. Philippart, Mr H. Loze Ing. and an anonymous referee for reading and criticising our manuscript.

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