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OBSERVATIONS AND EXPERIMENTS ON DRAGON-FLIES IN BRACKISH WATER

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WHEN we consider the great variety and extent of adaptation among the insects, and especially when we recall the multitude of aquatic and semi-aquatic species, it seems rather remarkable that none of them has been able to take up marine life. Halobates, one of the Hemiptera, is truly oceanic, a few species of Diptera are known to live in sea water during their larval stage, a few larval forms have been found below high tide where they would be exposed to the sea water for a portion of the time, and a number of adult insects, chiefly beetles, range the shore finding their food when the tide is out.

In brackish water, however, many species are regularly found, belonging to nearly all the insect orders. It is a noteworthy fact that nearly all of these are more commonly found breeding in fresh water and are not peculiar to brackish water conditions.

While the occurrence of dragonfly nymphs in brackish ponds must have been noticed many times by observing naturalists, references in literature are exceedingly scant. Mr. E. A. Schwartz ("Preliminary Remarks on the Insect Fauna of the Gt. Salt Lake, Utah," *Can. Ent.*, vol. 23), found nymphs living in a mixture of salt and sulphurous or fresh water about Gt. Salt Lake, but adds: "The same species were also seen at Utah Lake, which is fresh water"; and the eminent authority on the dragonflies, Dr. P. P. Calvert in his "Catalogue of the Odonata of the Vicinity of Philadelphia" (*Trans. Amer. Ent. Soc.*, vol. 20, 1893) makes the following statement: "No Odonate nymphs are known to live in salt water, but probably some coast species, such as *Ischnura ramburii* and *Micrathyria berenice* live in that which is brackish."

The writer's attention was first attracted to the presence of dragonflies in brackish water by the discovery that many common Pacific Coast species were breeding abundantly in a slightly brackish pond near Victoria, British Columbia. No estimate of the salinity could be made but it was slight. Again at Wood's Hole, Mass., many common forms were also found living in brackish ponds of varying density. The following list of species noted breeding in brackish water will serve to show what a variety of those ordinarily breeding in fresh water may, if occasion require, live equally well to all appearances in slightly salt water. At Victoria, B. C.: *Enallagma carunculatum, Ischnura pervarva, I. cervula, Aeschna californica, Sympetrum madidum, Mesothemis simplicicollis* var. *collocata, Libellula quadrimaculata,* and *L. forensis.* At Wood's Hole, Mass.: *Lestes unguiculatus, L. rectangularis, Nehalennia irene, Enallagma civile, Ischnura verticalis, Anax junius, Leucorhinia intacta, Micrathyria berenice, Sympetrum rubicundulum, Libellula pulchella, L. auripennis,* and *Plathemis lydia.* These records were obtained partly by identification of the nymphs, partly by rearing the imagos, and partly by collecting the young imagos just after their transformation. The Wood's Hole list represents only seven weeks collecting in July and August and in a very restricted locality so it is highly probable that the list represents only a few of those that may be found in brackish water. Of the above species, only one, *Micrathyria berenice,* is limited in its range to near the coast, and as it also breeds in fresh water in the same region it can hardly be said to be a typical brackish water species.

In order to determine the salinity of water in which dragonflies may live the following experiments and tests were made at Wood's Hole during the summer of 1905. As the work had to be pursued for the most part at odd moments my observations are not as complete as could be wished, and yet they are full enough to be quite significant. My thanks are due the U. S. Bureau of Fisheries for the opportunity to carry on the work while connected with the Wood's Hole Station as temporary scientific assistant.

In the first place, a series of salinometer tests of the water in all the ponds in which dragonfly nymphs were found, was made. Water from four such ponds on Nonnamesset Island and from three on the mainland was tested and in none of them was the density greater than 1.0015, while the average was about 1.0008. These tests were made at a temperature of 72° Fahr. and as the figures have not been reduced the actual density would be considerably greater. It will be noted, however, that water of such density contains but little salt in comparison with that of sea water, which has an average density of 1.026. One pond examined had a density of 1.015 at 72°, but, though dragonflies of several species were seen about this pond, a careful examination revealed no dragonfly nymphs living in the water and it is a safe assumption that the adults came from less saline ponds in the vicinity. Even if oviposition should take place under such conditions it is highly probable, as will be shown by the experiments to be discussed, that no eggs would develop.

Next, the experiment of placing nymphs in saline solutions of various densities was tried. Chiefly the nymphs of *Lestes unguiculatus*, an Agrionid, were used. These were taken from a pond of the density of 1.0012. Those placed in water which was entirely fresh showed no ill effects from the change, and the same is true of those put into saline solutions of low density, up to about 1.003. Beyond this point the larvæ showed increasing signs of irritation. In solutions at 1.005, 1.0075, and 1.01 the nymphs at first wriggled and swam violently, tried to climb up the sides of the aquaria and otherwise gave evidence of much irritation, but they apparently became inured to it after a day or so and lived as well in these solutions as in that in which they were found. Higher solutions were always fatal. In sea water at 1.02 they lived only a few hours, and at 1.015 they showed every sign of discomfort and invariably died within a day or so.

The larvæ of *Ischnura verticalis*, also an Agrionid, of *Anax junius*, an Aeschnid, and of several Libellulids, chiefly *Sympetrum rubicundulum*, showed entirely similar results.

Further experiments on the development of the eggs in brackish water yielded some interesting results tallying well with those made on the nymphs. Eggs of *Libellula auripennis* Burmeister were taken just prior to oviposition on July 16, 1905. These were placed in solutions of various densities at 75° F. as indicated in the following table with the results noted:—

Density of water	Result
Fresh	hatched July 30
1.001	" " "
1.002	" " "
1.003	" " "
1.004	" " "
1.005	" " "
1.0075	" " "
1.010	" " "
1.015	Failed to hatch, partial development
1.020	" " " no development (?)

A glance at the above table shows that the amount of salinity from fresh water up to 1.010 had no effect whatever on the time of hatching; all hatched out together 14 days after fertilization. The 1.015 and 1.020 cultures were kept under exactly the same conditions but neither developed to the point of hatching. In the former considerable development took place, to the extent that the main structures of the larva were outlined, but in the latter no indications of development could be observed except some cases of questionable segmentation.

No differences could be noted between the larvæ hatched in 1.010 and those hatched in weaker solutions or fresh water and later experiments proved them to be equally hardy.

The young larvæ were now transferred to solutions differing from those in which they had been hatched, in order to test their resistance to density changes at this period. The results tally remarkably with those on the older nymphs and with the hatching experiments. Larvæ hatched in 1.010, 1.0075, and 1.005 solutions when placed in fresh water showed no discomfort and lived as well as those hatched in the fresh water, while those hatched in fresh water stood the change into the above solutions without any noticeable effect. The attempt to run any of them into higher solutions, however, always resulted fatally in a short time. In 1.015 they died in less than a day, in the 1.020 they were killed in a few hours. Those hatched in the 1.010 solution had apparently gained no further power of resistance but succumbed as quickly as those from fresh water. This test was repeated after two weeks but with the same result, they still were overcome as readily as when first hatched.

The above experiments indicate that there is in the Odonata a very definite barrier to their assumption of marine life, and that this barrier remains unchanged during the life of the individual. That it is the same for all species has not yet been determined, and it may be that forms such as *Micrathyria berenice* which are limited in distribution to the coastline have a higher limit than those species which occur in the interior only. As to the nature of the barrier we are entirely in the dark. It may be that the eggs and nymphs of Odonata are able to prevent the osmosis of salt in solution up to a certain point, but it seems more probable that the metabolism is interfered with only by salt in solution above a certain density. Whether other groups of insects are similarly restricted is also unknown.

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