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Age structure, age specific mortality rates and population trend of the freshwater pearl mussel (*Margaritifera margaritifera*) in North Bavaria

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With 6 figures and 3 tables in the text

Abstract

The age structure of five pearl mussel populations is investigated. A method is developed to calculate age specific mortality rates using the age structure of mussels and dead shells. Mortality rates are compared with chemical data to determine whether mortality is influenced by water pollution. With the results of this study it is possible to calculate population trends.

Introduction

In many parts of the northern hemisphere a catastrophic decline in numbers of freshwater pearl mussels has been described (Björk 1962; Jungbluth & Lehmann 1976; Valovirta 1977; Young & Williams in press; Baer 1969; Bauer 1980). The few detailed investigations concerning the population structure state a lack of young mussels not only in the densely settled region of Central Europe (Dettmer 1982; Bauer 1979), but also in Sweden (Hendelberg 1961) and in the USA (Stober 1972). Therefore it is likely that most populations will die out in the next few decades.

The critical stage is the young mussel after it left the host fish. Even a slight eutrophication can inhibit the growth of juveniles (Bauer et al. 1980). This paper deals with the population ecology of the next stage, the fully developed mussel (more than five years old).

The following questions are discussed:

1. What is the age structure of the populations?
2. What are the age specific mortality rates?
3. Do the mortality rates depend on water pollution?
4. What is the population trend in the study area?

Methods

The investigations were made in five rivers, containing ca. 95 % of all pearl mussels in North Bavaria (Fichtelgebirge).

For every population a growth curve of the ligament was developed, using the method described by Hendelberg (1961). In each river four plots were chosen at

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random. The ligament of mussels and dead shells was measured and converted to the age.

After discovering drift and solubility of dead shells it is possible to calculate the age specific mortality, using the age structure of mussels and shells.

Results

Age structure

There is hardly any difference in the growth of the ligament (Table 1) between the populations.

Table 1. Growth curves for the ligament in five pearl mussel populations. n = number of shells which were used to develop the equations, y = length of the ligament, x = age (years).

river	n	equation	r	P
A	31	$y = 13.3 + 0.74x - 0.002x^2$	0.93	<0.001
B	45	$y = 2.6 + 1.14x - 0.005x^2$	0.97	<0.001
C	27	$y = 6.7 + 0.89x - 0.0038x^2$	0.99	<0.001
D	48	$y = 4.1 + 0.94x - 0.0034x^2$	0.95	<0.001
E	46	$y = 18 + 0.69x - 0.002x^2$	0.93	<0.001

In river A the mussels reach a maximum age of only 60 years, whereas in the other rivers the maximum life expectancy is 100—110 years (Fig. 1).

The age analyses indicate that all populations are dominated by the older year classes, only in river A, mussels younger than ten years were found.

Apparently pollution was very low in river B during the war and post war period (Fig. 1B). In all other rivers, an increasing eutrophication started 70—80 years ago, which led to a complete lack of young mussels.

Age specific mortality rates

For each plot the numbers as well as the age structure of mussels and dead shells is determined. Hence the present number of dead animals in each age class can be estimated.

To calculate the mortality rate (in the last ten years), it is necessary to find a relation between the present number of empty shells and the number of animals which have died in the last ten years. Therefore drift and solubility of the shells have to be considered.

a) Drift of shells

In river A shells were counted in 10 m zones over a total length of 800 m. The first 200 m contained mussels, the remaining 600 m downstream was not populated.

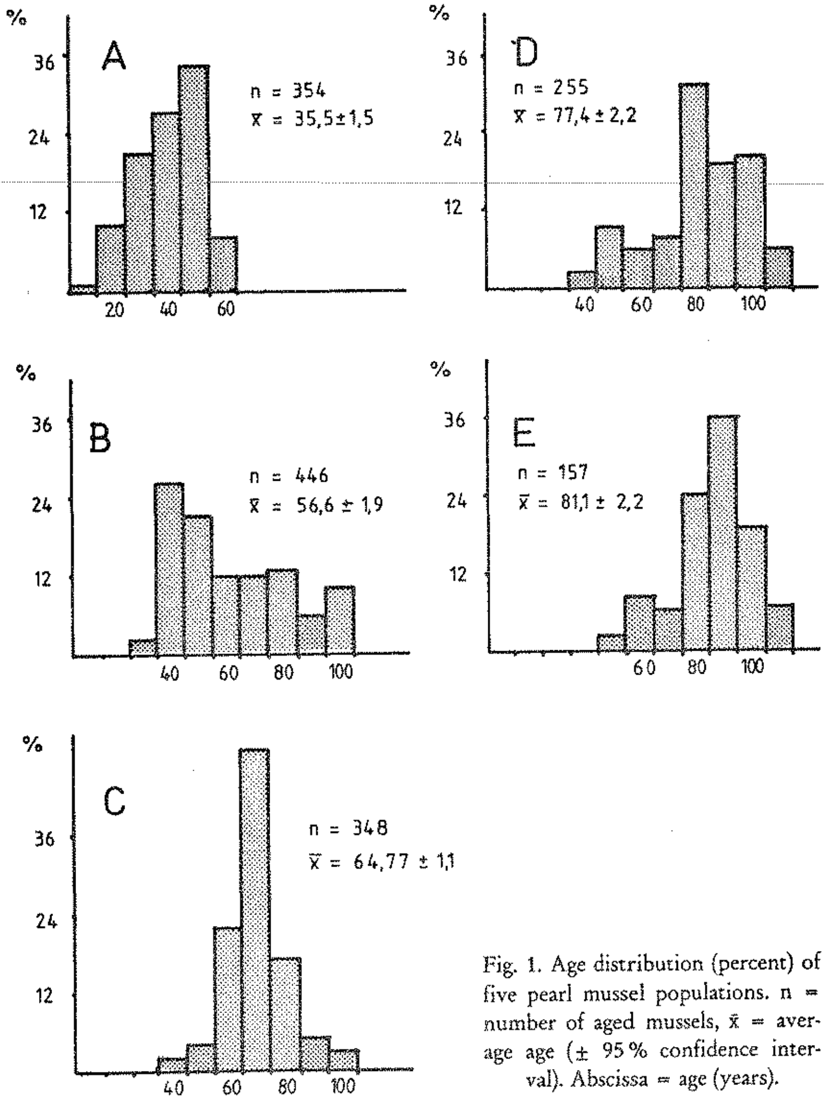

Fig. 1. Age distribution (percent) of five pearl mussel populations. n = number of aged mussels, x̄ = average age (± 95% confidence interval). Abscissa = age (years).

No difference was found in the average length of the shells within the population and downstream (Fig. 2). This indicates that all size classes are washed away equally.

Only approximately 2% of the empty shells within the mussel population drift downstream. Moreover, shells which are washed away show a considerable loss in weight (Fig. 2). Since solubility is considered in the following part, the drift can be disregarded.

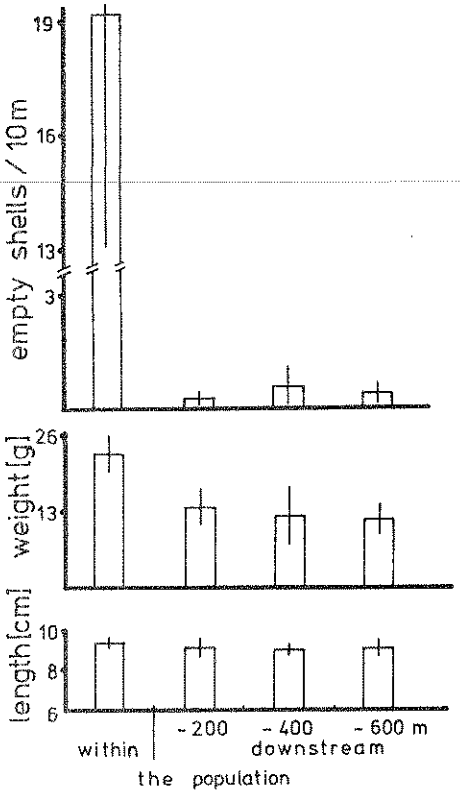

Fig. 2. Drift of empty shells (all means with 95% confidence interval).

Table 2. Shell material ($P < 0.05$) which is dissolved in 80 days.

river	n shells	dissolved (g)
A	13	1.3 ±0.15
B	5	1.44±0.4
C	6	1.41±0.4
D	5	1.25±0.4
Lüneburger Heath	6 (305 days)	1.17±0.26
	6 (133 days)	1.27±0.4

b) Solubility of shells

At least five shells of known dry weight were put in every river. Furthermore ten shells of various size and weight (dry weight 12—51 g) were exposed in river A. The amount of dissolved shell material was determined after 80 days.

The loss of weight was identical for all the rivers (Table 2) and seems to be characteristic for pearl mussel rivers generally. Wellmann (1938) investigated the solubility of pearl mussel shells in the Lüneburger Heath. He exposed shells for 305 and 133 days in the rivers. Converting his values to an exposure time of 80 days gives the same loss of weight as in North Bavaria (Table 2).

The experiment with the ten shells of various size and weight indicates, that there is no relationship between the size of the shells and the loss of weight. The regression coefficient between original weight and loss of weight ($b = 0.0009$) is not significantly different from $b = 0$.

Consequently, in every pearl mussel river the same amount is dissolved from all shells in the same unit of time, namely 1.4 ± 0.15 g in 80 days. This means a weight-loss of 63.8 g in 10 years.

Calculation of the age specific mortality rates

The present number of dead shells in every age class $= n_p$ can be counted[1]. For the calculation of the number of mussels which have died in the last ten years ($= n$), the time has to be considered, from which the present number of shells n_p date. Light shells are dissolved very quickly, therefore only shells of those animals, which have died recently can be found. Heavy shells last longer than ten years; the number of shells is greater than the number of animals which have died in the last ten years (Fig. 3).

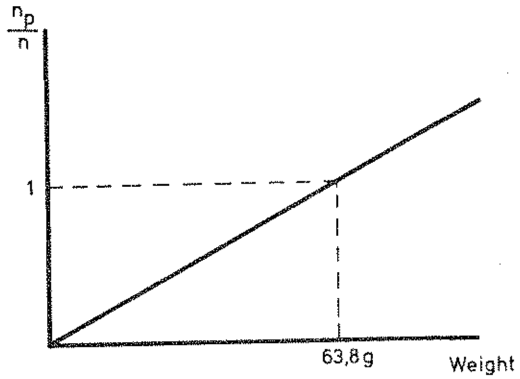

Fig. 3. Present number of empty shells (n_p) in proportion to the number of mussels which have died in the last ten years (n) as a function of the shell-weight (see text for further explanation).

Thus n_p is a function of n and the weight of the shells $= w$. If one assumes that mortality was rather constant in the last ten years, this function is linear as in Fig. 3.

$$n_p = a \cdot n \cdot w \qquad (1)$$

Shells at 63.8 g of weight last for exactly ten years. These shells represent all the animals which have died in this time. Therefore if $w = 63.8$ g, then $n_p = n$.

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[1] No difference in the age specific percentage of shells was found between the four plots in every river (Chi^2-Tes).

Incorporating this in equation (1), the constant a is given by

$$a = \frac{1}{63.8\ \mathrm{g}}$$

n can now be expressed as

$$n = n_p \cdot \frac{63.8\ \mathrm{g}}{w}$$

The age specific mortality (m) is

$$m\ (\%) = \frac{n}{(N + n)} \cdot 100$$

(N = number of living mussels in every age class. Data for calculation in Table 3.)

Table 3. Percentage and weight of empty shells in every age class.

							age classes					
river		−10	−20	−30	−40	−50	−60	−70	−80	−90	−100	−110
	Nl	3	35	73	94	131	33					
A	% dead	0	0	0.7±6	5.2±2	7.5±5	11.6± 8.4					
	x̄ w			1.4±4	16 ±2.6	21 ±3.4	28.3± 2					
	Nl						53	46	51	29	53	
B	% dead						3.6± 5	9 ± 7	15.5±10	6 ±10	6 ± 6	
	x̄ w						30.5± 5	42.2± 6	44.4± 4	48 ± 7	50 ± 3.2	
	Nl					21	83	112	85	31	25	
C	% dead					25 ±20	9.8± 6	5 ± 4	4.2± 4.5	4.6± 7	5.3±10	
	x̄ w					24.4± 4	32.2± 4	30 ± 6	37 ± 8	39.4± 6	43 ± 3	
	Nl				15	39	68	113	206	189	113	
D	% dead				54 ±28	46 ±17	69 ±11	74 ± 8	65 ± 6	76 ± 6	50 ±10	
	x̄ w				28.7± 5	30.5± 3	32.8± 5	37.7± 2.4	38.5± 3	45 ± 4	49 ± 5	
	Nl						29	40	150	175	92	37
E	% dead						55 ±20	78 ±13	75 ± 7	69 ± 7	67 ±10	75±15
	x̄ w						32 ± 8	43 ±10	49 ± 5	58 ±11	62 ± 8	61±12

Nl = number of living mussel, % dead = present percentage of empty shells ($P < 0.05$), x̄ w = average weight of shells ($P < 0.05$).

Mortality rates are very similar in river A and B. There is almost no mortality in the younger age classes, then it rises to about 20%. In river C mortality of middle aged mussels is very high, whereas in river D and E mortality is high in all age classes (Fig. 4).

Mortality and water pollution

Even in rivers where the youngest specimens are 60 years old, mussels are as fertile as in rivers where young mussels can still grow up (Bauer 1979). This may lead to the conclusion that mussels, after having survived the critical stage, are not very sensitive to water pollution.

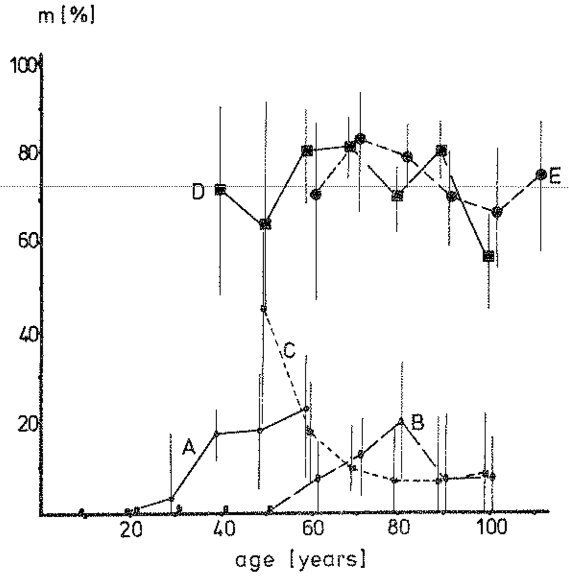

Fig. 4. Age specific mortality rate (mean and 95 % confidence interval) in five pearl mussel populations. Because of the small number of mussels the following age classes had to be combined: C 20—40 years, E 40—60 years, D 90—100 years.

But this study shows, that the populations are very different concerning their mortality. Therefore the relationship between water quality and mortality was tested.

For every river an average mortality ($\bar{m}$ = number of dead animals in ten years/population) was calculated. As $\bar{m}$ also depends on the age structure, the populations are standardized before calculating $\bar{m}$: it is assumed that all age classes are represented equally.

$\bar{m}$ is compared to data of a chemical analysis carried out in 1978 (BAUER et al. 1980).

The following factors were measured:

1. in flowing water: copper, lead, zinc, cadmium, manganese, calcium, phosphate, nitrate, nitrite, ammonia, chloride, electrolytic conductivity, pH
2. in the sediment: copper, lead, zinc, chromium, cadmium, manganese, phosphate, nitrate, nitrite, ammonia, chloride, electrolytic conductivity, pH, TOC
3. in the mussels: copper, lead, zinc, chromium, cadmium.

Out of these factors only phosphate, calcium and pH show a relationship to the mortality rate (Fig. 5). These are exactly those factors which account for the lack of young mussels in North Bavaria (BAUER et al. 1980). So eutrophication does not only inhibit the growth of young mussels in the critical

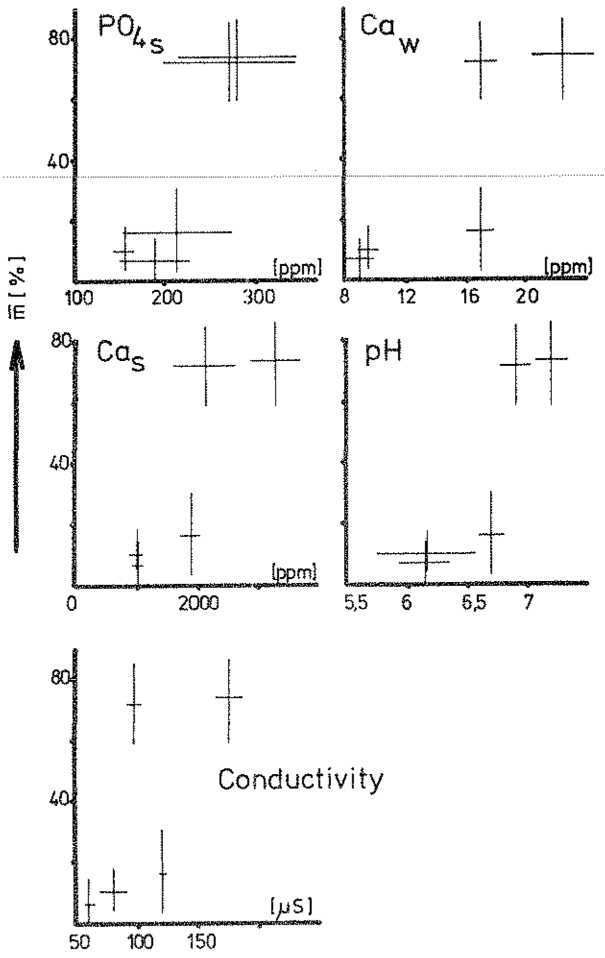

Fig. 5. Relationship between average mortality (m̄) and hydrochemical variables (mean and 95 % confidence interval). The rank correlation coefficients (Spearman) are significant ($P < 0.01$). Index s, w = sediment, water.

stage, but it also causes a steep rise in mortality (from 10 % to 70 %) of older mussels.

Population trend

The total number of mussels in every age class can be calculated from the age distribution (percentage) and the number of mussels in the population. Considering the mortality rate and the maximum life span, one can calculate the number of mussels in 10, 20 … years (Fig. 6). (It is assumed that the present conditions remain constant, but that surely is unlikely to remain true for the rejuvenation in A.)

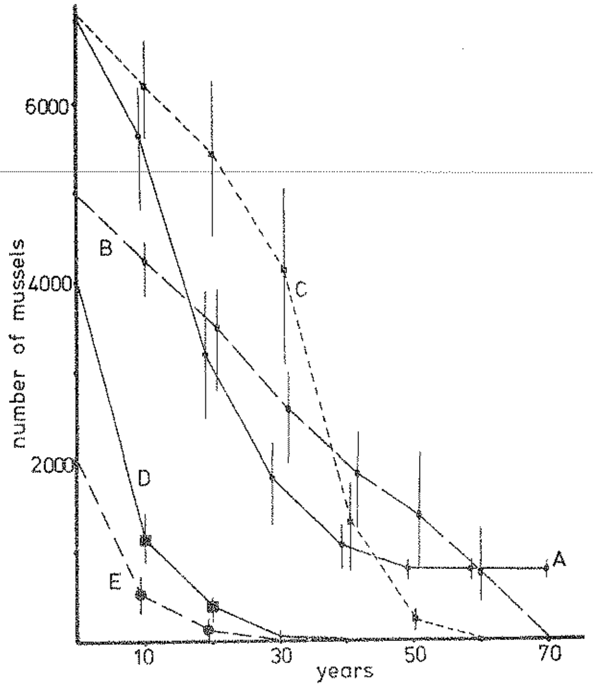

Fig. 6. Population trend of the five investigated pearl mussel populations in the next 70 years. The values (± 95 % confidence limits) were calculated, considering the present number of mussels, the age distribution, the age specific mortality and the maximum life span.

According to these calculations the total number of pearl mussels in North Bavaria will decrease by more than 90 % in the next 50 years. The populations in D and E will virtually die out in the next 20 years because of the high mortality.

In fact, the decline is likely to be more rapid, as a deterioration in water quality must be expected for some rivers.

Between 1914 (MEISSNER 1914) and 1980 the number of pearl mussels in North Bavaria have declined more than 95 %. Therefore the assumption seems to be well founded that less than 1 % of the original stock will survive until the end of this century.

Summary

All pearl mussel populations in North Bavaria are dominated by the older year classes (Fig. 1). Mortality of mussels depends on the water quality (Fig. 5), it is increased by those factors which inhibit the growth of young mussels. The populations in North Bavaria will decline considerably in the next decades (Fig. 6).

Zusammenfassung

Alle Perlmuschelpopulationen Nordbayerns sind überaltert (Fig. 1). Die Mortalität der Muscheln hängt von der Gewässergüte ab (Fig. 5), sie wird durch jene Faktoren erhöht, die das Aufwachsen der Jungmuscheln verhindern. Die Populationen in Nordbayern werden in den nächsten Jahrzehnten beträchtlich abnehmen (Abb. 6).

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