appears to have some effect, as when the antennæ were cut between the first and second segments nothing but a knot developed but when the cut was made between the second and third segments a foot was regenerated.

A. N. CAUDELL

SPECIAL ARTICLES

A SECOND CASE OF METAMORPHOSIS WITHOUT PARASITISM IN THE UNIONIDÆ [1]

THE discovery[2] three years ago that the species *Strophitus edentulus* (Say) passes through its metamorphosis in the entire absence of parasitism placed that species in a unique position among fresh-water mussels. Since Leydig in 1866 solved the mystery as to the post-embryonic development of the Unionidæ in the discovery that the glochidia are parasitic on fishes, the announcement by Lefevre and Curtis seems to have been the first reported exception.

Lefevre and Curtis[3] in their investigations into methods of propagation of fresh-water mussels found that certain species of fish are more susceptible than others to infection by glochidia. In their operations a number of species of mussel were employed, but the commercially important species were chiefly confined to members of the subfamily Lampsilinæ Ortmann.[4] The fishes found adaptable to infection were the common game fish of the family Centrarchidæ. The fishes which did not take artificial infection were considered by them examples of specific immunity to infection by glochidia.

Following the work of Lefevre and Curtis considerable effort was made to carry through artificial infections with mussels of the genus *Quadrula* (Rafinesque, 1820) Agassiz, a group economically important because of their heavy shells. These attempts, employing the method of artificially infecting the common and readily obtainable game fish, met with little success. In 1912 I undertook the investigation of this problem. The previous negative results seemed to indicate that suitable fishes were not being used. It seemed probable that the parasitic glochidia, like other parasites, might be considerably restricted as to the species of host to which they were adapted. Working upon this theory I examined considerable numbers of fishes taken at large, with a view to finding those species that were carrying in nature the glochidia of *Quadrula* mussels. These studies supplemented by experimentation in artificial infection confirmed the chief postulate of the theory, namely, that there does exist a decided restriction as to species of hosts for the glochidia of some mussels. In the case of the warty-back mussel, *Quadrula pustulosa* (Lea), for example, I found infection restricted almost exclusively to the Channel catfish, *Ictalurus punctatus* (Rafinesque).[5] The investigation of these natural infections which has been taken up quite extensively by Mr. T. Surber[6] in the mussel investigations by the U. S. Bureau of Fisheries, revealed other points of interest. Among these was noteworthy the entire absence of evidence of infection by some common species. Such observations for a given species of mussel obviously indicate something unusual in the life history. One of the mussels for which I found no natural infection and for which none have been reported was *Anodenta imbecillis* (Say).

During the first part of last November I succeeded in securing several specimens of this mussel. These were all gravid, as is usually to be expected, since this species is hermaphroditic. Upon examining the contents of the marsupium of one individual I found that what at first glance I had supposed were mature glochidia were instead juvenile mussels with organs developed to the stage usually seen at the end of parasitism when the young

[1] Printed by permission of the Commissioner of Fisheries.

[2] Lefevre and Curtis, SCIENCE, Vol. 33, pp. 863–865, 1911.

[3] Bulletin of the Bureau of Fisheries, Vol. XXX., 1910 (issued 1912).

[4] *Annals of the Carnegie Museum*, Vol. VIII., No. 2, 1912.

[5] Howard, A. D., *Transactions American Fisheries Society*, 1912, pp. 65–70.

[6] "Notes on the Natural Hosts of Freshwater Mussels," Bull. Bureau of Fisheries, Vol. 22, 1912 (issued June 28, 1913).

mussel escapes from its host. These young mussels lie crowded in the marsupial gill of the parent without apparently any matrix or conglutinate structure whatever. The outer gills as in other Anodontas are marsupial and these become well distended throughout their whole length when gravid.

In regard to the breeding of this species Ortmann[7] says it is gravid from September to May. My observations, which are rather limited on this point, I give below:

Place	Date	No. of Individuals	Stage of Gravidity
Fairport, Iowa	Feb. 2	1	Early embryo
" "	May 13	1	Glochidia
" "	May 27	1	Glochidia
" "	July 16	1	Glochidia
Moline, Ill.	Sept. 24	1	Not gravid
" "	Nov. 7	2	Early embryos
" "	Nov. 7	1	Late embryos and glochidia
" "	Nov. 7	6	Juveniles

In addition to these I have found numbers of free juveniles not sexually mature ranging in length from 5 to 30 millimeters. These stages are remarkable for the thinness of their shells and the flatness of the mussel as a whole. The term "floater," of the mussel-fishermen, for this type of mussel is well applied in its use for this immature stage.

The presence of juveniles in the marsupia during November in a majority of the specimens examined seems to indicate that metamorphosis is probably completed in the fall. The time of discharge of the young mussels is yet to be determined but the appearance of glochidia again in early spring would seem to indicate that the juveniles escape in the fall or early winter.

Among the six lots of marsupial juveniles that I collected the degree of development varied slightly as to amount of shell growth, otherwise there seemed to be little difference. This growth consists of a narrow rim only, around the edge of the glochidial shell. The hooks of the glochidium are still much in evidence but are much weaker than in parasitic forms. A noticeable feature is the large proportion of gaping shells as compared with a similar lot of glochidia. It would seem that with the loss of the powerful single adductor muscle the action of closing is less vigorous. Between the gaping valves can be seen the ciliated foot, two adductor muscles, the mantle, on each side the gill papillæ, etc., indicating a development equal to that of other young Naiades at the end of parasitism.

I have tested the reaction of the glochidia in the presence of fish and obtained strong evidence that they do not respond as other known parasitic forms. Mature glochidia taken in March were employed; in an exposure to fish for an hour they failed to give the usual infection. A few glochidia lodged in the mouths of the fish but no encystment could be detected. The fish showed no response. Following this test the fish were exposed for ten minutes to the glochidia of *Symphynota complanata* (Barnes). These rapidly became attached and the fish showed considerable uneasiness in marked contrast to their indifference in the presence of the other glochidia.

From these observations I think we are warranted in concluding that this mussel passes through its metamorphosis in the entire absence of parasitism. The period immediately succeeding this metamorphosis has not been followed but there seems to be little reason for suspecting any parasitism here.

In *Strophitus edentulus* the mussel for which Lefevre and Curtis found a non-parasitic metamorphosis the arrangement of the glochidia in the gills is very unusual as has been described by them and other authors. The glochidia at first and later the juveniles are imbedded in cords of a gelatinous semi-transparent substance which lie like crayons in a box packed in the water tubes of the marsupium. Under natural conditions these are shed into the water from time to time. Sterki[8] called these cords placentæ and Lefevre and Curtis[9] have concluded that they

[7] *Op. cit.*

[8] "Some Observations on the Genital Organs of Unionidæ," *Nautilus*, Vol. 12, pp. 18–21 and 28–32.

[9] *Op. cit.*

have a nutritive function. The absence of a placenta or any matrix about the glochidia of *Anodonta imbecillis* is of interest since the non-existence of parasitism in this case is apparently under quite different conditions from those governing in *Strophitus*. I have mentioned above the extreme lightness of the juvenile shells in *Anodonta imbecillis* up to a considerable size. In the resulting buoyancy we have undoubtedly a device for distribution of the young and thus a compensatory provision for the loss of the usual means of distribution by fishes.

At the U. S. Fisheries Station, Fairport, Iowa, there are several ponds used for retaining fish seined from the Mississippi River. In these ponds have been found a great many young mussels of species known to be parasitic on fish and evidently introduced into the ponds during the parasitic stage. A concrete reservoir was at first used to supply the water to the ponds. Upon examining the bottom of this reservoir in 1912 the presence of mussels (Unionidæ) was discovered. This at first seemed surprising as no fish had been put in the reservoir, but it was noteworthy that these mussels were all of one species, *Anodonta imbecillis*. The explanation given for their presence was that owing to the lightness of their shells in the juvenile stage they had been pumped through the intake pipe from the river. This explanation made without the knowledge of the non-parasitic metamorphosis was undoubtedly the correct one and I give the incident only as an illustration of the possibilities of their distribution in water currents. It is my opinion that the so-called "placenta" of *Strophitus edentulus* has a similar distributing function; the cords being buoyant may be readily carried by flowing water. In this case, however, the mechanism is quite different and thus we have in the two species different devices for accomplishing the same purpose.

The question arises as to the nutrition of these non-parasitic glochidia during the period of metamorphosis. Both of these species undoubtedly have come from parasitic ancestors which received at this stage nutriment from their hosts so that one would look for some provision for nutrition here.

I have not as yet observed any such provision in *Anodonta imbecillis* and I do not know that this has been demonstrated for *Strophitus*. In the latter case to prove a nutritive function for the cords it would seem necessary to demonstrate an absorption of the substance of the cords by the young mussels. As the cords swell considerably upon leaving the gills such a determination is difficult.

The discovery of so fundamental a change of habit, apparently derived independently by two lines, should give opportunity for many interesting comparisons; for *Anodonta imbecillis* already possessing the distinction of being an hermaphroditic species it adds another eccentricity to its reputation.[10]

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LABORATORY NOTES

I. EMBEDDING TRAYS

IN the laboratories of this country and Europe a variety of receptacles are used to hold the melted paraffin in embedding. Doubtless all of them have certain advantages and it is certain that most of them have annoying disadvantages. Paper trays are not stiff enough for large cakes and are very likely to stick. L-shaped bars of metal that can be adjusted to a variety of sizes are placed on glass plates. They are very likely to leak if the paraffine must be kept liquid any length of

[10] Since the above was written I have been able to secure infections and encystment on fishes with *Anodonta imbecillis* as well as *Strophitus edentulus*. In the latter complete metamorphosis was observed. Thus for *edentulus* we have indicated facultative parasitism while in the other we have a persistence of the parasitic reaction at least when artificially brought in contact with a host. Metamorphosis on fishes was not secured in *A. imbecillis*. Abundant additional evidence is at hand that development in this (*imbecillis*) species normally proceeds without parasitism.