SPECIAL ARTICLES

THE LARVAL DEVELOPMENT OF DRAGONFLIES OF THE GENUS AESHNA

THE Odonata of the genus *Aeshna* (also spelled *Aeschna*) are among the largest dragonflies and are cosmopolitan in distribution. Their larval (nymphal) development has been studied in recent years by Walker (1912), Wesenberg-Lund (1913), Portmann (1921), Münchberg (1930) and Lucas (1930), but the statements of these authors concerning the number of instars through which a given species passes and the length of its larval life are somewhat at variance.

The youngest material which Walker[1] (pp. 46–47) had was a nymph of *Ae. canadensis,* 10.5 mm long, in which the wing-cases were barely indicated by a pair of minute buds. "Beginning with this stage the nymph apparently moults eight times before emerging as the adult insect, there being eight instars, including the full-grown nymph. Judging by the size of the egg and the relative sizes of the known instars it appears probable that there are three or four ecdyses in addition to those observed, making a probable total of twelve or thirteen stages. . . . It is possible that the number varies . . . in *Aeshna* but I am inclined to believe that the number of stages in a given species is constant." On the length of nymphal life he wrote: "Our knowledge of the nymphal life of *Aeshna* is not sufficient to warrant a positive statement as to its length, which indeed is not necessarily the same in all species, nor in every locality. It is, however, exceedingly probable that in southern Canada and the northern United States three years is the normal length of life of *Ae. canadensis* and *Ae. umbrosa,* if not of all the species found there . . . it seems very probable that in *Ae. canadensis* the imago appears in the third season after the egg is deposited." (pp. 49, 50).

Wesenberg-Lund,[2] from observations on oviposition and comparison of larvae observed every eight to fourteen days in ponds in Denmark, concluded that larvae of *Aeshna grandis* hatched in late May from overwintered eggs and that these transformed into imagos three years later after having lived *as larvae* over three successive winters (pp. 380–381); that *Ae. isosceles* has a larval life of one to two years; that *Ae. viridis* may have normally a larval life of two years and that the other species of the genus are probably like *grandis* (p. 382). Wesenberg-Lund's conclusions have been dealt with at length by Münchberg and will not be discussed further here.

Portmann[3] took larvae of *Aeshna cyanea,* 17 mm long, and reared them at Basle, Switzerland, between January and June, under higher than normal temperatures and with abundant food supply. Although it was not possible to maintain a constant temperature, one of his larvae moulted six times, the sixth moult yielding the imago. The combined length of the last five larval instars totalled 95 days, the antepenultimate instar, in which the winter rest occurs under normal conditions, being reduced to 25 days. "The larval life of *Aeshna cyanea* lasts 26 months with us in nature. The young larvae of 17 mm experimented with were from 7 to 8 months old at the beginning of the experiment and developed into imagos in six additional months by optimal rearing. The larval period of the experimental animals lasted only 14 months instead of 26. The entire development of *Ae. cyanea* in nature requires three years but would extend through only 23 months, consequently not quite two years, under the influence of food and heat. Moreover, neither the eggs nor the youngest larval stages were exposed to these optimal conditions" (p. 37, translated). Portmann expresses no opinion as to the number of larval moults.

Münchberg[4] reared *Aeshna viridis* and *Ae. mixta* from eggs to imagos in a laboratory, in Schwerin, Germany, "in order to fix the number of moults and of stages." Omitting the prolarval (pronymphal) stage, he lists 12 larval moults for *viridis* and 10 larval moults for *mixta,* the last moult in each case respectively yielding the imago (pp. 188, 189). The number of individuals of these two species reared is not stated. He designated the larval stages of *Ae. viridis* by the capital letters A, B, etc., to M inclusive, larval stage A terminating with the first larval moult, stage G with the seventh larval moult, and so on.

To determine the length of larval life of Aeshnine (and presumably other Odonate) larvae, Münchberg, following Wesenberg-Lund, rejected the method of rearing in the laboratory for that of collecting, measuring and comparing larvae in nature at frequent intervals throughout four years. Assuming that the earlier larval stages of all the European species of *Aeshna* reach the length of 12 mm at the conclusion of stage G (seventh larval moult), as his reared *viridis* did (p. 193), he compared his material of this and other species collected at frequent intervals and referred them, according to total length, width of the seventh abdominal segment and the point on the abdomen to which the external, or posterior, wing sheaths reach, to the corresponding stages of *viridis.* The observed dates of oviposition and of collection of larvae referred to stages A to L enable him to formulate the length of larval life. Briefly stated, his results for northeastern Germany are as follows:

[1] University of Toronto Studies, Biological Series, No. 11, pp. viii, 213, 28 pls., 1912.

[2] *Int. Rev. gesamt. Hydrobiol. u. Hydrog.,* 6(2/3): 155–228, (4/5): 373–422, 1913.

[3] "Die Odonaten der Umgebung von Basel." Inaugural Dissertation, pp. 103, 3 taf., Lörrach, 1921.

[4] *Zeitschr. f. Morph. u. Oekol. der Tiere,* 20 (1): 172–232, 1930.

Aeshna grandis, mostly two years, but in peat bogs of Breitebruch three years (p. 198), from overwintered eggs.

Ae. viridis, in non-peaty ponds two years as a rule (p. 203), in a peat brook, separated from the ponds by only a few hundred meters, more often three years (p. 204), from overwintered eggs (p. 201).

Ae. cyanea, two years as a rule, from overwintered eggs (p. 207).

Ae. subarctica, four years as a rule, three years as a minimum, from probably overwintered eggs (p. 210).

Ae. mixta, one year, from overwintered eggs (pp. 211–214).

Lucas,[5] largely on the basis of earlier work by East, lists 12 ecdyses for *Aeshna cyanea* in captivity in England, but adds: "Probably the first moult immediately after hatching is omitted and possibly the next also." On the supposition that eggs overwintered and hatched in the spring, the dates given indicate that larval life occupied perhaps 14 months (pp. 51–52). East, he says, "succeeded in making certain that it requires two seasons to reach maturity; but individual specimens sometimes develop abnormally at a slower rate, and it seems clear that there is not quite absolute fixity in the matter. As regards the first winter we are uncertain, and possibly the eggs laid in the autumn may remain dormant during that period and hatch in the spring. It may be, however, that the earlier laid eggs hatch in the autumn, the late ones in the spring, and this may account for irregularity in size at the same date in this and other species that have a long life as imagines; for emergence of *Ae. cyanea* usually commences late in June or early in July, while egg-laying may take place during August, September, and even October."

In view of the gaps and divergences in the development of the insects described in these preceding accounts, it is of interest to state briefly the results obtained from rearing four individuals of *Aeshna tuberculifera,* a North American species, from egg to, or almost to, imago. This species, known from Maine, Ontario and Wisconsin south to Connecticut, New York and Indiana, had not been recorded from Pennsylvania previous to the writer's taking ten males and two females at Smithson's Pond, near Cheyney, Delaware County, Pennsylvania, on five days, September 8 to 27, 1935. One of the females was taken pairing, brought home alive and on the following day (September 16) laid eggs in a leaf of cat-tail (*Typha*). Three lengths of *Typha* leaf containing the oviposition punctures were placed in a jar containing some water, some of the punctures being below, some above, the water's surface. The jar, the three pieces of leaf and water, the last renewed at intervals, were kept in my study, a moderately heated room, and examined from time to time during the winter. On March 13, 1936, the first living, active larva was found in the water. Between this date and April 5, 85 larvae were obtained. I attempted to rear 33 of them, the remainder being used for other purposes. Two of these transformed to imagos on July 27 and August 3, 1937, respectively, both males, the former as its *thirteenth* larval moult, the latter as its *fifteenth* larval moult. Two female larvae died, without transforming, on June 7 and July 17, 1937, respectively, both of them having completed fourteen larval moults; had they lived to adulthood each would, of course, have made at least one more moult.

Each larva of *tuberculifera* was reared in a separate container by the methods employed for *Anax junius* (Calvert 1929).[6] The conditions under which these four, and other shorter lived, *tuberculifera* were kept appear to have been identical, so that the differences in the number of moults do not seem to be due to environment.

A detailed account of these larvae of *tuberculifera,* their growth and development, is in preparation by Miss Elsie Lincoln.

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[5] "The Aquatic (Naiad) Stage of the British Dragonflies (Paraneuroptera)." Ray Society, No. 117, pp. xii, 132, 35 pls., 1930.

A PHYSIOLOGICAL STUDY OF THE RIND COLOR OF CERTAIN CITRUS FRUITS

DURING the course of an investigation of the physiological effects of ethylene on citrus fruits in Florida it was noted that carotenoid pigments were present in the rinds of limes, lemons and grapefruit which were mature but still green. This would ordinarily not be considered unusual, since carotenoids are known to be present in green oranges though masked by the presence of chlorophyll. It is significant, however, that these plastid pigments diminish in quantity, and sometimes disappear, as the light-colored citrus fruits attain full color. The above is true, whether the fruit be degreened by ethylene or permitted to degreen on the tree. This is illustrated in Tables 1 and 2.

TABLE 1

CAROTENOID CONTENT OF THE RIND OF GREEN-COLORED AND ETHYLENE-DEGREENED CITRUS FRUITS OF SIMILAR MATURITY

Variety	Mature green (Control)		Degreened with ethylene	
	Carotene (mgs per 100 gms fresh peel)	Xanthophyll (mgs per 100 gms fresh peel)	Carotene (mgs per 100 gms fresh peel)	Xanthophyll (mgs per 100 gms fresh peel)
Villa Franca lemon	.085	.830	.030	.360
Grapefruit (Duncan type).	.150	1.040	.075	.510
Persian limes ...	.180	1.850	.055	.470
Perrine lemons ..	.065	.670	.025	.275
Key limes	.100	1.090	.095	.480

[6] *Proc. Am. Phil. Soc.,* 68 (3): 227–274, 1929.