

THE RELATION OF THE DEGREE OF INJURY TO THE RATE OF REGENERATION AND THE MOULTING PERIOD IN THE GAMMARUS.

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INTRODUCTION.

In 1905 in some experiments on the crayfish, Zeleny found that in the series of crayfish with the greater degree of injury each chela regenerated more rapidly than the chela in the series with the lesser degree of injury. He also found that the members of the series with the greater degree of injury moulted more rapidly than the members of the series with the lesser degree of injury. In 1906, in some experiments on the lobster, Emmel found that in the series of lobsters with the lesser degree of injury the regeneration was more rapid than in the series with the greater degree of injury and the members of the series with the lesser degree of injury moulted more rapidly than the members of the series with the greater degree of injury.

During the summer of 1905 at the Indiana University Biological Station at Winona Lake, Indiana, the author tried some experiments on gammarus. The death rate was so great that the number of animals of each series that survived was only six, and those showed little difference in the per cent. of regeneration. The series with the lesser degree of injury showed a little greater per cent. of regeneration than the series with the greater degree of injury. No observations were made on the relation of the degree of injury to the moulting period. During the summer of 1907 at the same place the author tried some similar experiments on the same gammarus. The death rate was again great and the difference in the per cent. of regeneration was less than in the first experiments. The degree of injury made very little difference in the length of the moulting period.

METHOD.

The gammarus used in these experiments were obtained from Winona Lake, Indiana, near the mouth of Cherry Creek. On July 9, 1905, about two hundred gammarus were taken from the lake near the mouth of

Cherry Creek and put in a glass jar partially filled with lake water. On July 11, sixty of these were selected for operation. The right hind leg was removed from each of thirty and the two pairs of hind legs were removed from the other thirty. Each series was put into a glass dish partially filled with lake water. The water was changed daily. At the end of eighteen days the death rate had been so great that only six individuals of each series survived. On examination it was found that some regeneration had taken place and it was thought best to kill those that survived. They were killed in eighty-five per cent. alcohol. The right hind leg of each individual was removed and measured under the microscope segment by segment. Likewise the right second leg was removed and measured. A comparison was made between the regenerated right hind leg and the normal right second leg. Also the body length was measured and its length was compared with the length of the regenerated right hind leg.

On July 8, 1907, the author took several gammarus from the lake near the mouth of Cherry Creek. On July 8, 9, and 10 the right hind leg was removed from each of twenty-six individuals and the two pairs of hind legs were removed from thirty individuals. This time the legs were mounted in glycerine. Each gammarus was placed in a separate dish. The animals were fed every five days and the water was changed daily. Two days after the moult the gammarus were killed in eighty-five per cent. alcohol. The right hind leg was removed and measured as before. The length of the regenerated leg was compared with the length of the original leg.

On July 17 several gammarus were taken from the lake in about the same place as before. They were put in separate dishes partially filled with lake water. The water was changed daily and the animals were fed every five days. One day after the moult either the right hind leg or the two pairs of hind legs were removed. The removed legs were mounted in glycerine. Two days after the second moult each animal was killed in eighty-five per cent. alcohol. The right hind leg was removed and measured as before. The length of the regenerated right hind leg was compared with the length of the original leg.

TABLE I.—Series A.

Catalog number.	Uninjured leg.				Regenerated leg.			Body length.	Regenerated leg l'n g.		Per cent. Regeneration.	
	Seg. 1.	Seg. 2.	Seg. 3.	Total.	Seg. 1.	Seg. 2.	Seg. 3.		Total.	Regenerated leg l'n g.		Body length.
										Uninjured leg l'n g.		Per cent. Regeneration.
1.....	10.	7.4	9.1	26.5	10.1	8.1	8.9	27.1	$\frac{10.1+8.1+8.9}{10. + 7.4+9.1}$	102.26+		
2.....	8.1	6.2	6.5	20.8	5.3	3.9	4.5	13.7	$\frac{5.3+3.9+4.5}{8.1+6.2+6.5}$	65.86+	11.60+	
3.....	9.4	8.	9.4	26.8	7.	6.2	6.	19.2	$\frac{7 + 6.2+6.}{9.4+8.+9.4}$	71.04+	12.37+	
4.....	9.	6.4	8.	23.4	8.	6.	6.4	20.4	$\frac{8.+6.+6.4}{9 + 6.4+8}$	87.18+	13.03+	
5.....	9.1	6.5	7.3	22.9	7.	6.7	5.8	19.5	$\frac{7 + 6.7+5.8}{9.1+6.5+7.3}$	85.58+	13.34+	
.....	8.7	5.4	5.	19.1	6.	5.3	4.1	15.4	$\frac{6.+5.3+4.1}{8.7+5.4+5}$	80.99+	11.11+	

*The body was torn before the measurement was taken.
Right legs were more slender than the left legs and all of them seemed to be filled with air bubbles.

TABLE II. — *Series B.*

Catalog number.	Uninjured leg.				Regenerated leg.			Body length.	Regenerated leg In g.		Per cent. Regeneration.	
	Seg. 1.	Seg. 2.	Seg. 3.	Total.	Seg. 1.	Seg. 2.	Seg. 3.		Total.	Uninjured leg In g.		Regenerated leg In g.
1	10.5	8.8	8.6	27.9	10.1	9.8	9.5	29.4	$\frac{10.1+9.8+9.5}{10.5+8.8+8.6}$	$\frac{29.4}{105.9}$	19.48+	
2	10.6	9.	8.8	28.4	7.	6.5	6.	19.5	$\frac{7+6.5+6}{10.6+9+8.8}$	$\frac{19.5}{165.2}$	11.80+	
3	10.6	7.9	8.	26.5	9.1	7.8	6.8	23.7	$\frac{9.1+7.8+6.8}{10.6+7.9+8}$	$\frac{23.7}{147.8}$	16.04+	
4	11.8	8.5	9.1	29.4	6.9	6.8	6.8	20.5	$\frac{6.9+6.8+6.8}{11.8+8.5+9.1}$	$\frac{20.5}{157.9}$	12.98+	
5	9.	6.	7.8	22.8	7.8	6.9	6.	20.8	$\frac{7.9+6.9+6}{9+6+7.8}$	$\frac{20.8}{128.3}$	16.24+	
6	7.9	5.	6.1	*19	6.	5.2	5.5	16.7	$\frac{6+5.2+5.5}{7.9+5.+}$	$\frac{16.7}{118.6}$	11.08+	

*The claw and first segment were broken off and lost. The length of the first segment was calculated.

Average 81.79.

TABLE III.—Series A.

Catalog number.	Uninjured leg.				Regenerated leg.			Regenerated leg In g.	Per cent. Regenera- tion.
	Seg. 1.		Seg. 3.		Seg. 1	Seg. 2	Seg. 3		
	Seg. 2	Seg. 1	Seg. 2	Total	Total	Total	Uninjured leg In g.		
68-A-2.....	6.9	5.6	5.4	17.9	3.8	2.8	2.8	9.4	$\frac{3.8+2.8+2.8}{6.9+5.6+5.4}$ 52.5+
68-A-3.....	7.4	7.2	6.0	20.6	4.2	3.6	3.6	11.4	$\frac{4.2+3.6+3.6}{7.4+7.2+6.0}$ 55.3+
68-A-4.....	6.4	5.8	5.6	17.8	4.2	4.0	3.2	11.4	$\frac{4.2+4.0+3.2}{6.4+5.8+5.6}$ 63.8+
68-A-6.....	5.0	4.8	4.2	14.0	2.8	2.4	2.2	7.4	$\frac{2.8+2.4+2.2}{5.0+4.8+4.2}$ 52.8+
68-A-8.....	5.2	5.2	4.8	15.2	3.6	3.7	3.	10.3	$\frac{3.6+3.7+3}{5.2+5.2+4.8}$ 67.7+
68-A-10.....	6.8	6.0	5.2	18.0	4.6	4.2	3.2	12.0	$\frac{4.6+4.2+3.2}{6.8+6.0+5.2}$ 66.6+
68-A-11.....	4.8	5.0	4.8	14.6	3.6	3.2	3.	9.8	$\frac{3.6+3.2+3}{4.8+5.0+4.8}$ 67.1+
Average 60.8+									

TABLE IV.—Series B.

Catalog number.	Uninjured leg				Regenerated leg				Per cent. Regeneration.	
	Seg. 1.	Seg. 2.	Seg. 3.	Total.	Seg. 1.	Seg. 2.	Seg. 3.	Total.		
	Uninjured leg In g.				Regenerated leg In g.					
68-B-3.....	6.8	6.6	6.	19.4	3.2	3.2	3.	9.4	$\frac{3.2+3.2+3}{6.8+6.6+6}$	48.4+
68-B-4.....	5.2	5.4	4.8	15.4	3.2	2.8	3.2	9.2	$\frac{3.2+2.8+3.2}{5.2+5.4+4.8}$	59.7+
68-B-5.....	5.	5.2	4.8	15.0	1.2	3.4	3	10.6	$\frac{4.2+3.4+3.}{5.+5.2+4.8}$	70.6+
68-B-7.....	5.6	5.4	5.	16.0	3.	3.2	3.4	9.6	$\frac{3.+3.2+3.4}{5.6+5.4+5.}$	60.
68-B-8.....	6.2	6.	5.4	17.6	4.	3.2	3.	10.2	$\frac{4.+3.2+3.}{6.2+6.+5.4}$	58 —
68-B-10.....	5.8	4.	4.	13.8	3.8	2.6	3.4	10.8	$\frac{3.8+3.6+3.4}{5.8+4.+4.}$	78.2+

Average 62.5+

TABLE V.—Series A.

Catalog number.	Uninjured leg.				Regenerated leg.				Regenerated leg In g.		Per cent. Regenera- tion.
	Seg. 1		Seg. 3		Seg. 1.		Seg. 3.		Uninjured leg In g.		
	Seg. 1	Seg. 2	Seg. 3	Total	Seg. 1.	Seg. 2	Seg. 3.	Total			
72.	5.8	5.4	5.	16.2	3.4	3.	3.4	9.8	3.1+3.+3.4	5.8+5.4+5	60.4+
98.	5.	4.2	4.2	13.4	2.8	2.2	2.2	8.2	2.8+2.2+2.2	5.+4.2+4.2	60.4+
76.	5.4	4.4	4.	13.8	3.	2.2	2.2	8.4	3.+2.2+2.2	5.4+4.4+4	60.8+
87.	5.2	4.8	5.	15.0	3.2	3.	3.2	9.4	3.2+3.+3.2	5.2+4.8+5	62.6+
102.	6.	5.8	5.2	17.0	3.5	3.2	3.2	10.0	3.6+3.2+3.2	6.+5.8+5.2	58.8+
109.	5.4	5.2	5.	15.6	3.2	3.	3.2	9.4	3.2+3.+3.2	5.4+5.2+5.	60.2+

Average 60.5+

TABLE VI.—Series B.

Catalog number.	Uninjured leg.				Regenerated leg.			Regenerated leg In g.		Per cent. Regenera- tion.
	Seg. 1.	Seg. 2.	Seg. 3.	Total.	Seg. 1.	Seg. 2.	Seg. 3.	Total.	Uninjured leg In g.	
77.....	4.4	3.8	3.8	12.	3.2	2.6	2.4	8.2	$\frac{3.2+2.6+2.4}{4.4+3.8+3.8}$	68.3+
88.....	5.2	4.8	4.6	14.6	3.4	2.8	2.6	8.8	$\frac{3.4+2.8+2.6}{5.2+4.8+4.6}$	60.2+
91.....	4.4	4.	3.8	12.2	2.6	2.4	2.4	7.4	$\frac{2.6+2.4+2.4}{4.4+4.+3.8}$	60.6+
100.....	4.6	4.4	3.4	12.4	2.2	2.4	2.2	6.8	$\frac{2.2+2.4+2.2}{4.6+4.4+3.4}$	54.8+
103.....	5.6	5.8	5.	16.4	3.4	2.8	2.6	8.8	$\frac{3.4+2.8+2.6}{5.6+5.8+5}$	53.5+

Average 59.5+

TABLE VII.—Series A.

Catalog number.	Date of operation.	Date of first moult.	Date of second moult.	Number of days after operation until first moult.	Number of days after first moult until second moult.	Per cent. Regeneration.
68-A-2	July 8	July 11	July 27	3	16	52.5+
68-A-3	July 8	July 10	July 28	2	18	55.3+
68-A-4	July 10	July 22	August 10	12	19	63.8+
68-A-6	July 10	July 15	July 30	5	15	52.8+
68-A-8	July 10	July 16	July 29	6	13	67.7+
68-A-10	July 10	July 21	August 10	11	20	66.6+
68-A-11	July 10	July 20	August 2	10	13	67.1+

Average 7 $\frac{1}{2}$ Average 16 $\frac{1}{2}$ Average 60.8

TABLE VIII. —Series B.

Catalog number.	Date of operation.	Date of first moult.	Date of second moult.	Number of days after operation until first moult.	Number of days after first moult until second moult.	Per cent. Regeneration.
68-B-3.....	July 8.....	July 10.....	August 2.....	2	23	48.4+
68-B-4.....	July 9.....	July 12.....	July 30.....	3	18	53.7+
68-B-5.....	July 9.....	July 16.....	July 28.....	7	12	70.6+
68-B-7.....	July 9.....	July 13.....	July 25.....	4	12	60
68-B-8.....	July 9.....	July 18.....	July 31.....	9	13	58.—
68-B-10.....	July 10.....	July 21.....	August 2.....	11	12	78.2+

Average 6. Average 15. Average 62.5—

TABLE IX.—Series A.

Catalog number.	Date of operation.	Date of Moul.	Number of days between moult and operation.	Per cent. Regeneration.
72	July 14	July 27	13	60.4+
98	July 26	August 7	12	60.4+
76	July 17	August 1	12	60.8+
87	July 20	August 6	17	62.6+
102	July 27	August 10	14	58.8+
109	July 30	August 13	14	60.2+

Average 13 $\frac{2}{3}$. Average 60.5+

TABLE X.—Series B.

Catalog number	Date of operation.	Date of Moul.	Number of days between moult and operation.	Per cent. Regeneration.
77	July 17	July 31	14	68.3+
88	July 22	August 6	15	60.2+
91	July 22	August 11	20	60.6+
100	July 26	August 10	15	54.8+
103	July 27	August 11	15	53.5+

Average 15½. Average 59.5—

Explanation of Tables—

From the individuals in series A the two pairs of hind legs were removed. From the individuals in series B the right hind leg was removed. The per cent. of regeneration was obtained by dividing the length of the regenerated leg by the length of the leg with which it was compared.

The animals of tables I and II are those on which the experiments were tried in 1905. The per cent. of regeneration was also obtained by dividing the regenerated leg length by the body length.

The animals of tables III and IV are those that were kept until they had moulted a second time.

The animals of tables V and VI are those that were operated upon on the next day after the moult.

Tables VII, VIII, IX, and X give the date of operation, date of moult, the time between moults and the per cent. of regeneration.

Discussion of results—

Table I shows that the average per cent. of regeneration as measured by comparing the length of the regenerated right hind leg with the length of the normal right second leg in series A is 82.25. Table II shows that the per cent. of regeneration as measured by comparing the length of regenerated right hind leg with the length of normal right second leg is 84.79. This shows that the series with the lesser degree of injury has regenerated 2.54 per cent. more than the series with the greater degree of injury. This difference is scarcely enough to take into account.

Table III shows that the average per cent. of regeneration as measured by comparing the length of the regenerated right hind leg with the length of the removed right hind leg in series A is 60.8. Table IV shows that the per cent. of regeneration as measured in the same way as series A, table III, in series B is 62.5. This shows that the series with the lesser degree of injury has regenerated 1.7 per cent. more than the series with the greater degree of injury. This difference is less than before.

Table V shows that the per cent. of regeneration as measured as above in series A is 60.5. Table VI shows that the per cent. of regeneration measured as above in series B is 59.5. This shows that the series with the greater degree of injury has regenerated 1 per cent. more than the series with the lesser degree of injury. In each case the two series compared were treated in as nearly the same way as possible with the exception of the degree of injury.

Table VII series A shows an average of 16 2-7 days between moults. Table VIII, series B, shows an average of 15 days between moults. This shows that the series with the greater degree of injury has an average of 1 2-7 days longer between moults than the series with the lesser degree of injury.

Table IX, series A, shows an average of 13 2-3 days between operation and moult, which would make 14 2-3 days between moults. Table X, series B, shows an average of 15 4-5 days between the operation and the moult, which would make a period of 16 4-5 days between moults. This shows that the series with the lesser degree of injury has an average of 1 2-15 days longer period between moults than the series with the greater degree of injury. An average of the two sets of observations shows practically no difference between the length of the moulting period of the series with the greater degree of injury and the series with the lesser degree of injury. In each case the series with the longer period between moults has the lesser per cent. of regeneration. Conclusions:

1. The degree of injury of the gammarus has no effect on the rate of regeneration in the legs of the gammarus.
2. The degree of injury in the gammarus has no effect on the length of the moulting period of the gammarus.