DRAGONFLIES AND DAMSELFLIES IN RELATION TO PONDFISH CULTURE, WITH A LIST OF THOSE FOUND NEAR FAIRPORT, IOWA

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Contribution from the U. S. Fisheries Biological Station, Fairport, Iowa

FOREWORD.

The accompanying paper by Prof. Charles Branch Wilson, concerning a group of common insects in relation to fish culture, merits a special comment. The author has not confined himself to a mere list of dragonflies and damselflies or to the recording of observations regarding their distribution, abundance, habits, and life history. He has supplied such necessary information, but, more important from the point of view of the Bureau of Fisheries, he has treated these insects fully and judiciously in their relations to fish, and thus in their relations to the food supply and welfare of man.

We know that some insects, through destruction of crops and property or through injurious effect upon public health, are to be classed as insidious enemies of humanity and to be combated in every possible way; but there are others which we have learned to class as allies in the struggle for existence, since they make it possible for us to have useful articles of food and clothing, or are destructive to enemy insects.

There are many insects of several orders, including the dragonflies and damselflies, which, before they begin to fly, spend a long period of existence in the water where they have direct or indirect relations to the useful fishes. The attitude assumed toward any of these must depend on whether they are found to be useful or harmful to fishes and to man. The relations of insects and fishes are complex. Voracious insect larvæ may destroy the fry of fishes or may consume food otherwise available to young fishes; they may destroy other and more dangerous enemies of fishes; or they may feed upon things that are not available to the desirable fishes and themselves become food for fishes. It is necessary to accumulate exact information and wisely to balance the good against the evil before we can determine whether the abundance of any particular aquatic insect should be opposed or promoted in the interests of an increased food supply from fishes.

After a thorough analysis of all that has been known regarding the dragonflies and damselflies and all that has been learned in the course of this investigation, the author concludes with evident justification that these insects are, on the whole, of great economic importance, and he recommends them to the favor of the fish-culturist.

Studies such as this, which can be applied not only to other insects but to various kinds of aquatic animals and plants, will necessarily have the effect of enabling us to apply more intelligence to the practices of fish culture and the production of food from private and public waters.

H. M. SMITH,
Commissioner of Fisheries.

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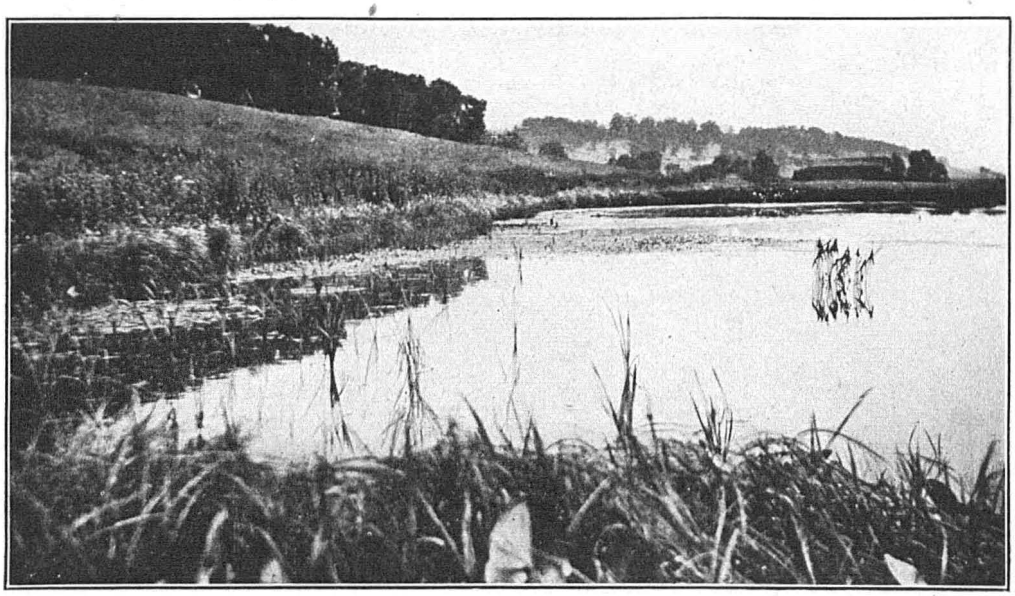

FIG. 1.—Pond No. 4, Series D, showing fringe of *Carex stricta* around the margin.

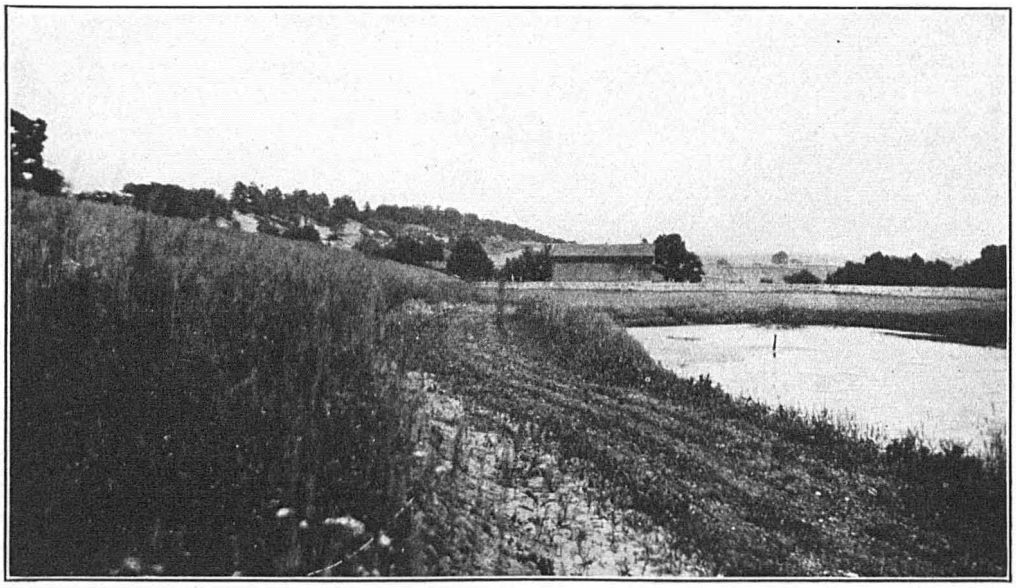

FIG. 2.—The cinder road along the north sides of ponds Nos. 1, 2, 3, and 4. To the left is seen the upland grass field which served as a roosting place at night for the dragonflies.

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INTRODUCTION.

Among the various activities carried on by the Fairport Fisheries Biological Station is that of fish propagation, not the artificial rearing of fry and fingerlings for subsequent distribution, as usually carried on at a national or State fish hatchery, but rather the comprehensive and experimental breeding and rearing of adult food fishes in artificial ponds made for that purpose. Such intensive culture of food fishes bids fair to attract wide attention in the near future.

The Bureau of Fisheries has repeatedly called attention to the opportunities and possibilities of such culture, and recently the State colleges of agriculture have taken up the subject, led by the New York State College, at Cornell University. This latter institution published, August 15, 1915, a paper on "The Farm Fishpond," by George C. Embody (The Cornell Reading Courses, vol. 4, No. 94), in which are found the following statements: "Farm fish culture has been almost wholly neglected in America, even though a large part of the country possesses exceptional advantages for it. * * * During the past four years the New York State College of Agriculture at Cornell University has been giving instruction in the propagation of useful aquatic animals to a steadily increasing number of students. Letters are continually coming in from persons in different parts of this and other States seeking information concerning the propagation of frogs and fishes" (pp. 214 and 215). Much suitable instruction is then given, but very little is said with reference to environmental ecology.

In an article published in the Popular Science Monthly for July, 1915, Dr. R. E. Coker said: "The artificial propagation of fish, even under present conditions, is producing results of significant value, but it is no disparagement of such operations to venture the prediction that the future will show that the effective conservation of fishery resources depends upon the coupling of intelligent fish culture with comprehensive and well-advised conservation of the environment favorable both to the natural propagation of fish and to the multiplication of the essential elements of food supply" (p. 95).

The same author, in a later paper (1916, p. 402), while discussing the equipment, organization, and functions of the Fairport Fisheries Biological Station, said: "It is

held as a most important responsibility of the station to stimulate and to guide the development of fish farming as a more widespread industry. This function as a fish-cultural experiment station should rightly be regarded as second to none."

On page 398 of the same report he stated: "It is manifest that the assembly of fish-cultural ponds, supplied originally with water from the Mississippi, but permitted to develop essentially pond conditions, stocked with abundant aquatic vegetation and rich in entomostraca, insect adults, and larvæ, together with the customary variety of smaller animal forms that thrive on the bottom, amidst the vegetation or in free-swimming condition, offer favorable opportunities for biological and physiological studies bearing upon problems of fish food, as well as for investigations of more particular scientific interest."

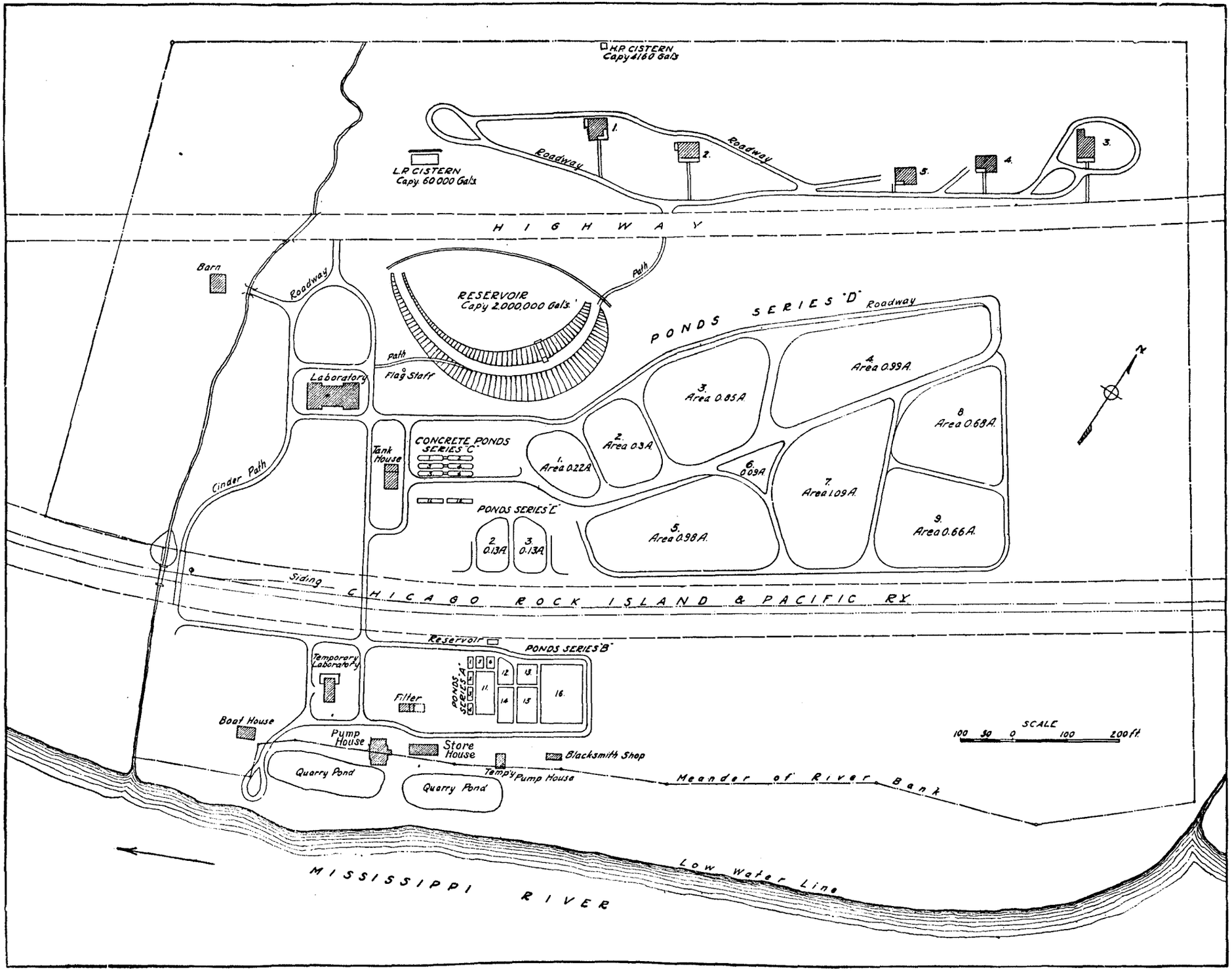
One feature of the environment, especially well developed at Fairport, and which will always be present in the pond culture of food fishes, is the presence of a greater or less number of dragonflies and damselflies which pass their larval life in the waters of the ponds and their adult life in the immediate vicinity. It becomes, therefore, of considerable importance to know whether the presence of these larvæ and adults is beneficial or injurious to the fishes. The ecology of this problem forms the main theme of the present paper, to which is added a list of such species as have been obtained at or near the station during three years of collecting.

The observations here recorded were made during the months of July and August, together with the last week in June and the first week in September. Some species emerge earlier in the year, but they usually have a second period of emergence within the limits just mentioned, and hence it is believed that the present observations cover all species of real importance.

GENERAL DESCRIPTION OF THE PONDS AND THEIR ENVIRONMENT.

The position and arrangement of the ponds of the Fairport station are clearly shown in the accompanying map. For convenience of manipulation they have been divided into six series called, respectively, A, B, C, D, E, and F, the ponds in each series being numbered independently. Series A and C are small cement ponds or out-of-doors aquaria for the temporary keeping of fish and mussels under experimentation and do not concern the present discussion at all. Series E and F are dirt ponds filled for the first time in July, 1916, and used the remainder of that summer and ever since. But owing to their newness when the present investigation on dragonflies and damselflies was begun, they were given no attention. During the summer of 1917, however, some of the observations on the food of odonate imagos were made around the shores of these ponds. Some of the young fishes also, the food contents of whose stomachs were examined during 1917, came from these ponds. This leaves only series B and D, the former south of the railroad and within 200 feet of the river bank, the latter north of the railroad and much farther from the river. Series B is made up of six small dirt ponds, the largest only 0.19 of an acre in extent, all of them heavily filled with algæ and water vegetation of various kinds.

Series D, on the other hand, contains nine large ponds with a total area of nearly 6 acres and presents admirable conditions for an ecological study of their environment. This is the series upon which the present study is based; they are all dirt ponds of the usual construction, having wide embankments thickly covered with vegetation, and



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United States Fisheries Biological Station, Fairport, Iowa.

each of them contains enough aquatic plants to make it very attractive to both dragonflies and damselflies. The distribution of fish and vegetation in and around these ponds is shown in the two tables which follow.

It may be noted that a heavy fringe of common crex grass, *Carex stricta*, has been planted at the water's edge around each of the ponds in order to prevent wave washing (Pl. LXVII, fig. 1). Ponds 1, 2, 3, and 7 are partially covered, at the proper season of the year, with a thick scum composed of the pollen of Philotria blossoms; ponds 4 and 8 show this scum in much smaller quantity, while it has not as yet appeared in the other ponds.

Along the north embankment of ponds 1, 2, 3 and 4 runs a cinder road (Pl. LXVII, fig. 2), to the north of which, away from the ponds, the land rises rapidly and was covered during the two summers of the present investigation with a heavy growth of grass, in which the dragonflies were accustomed to roost at night. This upland grass field up to the time of mowing was literally filled with odonate imagos, *Libellula luctuosa* being most numerous. Females could be found there at any time of day, and toward night or early in the morning, especially after a heavy dew, both sexes were present in large numbers. The algæ, pondweed, and rushes around these ponds furnish exactly the conditions favorable for odonate propagation, and, taken in connection with this ideal roosting place, with the constant supply of fresh water, and with the abundance of food, they present an exceptionally fine breeding ground for dragonflies and damselflies. This is shown not only by the comparatively large number of species found around these ponds but also by the extraordinary abundance of some of them.

To the south of the ponds along the railroad track is a ditch which always contains more or less water and which proves a favorite haunt for *Plathemis lydia*, *Anax junius*, *Libellula pulchella*, and *Pachydiplax longipennis*. There is a fringe of willows along the river bank opposite the ponds, and the slope of the terrace to the north of the dwelling houses beyond the highway is also wooded, but there are no trees or bushes anywhere in the vicinity of the ponds themselves.

The plankton of the ponds is very rich in entomostraca and other forms of life, and the water plants are covered with snails and insect larvæ of all kinds, furnishing a good food supply.

FISH DISTRIBUTION IN PONDS OF SERIES D, FAIRPORT, IOWA, 1916.

Species.	Pond numbers.								
	1	2	3	4	5	6	7	8	9
Micropterus salmoides: Largemouth black bass, adults	×	×	×			×			
Micropterus salmoides: Largemouth black bass, yearlings	×								
Micropterus dolomieu: Smallmouth black bass, adults						×			
Pomoxis sparoides: Black crappie, adults	×					×		×	
Pomoxis sparoides: Black crappie, yearlings	×								
Lepomis incisor: Bluegill, adults	×	×							
Lepomis incisor: Bluegill, 2-year olds	×								
Ictiobus cyprinella: Red-mouth buffalofish, adults				×					
Ictiobus bubalus: Smallmouth buffalofish, adults				×					
Ictiobus bubalus: Smallmouth buffalofish, yearlings					×				
Ictiobus bubalus: Smallmouth buffalofish, fry							×		
Lepomis gibbosus: Common sunfish, adults						×			
Lepomis euryorus: Wide-eared sunfish, adults								×	
Chænobryttus gulosus: Warmouth bass, adults								×	
Ictalurus punctatus: Channel catfish, adults									×
Ictalurus punctatus: Channel catfish, fry									×

PLANT DISTRIBUTION IN PONDS OF SERIES D, FAIRPORT, IOWA, 1916.

[a=abundant, c=common, s=scarce.]

Species.	Pond numbers.								
	1	2	3	4	5	6	7	8	9
IN THE WATER.									
Potamogeton illinoiensis: Illinois pondweed	.....	a	a	.....	.....	.....	.....	.....	.....
Potamogeton pusillus: Small pondweed	.....	a	.....	.....	c	.....	.....	.....	.....
Potamogeton pectinatus: Fennel-leaved pondweed	.....	.....	a	.....	.....	s	.....	a	.....
Trypha latifolia: Cattail	a	a	a	.....	.....	.....	s	.....	s
Ceratophyllum demersum: Hornwort	s	c	c	s	s	.....	c	s	c
Ranunculus aquatilis: Common water crowfoot	.....	.....	c	.....	.....	.....	.....	c	.....
Oedogonium, sp.: Filamentous alga	c	.....	c	.....	.....	.....	c	.....	.....
Elodea canadensis: Water weed	a	a	a	s	.....	.....	a	c	.....
Vallisneria spiralis: Eelgrass	.....	.....	c	.....	.....	s	.....	s	.....
Naias flexilis: Slender naias	s	s	s	s	s	s	s	s	.....
Castalia odorata: White pond lily	.....	.....	c	.....	.....	.....	.....	.....	.....
Blanket algæ	a	a	c	a	a	a	c	a	a
ALONG THE MARGINS.									
Carex stricta: Crex grass	a	a	a	a	a	a	a	a	a
Rumex crispus: Curled sorrel	c	.....	.....	.....	c	.....	s	.....	c
Eleocharis palustris: Creeping spike rush	s	.....	.....	c	c	c	.....	.....	s
Sagittaria latifolia: Broad-leaved arrowhead	.....	c	c	s	.....	.....	.....	.....	.....
Homalocenchrus oryzoides: Rice cut-grass	.....	.....	.....	.....	.....	.....	c	.....	.....
Juncus effusus: Common rush	.....	.....	.....	s	.....	.....	s	.....	s
Echinocloa crussgalli: Cockspur grass	.....	s	.....	.....	a	.....	s	.....	a
ON THE EMBANKMENTS.									
Convolvulus sepium: Bindweed	c	.....	c	s	.....	c	.....	.....	s
Lactuca scariloa: Prickly lettuce	c	.....	a	a	a	a	.....	.....	a
Equisetum fluviatile: Swamp horsetail	.....	a	c	s	.....	.....	.....	.....	.....
Trifolium pratense: Red clover	c	c	c	a	c	c	c	s	s
Plantago rugelii: Common plantain	a	a	a	a	c	c	c	s	s

ABUNDANCE OF DRAGONFLIES AND DAMSELFLIES.

The actual number of both dragonflies and damselflies varies greatly from time to time, due to a variety of causes.

1. PERIODICITY.—The emergence of the imago is periodic in occurrence; most of the Libellulidæ have a one-year cycle, and the great majority of any given species emerge at or near the same time. Just after this period of maximum emergence their numbers reach the highest point for the season, and then gradually decrease. Some species of Anax, Tramea, and Æschna may have two broods during the year, in spring or early summer, and again in late summer or early fall, and consequently would have two periods of maximum abundance. Even the Gomphidæ, whose nymphs require more than a year in which to mature, show similar periods of maximum emergence, large numbers being transformed within a few days and then diminishing rapidly in abundance. On the other hand, the damselflies apparently have several broods during the season, and their numbers rise and fall accordingly.

2. MIGRATION.—The imagos of many species have the habit of scattering rapidly soon after their emergence, even while they are still teneral, and they may sometimes entirely disappear. This is true of *Epicordulia princeps*, whose fresh nymph skins were second in abundance during the last of June, and yet not a single imago could be seen about the ponds at that time. The Gomphidæ furnish numerous similar examples; the most abundant of their nymph skins was that of *Gomphus plagiatus*, over a thousand of which were secured along the bank of the Mississippi opposite the ponds, but not a single

imago was found anywhere in the vicinity until the last of July, and then only a few. On the other hand, the imagos of both *Gomphus externus* and *G. vastus* were common about the ponds, but neither nymphs nor nymph skins were secured from the ponds themselves.

The nymphs of *Anax junius* and *Æschna constricta* were abundant in all the ponds, but comparatively few imagos could be found at any one time. This migratory scattering profoundly affects the numbers of imagos found about the ponds.

3. THE WEATHER.—"All dragonflies are most active in hot, quiet, sunshiny weather" (Needham and Hart, 1901, p. 11), and consequently they appear more abundant at such times than on a dull, lowering day, when many remain in the shelter of the grass and weeds. Hence if we are to estimate the number of dragonflies correctly we must take into account the kind of weather during which the observation is made.

4. CONCEALMENT.—Large numbers of the smaller damselflies, especially such species as *Ischnura verticalis*, frequent the dense grass and are sure to escape observation. Hence the actual number of damselflies in any locality is almost certain to be underestimated, unless the grass and weeds are closely examined. A vigorous sweeping of the net over them always reveals far larger numbers than were first seen and often yields species that would otherwise escape detection.

Careful estimates, made by repeatedly walking around the ponds and counting such specimens as could be seen, making due allowance for repetitions and keeping in mind the considerations just presented, indicate that there is for each of the ponds a fairly constant average of 100 to 150 dragonflies, while the numbers of damselflies vary with their periods of emergence. Just after emergence there will be 300 to 500 for each pond, but between times the number may fall to 50 or even less. These numbers hold through the latter part of June, July, and the first of August, but become greatly reduced by the last of August.

RELATIVE ABUNDANCE OF DIFFERENT SPECIES.

Turning now to the relative abundance of the various species we can secure an exact numerical basis for our estimate. While it would be manifestly impossible to count the imagos of the different species and obtain any result worthy of record, good results can be obtained by gathering and counting the nymph skins. Such collections were made at intervals of two weeks during the summer of 1916 with the results shown in the following table. The successive counts were made along the north shores of ponds 4, 3, 2, and 1, respectively, the length of shore covered by each count being about the same. Over 2,000 nymph skins were obtained in the four counts, which indicates that the numbers given above under actual abundance are not too large.

NYMPH-SKIN COUNTS, PONDS 1 TO 4 D, FAIRPORT, IOWA, 1916.

Nymph skins obtained.	July 3.		July 16.		July 31.		Aug. 15.	
	No.	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
Æschna constricta	1	.....	2	.....	30	5	20	4
Anax junius	2	.....	10	2	46	7	48	10
Epicordulia princeps	31	6	1	.....	12	2	15	3
Pantala flavescens	.....	.....	.....	.....	4	.....	10	2
Tramea lacerata	2	.....	3	.....	4	.....	40	8.5
Perithemis domitia	.....	.....	1	.....	2	.....	4	.....
Celithemis eponina	5	1	3	.....	16	2.5	8	2
Leucorrhinia intacta	2	.....	1	.....	3	.....	25	5
Sympetrum rubicundulum	.....	.....	10	2	12	2	26	5.5
Sympetrum corruptum	3	.....	2	.....	.....	.....	.....	.....
Pachydiplax longipennis	1	.....	6	1	51	8	20	4
Libellula luctuosa	442	89	310	66	246	40	137	29.5
Libellula pulchella	1	.....	6	1	20	3	4	.....
Erythemis simplicicollis	2	.....	114	24	160	26	112	24
Plathemis lydia	5	1	.....	.....	8	1	.....	.....

Certain additional facts were noted during the gathering of the nymph skins.

1. CHOICE OF LOCALITY.—Upon reaching maturity the nymph does not crawl out of the water blindly wherever he may happen to be, but shows a definite preference for certain localities. Most of the nymphs here recorded transform in the early morning, at which time the west and north margins of the ponds receive the early sunshine, while the east and south margins are in the shade. It has been stated that the counts were made on the north shores; this was because those shores were found by actual trial to yield many more nymph skins than the east or south shores, and considerably more than the west shore. Another important reason is that the north shores border the shallower water of the ponds, and are thus naturally frequented by the nymphs when nearly ready for transformation.

A third factor which may influence the nymph in its choice of a locality for transformation is the kind of support obtainable. Some nymphs, such as those of *Libellula luctuosa*, Anax, and Epicordulia crawl up on anything that may be convenient, including wire screening, old boards, fence posts, and the like. Others show a decided preference for certain kinds of support and will even choose between different water plants. *Erythemis simplicicollis*, for example, selects the arrowleaf, *Sagittaria latifolia*, in preference to the cat-tail, *Trypha latifolia*, when the two are equally available. And this same species was the only one found in any abundance upon the stems of the crex grass, *Carex stricta*.

Erythemis transforms later in the day than many of the other species, and its exuviæ were found in large numbers along the eastern shores of the ponds. In five of the ponds these shores contain both cat-tails and arrowleaf in addition to the crex grass, but almost without exception the Erythemis nymphs had chosen the latter.

On the other hand, Anax usually emerges during the night, and its exuviæ were found upon the western and northern shores, and more of them upon the cat-tails than upon all other kinds of support combined. The large, sprawling nymphs of *Tramea lacerata* also take very kindly to the cat-tails, but shun the crex grass altogether.

Among the damselflies the Enallagmas are always found upon some convenient stem, a short distance above the water. Often there will be several exuviæ upon the same stem, and in one instance the number reached 21, as recorded upon page 230.

On the other hand, the nymphs of Ischnura very frequently crawl out upon the top of the lily pads and perch for transformation on the margin of the leaf, where it has

curled up in the sun, half or three-fourths of an inch above the water. Twenty-five such teneral Ischnuras were seen close to their exuviæ upon the pond-lily leaves of pond 3 on the afternoon of July 28, 1917, but not a single Enallagma. Nor have the exuviæ of the latter ever been found in such places around the Fairport ponds.

The nymphs of *Argia mœsta putrida* often crawl long distances over the land and then up the trunk of a tree and are the only damselfly exuviæ found in such positions. This leads naturally to the second consideration.

2. DISTANCE TRAVELED.—The distance to which the nymphs crawl before transforming varies greatly, not only for the different species, but also for different individuals of the same species. Some nymphs, like those of *Perithemis domitia* and the two Sympetrums, were always found upon rush or grass stems standing in the water, often at quite a distance from the shore. Others, like Anax, Æschna, and Erythemis, were close to the shore, sometimes over the water, and sometimes over the land, but never very far from the water's edge. *Libellula luctuosa*, Epicordulia, and Plathemis, on the other hand, crawl much farther and sometimes go a long distance. In the first count, 1 Plathemis, 5 Epicordulia, and 47 *L. luctuosa* crawled up the bank of the pond, across the cinder road, up a dirt bank bordering the road, and into the grass field, the entire distance being 50 or 60 feet. The other individuals of these species were all found between the road and the water's edge.

3. LACK OF PROTECTIVE INSTINCT.—While instinct may guide the nymph to the shallow and sunny side of the pond, it apparently fails him in some other directions. There were two red-winged blackbirds' nests in the cat-tails and crex grass on the shore of pond 2, where the second count was made. Twenty-five nymph skins were taken within a radius of 6 inches of one of these nests, three of which were actually fastened to the sides of the nest itself, and seven were found within a similar radius of the other nest. The young birds had only just left the nests and were still in the immediate vicinity, so that some of the nymphs must have transformed while the nests were still occupied.

4. RELATIVE ABUNDANCE OF SPECIES.—From the counts above recorded it appears that *L. luctuosa* is the most abundant species, and also that it emerges before the others. Its time of greatest abundance is during the last of June and the first of July, when it constitutes over 90 per cent of the dragonfly fauna of the ponds. Although it keeps up a good percentage and remains throughout the season more numerous than any other single species, it quickly loses its relative predominance and steadily declines during the latter part of the season, until by the middle of August it is only a little more numerous than *E. simplicicollis*.

On the other hand the latter does not begin to appear until *luctuosa* has reached its maximum. It then rapidly increases, while *luctuosa* is decreasing, and its time of greatest abundance is the latter part of July, following which it declines through August.

Tramea, Anax, and Æeschna did not really begin to appear until the middle of July and then steadily increased through the remainder of the season, until by the first of September, together with Epicordulia, they were about the only species left. In 1917 a very much larger number of Anax and Æschna exuviæ were found early in the season, by the last of June or the first of July; but the imagos were no more numerous than during the preceding year, because they scatter immediately after emergence. Both species must return to deposit their eggs either in the pond where they were hatched or

in some similar body of water. The Anax imagos are present in considerable numbers around the ponds by the first of August, and may be seen mating and ovipositing. The Æschna imagos delay much longer, and none have thus far been seen depositing eggs before the second week in September. In Massachusetts the same species, *constricta*, may be seen depositing its eggs as late as October.

Sympetrum corruptum appeared late in June and lasted for about three weeks and then entirely disappeared, its place being taken by *S. rubicundulum*, which remained the rest of the season.

Perithemis domitia was never present in sufficient numbers to really enter into the reckoning.

Plathemis lydia and *Libellula pulchella* were much more abundant in 1917 than in 1916, and both took an active part in the odonate life of the ponds. Previously they had remained quite constantly along the ditches beside the railroad tracks, but finally deserted them and assumed their appropriate places around the ponds.

LIFE HISTORY OF AN ODONATE.

In order to properly appreciate the relations between fish and dragonflies and damselflies it is well to consider briefly the life history of these insects.

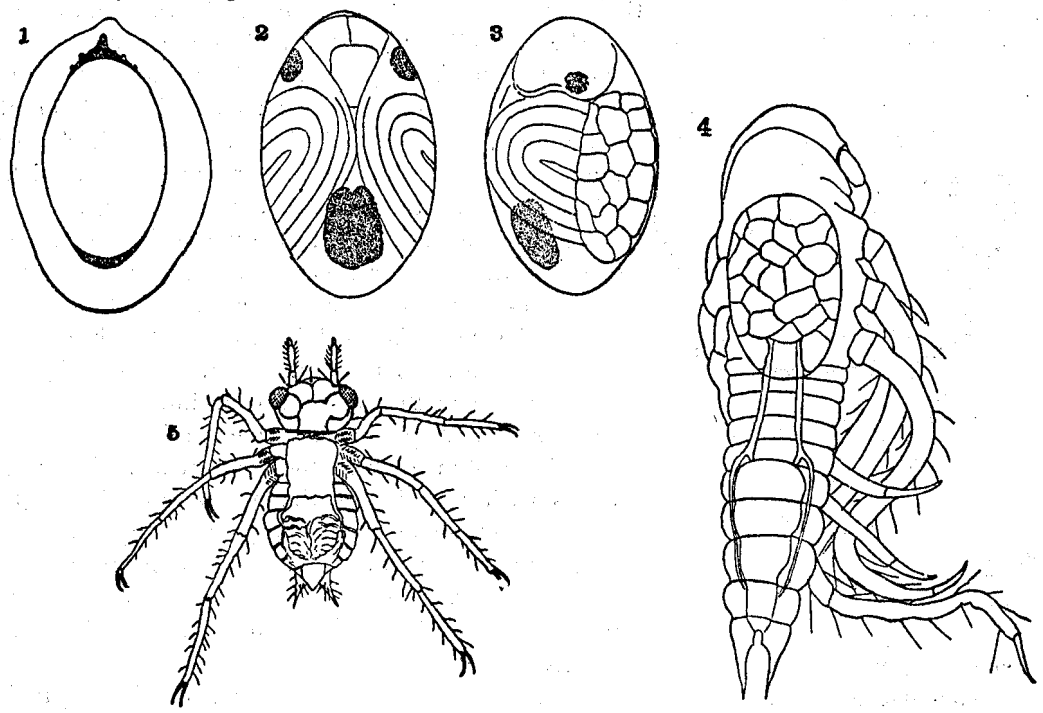
EGGS.—The eggs are laid in the water and hatch into larvæ called nymphs. The period of incubation varies greatly in different species; perhaps the average for dragonflies is from 5 to 10 days, and for damselflies about 20 days. Eggs laid by a Pachydiplax female and kept in the laboratory hatched in 5 days; Warren (1915, p. 8) also found the period of incubation in *Pantala flavescens* to be 5 days for two females and one male and 7 days for another male. The dragonfly's egg is ellipsoidal, narrowed a little at either end, and surrounded by a gelatinous envelope (fig. 1). There is a small projection or knob at the anterior end of the egg, which is known as the pedicel. It is formed of a thickening of the egg shell or chorion and furnishes the means by which the egg is attached to the egg string inside the ovary of the female.

The eggs of damselflies and of Anax, Æschna, and their relatives among the dragonflies are considerably elongated and assume a cylindrical form (fig. 58). The anterior end is pointed, with a short and wide pedicel, while the posterior end is bluntly rounded.

NYMPH.—At the end of the third day the larval pronymph could be seen inside the Pachydiplax egg and appeared as shown in figures 2 and 3, the long concentric lines being the folded legs. On emerging from the shell the pronymph is closely covered by a chitin sheath which holds the legs tightly to the body. It quickly molted out of this sheath and took the form shown in figure 5, but one was pulled out of the sheath before it had time to molt, and this one looked like figure 4. The body was elongate and fully segmented and the legs were more or less twisted from their previous folding. The pronymphal stage lasts usually but a very short time, less than a minute, sometimes only two or three seconds. The nymph, on the other hand, continues until it is ready to be transformed into the imago or perfect insect. Most nymphs require a year in which to fully mature; a few, like Gomphus, require more than a year, while others, like the damselflies Enallagma and Ischnura, may produce more than one brood in a season.

IMAGO.—In these latitudes the winter is passed in the nymph stage, and toward the close of the following spring the nymph, having passed through successive molts, is ready for transformation. This is accomplished by crawling out of the water onto some convenient object near at hand, to which it fastens with its claws. In a short time the skin splits across the top of the head and then along the back and the imago or perfect insect emerges, leaving the old nymph skin, called an exuvia, fastened to its support.

TENERAL.—After emerging, the imago is of a uniform pale yellow or tinged with blue, brown, or white, and it takes from a few hours to several days for it to acquire the bright colors of the mature adult. During this time it is called a teneral, its body is soft and flabby, its wings shine as if varnished, and its powers of flight are quite limited.



FIGS. 1 to 3.—The egg of *Pachydiplax longipennis:* 1, newly laid; 2, three days old, dorsal view; 3, three days old, side view, showing at the right the large ventral plate and in the center the folded legs. FIG. 4.—Pronymph of *Pachydiplax longipennis;* length, 0.90 mm. FIG. 5.—Nymph of *Pachydiplax longipennis* after the first moult; length, 1 mm.

PRUINOSE.—After becoming thoroughly hardened, some species, especially the males, are gradually covered with a bluish or whitish powder which may hide entirely the original bright colors; they are then said to be pruinose.

In *Plathemis lydia* the old males are almost white on the dorsal surface; in Erythemis and Pachydiplax they become blue; while in the damselfly, *Argia putrida*, the thorax and the last two segments of the abdomen appear to be blue, but this color disappears at once when they are put in alcohol.

MOUTH PARTS OF ODONATE NYMPHS.

DRAGONFLY NYMPHS.—In dealing with the food of nymphs and adults we need to know a little about the means which they possess for seizing, eating, and digesting their prey; let us begin with the mouth parts.

Mask.—The most noticeable thing about a nymph is the so-called mask, which is folded back beneath the head and which may or may not cover the lower part of the face (fig. 6), This mask is really the lower lip or labium, whose outer end terminates in three lobes, one median and two lateral; the latter may take the form of stout claws (Æschnidæ) or of spoon-shaped lamellæ (Libellulidæ). The mask is hinged near the center and when not in use is folded at the hinge; the lateral lobes are turned inward across the front end of the median lobe, and the whole apparatus is folded back beneath the head. Figure 7 is a side view of the head of *L. luctuosa*, showing the mask folded back, while the lateral lobes at its tip cover the lower half of the face. This is the condition found in the nymphs of all the Libellulidæ. Figure 9 is a side view of the head of *Anax junius;* here the lateral lobes do not cover the face at all, but extend straight forward as stout claws beneath the chin. This condition is found in the nymphs of the Æschnidæ, with the exception of the genus Cordulegaster, and as an accompanying character the head is depressed or flattened. The length of the labium varies considerably in different dragonflies, but is usually longer in the Æschnidæ than in the Libellulidæ and reaches back, when folded, between the bases of the second legs.

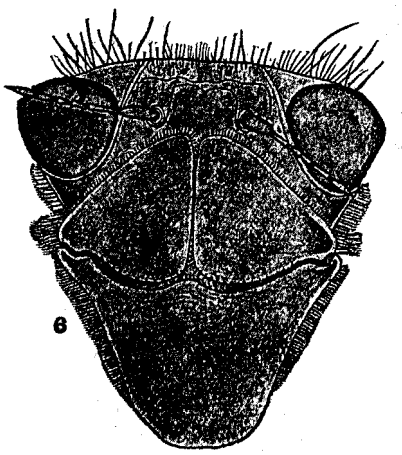


FIG. 6.—Face of nymph of *Erythemis simplicicollis*, showing the large mask-like labium covering the lower part of the face up to the antennæ and eyes.

With the mask folded the nymph either conceals itself in the mud or trash on the bottom or steals up on its prey and when within striking distance shoots the mask forward in front of the head and grasps the victim between the lateral lobes. Figures 8 and 10 show the same two specimens of *luctuosa* and *junius* with the mask thus extended.

The distance which they can reach, of course, varies with the size of the nymph and the length of the mask; some of the large Anax nymphs can cover 15 to 25 mm. This, in addition to the lurching forward of the body, enables them to catch insects like Corixa, much more agile than themselves, and even to capture small fishes.

To assist in holding their prey, the lateral lobes of the mask are toothed along their inner margins in the Æschnidæ (fig. 11). In the Libellulidæ they are armed with a long, slender spine at the tip and a row or raptorial setæ behind this along the outer margin, varying in number in the different species. There is a crescent of similar setæ, also varying in number, along the body of the mask, called the mentum, on either side of the median line. And there are more or less regularly arranged spines and hairs along the remaining margins of all three lobes. Figures 12 to 14 illustrate some differences between the species.

Maxillæ.—Once grasped between the lobes of the mask, the prey is drawn quickly to the mouth, where there are two pairs of organs ready to dispose of it. The first of these, the outside pair, are the maxillæ, which are very much alike in all nymphs; each maxilla has two fingerlike branches or rami, the outer (ventral) of which is

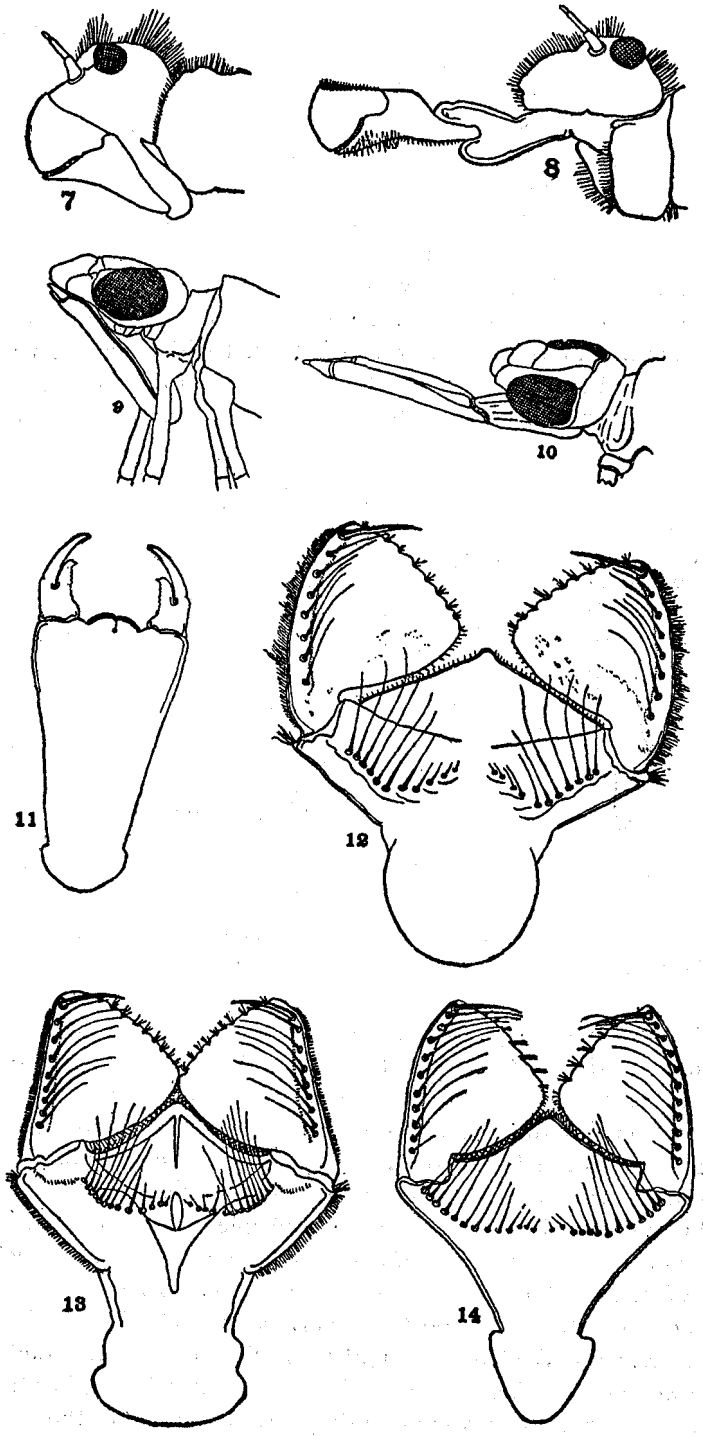


FIG. 7.—Side view of head of nymph of *Libellula luctuosa*, mask folded. FIG. 8.—Same, mask extended. FIG. 9.—Side view of head of nymph of *Anax junius*, mask folded. FIG. 10.—Same, mask extended. FIG. 11.—Mask of *Anax junius*. FIG. 12.—Mask of *Libellula luctuosa*. FIG. 13.—Mask of *Erythemis simplicicollis*. FIG. 14.—Mask of *Pachydiplax longipennis*.

armed with stout, curved claws, while the inner is covered with stiff hairs; these maxillæ are evidently used to help hold their prey securely (figs. 15 and 16).

Mandibles.—The second pair are the mandibles; they are much stouter, are hard and chitinous, and are armed with strong teeth (figs. 17 and 18). They can easily crush the shells of small pond snails like Limnea, Physa, and Planorbis, or they can bite through the hard chitin covering of beetles and water boatmen. The food contents of the stomachs of all the nymphs examined shows that the mandibles are used chiefly for crushing the food and not for chewing it. It is chewed only enough to get it down the gullet, and much of it is swallowed whole.

Gizzard teeth.—The real mastication takes place in the gizzard, and for this purpose the wall of the gizzard at the posterior end is armed with four longitudinal ridges of chitin—two dorsal and two ventral. Each ridge carries projecting teeth, whose number and arrangement varies a little in different species. The general character of these

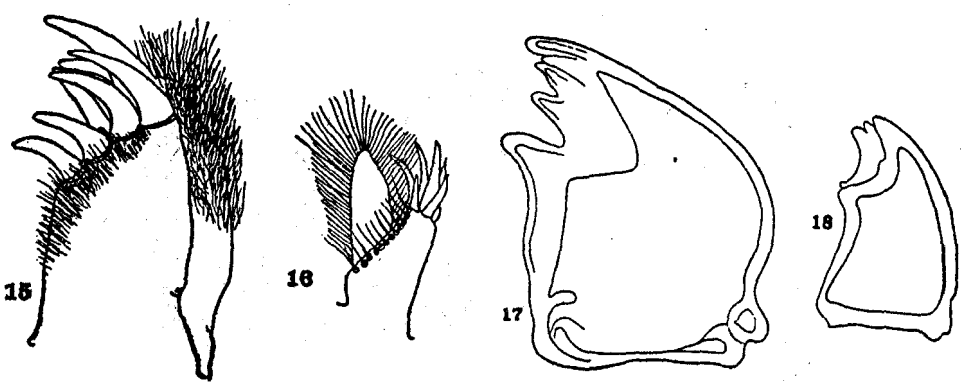
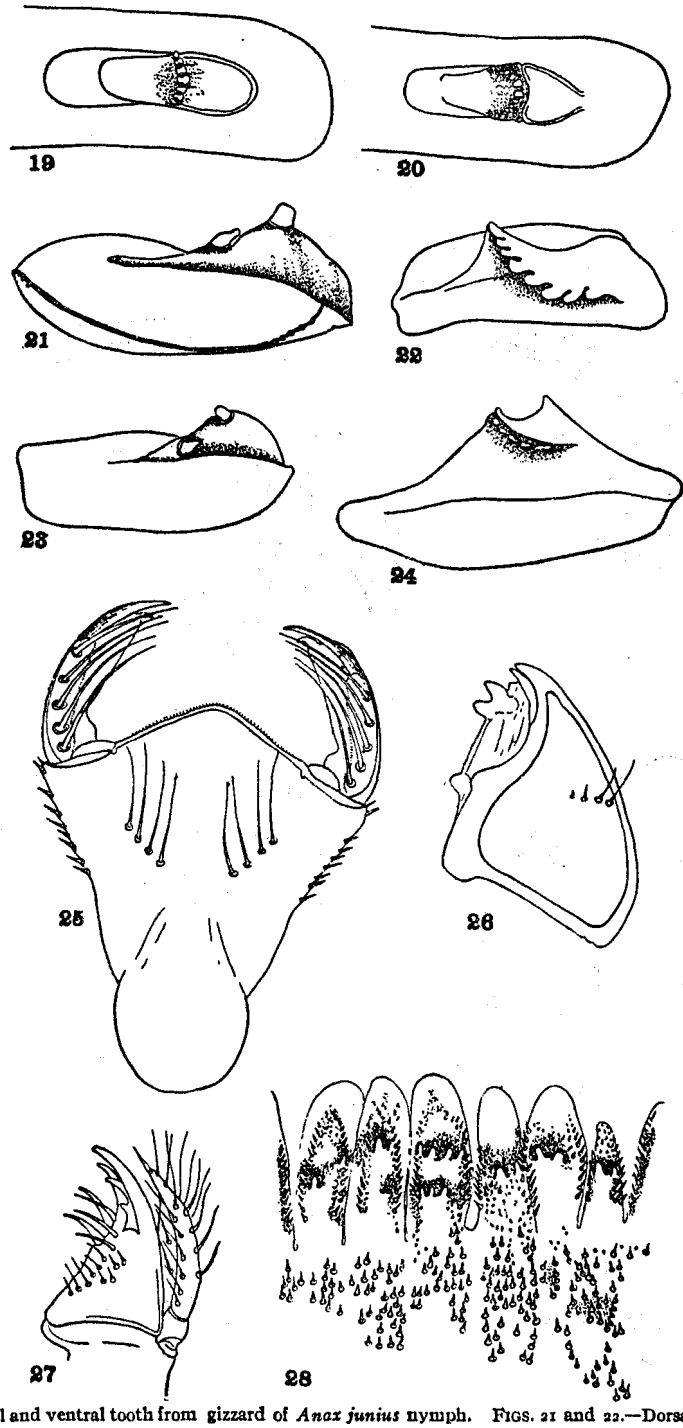


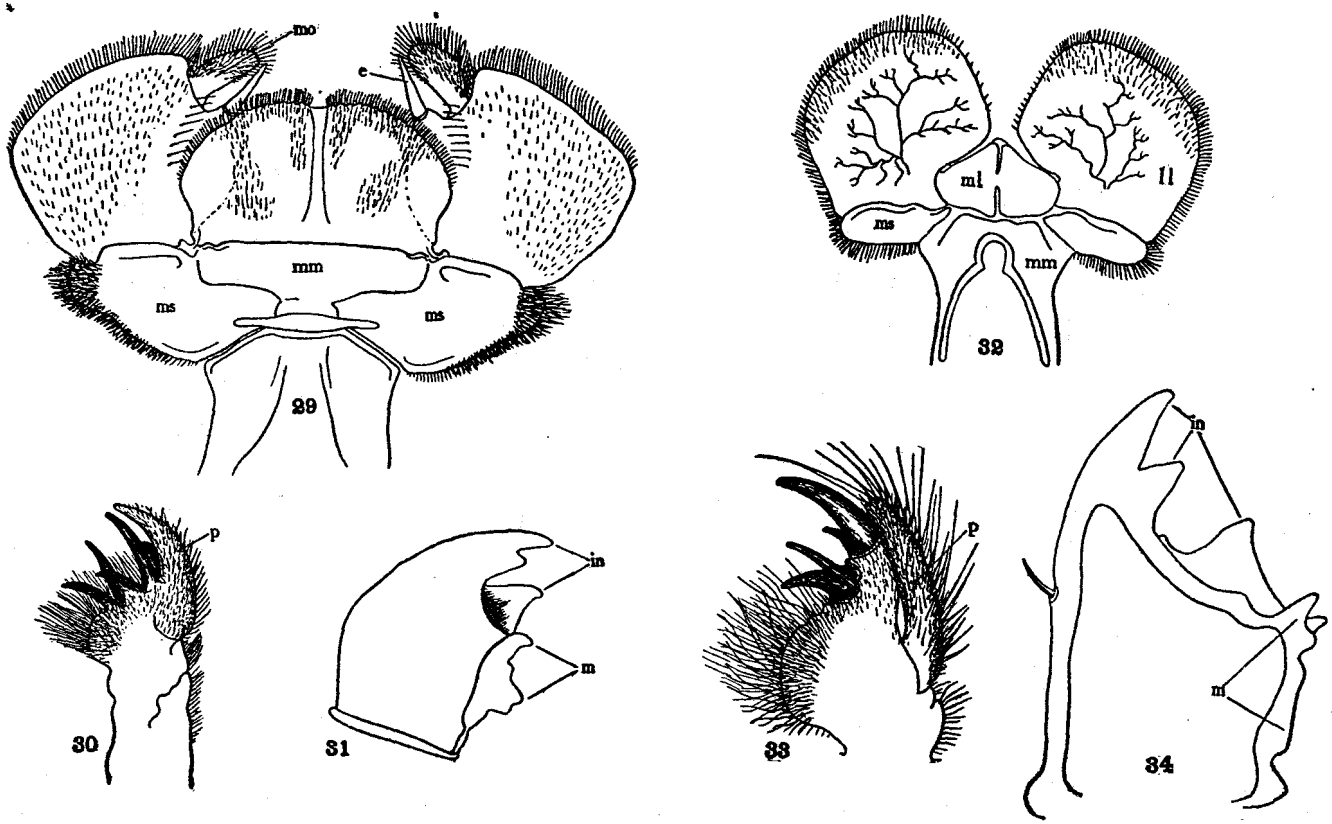
FIG. 15.—Maxilla of *Anax junius* nymph. FIG. 16.—Maxilla of *Erythemis simplicicollis* nymph. FIG. 17.—Mandible of *Anax junius* nymph. FIG. 18.—Mandible of *Erythemis simplicicollis* nymph.

toothed ridges is well shown in figures 19 to 24. The churning of the gizzard grinds the food against the teeth and soon reduces it to finer fragments; it then passes on into the intestine.

DAMSELFLY NYMPHS.—The structure of the mouth of the damselfly nymph is in all respects similar to that of the dragonfly. The mask (fig. 25) is more like that of the Libellulidæ, with raptorial setæ on the lateral lobes and the mentum, but the lateral lobes only cover a very small portion of the lower face. The mandibles (fig. 26) and the maxillæ (fig. 27) are so much like the larger ones of the dragonflies that they can be recognized at once by comparison. In the gizzard we find a somewhat different arrangement; instead of 4 chitin ridges there is some multiple of 4 up to as many as 32, 8 and 16 being the most common numbers. Each ridge has a row of small spinelike teeth along the anterior half of both lateral margins; there is a narrow space through the center which is unarmed, and the whole posterior surface is covered with short stout spines, curved forward (fig. 28). Such a mill ought to be able to grind the food into very small fragments, and we find that this is actually done. In other damselflies the gizzard varies greatly both in the number of ridges and in the size and number of the teeth. The differences in the various genera and species have been admirably worked out and figured by Miss Higgins (1901).



FIGS. 19 and 20.—Dorsal and ventral tooth from gizzard of *Anax junius* nymph. FIGS. 21 and 22.—Dorsal and ventral tooth from gizzard of *Libellula luctuosa* nymph. FIGS. 23 and 24.—Dorsal and ventral tooth from gizzard of *Epicordulia princeps* nymph. Posterior end of each tooth toward the right. FIGS. 25 to 28.—Enallagma nymph: 25, mask; 26, mandible; 27, maxilla; 28, gizzard teeth, the upper edge of figure anterior.

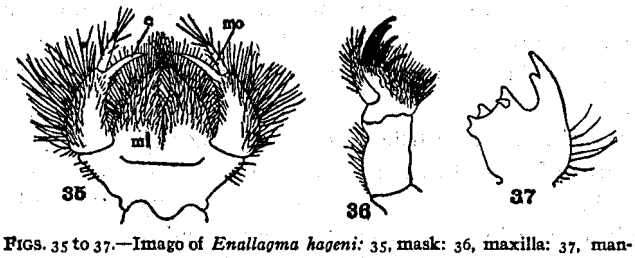


FIGS. 29 to 31.—Imago of *Anax junius:* 29, mask; 30, maxilla; 31, mandible. *e*, immovable end hook; *in*, incisors; *m*, molars; *mm*, mentum; *mo*, movable hook; *ms*, squame; *p*, palp. FIGS. 32 to 34.—Imago of *Erythemis simplicicolis:* 32, mask; 33, maxilla; 34, mandible. *ll*, lateral lobe of mask; *ml*, median lobe of mask; other letters same significance as above.

MOUTH PARTS OF ODONATE IMAGOS.

DRAGONFLY IMAGOS.—When the nymph transforms into an imago, the hinged mask disappears, and the labium or lower lip is now attached directly to the ventral surface of the head. In consequence there is a much greater similarity in the mouth parts of the imagos, though there are still some differences. In general, the labium of the imago consists of a basal portion, corresponding to the mentum of the nymphal mask, but destitute of raptorial setæ and very much shortened. From its anterior margin projects the median lobe, greatly enlarged in Anax and Æschna (fig. 29) and covered with hairs, but reduced to a small triangular piece in the Libellulids (fig. 32) and more or less free from hairs.

On either side of the mentum is a side piece known as the squame (ms) which supports the lateral lobe. These latter now fold together across the front of the face in all the imagos. In Anax and Æschna they are enlarged into concave lamellæ, strongly convex on their outer borders and covered with hairs. The inner border ends distally in a sharp end hook (e) which is immovable; just outside of this is a larger movable hook (mo), which is rounded and palplike and covered with hairs. When the lobes are folded across the front of the face, these four hooks meet on the median line, but the margins of the lobes beyond them diverge rapidly. In Erythemis (fig. 32) and the other Libellulids the margins of the lateral lobes, when folded, meet each other in a long median line, both hooks have practically entirely disappeared, and the lobes are covered with hairs. The mandibles (figs. 31 and 34) and the maxillæ (figs. 30 and 33) have changed a little in detail, but are practically the same as before. The teeth of the mandibles are very strong and may be divided into two sets, the incisors (in) at the tip of the mandible, which are long, curved, and sharply pointed, and the molars (m) near the base, which are much shorter and armed with separate cusps or points. The maxillæ still retain the outer lobe or palp (p), which is curved and covered with hairs, and the inner lobe, which is armed with curved and sharply pointed teeth and a pad covered with long sensory hairs.



FIGS. 35 to 37.—Imago of *Enallagma hageni:* 35, mask: 36, maxilla: 37, mandible. *e*, end hook: *ml*, median lobe of labium: *mo*, movable hook.

DAMSELFLY IMAGOS.—In the damselflies the general structure of the mouth parts is the same as in the dragon flies. Here the median lobe of the labium (ml, fig. 35) is fully as long as the lateral lobes, is divided by a deep median fissure, and is covered with long hairs. The lateral lobes retain the immovable end hook (e), which is very long and slender and curved to an acuminate point, and the movable hook (mo), which is also long and narrow, but is bluntly rounded and covered with hairs. These lobes are relatively much narrower than those of the dragonflies, and, when folded, only the terminal hooks meet on the median line. The mandibles (fig. 36) and maxillæ (fig. 37) are similar in all respects to those of the dragonflies, except that there is a sharper distinction between the incisors and the molar in the mandibles, while the maxillæ have long hairs on the outer margin near the base.

The gizzard in the imago is relatively much smaller and weaker in the nymph, and has very little functional use. The chitin ridges or folds along its walls are still retained,

but the teeth are either completely lost, as in the dragonflies and in Lestes among the damselflies, or they are reduced to a much simpler form. The imago evidently chews its food before swallowing it, as we may well believe after watching one munch its prey.

This brief description of the mouth parts of the nymphs and imagos will enable us to understand better both how they secure their prey and how they dispose of it afterwards.

ECONOMIC RELATIONS BETWEEN ODONATES AND FISHES.

The artificial propagation of fish falls very naturally into three great divisions: 1. Suitable methods of obtaining and hatching the eggs; 2. Care and protection of the young after they are hatched; 3. Provision of an abundance of the right kind of food.

Our national and State fish hatcheries are concerned very largely with the first two of these, and the progress they have achieved is marvelous, considering the difficulties surmounted. In a comparatively brief period of years they have accumulated a wealth of accurate information and statistics, which have attracted the attention and awakened the admiration of the entire world.

But the last factor, in so far as it concerns pond fishes, has thus far received almost no attention in this country. Europe has been studying the problems connected with fishponds for many years and has far outstripped us along these lines. In fact, we have made hardly a beginning as yet, and the few facts that have been ascertained still lack correlation and logical arrangement.

In speaking of the food relations of insects and fishes Needham (1901, p. 395) said: "And so little are the essential features of good foraging ground understood that each planting of fry in a new place is still largely an experiment. * * * Any new study of fish food should include the study of the feeding grounds, feeding habits, choice of food offered, and conditions that make for the continuance and possible increase of the food supply." In spite of the 15 years that have elapsed since then, the statement retains practically its full value to-day.

Prof. S. A. Forbes and his associates in Illinois were pioneers in this aspect of fish culture, and have put out much valuable information on the food of fresh-water fishes during the last 35 years; an admirable summary will be found in Forbes, 1888*b*. More recently papers have been published by L. L. Dyche, 1914; Wm. E. Meehan, 1913; A. S. Pearse, 1915; Geo. C. Embody, 1915, and Dr. Robert E. Coker, 1915.

These papers are all excellent in both their subject and its treatment, but of necessity they are general in character and do not treat any of the phases in detail. For this reason and for many others it is believed that a summary of the economic relations between odonates and fishes will prove of interest to all who are, and especially to those who may become, engaged in pondfish culture. At present the old idea prevails that the nymphs of the Odonata, especially those of Anax, Æschna, and other large species, are very destructive to small fishes.

So far as known, the other side of the question has never been presented, and we have not only drawn a one-sided and biased conclusion, but we have also been led into the common error of condemning the many for the sins of the few. A hawk steals a farmer's chicken, and immediately all hawks are condemned as pests and robbers, irrespective of species, and a loaded shotgun is kept for their reception. Similarly because Anax and Æschna nymphs have been known to kill small fish, all dragonfly nymphs have been condemned as nuisances and dangerous to have around a fishpond.

Such a conclusion is, of course, not warranted, and even with reference to Æschna itself it does not follow that it must be considered dangerous simply because it eats a few small fish. Needham (1903, p. 213), one of our most experienced observers, said with reference to *Æschna constricta*, which was common at Bone Pond, one of the three propagating ponds controlled by the Adirondack hatchery in New York, and artificially stocked with brook trout: "I have not been able to determine as yet whether in relation to trout culture Æschna is more disadvantageous than otherwise. It eats a few fry and it eats the food of the larger trout, but, on the other hand, it furnishes a moderate supply of food itself for the larger trout." In order to solve such a problem satisfactorily we must consider in detail all phases of the economic relations between odonates and fishes. An endeavor to do this has been made in the following pages by a careful consideration of the food and enemies of dragonfly and damselfly nymphs and imagos, by a summary of all that is known of nymphs and imagos as fish food, and by extensive observation and experimenting.

FOOD OF ODONATE NYMPHS.

The alimentary canals of 50 nymphs of each of the four dragonflies enumerated in the following table and 50 others of various damselfly species, making 250 in all, were examined to ascertain what food had been eaten. The presence in a nymph's digestive tract of any of the various kinds of food listed was represented by a single unit, whether found in large or small quantities. The figures in the table, therefore, tell us how many of the nymphs had eaten any specified food, but do not indicate how much they had consumed.

FOOD OF 250 ODONATE NYMPHS FROM FAIRPORT, IOWA.

[The figures indicate the number of nymphs in which each kind of food was found.]

Contents of alimentary canal.	Anax junius.	Libellula luctuosa.	Erythemis simplicicollis.	Pachydiplax longipennis.	Damselfly nymphs.
Mollusca:					
Physa shells, mostly fragments	16	6	16	4	8
Planorbis shells, mostly fragments	15	34	22	4	12
Beetles:					
Dytiscus larvæ	10	8	2	2	.....
Haliplid beetle, elytra of adults	8	3	8	12	.....
Peltodyes larvæ, jointed hairs	....	7	6	....	.....
Diptera:					
Ceratopogon larvæ	2	3	6	....	2
Chironomid larvæ	....	....	5	3	8
Mosquito larvæ	....	1	....	1	6
Simulid larvæ	....	....	8	4	9
Hemiptera: Corixa, sp., elytra of adult	14	4	3	1	.....
Sialidæ: Sialid larvæ	3	....	2	....	.....
Perlidæ: Stonefly larvæ	....	2	6	2	.....
Ephemeridæ: Mayfly larvæ	27	9	7	4	6
Crustacea:					
Entomostraca, fragments unidentified	5	21	26	15	20
Cladoceran eggs, with ephippium	2	7	9	6	10
Bosmina, sp	3	8	6	4	12
Cypris, sp	6	35	2	20	15

Contents of alimentary canal.	Anax junius.	Libellula luctuosa.	Erythemis simplicicollis.	Pachydiplax longipennis.	Damselfly nymphs.
Crustacea—Continued.					
Simocephalus, sp	5	2	2	4	8
Daphnia, sp	2	....	....	4	17
Pleuroxus, sp	....	....	3	5	5
Copepods, fragments unidentified	2	2	4	14	15
Diaptomus, sp	....	1	1	4	6
Hyalella, sp	....	2	2	1	....
Crayfish, sp	11	....	1	2	....
Odonata:					
Damselfly nymphs, unidentified	11	15	1	2	2
Ischnura verticalis nymphs	12	3	2	1	....
Enallagma, sp., nymphs	3	2	5	1	....
Lestes, sp., nymphs	6	2	4	5	....
Libellula luctuosa, nymphs	5	....	....	....	....
Anax junius, nymphs	2	....	....	....	....
Erythemis simplicicollis, nymphs	6	4	1	....	....
Algæ:					
Desmids	....	9	4	2	13
Diatoms	....	....	8	2	....
Sponge spicules, in masses	....	5	....	....	....
Œdogonium, scattered filaments	....	....	6	3	14
Algæ filaments	7	7	32	1	25

GENERAL CHARACTER OF THE DIET.—On the whole there is a remarkable similarity in the diet of the various species. Eleven of the food items appear in all five of the columns and nine more are found in four out of the five. There are only three foods confined to a single species and three others that are restricted to two columns.

Perhaps the most noticeable items are those which begin and end the list. Two species of snails are very common in all the ponds, and upon these every kind of nymph examined had been feeding freely. Not only had more than half of the nymphs partaken of these snails, but in several instances no other food was found in their digestive tract.

With reference to the algæ, it is of course understood that inasmuch as the nymphs catch their prey among the algæ, they would be expected to swallow some of the latter. Hence its presence was not noted unless in sufficient quantity to make it reasonably certain that it had been taken voluntarily. Like the snails, in a few instances it constituted the sole article of diet.

The other popular foods were the mayfly larvæ and the small crustacea, the latter being consumed in large quantities.

Cannibalistic tendencies are shown by the presence of odonate nymphs in all five columns; and in four out of the five, nymphs were found which had eaten others of their own species.

There is a good showing of beetle larvæ and adults, and of adult water boatmen, all of which are injurious to young fishes.

SPECIFIC DIFFERENCES IN THE DIET.—Notwithstanding the wonderful agreement just mentioned, a careful examination reveals also striking differences in diet. Every one of the Anax nymphs was fully grown, with well-developed wing cases, and was captured in pond 4, which contained only adult buffalofish. Of course the nymphs could not eat these fish, and hence the absence of fish in their diet is a matter of necessity rather than choice. (See p. 206.) Neither did the fish eat the nymphs, however, and this probably accounts for the exceptional abundance of the latter, as evidenced by the exuviæ obtained. The bulk of the food of these nymphs was made up of mayfly larvæ and snails, but it is worthy of note that they also ate large quantities of Dytiscus larvæ, the water boatman Corixa, and small crayfish. The proportion of odonate nymphs in their food was much greater than for any of the other species examined. One very large specimen had eaten nothing but crayfish, and its stomach was packed full of their shells and claws, which had turned red in color like a boiled lobster. The Dytiscus larvæ were identified by their heads and mandibles, Corixa by the peculiar color pattern of the elytra, and the Haliplid beetles also by the color pattern of the elytra. All three of these foods were especially abundant in this pond.

The bulk of the food of the Libellula nymphs consisted of snails and various entomostraca, Cypris being a particularly toothsome tidbit; there were also quite a number of damselfly nymphs and a good representation of the beetle larvæ. A beetle larva belonging to the genus Peltodyes was found to be common on the algæ in the ponds, and its body was covered with long, jointed, bristlelike processes. The broken fragments of these processes were found in the gizzards of seven nymphs, in three of which the larvæ were the only food eaten.

In the gizzards of five of the nymphs were rounded masses of the spicules of a fresh-water sponge. Sponges are common in two of the ponds, and on them live a species of Sigara, which is a minute water boatman, and one of the caddisworms, Leptocerus.

Of course, the snails crawl about over these sponges, as well as over the algæ. The nymphs probably took in the spicules while feeding on these insects and snails, for they would hardly eat the sponge itself. The Libellula nymphs had eaten a much smaller number of mayfly larvæ than those of Anax and were content with the Amphipod Hyalella, in place of crayfish.

Twenty of these nymphs were taken from pond 7 D, June 23, 1916, while the others came from ponds 1, 2, and 3 D, at different dates in July and August. Pond 7 had been stocked in the spring with 75,000 small fry of the buffalofish; on July 1 these young fish had reached a length of 1 inch, and on July 15 specimens were taken an inch and a half long. Previous to June 23, on this basis of growth, the fish were small enough to be caught and eaten by the nymphs, if the latter had made the attempt. The entire absence of fish from the diet of these nymphs shows that they chose other food even when fish were present. The remains of odonate nymphs in so many of their gizzards is good evidence, on the other hand, that the *luctuosa* nymph is not inert and lethargic.

The food of the Erythemis nymphs consists also of snails and entomostraca, with a moderate amount of beetle and mayfly larvæ, and an almost complete absence of the larger crustacea and of damselfly nymphs. A large amount of algæ was present in 64 per cent of the gizzards, and in several individuals nothing else had been eaten; at least, there were no remains in either gizzard or intestines. Algæ, therefore, must constitute a respectable portion of the food of these nymphs.

It might seem strange to report Simulid larvæ from a fishpond, but the screens at the outlets of all of the ponds were covered with the larvæ of *Simulium vittatum*, and some of the nymphs evidently picked them off the screens. The ephippium surrounding the Cladoceran egg is proof against the digestive juices of the nymphs, and eggs taken from the posterior end of the intestines were as plump and uninjured as those just swallowed. The Desmids and Diatoms, like those found in *luctuosa* nymphs, are not numerous enough to make it certain that they were really sought for and eaten. They might well have been taken in accidentally with some of the food. Ten of these nymphs were taken from pond 7 D on June 26, 1916, and 15 were taken from pond 9 D on July 7. As already stated, the former pond contained an abundance of small fish, while the channel cats in the latter pond had produced a brood of fry previous to the capture of the nymphs. None of them had eaten fish, however, and their small size makes it improbable that they could overpower any but the smallest fry.

Entomostraca and copepods are the chief articles of diet for the Pachydiplax nymphs, and there is a minimum amount of snails, beetle larvæ, and mayfly larvæ. The larger crustacea are practically absent, and damselfly nymphs are the only odonates represented. The food in the gizzards of these nymphs and that in the Erythemis nymphs was particularly well ground up, so that only small fragments were left. Even the shells of the small entomostraca were broken and resembled the débris obtained from the posterior intestine of Anax and Libellula.

The damselfly nymphs included species of Enallagma, Ischnura, Argia, and Lestes, and were obtained from the various ponds indiscriminately. No attempt was made to separate the different species, and they were treated as though all one kind. The food in the gizzards of these numphs was broken up into smaller fragments than that of any of the dragonflies, and in much of it the identification of species or even genera was almost impossible. As will be seen the great bulk of the food consisted of ento-

mostraca of various kinds, with a good percentage of snails. Many of these nymphs also, like those of Erythemis, had eaten large quantities of algæ, and two of the larger nymphs, *Argia mœsta putrida*, had shown cannibalistic tendencies and had eaten smaller nymphs.

BENEFITS OF DIET TO FISH BREEDING.—A very respectable portion of the nymph food consists of the adults and larvæ of insects and crustacea that are known to be injurious to fish fry. Here belong the larvæ of the diving beetle Dytiscus, the adult water boatman Corixa, and the crayfish. The Dytiscus larvæ are known by all fish-culturists to prey upon small fish, and they have been repeatedly observed doing this in these ponds at Fairport, whenever the water is drawn out of them for any purpose. Corixa and the closely related genus Notonecta have proved to be serious pests in European fishponds, killing so many of the young fry that they have to be exterminated before the culture can go on successfully (Benecke, 1886, p. 340).

Crayfish not only prey upon young fish but are also a great nuisance in a fishpond because of their burrowing habits, and therefore anything which diminishes their numbers must be looked upon as beneficial.

Curiously enough the entomostracan genus, Cypris, which is eaten in large numbers by the nymphs of *L. luctuosa* and the various damselflies, is sometimes less innocent than it may appear. In a report on fish-cultural operations at Beaune, France, M. Chabot-Karlen (1889, p. 310), said:

> The rearing of *Daphnia pulex* and *Cypris fusca* was also tried [to serve as fish food]. * * * The Cypris, however, were found to prey upon the young fish. Having been put in with the embryos of the carp, they were often discovered to the number of two or three fixed upon the back of an alevin devouring it, notwithstanding the efforts of the poor animal to shake itself free.

CLAIMS OF INJURIES OF DIET TO FISH BREEDING.—Much of the food eaten by these nymphs is the same as that of small fish, and it is often claimed that they thus diminish the quantity of food available for the fish fry. But the young fish increase rapidly in size, and if they are to be reared successfully larger prey must be provided for them as they grow older. These odonate nymphs furnish such larger prey and are apparently quite acceptable to the fish. (See p. 225.)

Hence if the above argument against the nymphs is to prevail, it must be proved that their value as food for the larger fish plus their value as destroyers of certain enemies of the smaller fish does not recompense for the food they themselves consume plus the few fish fry that the largest species may destroy. This leads very naturally to a discussion of the last statement, which is worthy of separate consideration.

NYMPHS AS FISH EATERS.—There seems to be a prevailing opinion among fish-culturists that dragonfly nymphs are very destructive to young fish, but when we examine the testimony upon which this opinion is founded it does not prove to be very satisfactory.

Two insects were sent to Prof. C. V. Riley for identification in October, 1884, as recorded in Insect Life, volume 1, 1888, page 58. They came from W. L. Jones, of Atlanta, Ga., who stated that the larger one, identified as a nymph of *Anax junius*, was sent to him by a gentleman who stated that "it fastens on the carp fish and finally kills it." Accepting all this as true, we must acknowledge that the evidence is rather indirect and roundabout. No details are given; we are told nothing as to how or when or where; and it is not even stated whether the fish was eaten after being killed, or whether more than one fish was destroyed in this manner.

Another so-called proof has been widely copied by both entomologists and fish-culturists and appeared even in the Cambridge Natural History (Insects, 1901, pt. 1, p. 425). It was originally published in the Hungarian Rovartani Lapok for December, 1884, and consisted of a statement by L. Birò that in a pond belonging to the piscicultural establishment of M. le Comte Palffy at Szomolony, Hungary, only 54 small fish could be found in September, although 50,000 had been placed there the previous spring, but there were present an enormous number of Libellulid larvæ, species not determined. Hence the nymphs must have eaten the fish. The simple facts, however, that the fish were gone and the nymphs were present could hardly be accepted as scientific proof that the latter ate all of the former or any part of them. There are too many other causes which might have removed the fish. It was not even determined to what species the nymphs belonged, none of them were seen eating fish, and no stomachs were examined for fish remains. Then, too, the nymphs found in September, if they were Libellulids, were hatched from eggs laid during that summer and could not have been large enough to eat any fish.

James G. Needham has two records of nymphs eating fish: In Aquatic Insects in the Adirondacks (Needham and Betten, 1901, p. 474) he states that "nymphs of the species described below as *Cordulegaster maculatus* supposition" captured and ate young trout as long as themselves at Saranac Inn, when the trout were placed in their cage. In Aquatic Insects in New York State (1903, pt. 2, p. 213) he says that the nymphs of *Æschna constricta* eat a few trout fry, but he does not tell how this was proved unless his statement on page 212, "I demonstrated this at Saranac Inn by confining them together in a breeding cage" is understood to apply to Æschna as well as to Cordulegaster. That is no proof, however, that trout constitute any part of the regular diet of either nymph mentioned, or of any other nymph.

Warren (1915) found that the nymphs of *Pantala flavescens* would eat practically anything he gave them, even earth worms and chicken lice, but one would hardly care to draw any argument from this fact. When confined together in a besieged fortress or town human beings have been known to eat horses, dogs, or even one another. A nymph must be observed actually eating fish under natural conditions, or fish remains must be found in its stomach when captured, before anything can be really "demonstrated" with reference to its normal diet.

For this reason such pictures as figure 232 on page 389 of The Life of Inland Waters, by Needham and Lloyd (1916), are likely to be very misleading. The authors were there discussing the forage problem in connection with fish culture, and introduced this picture of the nymph of *Anax junius* devouring a small sunfish without a word of comment or explanation. It is evidently a photograph and must have been taken under either natural or artificial conditions. If the conditions were natural, we have a perfect right to know it, because it would add greatly to the value of the picture; but if the conditions were artificial, the picture never should have been published. In either event it is misleading unless fully explained, because it gives the prospective fish breeder the idea that all dragonfly nymphs eat small fish whenever they get a chance. The ordinary individual will comprehend the words "nymph" and "dragonfly," but the specific name, *Anax junius*, will mean nothing to him. He will keep the picture and its implied testimony constantly in mind during his subsequent fish breeding, and it will require long-continued and patient efforts to correct its influence. It is unfortunate that this was not recognized by the authors of a book so admirably designed and executed in its general features.

All the ponds of series D usually contain both Anax and Æschna nymphs, and several of them contain young fishes. When the ponds are drawn, as is done for each of them twice a year and sometimes oftener, the young fish and the nymphs, as well as all the other denizens of the pond, are brought into close contact. At such times crayfish, Dytiscus larvæ, and the like have been repeatedly observed catching and eating small fish, but no dragonfly nymph has been thus far seen attacking a fish. There is always an abundance of other food for them, and they evidently prefer it. In further proof of this 18 Anax and Æschna nymphs were taken from ponds 7 and 9 on July 6, 1916, when they had attained their maximum size. Both ponds at that time contained an abundance of small fish, but no fish remains could be found in the alimentary canal of the nymphs.

Hence when an Anax or Æschna nymph does prey upon fish it may well be because of a scarcity of other food. In evidence of this, Warren (1915, p. 35) has recorded a very interesting experiment. He placed 69 nymphs of *Pantala flavescens* and one of *Anax junius* in a small aquarium and gave them no food except one young fish. At the end of a week there were left 7 Pantala nymphs, the Anax nymph, and the little fish. As long as other food was present, therefore, the fish remained untouched.

Furthermore, Warren examined the contents of the alimentary canal of 253 Anax and Pantala nymphs and found fish in only one of them. (See p. 207.) Even there the remains were so doubtful that he placed a question mark after his identification of them. In a series of experiments made "with the view of finding out how far the food range of the nymphs extended among the aquatic forms of life," he placed various aquatic animals in the breeding jars and allowed the nymphs to eat them at their leisure. Among the forms thus eaten were several kinds of fish, which were common in the localities from whence the nymphs were obtained. Under natural conditions when other food was abundant the fish were not touched, but when brought into the laboratory and deprived of other food the nymphs ate the fish freely.

Garman (1917, p. 441) gave as one of the foods known to be eaten by damselfly nymphs very young fish. No authority was given for this statement, and inquiry has revealed that it was a mistake. We thus see that practically all the positive evidence shows that when an Anax or Æschna nymph does eat a young fish it is because of a scarcity of other food. Even if they do eat them occasionally they also eat enough Dytiscus larvæ, adult Corixas, Cypris, and crayfish to more than offset this. We must remember that it is only with reference to a very few of the largest species that any claims are made—2 dragonflies out of the 27 on the present list. The other 25 and all of the damselflies are admitted to be perfectly harmless so far as young fish are concerned.

AMOUNT OF FOOD CONSUMED.—The nymphs are not only predatory and omnivorous, but they may fairly be called voracious. They gorge themselves to the full extent of their capacity, and the distended gizzard with its dark contents is often visible through the skin and always stands out prominently when the thorax is opened. Usually also the intestine behind the gizzard is filled out into a plump cylinder for 4 or 5 mm. with finely ground indigestible material, such as the mandibles of insect larvæ, fragments of snail shells, broken elytra, etc.

There is a great difference in the amount of food consumed according to the condition of the nymph. Just after a molt the nymph is light in color, yellowish or greenish, and shows a characteristic color pattern very distinctly. As development progresses toward the next molt the color pattern gradually disappears, and the nymph becomes darker and darker until, in *L. luctuosa* and *E. simplicicollis*, it turns to a uniform dark brown.

The nymph eats voraciously as long as it remains light colored; while the color pattern is disappearing the amount eaten also diminishes, and after it has turned brown the nymph's gizzard contains little if any food. All the nymphs whose gizzards were empty were dark-colored, but the intestine usually contained indigestible débris from food previously eaten. One very dark nymph of *L. luctuosa* contained only a single tiny *Cypris inequivala*, another had but one Ceratopogon larva, while a third yielded two Ischnura nymphs with nothing in the intestine. Similarly two dark-colored nymphs of Anax had each eaten but one Ischnura nymph, and the intestines were empty. A dark nymph of *E. simplicicollis* contained only half a dozen short algal filaments with nothing in the intestine. This condition is particularly true of nymphs as they approach their final transformation, when they apparently fast for quite a long period before crawling out of the water. Hence we conclude that an empty digestive tube is one of the essential prerequisites for the great change which then takes place.

Warren (1915, p. 8) has given the lengths of the various instars, meaning by that the periods between molts, during the entire nymphal life of four specimens of *Pantala flavescens*. These periods are about the same length for the first 9 or 10 molts and then increase greatly the last two molts. The final period, corresponding to the pupal stage in insects which have a complete metamorphosis, lasted for a month, while the first nine molts were only five or six days each. He did not record the periods of fasting, but it is probable that these nymphs ate very little during the last week before transformation.

Balfour-Brown (1909, p. 270) similarly found that the periods between molts tend to lengthen as the nymph grows larger. In some of his damselflies there were nearly two months in the last period; in such cases the fast preceding transformation would also be lengthened.

Besides these fasts which accompany the various molts and the one which precedes the final emergence, the nymph is able to go without food for long intervals when necessary and apparently suffer no injury. It is doubtful, however, if a nymph could transform when the fast preceding emergence was considerably lengthened. It is quite possible that some of the failures to fully emerge from the nymph skin (p. 222) may be caused by an insufficiency of food.

Food of Hawaiian Nymphs.—Warren examined the contents of the alimentary canal of 253 Anax and Pantala nymphs captured in the vicinity of Honolulu, Hawaii, and it is interesting to compare his results with those recorded for Fairport. (See table, p. 201.)

Food Found in Alimentary Canal of 253 Odonate Nymphs from Honolulu, Hawaii, Examined by A. Warren.

Mollusca: Spiral shells	14	Ants and bees:	
Beetles: Dytiscidæ	16	Pheidole megacephala (Myrmicidæ)	2
Flies:		Ants, undetermined species	11
Chironomid larvæ	168	Dragonflies: Pantala flavescens, nymphs	6
Chironomid adults	4	Crustacea:	
Mosquito larvæ and pupæ	12	Cypris, sp	108
Mosquito adult	1	Shrimps, sp	3
Dolichopodid fly	1	Protozoa: Euglena, sp	30
Adult fly, undetermined	1	Worms: Nereis, sp	1
Bugs:		Amphibians: Tadpoles	8
Merragata hebroides (Næogeidæ)	1	Fish: Top minnow (?)	1
Microvelia vagans (Veliidæ)	2		

The first thing to be noticed is the general similarity in the food. The Hawaiian nymphs ate mollusks, beetles, flies, bugs, crustacea, odonates, and protozoa, the same as the Fairport nymphs. Many of the food species were different, as would naturally be expected, but they belong to the same families and sometimes to the same genera. Unlike the nymphs at Fairport, those at Honolulu ate bees, ants, and adult Chironomids, mosquitoes, and flies. These land insects undoubtedly dropped into the water before they were captured, and Warren has suggested that since the Hawaiian streams and pools contain but few aquatic insects, while the dragonfly nymphs are numerous in many localities, the latter must obtain a part of their food from land insects that fall into the water. This idea induced him to try them with all kinds of land insects, and he found they would eat anything he offered. (See p. 206.)

Tadpoles also appear in their diet, probably due to the scarcity of insect food just mentioned and also to the fact that the frogs and dragonflies are compelled to breed in restricted bodies of water, so that they are brought into close contact. Another result of the scarcity of insect food is that the majority of the nymphs fed upon a single Chironomid species, *Chironomus hawaiiensis*, and upon the crustacean genus Cypris. If the food had been more plentiful there would have been a greater variety in the diet. Consequently the extreme variety in the food of the Fairport nymphs is a good indication of the richness of the food supply.

FOOD OF NYMPHS FROM ITHICA, N. Y.—A table has been made out by Miss Lyon (1915) showing the food of 36 nymphs, distributed among 3 Æschnid species, 2 Gomphids, 4 Libellulids, and 4 damselflies. Cascadilla Creek, from which the nymphs were obtained, flows along the southern border of the Cornell University campus at Ithaca. The nymphs were collected at intervals from November to July, thus covering nine months of the year.

For the sake of convenience, her figures have been reduced to the same method of treatment as used in the statement on page 201.

FOOD FOUND IN ALIMENTARY CANAL OF 36 ODONATE NYMPHS FROM CASCADILLA CREEK, ITHACA, N. Y., EXAMINED BY M. B. LYON.

Mollusca: Physa, partly digested	1	Crustacea—Continued.	
Beetles: Dytiscus, sp	2	Cyclops, sp	2
Diptera:		Cypris, sp	2
Chironomid larvæ	24	Undetermined	1
Mosquito larvæ, Anopheles, sp	1	Odonata:	
Undetermined larva	1	Libellulid, sp., nymph	1
Hemiptera:		Ophiogomphus, sp., nymph	1
Corixa nymphs	6	Damselfly nymphs	9
Corixa adults	2	Arachnid:	
Ephemeridæ:		Mite	2
Heptagenia, sp	4	Macrobiotus, sp	1
Hexagenia, sp	1	Algæ:	
Cænis, sp	1	Diatoms	5
Undetermined mayflies	2	Closterium, sp	3
Crustacea:		Œdogonium, sp	1
Hayalella, sp	5		
Diaptomus, sp	2		

Miss Lyon's investigations showed that while Chironomids, mayflies, and odonates were eaten voraciously throughout the year, the crustacea and Hemiptera were con-

fined to the warmer months, when they are present in greater numbers. The abundance of crustacea in the Fairport list will thus depend somewhat upon the fact that all the nymphs were examined during the months of July and August.

CONCLUSIONS.—Comparing the three food lists here presented from widely separated localities, it would seem that odonate nymphs eat very much the same food everywhere. They feed largely upon insects and are able to confine themselves practically to a single species that happens to be abundant, as in Hawaii, or they may extend their diet to include a rich variety of genera and species, as in the other two lists. In her text notes Miss Lyon enumerates 11 species that could be identified amongst the Chironomid larvæ, with the probability that still others were represented in the unidentified material.

Judging from the lists, odonate nymphs do not devour many mosquito larvæ or pupæ, although Warren (1915) was firmly convinced that the Hawaiian nymph was a great destroyer of mosquitoes, in spite of the unfavorable showing of his list. He even fed some of his nymphs with mosquito larvæ and adults. One Pantala nymph ate during a single night 40 imagos of *Stegomyia scutellaris* that had been stunned with cyanide fumes and placed in the aquarium with the nymph. Another Pantala nymph ate 75 full-grown mosquito larvæ within 12 hours. But here, as in the eating of the fish, no convincing argument can be drawn from what is fed to a nymph when no other food is available.

The food of the odonate nymphs is by no means confined to insects, however; they also eat quantities of crustacea and mollusks and may include protozoa, algæ, and even vertebrates in their diet. In fact, the nymph seems capable of accommodating itself wonderfully well to its environment and can seemingly thrive upon whatever form of food happens to be available. Consequently if the nymphs are introduced into a fishpond, no special food will need to be provided for them. If the pond is stocked with the usual insect larvæ, crustacea, etc., whatever the species may be, the nymphs will quickly adapt themselves to them.

ENEMIES OF ODONATE NYMPHS.

1. FISH.—A full discussion of nymphs as food for fishes is given on page 225.

2. LARGER NYMPHS.—The proportion in which the smaller nymphs are destroyed by the larger ones is well shown in the table and statements already given.

About 20 per cent of the food of Anax nymphs and 10 per cent of the food of the nymphs of *L. luctuosa* consist of other nymphs smaller than themselves. In general, the nymphs that are eaten belong to a different genus, but the large nymphs are cannibalistic as well as rapacious and sometimes eat others of their own species. This is not as likely to occur, because all the nymphs of a given species develop at about the same time and are consequently nearer the same size. But they always vary more or less in their rapidity of growth, so that some are larger than others, and even if two were of the same size it would not be safe to keep them together unless plenty of suitable food were provided for them. If they once became real hungry, they would fight it out and the stronger would devour the weaker. To protect themselves against one another, as well as against all their enemies, the Gomphid nymphs habitually burrow in the mud or débris of the bottom; *L. luctuosa* and the heavier Libellulids sprawl

amongst the rubbish, while Erythemis, Celithemis, Tramea, etc., and all the damselfly nymphs hide in the matted vegetation. Such lurking places also serve as admirable ambushes whence to secure their prey.

3. DIVING BEETLES, WATER SCORPIONS, AND AQUATIC HEMIPTERA.—These retaliate by eating the nymphs before they are large enough to defend themselves. An adult Dytiscus beetle was seen in pond 7 eating a small Erythemis nymph, which would partly compensate for the beetle larvæ of the same species that are found in the table on page 201. Dr. Muttkowski has observed both Dytiscus and Zaitha feeding upon nymphs and noted that after capturing the nymph they invariably stick their beak first into its head. Garman (1917, p. 441) has recorded that "among aquatic Hemiptera the genera Ranatra, Belostoma, and Notonecta, and probably others feed upon damselfly nymphs." The fact that the water boatman, Notonecta, attacks the nymphs of dragonflies was also recorded by W. J. Lucas (1908, p. 16).

4. FRESH-WATER HYDRA.—Another enemy of the nymph is found in the common hydra; the green species, *H. viridis*, does not probably reach a size sufficiently large to overcome even a newly hatched nymph, but the brown species, *H. fusca*, can and does eat small nymphs. Two leaves of *Potamogeton illinoiensis*, which contained a large number of Enallagma eggs that were just hatching, were brought into the laboratory August 11, 1917, and placed in a small aquarium. On going over them with a hand lens to remove the nymphs already hatched, a large brown hydra was found eating one of the tiny nymphs. It was attached to the under surface of the leaf, nearly in the center of a large cluster of the Enallagma eggs, and could reach many of the nymphs with its tentacles as they emerged. If this species of hydra became at all plentiful in a fishpond it might kill a large number of the young nymphs.

5. NEMATODES.—Good-sized specimens were found in the stomachs of several nymphs of both Anax and *L. luctuosa*, and Needham (1898, p. 86) found the intestine of a nymph parasitized by large Gregarines a millimeter in length. An Enallagma nymph examined July 27, 1917, contained a dozen large Gregarines, and several others contained one or two apiece. These intestinal parasites probably never become numerous enough to actually kill their host, but their presence may weaken the nymph and make it more susceptible to its other enemies.

6. PARASITIC MITES AND FLIES.—Some of the Ischnura and Enallagma nymphs were found infested with small mites between the wing pads and around the bases of the legs; 10 of these were taken from a single Ischnura nymph.

Mrs. Aaron (Lamborn, 1890, p. 50) mentioned another small red mite "which skims rapidly over the water in search of an Odonat egg, upon which it either deposits an egg or excavates it for immediate nourishment." She also saw one of the parasitic Diptera ovipositing on the egg of Diplax. In these two cases, of course, the larvæ of the mite and the fly when they hatch feed upon the dragonfly's egg.

Needham (1903) reported that many hymenopterous parasites prey upon the eggs of Lestes, which are inserted in plant tissues above the water line, where they are exposed to such attacks. He succeeded in rearing three species of the parasite, belonging to different genera.

Brandt (1869) similarly reported rearing another parasite, *Polynema ovulorum*, from the eggs of Agrion (Calopteryx), and added that half the eggs were sometimes destroyed in this way.

7. ALGÆ, FUNGI, AND VORTICELLIDS.—"The Confervoid alga, Œdogonium, is often found growing upon the larva of *Æschna brevistyla*. I found by means of sections that the Œdogonium does not penetrate the cuticle of the larva, but simply grows on it as it grows on everything else in such places. On one larva of Æschna there were no less than 3 species of Œdogonium, 15 species of Diatoms, and a large number of Vorticella." (Tillyard, 1917, p. 332.) Œdogonium is very common in several of the ponds at Fairport and is found growing over many of the pond contents, including nymphs, but it appears to do them no injury further than to impede their movements slightly.

Miss Lyon (1915, p. 5) published a table giving the Diatoms, green and blue-green algæ, the protozoa, and the epizoa found growing upon the nymphs of Cascadilla Creek She noted the similarity between these species and those of the mud and water plants in the immediate vicinity. She concluded that the relationship between the two was simply a natural one, resulting from the proximity of the various forms, and not one of symbiosis, as Kammerer and others would have us believe.

Similarly a Saprolegnious fungus frequently attacks damselfly nymphs, especially if they are enfeebled from any cause. This fungus is related to the one attacking young fishes and often causes the death of the nymph. (Garman, 1917, p. 442.)

8. BIRDS.—Needham has recorded dragonfly nymphs as found in considerable numbers in the stomachs of herons (1898, p. 85). McAtee (1912) also recorded nymphs as forming part of the food of the horned grebe, *Colymbus auritus*. But herons and grebes and their kin are deadly enemies of fish, and hence should always be kept away from fishponds. Under natural conditions, however, they might well consume a considerable quantity of nymphs.

9. REPTILES.—Martin (1886, p. 232) said with reference to the Odonata of the Département de l'Indre in France:

> The eggs, larvæ, and nymphs are the prey of several fishes, snakes, newts, Coleoptera, aquatic Hemiptera, and of some diving birds. Sometimes the destruction is on a considerable scale, and one may notice the dragonflies of some piece of water diminish gradually in numbers, while the animals that prey on them increase, so that a species may for a time entirely disappear in a particular spot, owing to the attacks of some enemy that has been specially prosperous and also eager in their pursuit.

Baker (1906, pp. 231, 232) in his study of The Relation of Mollusks to Fish in Oneida Lake found numerous dragonfly nymphs in the stomachs of painted terrapins, *Chrysemys picta*.

None of the terrapin at Fairport were examined for the food they had eaten, but they may fairly be reckoned among the enemies of the nymphs.

Ordinarily the dragonfly nymph is able to hold its own in spite of its enemies, and it requires conditions exceptionally adverse to the nymph and exceptionally favorable to its foes before there is any danger of the extermination of the nymphs.

FOOD OF ODONATE IMAGOS.

There are several things which make it difficult to obtain specific lists of the food of the imagos similar to those presented for the nymphs.

A considerable portion of the animals eaten by the nymphs, such as snails, entomostraca, beetles, hemiptera, and the like, are inclosed in hard shells or elytra, which persist inside the digestive canal of the nymph and are easily recognized. The food

of the imagos, however, consists chiefly of soft-bodied insects, destitute of elytra, or of insects from which the harder parts, if present, are carefully rejected. Consequently the only things that can be recognized with any certainty in the contents of the imago's digestive canal are an occasional mandible or maxilla, portions of the wings of various insects, legs and antennæ, scales of butterflies and moths, hairs, and claws. The accurate identification of such minutiæ is a painstaking and laborious task, and the frequency with which the species or even the genus must be left undetermined is not surprising.

Again, the nymph swallows much of its food whole or at least in large fragments, so that the relation of the various parts remains undisturbed. The imago, on the other hand, believes in thoroughly masticating its food, and every mouthful is chewed into fine fragments before being swallowed. At the same time such parts as the wings and legs, which would be of great value for identification, and even the harder tissues of the body, are carefully rejected. Occasionally fragments of a wing or elytron are sometimes included, but they are usually badly torn and often lack the very part that is wanted. The imago is particularly fond of teneral insects, whose chitin has not yet hardened, and whose pigment markings have not been developed. Such insects, after being chewed and swallowed, form an indistinguishable mass in which there is very little hope of finding anything that can be identified.

A third difficulty is found in the fact that, although the digestion of the nymph's food is comparatively slow and the large fragments are recognizable for some time after they have been swallowed, the food of the imago, on the other hand, is digested with exceptional rapidity and must be examined as soon as it is swallowed, if anything definite is to be hoped for. Even the short space of time between the insertion of the insect into a cyanide bottle and its subsequent death is sufficient to materially affect the contents of the alimentary canal, and the changes apparently continue a short time after the insect's death. To obviate this, good results were obtained by making an incision in the thorax and abdomen, and then plunging the imago into 95 per cent alcohol as soon as it was taken from the net. All the examinations of the alimentary canal here tabulated were made in this way.

In view of these difficulties the most feasible method of determining the food of the imago is to watch it while feeding and capture it with enough of its food still uneaten to render identification possible. That this method has proved very satisfactory is shown by the frequency with which it appears in the following statements. In addition, all the available American records have been included, with acknowledgment of their source.

FOOD OF GOMPHID IMAGOS, FAIRPORT, IOWA, 1916.

Gomphus fraternus:

Diptera—House fly, *Musca domestica*.....Captured while eating.
Trichoptera—Caddisfly, undetermined .....In alimentary canal.
Odonata—
Erythemis simplicicollis.....Needham and Hart, 1901, p. 64.
Libellula luctuosa.....Captured while eating.
Argia mœsta putrida..... Do.
Teneral dragonflies.....In alimentary canal.

FOOD OF GOMPHID IMAGOS, FAIRPORT, IOWA, 1916—Continued.

Gomphus vastus:
- Diptera—House fly, *Musca domestica*.....Seen picking from window screen.
- Trichoptera—
  - Caddisfly, undetermined.....In alimentary canal.
  - Caddisfly, *Macronema zebratum*.....Walsh, 1862, p. 391.
- Ephemeridæ—Mayfly, *Hexagenia*, sp.....Captured while eating.
- Odonata—
  - *Libellula luctuosa*..... Do.
  - *Leucorrhinia intacta*..... Do.
  - *Argia mœsta putrida*..... Do.
  - Libellulidæ.....Needham and Hart, 1901, p. 21.
  - Dragonfly tenerals.....In alimentary canal.

Dromogomphus spoliatus:
- Lepidoptera—*Pieris rapæ*.....Williamson, 1901, p. 119.
- Odonata—
  - *Hetærina americana*..... Do.
  - *Argia mœsta putrida*..... Do.

FOOD OF ÆSCHNID IMAGOS, FAIRPORT, IOWA, 1916.

Anax junius:
- Diptera—
  - Mosquito, *Culex*, sp.....Taken from mouth.
  - Black fly. *Simulium*, sp.....In alimentary canal.
  - Midge, *Chironomus*, sp.....Captured while eating.
  - Midge, *Ceratopogon*, sp.....In alimentary canal.
  - Syrphid fly.....Captured while eating.
  - Undetermined flies.....In alimentary canal.
- Ephemeridæ—
  - Mayfly, *Calliabetes*, sp.....Captured while eating.
  - Mayfly, *Hexagenia*, sp..... Do.
- Trichoptera—Caddisfly, undetermined.....In alimentary canal.
- Lepidoptera—
  - Butterfly, undetermined.....Scales in alimentary canal.
  - Moth, Tortricidae.....Captured while eating.
  - Butterfly, *Ancyloxypha*, sp..... Do.
- Odonata—
  - *Leucorrhinia intacta* ♂..... Do.
  - *Erythemis simplicicollis* ♀..... Do.
  - *Argia mœsta putrida* ♂..... Do.
  - Damselflies, undetermined.....In alimentary canal.

Æschna constricta:
- Diptera—
  - House fly, *Musca domestica*.....Seen picking off screen door.
  - Mosquito, *Culex*, sp.....Taken from mouth.

Æschna brevistyla:
- Diptera—
  - Mosquitoes.....Tillyard, 1917, p. 328.
  - Gnats..... Do.

FOOD OF LIBELLULID IMAGOS, FAIRPORT, IOWA, 1916.

Leucorrhinia intacta:
- Diptera—
  - House fly, *Musca domestica*.....Seen picking off window screen.
  - Midge, *Chironomus*, sp.....In alimentary canal.
  - Muscid fly, *Sarcophaga*, sp.....Captured while eating.

FOOD OF LIBELLULID IMAGOS, FAIRPORT, IOWA, 1916—Continued.

Leucorrhinia intacta—Continued.
- Lepidoptera—
  - Butterfly, undetermined.....Scales in alimentary canal.
  - Butterfly, *Lycaena comyntas*.....Captured while eating.
- Ephemeridæ—Mayfly, *Calliabetes*, sp..... Do.
- Odonata—
  - *Enallagma civile* ♂..... Do.
  - *Enallagma hageni* ♂..... Do.
  - Tenerals, undetermined.....In alimentary canal.

Libellula luctuosa:
- Diptera—
  - House fly, *Musca domestica*.....Taken from mouth.
  - Muscid fly.....In alimentary canal.
  - Midge, *Chironomus*, sp..... Do.
- Lepidoptera—
  - *Lycæna comyntas*.....Captured while eating.
  - Butterfly, undetermined.....Scales in alimentary canal.
  - Moth, Tortricidæ.....Captured while eating.
- Odonata—
  - *Ischnura verticalis*..... Do.
  - *Leucorrhinia intacta*.....Seen eating.
  - *Sympetrum*, sp.....In alimentary canal.
  - Tenerals, undetermined..... Do.
- Ephemeridæ—Mayfly, undetermined..... Do.

Erythemis simplicicollis:
- Diptera:
  - House fly, *Musca domestica*.....Seen picking off window screen.
  - Midge, *Chironomus*, sp.....In alimentary canal.
  - *Sarcophaga sarracenia*.....Captured while eating.
  - Tabanid fly, *Chrysops*.....Williamson, 1900, p. 326.
- Lepidoptera—
  - *Hæmatopsis gratavia*.....Captured while eating.
  - *Ancyloxcypha numitor*..... Do.
  - *Pamphila*, sp.....Williamson, 1900, p. 326.
  - *Pieris rapæ*.....Captured while eating.
- Ephemeridæ—Mayfly, undetermined.....In alimentary canal.
- Odonata—
  - *Erythemis simplicicollis*.....Captured while eating.
  - *Argia mæsta putrida*..... Do.
  - *Enallagma hageni*..... Do.
  - *Lestes vigilax*.....Williamson, 1900, p. 326.
  - *Argia violacea*..... Do.
  - *Lestes unguiculatus*.....Captured while eating.

Plathemis lydia:
- Diptera—House fly, *Musca domestica*.....Seen picking off window screen.
- Lepidoptera—*Ancyloxcypha numitor*.....Captured while eating.

Celithemis eponina:
- Diptera—Syrphid flies..... Do.

FOOD OF DAMSELFLY IMAGOS, FAIRPORT, IOWA, 1916.

Enallagma hageni:
- Diptera—
  - Midge, *Orthocladius*, sp.....Captured while eating.
  - Midge, *Corynoneura*, sp..... Do.
  - Midge, *Chironomus*, sp.....In alimentary canal.

FOOD OF DAMSELFLY IMAGOS, FAIRPORT, IOWA, 1916—Continued.

Enallagma hageni—Continued.
Diptera—Contiuued.
Dolichopodid fly.....Captured while eating.
Anthomyiid fly..... Do.
Syrphid fly..... Do.
Simulium vittatum.....Taken from mouth.
Undetermined flies.....In alimentary canal.
Palpomya, sp.....Captured while eating.
Nematocera, sp.....Garman, 1917, p. 445.
Lepidoptera—*Ancyloxcypha numitor*.....Captured while eating.
Odonata—
Ischnura verticalis..... Do.
Enallagma, sp. (dead).....Seen eating.
Ischnura verticalis:
Diptera—
Midge, *Orthocladius*, sp.....Captured while eating.
Grass-stem fly, Geomyzidae..... Do.
Midge, *Chironomus*, sp..... Do.
Undetermined..... Do.
Lepidoptera—Butterfly.....Garman, 1917, p. 445.
Ischnura kellicotti: Diptera—Undetermined.....Williamson, 1899, p. 280.
Lestes vigilax: Diptera, Nematocera.....Garman, 1917, p. 445.
Argia mœsta putrida:
Coleoptera—Beetle, *Berosus striatus*.....Captured while eating.
Ephemeridæ—
Mayfly—*Calliabetes*, sp..... Do.
Mayfly—*Hexagenia*, sp..... Do.
Hemiptera—Plant louse, *Aphis*, sp..... Do.
Diptera—Undetermined flies.....In alimentary canal.
Argia apicalis: Diptera—Nematocera.....Garman, 1917, p. 445.
Enallagma civile and *E. antennatum:* Diptera—Nematocera. Do.

GENERAL STATEMENT.—Williamson (1899, p. 235) has given one of the best general statements.

> The food of the imagos consists almost entirely of other insects, though some are known to occasionally eat the flesh of dead animals. Of the insects eaten Diptera are more preferred than any other order, though all soft-bodied insects seem to fall a prey to their ravenous appetites. Larger species eat their smaller relations. Leaf hoppers and other Hemiptera and Lepidoptera are consumed.

The above statements very strongly substantiate Williamson's statement that the Diptera form a favorite food. Every odonate species included in them, with one exception, has eaten Diptera of some sort. And, curiously enough, all we know about the food of this one exception, *Dromogomphus spoliatus*, is derived from Williamson himself. Some of the species, such as *Anax junius* and *Enallagma hageni*, show a decided preference for flies and midges. The statement that the larger species eat the smaller ones is also well verified, even among the damselflies.

Williamson also recorded on the same page that he once captured a dragonfly holding a large wasp in its mandibles. There were two wasps in Poulton's list of the prey of the Odonata (1906, p. 399), and honeybees were included in Campion's list (1914, p. 499). The English paper Field for March 21, 1908 (p. 486), mentioned a bee keeper in Australia who complained that the dragonfly destroyed more of his bees than any of the birds. None of these records were American, but they serve to indicate that our

American species may possibly eat more Hymenoptera than we are aware. Termites, winged ants, and cicadas are also interesting victims of the odonata which have been recorded in other parts of the world. A dragonfly is reported to have dug a cricket out of the ground and eaten it (Habit of a Dragonfly, editorial notes, Psyche, vol. 5, p. 364), but this is the only instance, so far as known, where odonates have eaten any of the Orthoptera.

SIZE OF PREY.—Perhaps the food of the damselflies is usually made up of smaller insects than that of the dragonflies, but the size of the prey is not always in proportion to the size of the imago that eats it. Æschna and Anax, two of our largest dragonflies, are among the most persistent eaters of gnats, midges, and mosquitoes, while one of the favorite foods of the damselfly, *Argia mœsta putrida*, is a black mayfly almost as large as itself. Like that of the nymphs, the appetite of the imago seems well-nigh insatiable, and no sooner is one insect devoured than another is caught. Stories of the amount eaten by some imago are told by nearly every observer, and the present author would add one more to the list. A male *A. m. putrida* was given eight black mayflies, one after the other, and he ate every one of them, simply throwing away the legs and wings; yet any two of them exceeded in bulk the damselfly's whole body, minus its wings and legs.

SOURCE OF FOOD SUPPLY.—The food is usually captured in greater or less proximity to the water, sometimes being picked off the very surface of the latter. However, the female dragonfly habitually hunts at a greater distance from the water than the male. The females of *Plathemis lydia* and *Perithemis domitia* are only rarely seen around the ponds. The females of other species come to the water for the purpose only of laying their eggs, while the males are constantly patrolling the surface of the ponds, as well as the banks in the immediate vicinity.

Even the males, however, do not obtain all their food near the water. Anax, Æschna, *Libellula pulchella*, Tramea, and Epicordulia make long foraging trips out into the surrounding country and are often found a considerable distance from any body of water. In this way they help to rid the countryside of some of its worst insect pests, especially flies, mosquitoes, gnats, and midges. Such foraging trips are made more often late in the afternoon, toward sunset, and sometimes after. The males, and occasionally a female, of many of the species around the ponds came regularly every evening to the laboratory building and hawked for food. They picked flies off the window screens and the sides of the building, they decimated the hordes of gnats and midges that swarmed in the waning sunshine, and sometimes they ascended high in the air in search of the tiny insects to be found there. Occasionally their hunting was prolonged after sunset, when the insects were particularly numerous. *Libellula luctuosa* was the most common of these visitors, but they also included Erythemis, Leucorrhinia, Plathemis, Tramea, Pantala, Anax, Æschna, and even *Gomphus vastus* and *G. fraternus*.

MIGRATION OF TENERALS.—As soon as possible after emerging the teneral imagos of *Libellula luctuosa* fly back onto the prairie, away from the ponds and the river. There they remain in the gullies and among the underbrush until they become ready for pairing and egg laying. A trip of a mile or two up some of the gullies leading back onto the prairie will reveal thousands of these tenerals roosting on the weeds and underbrush. Occasionally an imago of Erythemis, Leucorrhinia, some Gomphus species, or an Enallagma will be found with them. Usually there is no water within reach, but if

there happens to be a small brook at the bottom of the gully fully developed imagos of *Libellula pulchella* and Plathemis will be found, as is usual in such places. These hordes of tenerals are simply resting and feeding in comparative security until they become ready for the active duties of propagation. The time thus occupied is apparently about five or six days but is difficult to determine, because new tenerals are arriving and matured individuals are leaving all the time, and it is practically impossible to tell just how long any of them remain.

It is probably a similar retirement from the vicinity of the water during the interval between emergence and sexual activity that accounts for the disappearance of some of the Gomphus species. (See p. 188.)

The food obtained in these gullies and out on the prairie is of necessity somewhat different from that captured around the ponds, but still consists largely of flies, gnats, and mosquitoes, with an occasional lepidopter.

PERIODIC EATING.—Since most of their prey is captured while on the wing, when it is bright and sunny the imagos are eating much of the time, while in dull and cloudy weather they eat very little, if at all.

Microscopic examination of the digestive tract shows that the newly emerged tenerals do not eat anything for a day or two, until about the time their color pattern is fully formed. Probably the tenerals of *L. luctuosa* just mentioned take no food before reaching the gullies and the prairie. Other tenerals that remain near the ponds of course obtain their first food there.

Again, such an examination shows that, while the imago is voracious and often feeds all the time, we can still distinguish two periods of maximum eating, fairly well marked. Whatever is eaten during any day is all digested long before the next morning, so that imagos captured before leaving their roost in the morning will have nothing in their gizzards and very little in the intestine. Accordingly the first period of maximum eating comes in the forenoon, shortly after the imago leaves its roost, as soon as the insects which constitute its food begin to swarm. This is followed by a lull, or at least a diminution in the amount eaten, which lasts until well into the afternoon, and during this period they are occupied with mating and egg laying. The eating then increases again, and the second period of maximum feeding, which is more intensive than the first, comes toward sunset.

Of course, it will be understood that there is no intention of implying that imagos eat two meals a day, or anything of the sort. There are simply more of them feeding in the morning and late in the afternoon and more of them depositing their eggs through the middle of the day. Moreover, the gizzards of those captured at 9 or 10 a. m. and toward sunset are more apt to be well filled. They are thorough believers, however, in eating between meals, and are not restrained in their desires by any irksome rules of hygiene.

FOOD FOUND IN THE ALIMENTARY CANAL OF 218 IMAGOS OF PANTALA FLAVESCENS IN HAWAII.

Diptera:	
Midges, *Chironomus hawaiiensis*	1
Night mosquitoes, *Culex fatigans*	1
Day mosquitoes, *Stegomyia scutellaris*	1
Undetermined mosquitoes	3
Pomace flies, Drosophilidæ	3
Undetermined flies	140

FOOD FOUND IN THE ALIMENTARY CANAL OF 218 IMAGOS OF PANTALA FLAVESCENS IN HAWAII—Continued.

Coleoptera:	
Scarabæid beetle, *Psammodius*, sp	22
Bostrichid beetle, *Rhizopertha pusila*	1
Staphylinid beetle	31
Undetermined beetles	30
Hemiptera:	
Plant lice, Aphidæ	24
Water boatman, *Corixa blackburni*	4
Leaf hopper, *Perkinsiella saccharicida*	4
Leaf hopper, *Draeculacephala mollipes*	3
Leaf hopper, *Nesophrosyne perkinsi*	3
Chinch bugs, Lygæidæ	2
Lace bugs, *Teleonemia lantanæ*	4
Undetermined species	1
Hymenoptera:	
Apis, not the Honeybee	1
Parasite, *Chelonus blackburni*	1
Parasite, *Paranogrus optabilis*	1
Undetermined Hymenopterous parasites	3
Myrmicid ants, *Pheidole megacephala*	6
Undetermined ants	11
Lepidoptera:	
Tineid moth, *Cremastobombycia lantanella*	5
Undetermined forms	72
Odonata: Damselfly, *Agrion*, sp	1
Book lice: Psocidæ	8
Thysanoptera: *Thrips*, sp	9
Arachnida:	
Mites	1
Spiders	2

FOOD OF PANTALA FLAVESCENS IN HAWAII.—This statement is inserted here for several reasons. It is by far the most complete statement of the food of a single odonate species that has ever been published. This same species is one of those around the ponds at Fairport, and it is widely distributed throughout the United States. Hence a list of its food in Hawaii will give a good idea of the kind of insects it would be likely to eat elsewhere. It is also instructive to compare the Hawaiian foods with those eaten at Fairport. We notice that flies, beetles, and Lepidoptera make up the bulk of the food of this species in Hawaii. There are also present many kinds of Hemiptera or true bugs, especially plant lice, adult water boatmen, and leaf hoppers, some hymenopterous parasites, ants, and Thrips, a tiny insect which feeds upon the flowers and leaves of some plants.

In the Fairport list there is a much greater variety of both flies and Lepidoptera, but there are no beetles at all, and the only bug is the plant louse. Their place seems to be taken by the mayflies and caddisflies, which are lacking in the Hawaiian list.

ECONOMIC VALUE OF THESE FOODS.—The chief concern here is the effect upon the life of the fish produced by such wholesale and untiring destruction of the insects around the ponds, as is revealed in these food lists. In dealing with this problem certain considerations are forced upon the attention.

It will be urged, in the first place, as in the case of the nymphs, that the killing of so many adult Chironomids, Ephemerids, and Culicids seriously diminishes the number

of egg layers around the ponds, and thus affects the supply of fish food. Would it not be better to get rid of the dragonflies and allow these other insects to breed without hindrance? At first sight it seems as if the answer must be in the affirmative, but a little reflection makes it appear differently. If the nymphs of the dragonflies make as good food for the larger fish as the larvæ of these other insects make for the smaller fish, then it is as important for the dragonfly imago to survive and lay its eggs as for any of these other species. Larger fish will not thrive well on food suitable for fry, and if something is not provided for them they will eat one another. Bass, perch, sunfish, buffalofish, catfish, and crappies are well satisfied with the larvæ of mosquitoes, gnats, and flies for a while and will thrive on them. But the time soon comes when this food no longer satisfies them and they demand something larger. (See p. 225.)

The period during which the smaller larvæ prove sufficient varies considerably with the kind of fish, but they will all thrive better if the larger food is present in the pond, so that they can change to it gradually whenever they choose. It is definitely shown in another place (p. 228) that when the young fish reaches a length of about 25 mm. it begins to eat odonate nymphs. It takes some fish much longer to reach this length than it does others, and even in the same brood some fish grow faster than others. Hence the larger food must be present all the time to accommodate the different rates of growth.

Furthermore, actual observation shows that the presence of odonate nymphs and imagos does not necessarily diminish the supply of smaller fish food. The number of dragonflies has steadily increased around the Fairport ponds during the last five years, but at the same time the number of other insect larvæ and Entomostraca has increased apparently as much, so that conditions suitable for fish culture were never better than at the present time.

Again, whatever the kinds of fish, they must be successfully carried through the winter, and there must be enough food in the pond to keep them in good condition. By the time the pond freezes over most of the young fish have become large enough to demand good-sized food, and the larger they grow the more insistent will this demand become. Moreover, some of the animals which are included among this smaller food, such as the Entomostraca and several of the insect larvæ, are much less numerous during the winter. At other times of the year odonate nymphs furnish acceptable food for fish, and there is every reason to believe that they continue to do this through the winter, which is just the season when it is most needed. Only a few fish have been examined at Fairport during the winter, but the limited observations that have been made seem to support this idea. Twelve largemouth black bass, *Micropterus salmoides*, averaging 130 mm. in length and 18 bluegills, *Lepomis incisor*, averaging 107 mm. in length, from pond 1D, 19 of the same bass, 44 mm. in length, from pond 2D, and 12 bass, 185 mm. in length, from pond 3D, were examined February 15–17, 1917. Of these 61 fish, the stomachs of 46 were found to be either entirely empty or so near it that the dèbris present was indistinguishable. The food of four of the remaining fish, two bass and two bluegills, consisted entirely of odonate nymphs, and they were probably identified in the dèbris of the stomachs of two other bluegills. This record is too meager to possess much value beside the ample proof elsewhere presented (p. 225), but it does show that the fish will eat nymphs during the winter, as suggested.

As a third consideration, although nature's equilibrium must be made subservient to man's designs and control in intensive pondfish culture, it is still true that, other

things being equal, the more natural the pond and its surroundings can be kept the greater will be the likelihood of success. Artificial conditions are usually difficult of maintenance and should be established only when necessary. The dragonflies and nymphs constitute an important factor in the environment of the ordinary fishpond, and even their voracious appetite is accounted for in nature's methods of equalizing things. This is shown by the fact that they eat one another with as much avidity and as little compunction as is shown toward any other kind of food. Their removal, therefore, would considerably disturb the balance and impose artificial conditions that might be difficult to handle. The station is having much success in rearing various kinds of fish, among which are the buffalofish and channel catfish, whose breeding is admitted to be very difficult. Some of this success may well be due to the maintenance of a natural equilibrium in the animal and vegetable life of the fishponds.

Tillyard (1917, p. 335) has suggested that such an equilibrium may be advantageously modified without in the least impairing its value:

> Not only are the dragonflies the most powerful determining factor in preserving the balance of insect life in ponds, rivers, lakes, and their surroundings, but they do most certainly make war upon the flies, mosquitoes, and gnats, which we all desire to see exterminated. I believe that a successful checking of the mosquito pest in the ornamental waters of parks and gardens could be readily obtained by the introduction of species whose larvæ, as well as the imagines, would prey upon the nuisance. If a successful planting of a colony of dragonflies in such a position were to be tried, the species selected might also be chosen for its coloring, and thus add a new note of interest to the locality. The glorious red *Orthetrum villosovittatum* has now become well established in the Botanical Gardens at Brisbane (Australia) and certainly adds a vivid touch of color to its lovely surroundings.

The suggestions herein contained naturally lead up to the next consideration, which seems worthy of a separate heading.

ODONATES AS DESTROYERS OF MOSQUITOES, GNATS, AND FLIES.—The quiet waters of an artificial fishpond furnish admirable conditions for the breeding of mosquitoes, and the screens at their outlets afford similar breeding places for gnats. The mosquitoes may include, in the proper geographical localities, both *Anopheles* and *Stegomyia*, the carriers of malaria and yellow fever. Obviously in a fishpond these pests can not be kept down by treatment with an oil film, neither can they be allowed to breed unhindered. The consumption of the larvæ by young fish might furnish an important check, but in intensive fish culture very little attention can be paid to the attitude of the fish toward mosquito larvæ.

Of the nine ponds in series D at Fairport six were stocked in the spring with fish that would not eat mosquito larvæ. In some of these ponds broods of young fish were raised later in the season, but previous to their appearance the mosquitoes could breed unhindered by the fish. In at least two of the six ponds no young fish were raised, or they were removed before they had time to produce any effect upon insect larvæ. Here, therefore, so far as the fish were concerned, the mosquitoes might hold undisturbed sway during the entire season.

No fish eats adult mosquitoes; when the pupæ are once safely transformed into imagos they are in no danger of further molestation from that source. Hence if the fishpond is to be prevented from serving as a breeding ground for these obnoxious pests some other check must be provided. Mention has already been made of the fact that the odonate nymph eats mosquito larvæ and pupæ, and the adult dragonfly is an even greater enemy of the mosquito imago. Tillyard (1917, p. 328) stated that he

had repeatedly seen Æschninæ feeding upon gnats and mosquitoes in the late afternoon. A specimen of *Telephlebia godeffroyi* was once observed flying round and round a small bush at about 7 o'clock in the evening, when the mosquitoes were particularly troublesome. After 10 minutes it was captured and its mouth was found so full of mosquitoes that it was unable to shut it.

There must have been over a hundred all tightly packed into a black mass. I have frequently seen *Æschna brevistyla* take gnats and mosquitoes in dozens while on the wing. There can be no doubt that those dragonflies which fly late in the day are of great value in checking the spread of the various objectionable Culicidæ that are on the wing from just before sundown.

Needham and Hart (1901, p. 29) make a similar statement: "The usefulness of the Æschnidæ imagos, especially *Anax junius*, on account of the enormous quantities of pestiferous gnats and mosquitoes which they destroy, puts them among the particular friends of mankind." The Anax imago hunts after sunset, continues flying as long as there is light enough to render its prey visible, and is probably the last dragonfly to go to roost. In its search for food it frequently mounts high up in the air, sometimes disappearing from sight in this manner. The male of *L. luctuosa* has similar habits, but does not carry them quite as far.

Dr. Lamborn (1890) made an investigation to determine the practicability of the artificial use of dragonflies for destroying mosquitoes and flies. While nothing very practical in the way of artificial breeding was suggested, the investigation emphasized the immense service rendered by dragonflies under natural conditions in keeping down these pests.

The members of the family Simuliidæ are even greater pests than the mosquitoes. One species, *Simulium pecuarum*, is known as the southern buffalo gnat and causes the death of many mules and other domestic animals throughout the Mississippi Valley. Another species, *Simulium meridionale*, is known as the turkey gnat, and it also infests all kinds of domestic animals, especially the turkey. "Many cases of the death of human beings from the bites of buffalo gnats have been reported, and some of them seem well authenticated" (Needham, 1903, pt. 2, p. 343). However this may be, all the species are bloodsuckers and intolerable pests, and anything which eats them is thereby distinctly beneficial.

Consequently, even if it could be proved that nymphs had a fondness for young fish, and that they were not themselves of any value as fish food, it would still seem to the present author that the incessant warfare which they wage against gnats and mosquitoes ought to earn them a cordial welcome to every fishpond. It would certainly be better for some of the fish to die than for the pond to become a breeding place for bloodsuckers and disease carriers. And if, in addition to this service, it can be shown, as has been attempted, not only that the nymphs are harmless to the fish as long as they can obtain other food (p. 206), but also that they themselves furnish one of the best of foods for the growing fish (p. 225), they become practically a necessity if fish breeding is to be carried on successfully.

Another positive benefit to mankind is the wholesale destruction of house flies by so many of the odonates. It will be noted that this disease carrier appears as an article of diet in nearly every one of the lists. Æschna is frequently captured while devouring flies on the screens and screen doors of dwelling houses and factories, and Anax has often been reported from similar localities. A list has already been given of those species which

came to the laboratory building (100 yards from pond 1D) and picked house flies, Mayflies, and the like off the window screens. In view of the present widespread movement against the house fly conducted by boards of health and hygienists everywhere in the United States, this fly-eating habit of the odonates ought to receive every encouragement.

In this connection also it is worth noting that Dr. G. D. Carpenter, during his investigation of the sleeping sickness in Africa, observed one species of damselfly and two species of dragonflies feeding upon the dreaded tsetse fly, the damselfly even picking them off the clothing of the collector. (Campion, 1914, pp. 498 and 500.)

Another record in this same paper and one by Poulton (1906, p. 399) credit the odonates with eating horseflies (Tabanidæ).

ENEMIES OF ODONATE IMAGOS.

Most authors state that the imagos do not suffer much from natural enemies except during the teneral period, and this appears to be true. But during this teneral period, which lasts for a varying length of time after their emergence from the nymph skin, they are so weak and limp that they fall an easy prey to even the humblest enemies.

1. ACCIDENTS.—A small percentage always fails to emerge properly, and in collecting exuviæ one will occasionally be found with the imago only partially emerged. Something prevented it from getting clear of the nymph skin, and it perished in the effort. Again, one or two of the wings may fail to expand properly after the imago has gotten safely out of the skin, and it is then unable to fly and soon perishes. Sometimes the teneral is forced to try its powers of flight too soon, and it falls into the water and drowns. The number of these accidents is probably larger than appears at first, for such drowned imagos easily disappear.

Rain sometimes catches the tenerals before they have become sufficiently hardened to withstand it. Kennedy (1917, p. 530) makes a note of this:

> With many western species the most serious cause of premature death among imagos seemed to be the occasional cold rains which come even in desert regions. On Satus Creek (Yakima County, Wash.) I have seen *Ophiogomphus severus* practically wiped out for the first day or two after a rain and regaining its numbers only after more had emerged.

In the Mississippi Valley a heavy thundershower will sometimes produce the same effect upon the tenerals, the rain fairly sweeping them off their perch and drowning them in the gutters.

Usually those which perish in these different ways, however, form but a small percentage when compared with the innumerable hosts that pass through the metamorphosis successfully.

2. BIRDS.—*Libellula luctuosa* emerges mostly in the early morning, and for a long time hundreds of teneral wings of this species, easily recognizable by their markings and varnished appearance, were found every forenoon lying on the ground and among the vegetation on the embankments of the ponds. At length the culprits were caught in the very act of seizing and devouring the imagos, and they proved to be English sparrows. They flocked to the embankments at daybreak and hunted through the herbage until they found a teneral; they then seized it, beat its wings off, and either swallowed it or carried it to their young. In this way they destroyed large numbers every day and kept it up as long as the species continued to emerge. When its wings are once hardened, the sparrow can no longer catch the imago, and it is thereafter free from this enemy.

This destruction by the English sparrows is local and apparently casual; in the summer of 1917 they did not destroy as many of the tenerals as in 1916. It seems to be largely a matter of chance; if they happen upon the tenerals at just the right time and get a good meal, they return again and again. The localities frequented by the tenerals are not the ones from which these sparrows are accustomed to get their food, however, and hence there is no systematic hunting for them.

Another bird that causes great destruction among the imagos is the red-winged blackbird. Several pairs of these birds nested about the ponds, and they were seen repeatedly catching the tenerals and eating them or feeding them to their young. A small stake projecting a few inches above the water in pond 2 was a favorite roosting place for one of the male redwings, and from the algæ surrounding this stake were picked up more than 100 teneral wings of *Libellula luctuosa*. During experiments with the large breeding cage mentioned elsewhere (p. 235) adult dragonflies of several species and of both sexes were caught and placed in the cage. Every effort was made to induce them to eat, to mate, and to lay their eggs, but to no avail. One of the chief hindrances was an old male redwing who made it his duty to visit the cage as soon as possible after the dragonflies were placed in it and to pick them off through the wires. In this way he would have them all caught and devoured within a short time.

Kennedy (1915, p. 343) found teneral damselflies and dragonflies in the stomachs of four yellow-headed and one red-winged blackbird which he examined. He also stated on the same page that he believed the yellow-headed blackbirds ate most of the teneral *Anax junius* at one of the ponds where he collected. Other species, such as *Erythemis simplicicollis*, *Æschna multicolor*, and *A. californica* escaped this peril of the birds by emerging late in the evening, so that by daylight the next morning their wings were hard enough to fly.

Both *E. simplicicollis* and *L. luctuosa* roost at night in the tall grass and other vegetation around the ponds, and when there is a rain in the night, or an exceptionally heavy dew, are sometimes so bedraggled in the early morning that they are caught by the birds.

In a later paper Kennedy (1917, p. 530) has noted that *Ophiogomphus morrisoni* at Donner Lake, Oreg., was seriously attacked by robins while emerging.

In the Canadian Entomologist, volume 5, 1873, p. 159, Mr. Gould, in a communication to the Entomological Society of London, said:

> I believe that the larger dragonflies are very liable to the attacks of birds, and have no doubt that the hobby and kestrel occasionally feed upon them; with regard to the small blue-bodied species (Agrionidæ) frequenting the sedgy bank of the Thames, I have seen smaller birds, sparrows, etc., capture and eat them before my eyes after having carefully nipped off the wings, which are not swallowed. This must take place to a considerable extent, as I have observed the towpath strewn with the rejected wings.

The hobby and the kestrel are English hawks, but Fisher (1893) has recorded the swallow-tailed kite, the sharp-shinned hawk, the red-shouldered hawk, the broad-winged hawk, the duck hawk, the sparrow hawk, and the pigeon hawk as feeding on dragonflies here in the United States.

Tillyard (1917, p. 330) has stated that kingfishers are wonderfully expert at catching dragonflies skimming close to the water. That may be true of the kingfishers of Australia and New Zealand, but it is doubtful if our own belted kingfisher of the eastern

United States ever eats them. Shrikes, cuckoos, and kingbirds, however, catch and eat the imagos, even after the wings of the latter have become fully hardened. Hence they are active enemies during the entire adult life of the dragonflies and cause considerable destruction.

3. LARGER IMAGOS.—The imagos of the larger species are great enemies of the smaller species; this is especially true of the gomphids, of Anax, and of Erythemis. All of these were observed eating teneral damselflies and sometimes teneral dragonflies, and these seem to be the favorite food of the female gomphids.

An editorial in Nature, volume 26, 1882, page 89, related a curious fact observed by Signor Stefanelli in regard to a dragonfly (*Æschna cyanea*) often met with near Florence. There were several nymphs of this species in a cistern of water. Some which were almost ready for transformation came out of the water a little way during the night, and attacked several teneral imagos which could not yet fly and voraciously devoured them. It was suggested that this singular practice may explain why one finds such a small number of *Æschna cyanea* in comparison with the number of nymphs. But this is more easily explained by the migration of the tenerals already described (p. 188), and we must regard such a practice as this as extremely exceptional rather than as an ordinary occurrence.

4. ANTS, SPIDERS, ROBBER FLIES, AND FROGS.—These also eat teneral dragonflies, and the spiders capture fully matured adults. Two tenerals of *L. luctuosa* were eaten alive by a colony of black ants on the banks of pond 4. The ants seized them on all sides with their mandibles and tore them in pieces, dragging off the fragments to their nest.

The webs of the common black and yellow spider, Argiope, are thickly scattered through the vegetation along the shores of the ponds, and from them the author secured many specimens of *Ischnura verticalis*, *Enallagma civile*, *E. hageni*, *Argia putrida*, and tenerals of *Sympetrum rubicundulum*, *L. luctuosa*, and *Erythemis simplicicollis*. Williamson (1899, p. 236) has recorded a similar experience in Indiana. A large water spider, common around the shores of the ponds, also catches teneral dragonflies on the grass stems at the edge of the water.

Williamson (1899, p. 235) noted a large robber fly carrying a teneral *Sympetrum rubicundulum*, which it had doubtless killed, and Dyche (1914, pp. 151 to 153) found dragonflies in the stomachs of several large bullfrogs.

The little cricket frog, *Acris gryllus*, is also a confirmed eater of damselfly imagos. His usual roosting place is upon the floating algæ at the surface of the water, where he watches for the damselflies when they come to deposit their eggs. When caught, the damselfly is much longer than the frog's body, but the latter swallows it slowly and keeps swallowing until it has entirely disappeared.

5. PARASITIC MITES AND FLIES.—Tillyard (1917, p. 331) made the following statement:

> Dragonflies whose larvæ live in still water are frequently found covered with the young of a species of small red mites (family Hydrachnidæ). The adult probably attacks the dragonfly at metamorphosis, placing either its eggs or viviparous young on the under side of the thorax, the bases of the wings and legs, or the abdomen, to which they are afterwards found clinging. In this way the dragonfly is used as a means of dispersal by the Arachnid, and the young mites are carried from one pond to another, where some of them drop off.

Ischnura and Enallagma among the damselflies and Leucorrhinia among the dragonflies seem particularly susceptible to these mites. Ten or a dozen of the young mites were found between the wing pads and around the bases of the legs on each of five Ischnura and seven Enallagma nymphs. Forty-four of them were taken from the ventral surface of the thorax of a single female imago of *Enallagma hageni* and 110 were removed from the ventral surface of the abdomen of a single male imago of *Leucorrhinia intacta*. Tillyard said that the young mites cling to the dragonfly without doing it any harm, but in this Leucorrhinia the considerable surface covered by the mites was badly discolored, being changed from black to a yellowish red. The points where each mite was attached were also somewhat swollen and deep red in color, so that the integument seemed to be honeycombed. So far as this particular specimen was concerned, the mites had been obtaining sustenance as well as transportation.

In the family of flies known as Asilidæ there are two genera, Promachus and Lophonotus, which have been seen to capture and eat dragonflies (Poulton, 1906, p. 342).

6. INTERNAL PARASITES.—The imagos are susceptible to intestinal parasites as well as the nymphs, and Selys-Longchamps (1850, p. 36) recorded the finding of a Filaria in the abdomen of a dragonfly which inflated it to such an extent as to hinder the insect's flight.

Ssinitzin (1907, p. 24) reported stages of a frog-lung fluke, *Pneumonœces variegatus*, free in the body cavity of both nymphs and adults of the damselfly *Agrion (Calopteryx) virgo*. By feeding experiments he was able to infect frogs with these forms, showing that the damselfly here serves as an intermediate host for the frog fluke.

7. SUNDEW AND PITCHER PLANTS.—An observation of Tillyard's (1917, p. 329) is worthy of mention here. He said that in Australia the giant sundew, *Drosera binata*, takes heavy toll of those damselflies which frequent the swamps and marshes. It is doubtful whether any of our North American sundews are capable of capturing damselflies, but our pitcher plants certainly are, and it would be interesting to know if some of them do not occasionally claim odonate victims.

ODONATE NYMPHS AS FISH FOOD.

EVIDENCE FROM FISH BAIT.—The first and most obvious proof that nymphs make good food for fish is the fact that they are used successfully for fish bait. Tillyard (1917, p. 337) recorded that the larvæ of Hemicordulia, called appropriately by the Australians mud eyes, are much sought after as bait for trout and perch. Needham (1903, p. 212) said: "Nymphs attached to hooks were taken by trout, but not more readily than minnows, small frogs, or other bait." He could also probably have said with equal truth that they were not taken any less readily than other bait.

Fishermen in certain parts of the country use nymphs regularly as bait in the same way that "dobsons" are used for bass bait. In Michigan and Minnesota the nymphs are locally called "crabs," and it is said that the rock bass or redeye will take them when it refuses other bait. In the vicinity of Torrington, Conn., the nymphs are known as "perch bait," and boys make a business of catching and selling them to the fishermen. But, of course, the best proof that nymphs serve as fish food is the fact that they are found in goodly numbers whenever the stomach contents of fishes are examined.

EVIDENCE FROM STOMACH CONTENTS.—Prof. S. A. Forbes has made very valuable and extensive studies of the food of fresh-water fishes, of which he published a summary and discussion in 1888. In this paper he gave a detailed list of the stomach contents of many of our food and game fishes, from which we may select those which had eaten nymphs and put them in tabular form. Such a table will be useful as an indication of the kind of fishes for which dragonfly nymphs would furnish acceptable food in pond-fish culture.

FOOD OF FISHES EXAMINED BY S. A. FORBES.

Kind of fish.	Period of life of fish.		Number of fish eating—	
	Adult.	Young.	Dragon nymphs.	Damsel nymphs.
Ictiobus bubalus: Small-mouthed buffalo	×	×	4	2
Ictiobus urus: Mongrel buffalo	×		1	
Moxostoma macrolepidotum: Sucker	×			2
Polyodon spathula: Spoonbill cat	×		1	1
Erimyzon sucetta: Common chub		×		1
Amia calva: Dogfish	×		2	
Lucius vermiculatus: Grass pickerel	×	×	6	7
Lucius lucius: Common pike	×		1	
Aplodinotus grunniens: Sheepshead, croaker	×		4	
Aphredoderus savanus: Pirate perch	×		1	
Ictalurus punctatus: Channel cat	×		6	4
Ameiurus nebulosus: Bullhead	×		2	
Labidesthes siculus: Brook silversides	×		1	2
Fundulus notatus: Top minnow	×			1
Hadropterus aspro: Black-sided darter	×			1
Lepomis gibbosus: Common sunfish	×	×	2	2
Lepomis incisor: Bluegill	×	×	5	4
Apomotis cyanellus: Green sunfish	×	×	2	
Pomoxis annularis: White crappie	×	×	1	4
Pomoxis sparoides: Black crappie	×			5
Perca flavescens: Common perch	×	×	5	4
Ambloplites rupestris: Rock bass, redeye	×		1	1
Chænobryttus gulosus: Warmouth bass		×		3
Micropterus dolomieu: Smallmouth black bass		×		2
Micropterus salmoides: Largemouth black bass	×			1
Archoplites interruptus: Sacramento perch	×			1
Fundulus diaphanus menona: Menona minnow	×			1

The numbers in this table seem very small when thus isolated; but if we compare them with the remainder of Forbes's list we find they are comparatively large and are surpassed by those of very few insects.

In his notes he stated that the various nymphs seemed to be most abundant (25 per cent) in the food of the grass pickerel, *Esox vermiculatus*, while they formed from 10 to 13 per cent of the food of the crappies, *Pomoxis annularis* and *P. sparoides*, the pirate perch, *Aphredoderus sayanus*, and the common perch, *Perca flavescens* (1888*b*, p. 485). Hankinson (1908, p. 234) stated that "nymphs were often found in the stomachs of rock bass and blue-spotted sunfish, less frequently in those of the common sunfish;" and in another place: "The nymphs of *Macromia illinoiensis* are much eaten by fishes" (p. 263). In his remarks upon the various species of fish he mentioned nymphs as the food of the bullhead, the rock bass, the blue-spotted sunfish, the common sunfish, the large-eared sunfish, the bluegill, and the large mouth black bass.

Baker (1916) gave the results of his examination of the stomachs of numerous specimens of different kinds of fish. He reported that nymphs of the odonata constituted 25 per cent of the food of one bullhead, *Ameiurus nebulosus* (p. 176); 62 per cent (with caddisflies) of the food of five bluegills, *Lepomis incisor* (p. 182); 15 per cent of the food of one redeye, *Ambloplites rupestris* (p. 182); 30 per cent of the food of one sunfish, *L.*

gibbosus, and 15 per cent of the food of another (p. 187); 60, 75, 85, and 100 per cent, respectively, of the food of four young yellow perch, *P. flavescens* (pp. 192, 193); 6 per cent (with Chironomid larvæ) of the food of six Manitou darters, *Percina caprodes zebra* (p. 194); 19 per cent of the food of four young grass pike, *Esox reticulatus;* and 36.66 per cent of the food of three preadults (p. 201).

Bean (1912, p. 203), in speaking of fish food said: "Important trout foods are snails, dragonflies, mayflies, and caddisflies."

A. S. Pearse, of the University of Wisconsin, in a manuscript paper seen by the present author verifies these observations and adds many other fish species which feed upon odonate nymphs.

Dr. R. A. Muttkowski has very kindly contributed some manuscript notes upon the food of fish from the vicinity of Madison, Wis. The odonate nymphs have been selected from these food data and arranged in the following table:

FOOD OF FISHES NEAR MADISON, WIS., EXAMINED BY DR. R. A. MUTTKOWSKI.

[Numerators represent number of fish in whose stomachs nymphs were found; denominators represent number of nymphs found.]

Kind of fish.	Argia, sp.	Enallagma antennatum.	Enallagma hageni.	Enallagma signatum.	Ischnura verticalis.	Nehalennia irene.	Æschna umbrosa.	Anax junius.	Celithemis eponina.	Libellula luctuosa.	Libellula, sp.
Ambloplites rupestris: Rock bass, redeye		15/24	1/35								
Ameiurus nebulosus: Common bullhead			2/6					1/1			
Ameiurus melas: Black bullhead			3/6								
Lepisosteus osseus: Long-nosed gar		1/1									
Eupomotis gibbosus: Common sunfish			3/5								
Lepomis pallidus: Bluegill		3/5	5/5								
Micropterus salmoides: Largemouth black bass		2/3						1/1			
Perca flavescens: Yellow perch	1/2	18/74	29/202	2/2	5/23	1/1	4/11	2/2	2/4	1/1	1/1
Pomoxis annularis: Crappie			1/1								
Pomoxis sparoides: Calico bass		1/12	9/30		6/89						
Schilbeodes gyrinus: Mad Tom		2/3	2/2								
Umbra limi: Mud minnow										1/1	

Two facts stand out very clearly in this table. The first is that the nymphs of the two species of Enallagma, which are common in the vicinity of Madison, form an important item in the food of the local fish. Every species of fish except the mud minnow has eaten of them in considerable numbers, and for the rock bass and calico bass they seem to constitute the chief item of diet. In all, 24 species of fish were examined, and it is worthy of note that 6 of the 12 which do not appear in this table are found in Forbes's table, where they are simply recorded as eating damselfly nymphs, without any designation of species.

The number of individual perch examined was very much larger than that of any other kind of fish, and the species of odonate nymphs found in their stomachs are corre-

spondingly numerous. They have eaten some of every kind of nymph listed, but their preference seemed to be for the damselflies rather than for the dragonflies, if we may judge by the numbers consumed. At all events, it can easily be seen that odonate nymphs are more toothsome to them than any other single article of diet.

The dragonfly nymphs recorded up to the present time are mostly Libellulides, and it is generally stated that gomphine nymphs escape the fish by burrowing in the sand, the mud, or the accumulated débris of the bottom. But even this burrowing habit does not save them from some fish. Of three spoonbill cats, *Polyodon spathula*, taken at Keokuk in May, 1916, 40 per cent of the stomach contents of one fish consisted of nymphs of *Gomphus notatus*. The second fish's stomach contained 1 *Gomphus vastus* nymph and 1 *Enallagma* nymph, constituting 10 per cent of the food; the third stomach contained 1 *Gomphus vastus* nymph, 25 per cent of the food. Of three moon-eye herrings, *Hiodon alosoides*, one taken March 24, 1916, near Hamilton, Ill., and the other two in June at Keokuk, Iowa, each contained a full-grown gomphine nymph and nothing else. A river drum, *Aplodinotus grunniens*, taken at Keokuk in June, contained a single gomphine nymph, constituting 60 per cent of its food.

Evidence from the fishponds themselves will be more convincing than that from rivers, streams, or lakes, and fortunately there is an abundance of evidence from this very source which furnishes just the proof desired. During the year from June, 1916, to June, 1917, H. E. Schradieck, an employee of the Bureau of Fisheries, was engaged in examining the food of the fishes in the very series of ponds (series D) here considered. Permission has been granted to select from his manuscript records the data relating to odonate food, and these data have been arranged in the following table:

FOOD OF FISHES FROM PONDS IN SERIES D, FAIRPORT, IOWA, EXAMINED BY H. C. SCHRADIECK.

Kind of fish.	Number of fish examined.	Pond from which taken.	Extremes in length.	Average length.	Number containing damsel nymphs.	Number containing damsel imagos.	Number containing dragon nymphs.	Odonate food, 100 per cent.	Odonate food, 75 to 99 per cent.	Average per cent odonate food.[a]	Odonate eggs.
			Mm.	*Mm.*							
Micropterus salmoides: Largemouth black bass	144	3	16/105	50	45	2	38	24	38	68.5	.....
Micropterus salmoides: Largemouth black bass	136	2	16/92	40	51	2	18	8	29	62	.....
Micropterus salmoides: Largemouth black bass	20	3	8/22	16	1	0	0	0	0	0	.....
Lepomis pallidus: Bluegill	103	2	20/60	42	29	0	2	0	4	34	.....
Ictiobus bubalis: Buffalofish	22	7	33/78	51	0	0	0	0	0	0	1
Ictiobus bubalis: Buffalofish	350	5 & 7	75/235	.....	0	0	0	0	0	0	.....
Eupomotis euryorus: McKay's sunfish	120	8	27/64	41	18	0	78	14	46	68.5	.....
Eupomotis gibbosus: Common sunfish	173	16 B	12/45	25	8	0	2	0	0	34	.....
Pomoxis sparoides: Calico bass	143	8	23/38	30	5	0	1	0	1	41	.....
Ictalurus punctatus: Channel cat	5	9	.....	9	0	0	0	0	0	0	.....
Ictalurus punctatus: Channel cat	21	9	45/95	70	.....	.....	.....	.....	.....	.....	.....

[a] This average includes only the fish that had eaten odonate food.

The number of fish included in this table is large enough to give considerable weight to the conclusions drawn; a thousand fish stomachs ought to furnish a fairly reliable basis for judgment. Furthermore, the fish have been taken from the ponds during every month in the year except December, January, and February, and thus include as much of the yearly life cycle as is available.

Very small fish do not eat odonate nymphs. Of the largemouth black bass from pond 3 only one, and that the largest of them all, had taken a damselfly nymph; eight specimens of bluegills, averaging less than 10 mm. in length, from ponds 1 and 2, did not show any trace of odonate food; and the five channel cats that averaged only 9 mm. in length from pond 9 had eaten nothing as large as an odonate nymph.

While these small fish refuse the nymphs, they do not refuse the eggs which the dragonflies distribute so freely about the ponds. Of the 22 buffalofish from pond 7D only 1 had eaten dragonfly eggs. But among 59 sunfish from pond 15B, 10 were found to have eaten dragonfly eggs; these 10 fish averaged but 13 mm. in length, the shortest being 10 mm. long and the longest 18 mm. Odonate eggs formed 55 per cent (average) of the food of these 10 fish and reached as high as 98 per cent in one of them. Hence for some kinds of fish odonate eggs will furnish an acceptable food, while the young fry are from 10 to 20 mm. in length.

Judging from the records of the largemouth bass, the bluegill, the common sunfish, and the calico bass, young fish must attain a length of from 22 to 25 mm. before they begin to eat odonate nymphs. From 25 to 40 mm. they take them in comparatively small numbers; from 40 to 100 mm. they eat them in much larger quantities, and often eat nothing else. In every instance where the odonate food constituted 100 per cent the fish was over 40 mm. in length and nine-tenths of them were over 50 mm. From 50 to 80 mm., therefore, may be taken as the size of fish for which odonate nymphs will prove most serviceable as food.

The stomach contents of a largemouth black bass, 80 mm. long, examined July 30, 1917, consisted of three fully grown nymphs of *L. luctuosa*, one fully grown nymph of Erythemis, and the remainder of the food fragments of similar nymphs too far digested for identification.

The small percentage of odonate food in the stomachs of the common sunfish and the calico bass may well be due to the small size of the fish examined. Of the 173 common sunfish included in the table, 96 were under 25 mm. in length and only 32 were 30 mm. or over in length, so that really the 10 fish which ate odonate nymphs were 10 out of 32 rather than 10 out of 173. Similarly, among the 143 calico bass there were only 21 that reached 35 mm. in length, while 100 were between 26 and 34 mm., just the size when they begin to eat sparingly of nymphs. The calico bass does not seem to begin this diet quite as early in life as some of the other fish, although the table of the Madison fish shows that the adults eat damselfly nymphs in goodly numbers. If we remove from the lists here given all the fish 25 mm. in length or under—namely, those that were too small to be expected to eat odonate food—it can readily be seen that the percentage of odonate feeders would be considerably increased.

We may next consider the fish's diet from a seasonal standpoint—the examination of fish food began in the latter part of June and continued through the summer and fall. Both the fish and the nymphs were steadily increasing in size during the period.

By following the charted records—say, of the largemouth black bass, for instance—it is very instructive to note that through June and July, while both nymphs and fish were quite small, the former do not appear in the diet of the latter. The bass began to eat nymphs about the first of August, and during that month in 10 out of the 30 bass examined odonate food reached from 90 to 100 per cent. The fish continued to eat nymphs in large quantities through the fall months. The largest bass was examined September 2 and was 105 mm. in length; 95 per cent of its food consisted of dragonfly nymphs. During the autumn of the first year, therefore, the odonates supply a very large percentage of the food of the young fish, and many fish feed entirely upon them.

Not all fish, however, will take odonate food, no matter how abundant it may be. The two examinations of buffalofish have been included in the table in order to show this fact. The first lot contained fish between 33 and 78 mm. in length, taken from pond 7D and several other ponds not in series D. These fish were all of just the right size to eat freely of the nymphs, judging by the records of the other fish enumerated. But with the exception of one which had eaten a few odonate eggs, probably accidentally, there was an entire absence of odonate food in their diet. Similarly, the 350 larger buffalofish did not show a single instance of the presence of odonate food. We may reasonably conclude, therefore, that such food is not palatable to them and will be of practically no assistance in their culture. It is worthy of note in this connection, however, that Prof. Forbes found both dragonfly and damselfly nymphs in the stomachs of adult buffalofish.

Evidence from Exuviæ.—There are also other methods of obtaining evidence besides an examination of the fish's stomach. Ponds 1, 2, 3, and 4 are as nearly alike as possible in their conditions and environment, but differ considerably in their fish contents. Pond 1 was stocked in the spring of 1916 with about 4,500 small bass and bluegills, while ponds 2 and 3 contained only a comparatively small number of adult bass and bluegills, together with the season's hatch of young, the latter, of course, being too small to eat any nymphs before autumn. There was no appreciable difference in the number of dragonflies hawking and ovipositing around these ponds, but there was a very marked difference in the number of nymph skins obtained along the margins of the ponds. The north shores of ponds 1 and 2 are of the same length and have a border of *Carex stricta* of the same width, but while this border yielded 450 nymph skins on pond 2, only 150 could be found on pond 1. The difference in damselfly skins was even more marked; only 6 were found on the whole margin of pond 1, while a single reed stem in pond 2 yielded 21 skins, and the entire margin yielded a trifle over 500 skins. It would suggest, at least, that the young fish in pond 1 had reduced the numbers of nymphs by eating them, since they were of just the size to eat them freely.

The same fact is even more markedly shown in the case of the Anax nymphs; a few were found in all of the ponds, but when pond 4, containing only adult buffalofish was drawn 200 nymphs were obtained and after the pond was refilled 100 more transformed and left their skins around the margin of the pond. Such disparity in numbers could hardly be due to a discriminating choice on the part of the adults as to the pond in which they laid their eggs.

Evidence from Feeding Nymphs Artificially to Fish.—Best of all, the eating of nymphs by adult fish has been demonstrated by feeding the nymphs directly to them. Pond 6 is the smallest of all the ponds, but it contains the largest number of

adult fish, which have been taken out of the other ponds to prevent them from eating the young fish. They get hungry in this small pond and have to be fed at times. Among the foods given to them have been dragonfly nymphs, *Anax junius* and *L. luctuosa*, obtained from other ponds when the water was drawn from them. The fish in pond 6 always eat these with avidity, consuming all that are thrown to them, sometimes several hundreds.

This fact carries with it several suggestions as to the methods of dealing with these nymphs. Whenever a pond is drained, as many of the nymphs as possible should be saved for further use. If the water is lowered gradually, the nymphs, like the fish, will follow it down to the last pool, from which they can be easily removed with a dip net. They can then be used to restock the pond from which they came, after it is filled again, or they can be fed to the fish in other ponds.

Atkins in a discussion of Foods for Young Salmonoid Fishes (1908) said: "Any departure, therefore, from a live-food regimen must be regarded as having the presumption against its entire stability" (p. 841); and, again quoting from the Allgemeine Fischerei Zeitung, "for breeding fishes under all circumstances live, natural food is the most suitable" (p. 841).

Here is a live-natural food that can often be obtained in large quantities and of various sizes suited to the different growths of fish, and methods of stocking a pond with this kind of food will be discussed later (p. 234).

ODONATE IMAGOS AS FISH FOOD.

The only time that a fish gets a chance to catch a dragonfly imago is during ovipositing. The Argia females that back down beneath the surface of the water to deposit their eggs must face the danger of being snapped up by some hungry fish, and many of them are probably caught at such times. (See p. 257.) The same will be true of other damselfly species, since most of them alight on something at the surface, and at least thrust their abdomen into the water while ovipositing.

Both bass and sunfish jump eagerly after ovipositing dragonflies, but, like Williamson, the present author has never seen a fish actually catch one of them. However, on opening the stomachs of bass from pond 6 that had been killed for experimental purposes dragonfly imagos were found in more than half of them, showing that at times they are successful in their efforts. Several times the author caught dragonflies in the net, crippled their wings so that they could not fly, and threw them on the surface of pond 6. In almost every instance they were seized and swallowed as soon as they struck the water, but two or three that failed to wiggle after hitting the water were left untouched. These fish would not snap at dead food of any sort, and they came up to these dragonflies until their nose almost touched the insect and waited patiently for some movement indicating life. If the dragonfly wiggled ever so little it was swallowed instantly, but if it remained motionless it was left untouched.

Tillyard (1917, p. 330) has the following record: "A 2-pound trout which I caught on the Macquarie River in Tasmania had in its stomach the undigested heads of 35 dragonflies, 28 belonging to the rather rare species *Procordulia jacksonensis*."

In the record of fish food given to the author by Dr. Muttkowski are two instances of fish eating imago damselflies. (See table, p. 227.) The stomach of a black bullhead,

Ameiurus melas, contained 6 *Enallagma hageni* imagos, and the stomach of a largemouth black bass contained 22 *Enallagma antennatum* imagos.

In a record made by Mr. Schradieck of the food of the largemouth black bass in ponds 2 and 3 D, a fish 48 mm. in length had for its stomach contents 95 per cent damselfly imagos and 5 per cent Chironomid larvæ. Another fish, 82 mm. long, contained nothing except a few damselfly imagos; a third, 65 mm. long, contained 50 per cent damselfly imagos and 20 per cent odonate eggs.

H. L. Canfield, superintendent of fish culture at the Fairport station, told the author that he had fed Anax imagos to largemouth black bass at Homer, Minn. The fish seized them avariciously and apparently swallowed them, but in a moment or two spit them out again. Perhaps the Anax was too large a mouthful for them, for the bass at Fairport certainly swallowed imagos of *L. luctuosa*, Erythemis, Plathemis, and Leucorrhinia and kept them down.

STOCKING THE FISHPOND.

Having tried to show, it is hoped with some success, that dragonflies and damselflies and their nymphs are not only desirable additions to the fauna of fishponds but that they may even prove of considerable importance, there remains the problem of obtaining a sufficient number of the right kind with which to stock a pond. How can this best be accomplished? With reference to the dragonflies several methods may be suggested and briefly discussed. Embody stated in The Farm Fishpond (1915, p. 242) that after the pond has been completed and filled with water:

> The aquatic plants should be the first organisms to be put into the pond * * * The forage animals should be collected next. As has been stated, until more is known about the propagation of aquatic insects it will be impossible to give definite and reliable directions for their introduction. Certain desirable forms will naturally be attracted to the pond for egg laying, and for the present this natural method of propagation is the only one to be depended on.

Of course dragonflies will be among the insects naturally attracted to the pond for egg laying, but it is desired that the pond be stocked at once and with the kinds most available for forage food. The author believes that, so far as the odonates are concerned, we already possess sufficient knowledge to enable us to take the initiative, and not only to introduce desirable species, but also to exercise considerable control over their subsequent abundance.

CHOICE OF DRAGONFLY SPECIES.—The species of dragonfly best suited to any particular fishpond is not by any means necessarily the one that has been tried successfully elsewhere. The condition of the pond and its environment will have as great an influence upon the dragonflies as upon the fish with which it is stocked. In general, a common local species of dragonfly will be far better than one imported from a distance. A visit to neighboring ponds and quiet streams and a careful comparison of their conditions and surroundings with those of the proposed fishpond will be the proper method of choosing the species. Find a place as close to the fishpond and as similar to it as possible, and use this as the source from whence to obtain the stock material.

In 1889 Dr. P. R. Uhler, at that time one of the best authorities upon the dragonflies, wrote the following to Dr. Robert H. Lamborn (1890, p. 12) in reference to the breeding of dragonflies for the purpose of killing off mosquitos:

> As I have raised all the common forms of our Atlantic coastal-plain region, I know that the dragonfly larvæ can be reared in vast numbers. Of course, you know that each locality supports its own species,

and the forms which develop in the brackish drains and pools near tide, where they are covered twice each day by salt water, can not flourish in fresh water. Accordingly, for the littoral belt from Long Island to Beaufort, N. C., I would select *Diplax* (*Erythrodiplax*) *berenice*, *Libellula auripennis*, and *Mezothemis* (*Pachydiplax*) *longipennis*. For the region next inland from this multitudes of common species could be had, such as *Anax junius*, *Æschna* (*Epiæschna*) *heros*, *Libellula pulchella*, *L. luctuosa*, *L. semifasciata*, *Plathemis trimaculata* (*lydia*), and most of the species of Diplax (Sympetrum). On the clear streams which rush down from the hills Cordulia, Epitheca (Epicordulia), and Gomphus prevail.

The above statement is just as good to-day as when it was written, only we must extend the area west of the Allegheny Mountains to cover the entire breadth of North America, and we must include damselflies as well as dragonflies. For the region east of the Alleghenies good damselflies would be *Lestes rectangularis*, *Ischnura verticalis*, *I. posita*, *Enallagma civile*, *E. hageni*, and *Anomalagrion hastatum*.

For the Mississippi Valley some of the desirable odonate species would be *Anax junius*, *Æschna constricta*, *Epicordulia princeps*, *Tramea lacerata*, *Libellula luctuosa*, *L. pulchella*, *Erythemis simplicicollis*, and *Plathemis lydia*, and local species of Argia, Ischnura, Enallagma, and Lestes.

West of the Rocky Mountains, Anax, Erythemis, Tramea and Plathemis would still remain, the species of Æschna and Libellula and of the four genera of damselflies could simply be changed to suit the locality, and Sympetrum could be added.

High up among the mountains Anax and Sympetrum, *Libellula quadrimaculata*, and *Leucorrhinia glacialis*, with local species of Enallagma and Lestes, would be most suitable.

It will appear at once that certain of the desirable forms, such as Anax, *L. pulchella*, *P. lydia*, and the damselfly genera Argia, Enallagma, and Lestes are very cosmopolitan, and their wide distribution increases by so much the chance that they will succeed wherever they may be introduced. They constitute, therefore, the very best stock material available, but still demand certain conditions if they are to be reared successfully. For example, the Anax female inserts her eggs into the tissue of the stems of water plants, and hence cat-tails, arrowhead, rushes, or some such water plant must be provided if this dragonfly is to breed in any numbers. On the other hand, Erythemis takes most kindly to floating blanket algæ; the damselflies insert their eggs in the stems of all kinds of water plants, occasionally above the surface (Lestes, etc.), though usually below it, the female sometimes descending several inches beneath the water for ovipositing.

The dragonfly genus Epicordulia deposits its eggs in long ropes of jelly coiled about the stem of some convenient water plant, while the great majority of the Libellulids deposit their eggs anywhere in clear water by hovering over the surface and repeatedly striking the water with the tip of the abdomen. In the latter case the eggs sink to the bottom separately and are fastened by the jelly that surrounds them to anything they may come in contact with. Hence for these different odonates the fishpond must contain water plants, with stems both above and below the surface, floating algæ, and plenty of open spaces.

PREPARATION OF THE POND.—No special preparation is required, because when a pond is suitably prepared for fish it will contain the requirements just enumerated and will be ready also for the dragonflies. While the condition of the embankments around the pond can not affect the fish or the nymphs in the water, it can and does exert an important influence on the odonate imagos. A total absence of trees, shrubs, bushes, and

weeds, with close-cut turf extending to the water's edge, may add to the sightliness of the pond, but it will operate against the odonate fauna. The larger vegetation is not necessary; an area covered with tall weeds and grass somewhere around the margin of the pond will prove amply sufficient.

If the breeding of fish and the rearing of forage for their consumption is confined to a single pond, of course that will be the place to stock with odonate eggs or nymphs. With proper care such combined breeding may be carried on successfully in the same pond, as is done at Fairport. "If not overstocked, the average pond may be managed so that it will furnish all the live food necessary for the adult fish." (Johnson and Stapleton, 1915, p. 19.)

In the last few years the forage problem in connection with fish culture has been receiving much more attention here in the United States. Embody (1915, p. 233) noted that "The propagation of minute organisms in great numbers as food for young fishes has been accomplished by the Chinese and the Japanese and more recently by the Germans," and he recommeded small forage ponds in connection with the larger fish pond (p. 235):

> There is good reason for believing that the supply of aquatic insects can be materially increased by building a few small breeding ponds along the margin of the main pond and excluding all fishes therefrom. Certain insects will naturally deposit their eggs in both breeding and main ponds. There are no very destructive insects in the former; hence there are sure to emerge a goodly number of adults, which, in turn, will continue year after year to repopulate the small ponds, as well as the main pond.

Needham and Lloyd have advocated the same idea in The Life of Inland Waters (1916). In figure 242, on page 408, they present a diagram illustrating conditions advisable for intensive fish raising on an 80-acre tract of wet upland traversed by a trout stream. The noticeable thing about it is the large area, 40 acres of ponds, to be placed under control for the production of fish forage.

Until experiments have been tried out in a practical way for some length of time, it will be impossible to decide definitely how much breeding area is necessary or advisable in order to produce the amount of food forage requisite for a given number of fish. Meanwhile, if forage breeding is to be attempted, the place to put the odonate eggs and nymphs will be with the other fish food in the breeding ponds, as well as in the main fishpond. Once well started in both places they will thereafter propagate themselves, as Embody has stated.

SECURING THE STOCK MATERIAL.—The method of securing the necessary odonate eggs or nymphs for stocking the pond will vary with the time of year. If the fishpond is to be started in the spring or fall, the best odonate material to put in it will be the nymphs. These may be collected from the nearest pond or from the still water of a stream or river. Some nymphs inhabit running water or places where there is a perceptible current, but such species are not suited for pond life.

An old ditch well choked with algæ and water plants, and in which the water stands throughout the year, is an admirable source whence to obtain the nymphs. There are two good methods of collecting them, and it would be well to use both. If there is much loose algæ and débris over the bottom of the ditch, the best implement to use is the common garden rake, as advised by Needham (1899). The collector can stand on the shore and rake the algæ and weeds out of the water onto the ground in front of him. As the water drains off the nymphs will make active efforts to get back, and are thus easily found and secured.

If there is more mud than water plants, the best implement is a sieve net like the one recommended by Needham and shown in figure 37*a*. With this the mud and silt can be drawn ashore and there sifted out, the mud escaping while the nymphs are retained. Much of the material pulled in by the rake can also be advantageously put through the sieve. Needham's sieve net had a framework of steel rods, sides of galvanized iron, and a bottom of galvanized-wire screen. If something of this sort can not be readily obtained or manufactured, the following may be substituted: Bend a piece of large and stiff wire 3 feet long into the shape of a stirrup, the ends coming together at the center of the curved side. Weld the ends together and insert them with a ferrule into a stout handle 6 or 7 feet long. Make a bag out of bobbinet and fasten its mouth securely to the wire stirrup. The mud will sift through this net as well as through the wire screen, but of course the net can be torn easily. Armed with such a net and a rake, a boy can easily secure several hundred nymphs in a few hours. Needham records that he once collected enough nymphs of *Gomphus descriptus* to fill a quart fruit jar from Six Mile Creek near Ithaca, N. Y., in an hour's time (Needham and Betten, 1901, p. 453). The only objection to this method of stocking a fishpond is the fact that no one but a scientific expert can distinguish between the different nymphs obtained. They must all be put into the pond together, good, bad, and indifferent; but there are likely to be plenty of the desirable species among them, and the rest can be safely ignored.

In the summer the pond can be stocked much more intelligently by obtaining the eggs of desirable species and hatching them. In the case of the dragonflies this can not be done by capturing the adults and breeding them artificially or in captivity, as is the unanimous testimony of all who have made the attempt.

A. C. Weeks, at that time secretary of the Brooklyn Entomological Society, made in 1889 an extensive experiment with *Libellula pulchella* and *Diplax* (*Sympetrum*) *rubicundulum* by catching the full-grown adults and confining them in the upper story of his dwelling house, which had been cleared of its furniture and arranged with a view to attract the dragonflies. But they would neither feed nor mate nor oviposit. The same experiment was tried later on *Anax junius* with equally negative results (Lamborn, 1890, p. 78). This was in a crowded city, however, and it might well be supposed that the insects were distracted by the surroundings.

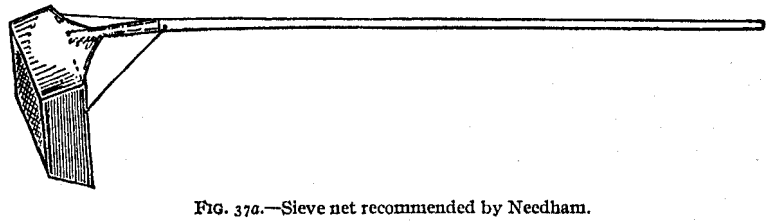


FIG. 37*a*.—Sieve net recommended by Needham.

To test this, the present author experimented with a breeding cage large enough to allow great freedom of motion under conditions that were ideally natural, except for the single element of restraint. This one thing proved a fatal stumbling block, and, although both sexes of *Libellula luctuosa*, *L. pulchella*, *Erythemis simplicicollis*, *Leucorrhinia intacta*, and *Anax junius* were placed in the cage at different times, they were all immediately imbued with an overwhelming desire to escape. The cage was open at the bottom and was put down over a section of pond 3D containing cat-tails, reeds, algæ, and other water plants,

everything being left undisturbed. The upper portion of the cage was covered with chicken wire whose meshes were large enough to allow free access to the insects upon which the dragonflies usually fed. But as soon as the dragonflies found they were shut in, they would neither alight on the water plants, nor touch the insects that flew through the cage, nor mate, nor oviposit. Instead, they spent their time beating their wings against the sides and top of the cage until they became exhausted and fell into the water, or were picked out through the meshes of the wire by red-winged blackbirds, which were attracted by the beating of the insects' wings.

While the dragonflies are thus averse to breeding in confinement the damselflies take kindly to it, and Balfour-Browne (1909) succeeded in obtaining a large number of eggs from specimens of two English species, *Agrion pulchellum* and *Ischnura elegans*, which he kept for a week in a cage. He fed the captives on flies and other insects captured in a sweeping net and placed alive in the cage. The eggs hatched into nymphs in about three weeks, so that he was able to determine definitely the period of incubation for these species. This method was not tried on our American damselflies, but there is little doubt that it would work as well with them as with the English species. It was found absolutely necessary to keep the cage in the bright sunlight, because in the shade and on dull days the damselflies became torpid and simply clung to the sides of the cage. It is evident, therefore, that nothing can be accomplished by endeavoring to breed dragonflies in this manner; their natural habits and instincts are against it. And although the damselflies are more susceptible to captivity, this artificial breeding is a rather laborious process for any except the scientific expert who wishes to absolutely isolate a given species.

Fortunately there are other ways of accomplishing the desired results, and these prove to be highly successful. As already stated, many female dragonflies deposit their eggs loosely in the water or upon the floating algæ by hovering close to the surface and touching the water at intervals with the tip of the abdomen. If such a female be caught as she comes down to the pond to lay her eggs or while she is ovipositing and one pair of wings be folded together over the back and held between the thumb and forefinger, leaving the other pair free, she will continue to lay eggs in large numbers if the tip of her abdomen be dipped in water in a convenient tumbler, basin, or small jar. Tillyard (1917, p. 358) claimed that it was "necessary to have the water dirty, with mud, sand, or small pieces of débris for the eggs to fall upon; otherwise the eggs will simply all stick together and quickly go moldy." While agreeing that the presence of dirt is a positive advantage in the way that Tillyard suggests, the present author can not agree that it is always "necessary." All the experiments hereinafter recorded were made in clean water, and while the eggs usually did stick together, they did not mold except in a single instance, and even then practically all of them hatched. However, if the nymphs are to be used simply to stock the fishpond, some dirt and débris are desirable, since then the conditions are more nearly natural. Similarly, when the male accompanies the female during ovipositing, on being captured the female will deposit her eggs freely in the tumbler or basin; this applies to such species as Tramea and Celithemis.

Needham recorded a female *Gomphus graslinellus* captured while ovipositing, from which he "obtained in a tumbler of water an immense number of eggs" (Needham and Hart, 1901, p. 69). Also a female *Gomphus externus*, "captured in the weeds

at the bank (Illinois River) deposited for me in a watch glass of water in a few minutes' time about 5,200 eggs. This number is an estimate from a partial count" (p. 75).

The present author stood in one spot on the bank of pond 4D and captured within half an hour six *L. luctuosa* females as they came to the pond to oviposit and from them fully 4,000 eggs were obtained.

For stocking purposes the eggs of the different species do not need to be kept separate. On another afternoon females of *L. luctuosa*, Erythemis, and Leucorrhinia were allowed to deposit their eggs in the same tumbler and all hatched out together without apparent trouble.

Armed then with an insect net and a convenient receptacle, thousands of eggs can be easily obtained in a short time at any place where the dragonflies are ovipositing and only the eggs of desirable species need be taken. These eggs can then be carried to the pond and placed loosely upon the bottom or on the floating algæ, care being taken that they do not get buried in silt or mud, but remain on the surface; or they can be kept in the original receptacle until they hatch, and then the nymphs can be turned loose in the pond, not all in one place, but well distributed. The number of nymphs obtained in this way need only be limited by the patience of the collector.

If the eggs are allowed to hatch before being placed in the fishpond, care should be taken that they do not require a long transportation. Mrs. Aaron gave this warning: "The question of transporting the young larvæ from the breeding tanks to the mosquito-infested ponds is to be considered. Although they are tough and can stand jolting, only a few can be carried in one receptacle. Twenty put in one jar would be found to be an inextricable, kicking mass of cannibals after a mile's transportation" (Lamborn, 1890, p. 63). While perhaps transportation for a mile would produce this result, no difficulty has been experienced in carrying thousands of newly hatched nymphs from the laboratory to the fishponds, a distance of 500 yards.

Anax, Æschna, and the damselflies insert their eggs by means of an ovipositor into living or dead vegetable tissue either beneath the water or resting upon its surface. The females of these species can be watched while ovipositing and after they have finished the leaves or stems containing the eggs can be removed and transferred to the fishpond or they may be kept in water until they hatch. These females will not deposit eggs in a tumbler or basin, like those previously mentioned, but just as many can be secured by gathering the vegetation containing them.

Sufficient experience might enable one to distinguish between the eggs of different species, but ordinarily the vegetation must be transferred to the fishpond with all the eggs it may happen to contain. It is surprising, however, to find how often it proves that practically all the eggs in a single leaf or stem are those of one species.

Females of *Enallagma hageni* were observed inserting their eggs in the tissue of crex-grass leaves that had fallen into the water. Five of these leaves that contained fully 1,500 eggs were obtained, and these were cut into short lengths and kept in tumblers of water until the eggs hatched. Similarly, *Argia mæsta putrida* was observed descending a small water-soaked branch of willow near one of the wing dams in the Mississippi River in order to deposit its eggs, the female dragging the male down with her during the process. On pulling the branch out of the water a dozen couples of this damselfly flew off from it at varying depths, and the softened wood was found to be literally filled with eggs for a distance of 2 feet. A partial count and an estimate

of the remainder indicated at least 2,000 eggs in this one branch. It also was cut into short lengths, and these were kept in tumblers of water until they hatched.

The damselflies will breed and deposit their eggs in captivity as already mentioned. (See p. 236.)

REARING THE NYMPHS.—The best method of caring for the nymphs is to place them in the fishpond as soon as they are hatched. Conditions might arise, however, which would render it desirable to rear the nymphs to a certain size before using them for fish food. And this can be easily accomplished by supplying them with requisite food.

The first lot (about 350) of nymphs of *L. luctuosa* that were hatched in the laboratory were kept throughout the entire season in a small aquarium. They were fed every two or three days with ordinary tow obtained from the river or one of the ponds. They seemed particularly fond of the minute crustacea and devoured large numbers of copepods, daphnids, and cladocerans.

Balfour-Browne fed his newly hatched nymphs upon Paramœcium, which he obtained by making an infusion of horse dung in water. One jar of this infusion produced for five or six months enough Paramœcium to supply all his nymphs. As the nymphs grew in size the Paramœcia were replaced by Daphnids, and in this way he carried the nymphs of *Agriom pulchellum* and *Ischnura elegans* through from the egg to the imago stage.

Warren placed individual nymphs in separate petri dishes as soon as they were hatched and fed them on newly hatched mosquito larvæ until the third or fourth molt. They were then transferred to larger dishes and fed on larger mosquito larvæ. In this way he carried four nymphs of *Pantala flavescens* successfully through their entire life history from the egg to the imago. Two of them were fed daily with large amounts of food, and they transformed into the imago stage in about two months. The other two were given much less food, and in consequence they required over three months for their development.

EXPERIMENTS IN HATCHING ODONATE EGGS.

There are but few records of the length of time spent by American dragonflies and damselflies in the egg state. Wm. Beutenmuller (Lamborn, 1890, p. 125) stated that *Libellula auripennis* and *L. pulchella* deposit 25 to 40 eggs each time the female dips her abdomen beneath the water. He added on the next page that eggs laid by *L. pulchella* July 23 hatched August 31, making the period of incubation 39 days. In *L. auripennis* the interval was only 8 days, in *Plathemis lydia* 10 days, and in *Diplax (Erythrodiplax) berenice* and *Sympetrum rubicundulum* 10 days.

Among the damselflies Needham (1903, p. 229) said of Lestes in New York State: "The eggs, deposited well above the water, develop normally from the first, and in the course of two or three weeks attain a condition which is apparently almost that in which they will hatch. They then estivate through the remainder of the summer and early autumn till the pools are refilled, and the stem and leaves, now dead, fall into the water." Eggs laid in July and gathered in October hatched within a week in his laboratory. But of course such a record would not apply to other genera and species where there is no estivation.

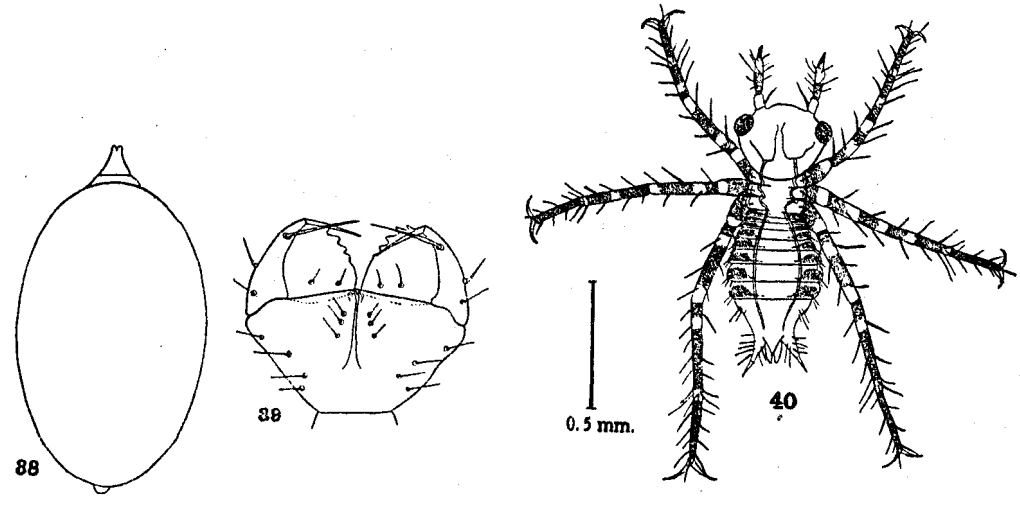
In view of the meagerness of American records, the following experiments at Fairport are recorded as a partial guide for the fish breeder, and there are also included descriptions and figures of the eggs and newly hatched nymphs to help in identification.

LIBELLULA LUCTUOSA.

The Egg.—The egg of this species is an almost perfect ellipse, 0.57 mm. long and 0.30 mm. wide. The neck is conical, as wide at the base as it is high, with a distinct basal segment and a divided tip. There is also a short process at the posterior end of the egg; the yolk granules are comparatively large and distinct. Eggs laid on July 12 began to hatch July 22, and the hatching was entirely completed by July 30. Several lots of eggs from this species were hatched during the summer, and the period of incubation was practically the same for each lot.

The Nymph.—The newly molted nymph is just 1 mm. in length, exclusive of the antennæ; the head and abdomen are the same width, 0.38 mm.; the head is one-fifth wider than long; the hind legs are about the same length as the body, the first two pairs are proportionally shorter; the antennæ are a little shorter than the head and rather stout. The head is a deep, sulphur yellow, the eyes are dark orange, with black spots, the digestive canal is light yellow, and the legs are banded with gray and white.

As soon as the pronymph has molted and becomes a true nymph, the latter swims up to the surface of the water, accomplishing this locomotion by means of the legs, without any help from water ejection at the rectum. Having reached the surface the nymph is able to hold itself there by clinging to the surface film with its claws. It remains there for a long time almost motionless, so that, if the tumbler be examined at any time, the undersurface of the water film will be found covered with nymphs as



FIGS. 38 to 40.—Development of *Libellula luctuosa:* 38, egg; 39, mask of newly hatched nymph; 40, newly hatched nymph.

close together as they can stick. It often happens that one coming up from the bottom finds another already clinging to the film when it reaches the latter. It then fastens to the other nymph instead of to the film, and the combined weight of the two nymphs is more than the film can sustain, so that they sink slowly back to the bottom. Under natural conditions such a seeking of the surface brings the nymphs to the floating algæ or other surface vegetation, which is evidently the location they seek for safety and food. It is also possible that the young nymph, like the teneral imago, needs the stronger sunlight for hardening its chitin integument and maturing its color pattern.

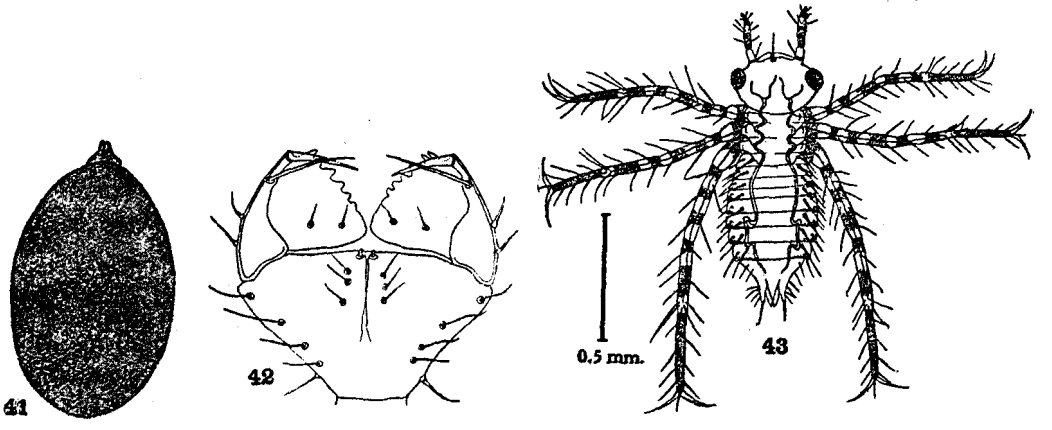
The Mask.—Mentum twice as wide as long; distal margin two times the length of the proximal; four setæ on the inner surface along either side near the lateral margin; three mental setæ on each side of the center in a straight line; a toothed prominence on the midline behind the distal margin. Lateral lobes one-half longer than wide; two marginal setæ on the outer border near the base; two laminate setæ on the blade of the lobe near the inner margin; raptorial seta just reaching the tip of the movable hook, the latter long and slender; distal border of lobe with five teeth near the outer corner, the second tooth the longest.

LIBELLULA PULCHELLA.

A pair was taken mating on the north shore of pond 4D, and the female deposited 1,500 eggs. These eggs were laid July 12; they began hatching July 22, and the hatching was completed by July 28.

The Egg.—Curiously enough, the egg of this large species is smaller than that of the little Leucorrhinia. It is ellipsoidal in form, measuring 0.48 mm. in length and 0.29 mm. in width. The neck is conical, the base nearly twice the height and without any visible segment, but the tip is divided; there is no process at the posterior end of the egg. The yolk granules are small and indistinct.

The Nymph.—This nymph is also just 1 mm. long; the head is one-third wider than long, one-fourth the entire length; the abdomen is as wide as the head, with two rows of stout bristles on the dorsal surface along either lateral margin; the latero-posterior appendages are very hairy. The antennæ are long and slender, black at the tips, with a single black band on the basal joint; the legs have black and white bands, as shown in the figure; the eyes are straw yellow, with two larger black dots and concentric rows of smaller ones; the head between the eyes and whole body is a pale yellow, deepening into orange over the gizzard and rectum; there are whitened areas along the sides of the abdomen at the posterior margins of segments 4 to 7, with darker areas anterior to them. The base of the antennæ is whitish, with a black distal band; first joint proximally gray, distally whitish; second joint nearly all dark gray, with a narrow, white distal band; third joint dark gray, except the very tip, which is



FIGS. 41 to 43.—Development of *Libellula pulchella:* 41, egg; 42, mask of newly hatched nymph; 43, newly hatched nymph.

whitish. The whole body is transparent and pale white, a little yellowish on the head and at the posterior end of the abdomen; the circulatory system is deeper white.

The Mask.—Mentum three-quarters wider than long, distal margin two and a half times the length of the proximal; four setæ on the inner surface, near the lateral margin, one proximal to them on the margin itself; three mental setæ on either side in nearly a straight line; two tiny spines at the center, near the distal margin. Lateral lobes one-fourth longer than wide; two setæ on the outer margin, near the base; two setæ on each blade; raptorial seta longer than the movable hook, the latter long and narrow; distal margin with six teeth near the outer border, the first two the longest.

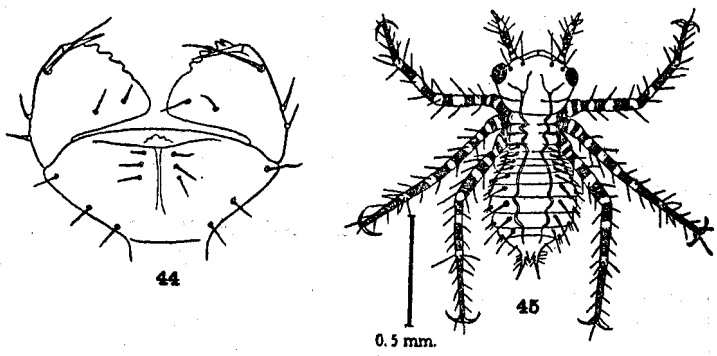
HYBRID BETWEEN LIBELLULA PULCHELLA AND L. LUCTUOSA.

A male *L. pulchella* and a female *L. luctuosa* were captured mating on the shore of pond 4D July 9, 1917. The female deposited about 100 eggs in a tumbler of water, and these subsequently hatched on July 20.

The Nymph.—This nymph is unlike those of either pulchella or luctuosa, especially in its markings. The head is one-third wider than long, and the same width as the abdomen, grayish yellow; the eyes are sulphur yellow, with small black retinal dots; the rest of the body is pale yellowish, but without much color and quite transparent, except along the lateral margins of the abdomen, where each segment is dark gray anteriorly and white posteriorly. The whole body is quite hairy, with a row of stout

bristles along the dorsal surface of the abdomen, between the respiratory system and the lateral margin on either side. The antennæ are relatively large; base white with a pale grayish distal band; first joint white through the center, pale grayish at either end; second joint with proximal three-fifths dark and distal two-fifths white; third joint dark, tipped with white. These nymphs did not ascend to the surface of the water, like those of *luctuosa*, but stayed down near the bottom of the tumbler.

The Mask.—Mentum twice as wide as long; the distal border two and a half times the proximal; the lateral margins curved; three setæ on either side, near the lateral margin; three mental setæ in a straight line; a slight lobed prominence behind the center of the distal margin, without spines. Lateral lobes one-third longer than wide; two setæ on the outer border near the base; two on each blade; raptorial seta considerably longer than the movable hook, the latter short and slender; distal margin with four teeth near the outer edge, the first two the longest.



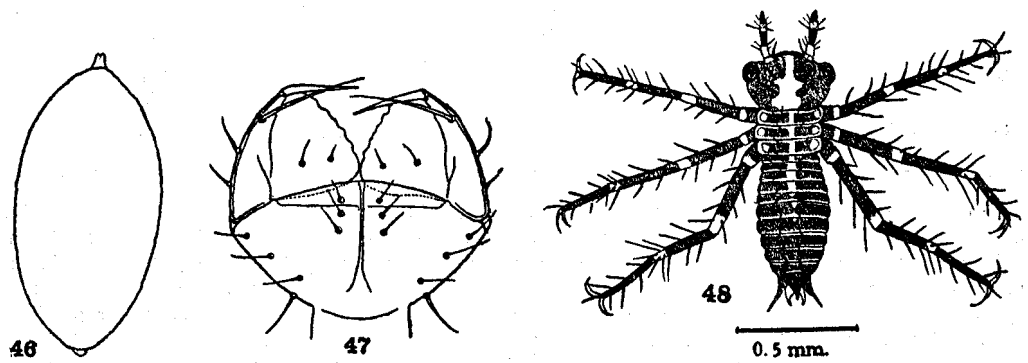
FIGS. 44 and 45.—Hybrid from male *Libellula pulchella* and female *Libellula luctuosa*: 44, mask of newly hatched hybrid nymph; 45, newly hatched hybrid nymph.

ERYTHEMIS SIMPLICICOLLIS.

The first females were seen laying in pond 4D on July 12, 1917. Eggs laid July 13 hatched July 23.

The Egg.—The egg of this species is an elongated ellipse, with rather pointed ends, and is a little more than twice as long as wide, the respective diameters being 0.60 mm. and 0.27 mm. The neck has a base narrower than its height, divided at the tip; there is a small process on the posterior end of the egg; the yolk granules are minute.

The Nymph.—This nymph has the most pigment of any of those examined, and is banded brown and yellowish white; the eyes are light orange yellow with comparatively large black spots; the sides of the head are brown shading into light yellow on the median line; each thorax segment is brown



FIGS. 46 to 48.—Development of *Erythemis simplicicollis*: 46, egg; 47, mask of newly hatched nymph; 48, newly hatched nymph.

bordered with dark yellow along the lateral margins and light yellow in the center, thus leaving a clear yellow longitudinal streak through the center of the body; the ninth and tenth segments are yellow; the legs are dark proximally, with a white band across the distal ends of the coxæ, femora, and tibiæ. The central yellow line of the head passes over the forehead and down between the antennæ onto the labrum. On the back of the head it is widened considerably and usually runs out into two rounded points on either side, with two small, brown spots, one on either side of the midline, at the level of the posterior points. Through the thorax it is narrow, then widens again on the first three or four abdomen

segments, and fades into small, yellow dots on the anterior margins of the fifth, sixth, and seventh, and sometimes the eighth, segment, disappearing entirely on the ninth, and often on the eighth segment. The dorsal appendages on the tenth segment are light brown at the base, yellow at the tip; the lateral and inferior appendages are dark brown. The base of the antennæ is yellow distally and proximally with a narrow, black band through the center; first joint dark, with a narrow, distal, white band; second joint with a broader, distal, white band; third joint entirely blackish brown.

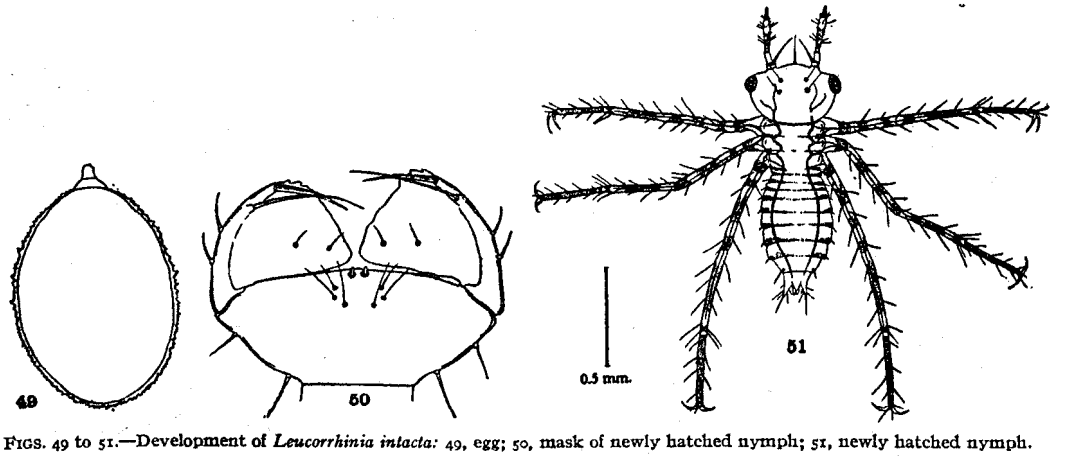
The Mask.—Mentum with the width to the length as 5 to 3, distal margin two-thirds wider than the proximal; three lateral setæ, one marginal seta; three mental setæ in a straight line on either side of the center. Lateral lobe with its length to its width as 9 to 7; two marginal setæ on the outer border; two setæ on the blade of the lobe; raptorial seta just reaching the tip of the movable hook, the latter long and stout; distal margin crenate, without teeth.

LEUCORRHINIA INTACTA.

The sexes remain in union only a short time and usually alight on some convenient weed or bush near the water's edge, where they can be easily secured. When thus captured, the female is ready to lay as soon as taken from the net and will deposit 100 to 200 eggs, the first 50 or 75 coming in a mass stuck together, the others coming singly. Eggs laid July 18 hatched July 30.

The Egg.—This egg is more nearly spherical than that of *Libellula luctuosa*, and has diameters of 0.60 mm. and 0.40 mm., respectively. The neck is wider at the base than it is high, and there is a distinct segmentation at about the center; the tip is not divided, and there is no process on the posterior end of egg. The yolk granules are comparatively large, and the jelly envelope is ragged around the surface of the egg and not smooth, as in other species.

The Nymph.—Although the imago of Leucorrhinia is much smaller than that of *Libellula luctuosa* the



FIGS. 49 to 51.—Development of *Leucorrhinia intacta:* 49, egg; 50, mask of newly hatched nymph; 51, newly hatched nymph.

nymph is considerably larger, measuring 1.20 mm. in length; the head is one-third wider than the abdomen; the front legs are the same length as the body, the others proportionally longer, and all three pairs slender. Both the body and the legs are quite transparent and pale orange yellow in color, the legs and antennæ transversely banded with gray and white, the eyes darker orange yellow, the black spots very small. The sides of the head and a wide transverse band across the anterior portion of each abdomen segment are whitish, the posterior margins of the segments are tinged with brown. The bases of the antennæ are whitish yellow proximally, with a narrow, gray, distal band; first joint entirely white, a little grayish through the center; second joint with a very narrow proximal band and a wider distal band white, grayish through the center; third joint entirely gray.

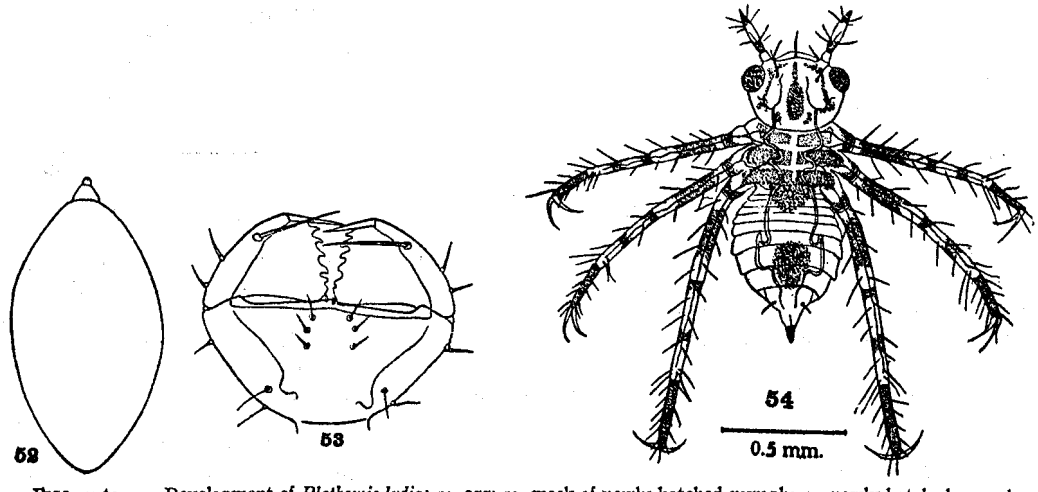
The Mask.—Mentum three times as wide as long; the distal margin twice the length of the proximal; no lateral setæ; two marginal setæ; three mental setæ on either side, not in line, but the proximal one nearest the midline; two stout spines at the center of the distal margin. Lateral lobes with length and width in the proportion of 13 to 9; two setæ on the outer margin on either side; two setæ on the blade of each lobe; raptorial seta reaching considerably beyond the tip of the movable hook, the latter long and narrow; three small teeth near the outer edge of the distal margin, the central tooth the largest, the rest of the margin smooth.

PLATHEMIS LYDIA.

The females of this species remain at some distance from the water, except at the time of ovipositing; one caught a quarter of a mile from the ponds deposited eggs freely on July 25, which began to hatch August 2, and were all hatched by August 9.

The Egg.—These eggs are elongate elliptical and rather pointed at both ends, just twice as long as wide, the two diameters being respectively 0.60 mm. and 0.30 mm. The neck is as wide at the base as it is high, with a distinct segmentation near the tip, the latter being undivided; there is no process on the posterior end of the egg.

The Nymph.—The general color of the nymph is yellowish white, with light-brown markings. On the center of the dorsal surface of the head is a longitudinal, club-shaped, brown area and on either side a broken semicircle; there is a large, irregular, brown spot in the center of the posterior thorax and anterior abdomen, and another smaller spot over the posterior end of the respiratory system. The eyes are dark brown, with black, retinal spots; the tracheal system is yellowish brown. The head is a trifle wider than long and not narrowed behind the eyes; the thorax is two-thirds as wide as the head; the



FIGS. 52 to 54.—Development of *Plathemis lydia:* 52, egg; 53, mask of newly hatched nymph; 54, newly hatched nymph.

abdomen the same width as the head, sharply pointed posteriorly, with strongly convex, lateral margins and no color markings except the two spots already noted. The base and basal joint of the antennæ are whitish; proximal end of second joint and the whole of the third joint light gray, distal part of second joint white. The legs are light gray and white; the tips of the posterior processes of the abdomen are dark brown; the terga of the thoracic segments are light gray.

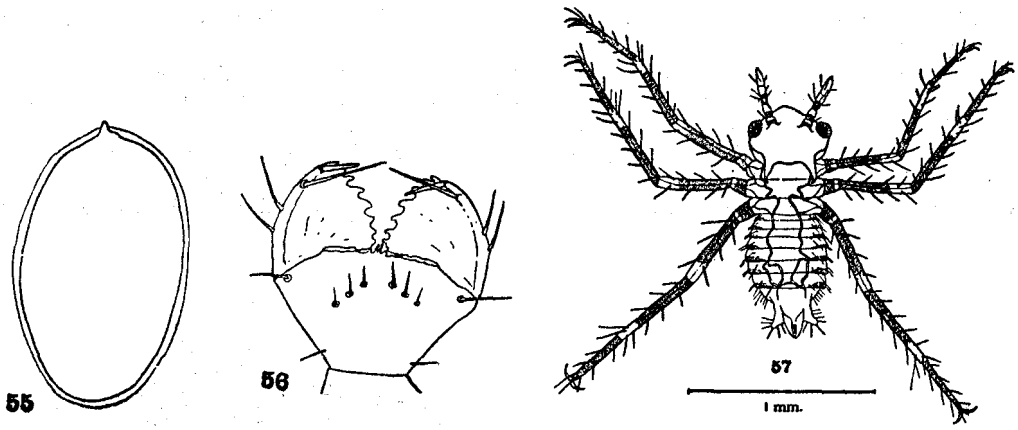
The Mask.—Mentum twice as wide as long, with convex sides; distal margin two and a half times the proximal; one lateral seta near the base on each side and two marginal setæ; three mental setæ on either side of the center in a curve concave to the midline; two small spines at the center of the distal margin. Lateral lobes one-half longer than wide; two setæ on the outer border, none on the blade; raptorial seta just reaching the tip of the movable hook, the latter short and stout; distal margin with seven teeth reaching nearly the entire width, the third tooth the longest.

EPICORDULIA PRINCEPS.

The eggs of this species are laid in long, jelly-like strings, similar to those of Tetragoneuria. Some of these strings were obtained from the leaves of *Potamogeton illinoiensis* in pond 3D on August 9, 1917; but, of course, there was no way to tell when they were laid; they began to hatch within a day or two.

The Egg.—This egg is the largest of any here described, being 0.72 mm. long and 0.40 mm. wide. The neck is a minute process of the same height and width, without segmentation, and there is no process on the posterior end of the egg.

The Nymph.—Like the egg from which it was hatched, the nymph is a little larger than any of the others here included, being 1.25 mm. long and 0.42 mm. in diameter. Its general color is white, the eyes and the center of the abdomen reddish brown, the respiratory system bright yellow. There are two comparatively large horns on the dorsal surface of the head at the posterior margin, with their tips turned back like hooks; that is, they are slightly "cultriform" (Needham). The inferior posterior appendages of the tenth abdomen segment are large and are turned over vertically at right angles to the body axis. The



FIGS. 55 to 57.—Development of *Epicordulia princeps:* 55, egg; 56, mask of newly hatched nymph; 57, newly hatched nymph.

antennæ are banded with black and white in sharp contrast; the base with a narrow, white, distal band; the basal half of the first joint black, the distal half white; the second joint the same, the third joint entirely white. The legs are transparent, with very little differentiation in color, the tips of the basal joint, the femur, and the tibia being somewhat whiter than the rest of the joint. The thorax is pale white, without any pigment; the abdomen is brownish red through the center over the intestine, with short, dark spots on the posterior margin at the outer edge of each segment, the rest white.

The Mask.—Mentum three-fifths wider than long, its sides slightly concave, the distal margin a little less than twice the proximal; one lateral seta, two marginal setæ on either side; three mental setæ on each half in a straight line, the distal one nearest the midline; four stout, sharp spines at the center of the distal margin. Lateral lobes about the same length and width; two setæ on the outer border, none on the blade of the lobe; raptorial seta reaching beyond the tip of the movable hook, the latter short and stout; distal margin with 10 teeth covering its entire width, the outer 5 much larger than the inner 5 and cultriform. Lateral seta on mentum often lacking as in figure 56.

ENALLAGMA HAGENI.

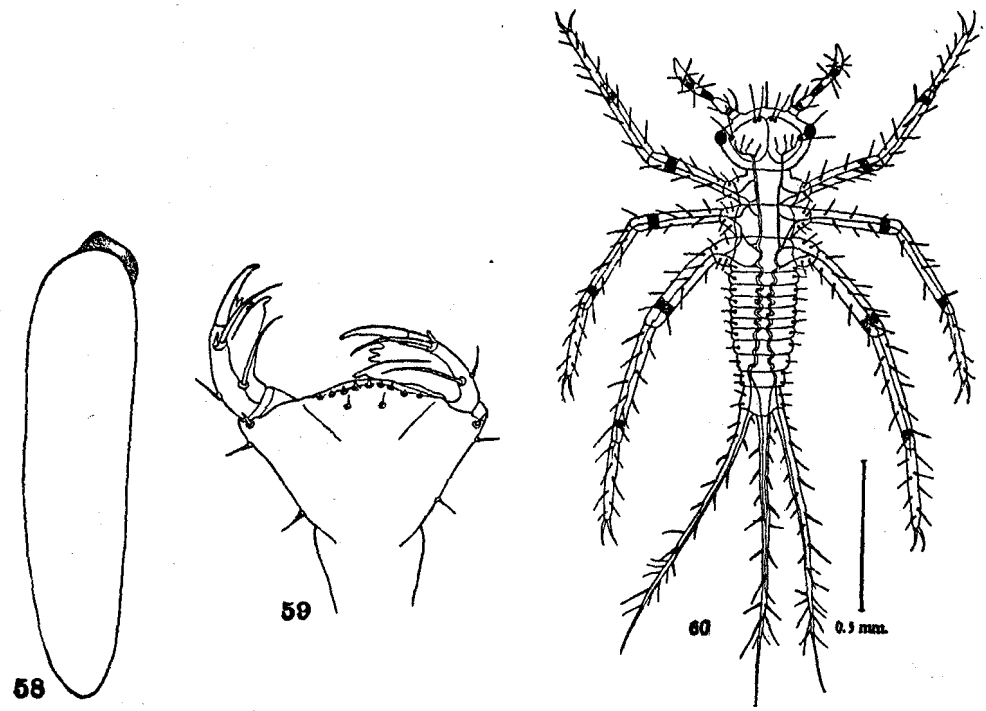
The eggs were laid in the leaves of crex grass; more than a thousand were obtained from five grass leaves July 26, 1917. These began to hatch in two weeks and continued hatching for 10 days, but, like the eggs of Epicordulia, there was no way to determine just when they were laid, so that the period of incubation is uncertain.

The Egg.—These eggs were in the form of an elongated ellipsoid, the long diameter four times the shorter one, the anterior end broadly and bluntly rounded, the posterior end pointed; neck short and broad and brown in color.

The Nymph.—The head is transversely elliptical in outline, the two diameters in the ratio of 8 to 5; there is a pair of setæ just inside of each eye on the dorsal surface, another pair close to the midline, just behind the anterior margin, and a single seta at the center of the margin itself. The thorax is considerably narrower, but almost twice as long as the head; the legs are long and stout, the posterior pair reaching somewhat beyond the center of the caudal gills. The abdomen is a little wider than the thorax anteriorly and does not narrow much in front of the seventh segment. The antennæ are long and stout, with a gray band at the base of each joint; caudal gills as long as the rest of the body and

cylindrical, covered with short and straight spines or setæ. All the leg joints, including the coxæ, are sparsely armed with setæ; and there is a row of setæ also along the dorsal surface of the abdomen close to the lateral margin. The color is a uniform, creamy white, except the three dark bands on the antennæ and a narrow band on each femur and tibia of the legs.

The Mask.—Mentum triangular, one-half wider than long; distal margin twice the length of the proximal; one mental seta on either side, one lateral seta at the base of each lobe, two marginal setæ; a row of nine small spines just behind the distal margin. Lateral lobes twice as long as wide, with one marginal seta and two raptorial setæ; movable hook long and stout; an accessory spine just outside the base of the distal raptorial seta.



FIGS. 58 to 60.—Development of *Enallagma hageni:* 58, egg; 59, mask of newly hatched nymph; 60, newly hatched nymph.

ENALLAGMA SIGNATUM.

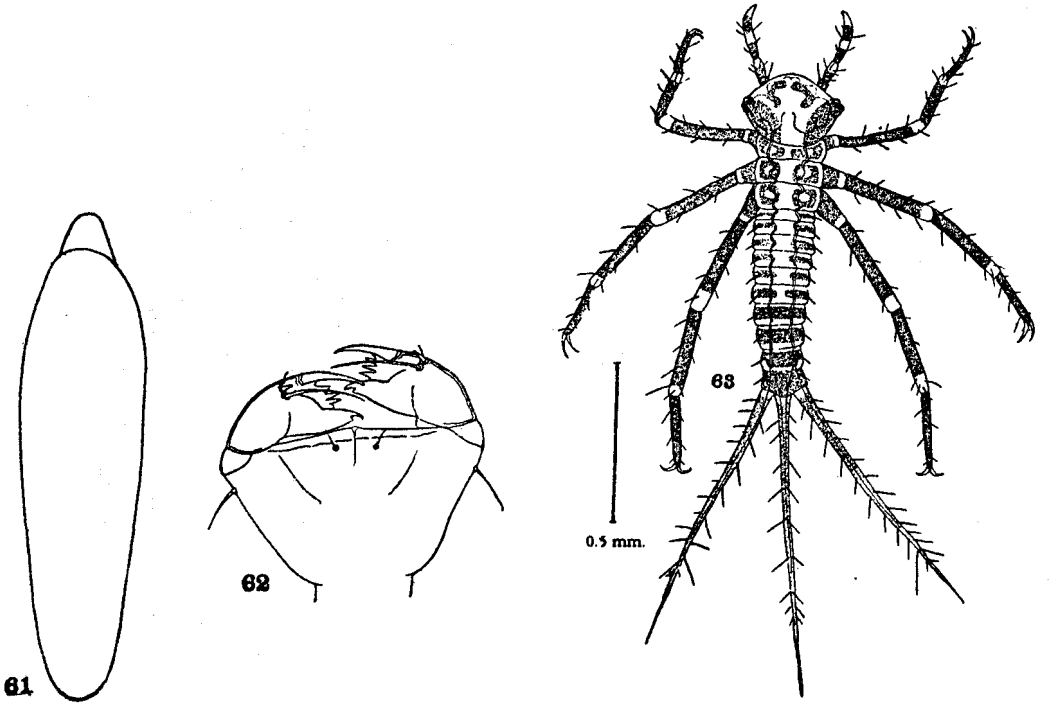
These eggs were obtained from pond-lily leaves on July 28, 1917, and began to hatch 18 days later, the period of incubation being again unknown.

The Egg.—The eggs are considerably like those of *E. hageni*, but they were arranged very differently in the tissues of the leaf. Those of *hageni* were inserted without any definite order anywhere in the leaf; these were arranged in a semicircle on the underside of the leaf around some convenient hole or close to the margin. The female evidently thrust her abdomen down through the hole or down over the edge of the leaf and, reaching as far as she could, inserted the eggs into the leaf.

The Nymph.—The nymph is just 1 mm. long, exclusive of the caudal gills; head wider than long, the two diameters in the proportion of 7 to 5, the anterior and posterior margins both strongly convex; thorax shorter than the head and two-thirds as wide; abdomen the same width as the thorax and tapering gradually backward; caudal gills short and slender; legs also comparatively short and slender, the posterior pair not reaching the center of the caudal gills; claws short and stout. The antennæ are long and stout; the eyes at the center of the lateral margins project strongly. There are no setæ on the dorsal surface of the head, on the thorax, or on the coxæ of the legs; there is a single seta on the center of each abdominal segment near the lateral margin on each side; and the setæ on the legs and

caudal gills are small and scattering. The ground color is white, covered with a complicated pattern of light russet brown; last four abdominal segments, legs, and caudal gills nearly all brown, with narrow stripes of white; respiratory tracheæ bright golden yellow.

The Mask.—Mentum one-half wider than long, with slightly convex sides; distal margin nearly three times the proximal; no lateral setæ, one marginal seta near the distal end, one mental seta; distal margin smooth. Lateral lobe three-fourths longer than wide; no setæ on the outer margin; raptorial seta just reaching the tip of the movable hook, the latter long and stout; a minute accessory spine outside the base of each raptorial seta; distal margin deeply toothed, inner tooth cultriform.



FIGS. 61 to 63.—Development of *Enallagma signatum:* 61, egg; 62, mask of newly hatched nymph; 63, newly hatched nymph.

GENERAL CONCLUSIONS.

1. Odonate nymphs feed upon small mollusks, insect larvæ (including smaller nymphs), pupæ and adults, entomostraca and larger crustacea, and algæ. Some of their food, such as Chironomid larvæ, mayfly larvæ, entomostraca, etc., is the same as that of young fish, but they also eat the larvæ or adults of many animals that are directly harmful to small fishes, such as diving beetles, water boatmen, crayfish, and Cypris.

2. A few of the largest species may sometimes eat a small fish under natural conditions, but this is apparently due to stress of hunger and the lack of other food. Warren has proved (p. 206) once for all that the diet of a nymph in captivity furnishes no criterion whatever as to its natural food. Careful observations under natural conditions show that even an Anax nymph need not be regarded as a menace to fish culture, but that it may become actually beneficial.

3. Odonate nymphs furnish one of the very best foods for fishes; the small species and the young of the larger species are freely eaten by the fingerlings of practically all

our fresh-water game and food fish, while the larger species when fully grown are just as toothsome to adult fish. The large percentage of nymphs in the food of fishes from the Fairport ponds (table, p. 228) effectively answers the objection that odonates rob the fishes of a part of their food.

4. If the Anax, Æschna, and other large nymphs are preying upon the fish in any given fishpond, this should be interpreted by the fish-culturist as evidence that the supply of food in that pond is running low. His efforts can better be directed toward replenishing the food supply than toward getting rid of the nymphs. On the other hand, if they do not disturb the young fish the food supply is adequate, and they themselves will contribute to it in due time. They thus furnish a convenient means of testing the food supply, since it is an easy matter to examine their stomachs and find out what they are eating.

5. Odonate imagos feed exclusively upon adult insects; their prey, like that of the nymphs, sometimes includes insects that are beneficial, such as other odonates, honeybees, and hymenopterous parasites; but the bulk of their food is made up of insects that are either positively injurious or negatively of no practical importance. Among these may be mentioned gall flies, tsetse flies, plant lice, leaf hoppers, ants, and all kinds of small moths and butterflies. They also confer an inestimable benefit upon mankind by waging an incessant warfare upon house flies, mosquitoes, black flies, and gnats. This one benefit alone far outweighs any harm they may do to the fish and should earn for them a cordial welcome to every fishpond, present and future.

6. Odonate imagos, like the nymphs, furnish good food for adult fishes, as is evidenced by finding them in the stomachs of various fishes taken under natural conditions and from the fishponds. It has also been demonstrated by feeding live dragonfly imagos to game fish in fishponds.

7. Both nymphs and imagos are important factors in establishing a natural equilibrium in the fauna and flora of the fishpond and its immediate environment. Other things being equal, such an equilibrium contributes materially to success in fish culture, and it can not be obtained without the presence of the nymphs and imagos. Incidentally, if properly chosen, the imagos will add greatly to the attractiveness of the fishpond and its surroundings.

8. Hence care should be taken that the pond is supplied with odonates, as well as with fish; after the original stocking they can be left to take care of themselves. For stocking purposes use common local species of dragonflies and damselflies; Anax, *L. pulchella*, Plathemis, and the damselfly genera, Argia, Enallagma, and Lestes are so cosmopolitan that they will make good stock almost anywhere in the United States. Here again the odonates constitute a sort of visible pulse of the life of the pond; so long as they remain vigorous and healthy the pond life is probably moving along smoothly.

9. Small breeding ponds along the margin of the fishpond from which the fish are excluded will materially increase the supply of all aquatic insects, including the odonates. If these are started in the spring or fall, the best odonate material to put into them will be the nymphs. If they are started in the summer, they can be stocked more intelligently by obtaining the eggs of desirable odonates and hatching them.

10. Dragonflies will not feed, nor mate, nor lay their eggs in captivity, but damselflies are more susceptible, and eggs could probably be obtained from any common species. If a female dragonfly be caught while ovipositing and held by one pair of wings, leaving

the other pair free, she will deposit her eggs freely in any convenient receptacle if the tip of her abdomen be dipped in water. Thousands of eggs can be obtained in this way in a short time and kept until they hatch, or they can be placed at once in the breeding pond. The eggs of Anax, Æschna, and the damselflies can be secured by watching the females while ovipositing and then transferring the leaves or stems containing the eggs to the breeding pond.

11. If there is any necessity for rearing the nymphs before placing them in the breeding pond, they can be fed on Paramœcium obtained by making an infusion of manure in water, or on ordinary tow, especially the small crustacea, which they will devour in large numbers. Warren carried dragonfly nymphs successfully through their entire life history by feeding them with mosquito larvæ and pupæ.

12. Whenever a fishpond is drained, the nymphs in it should be saved; they make excellent food for fish in other ponds and can be fed to them or can be used to restock the drained pond when it is filled again.

13. Dragonfly eggs hatch in 8 to 12 days; the nympn is short and thickset, the thorax and abdomen about as wide as the head, the legs long and slender, the antennæ short and fairly stout, the eyes large, with black retinal spots surrounded by rings of colored pigment. The mentum of the mask is much wider than long, with three mental setæ on either side and a varying number of lateral and marginal setæ. The lateral lobes have a terminal, movable hook, one raptorial seta, marginal setæ on the outer margin, and usually two small setæ on the blade of the lobe. The respiratory tracheæ are convoluted in the thorax and posterior abdomen and comparatively straight between the two, and are highly colored.

14. Damselfly eggs hatch in about three weeks; the nymph is long and slender, the thorax and abdomen considerably narrower than the head; the legs relatively short and slender; the antennæ stout and long; the eyes small with few retinal spots, but each surrounded by colored pigment. The mentum is somewhat wider than long, with a single mental seta on either side and one or two lateral and marginal setæ. The lateral lobes have a stout, terminal, movable hook and one raptorial seta. The respiratory tracheæ are highly colored and are convoluted in the thorax and anterior abdomen and are comparatively straight posteriorly. The caudal gills are cylindrical, very long and slender, and taper regularly from the base to the tip.

ANNOTATED LIST OF DRAGONFLIES AND DAMSELFLIES OBTAINED NEAR FAIRPORT, IOWA.

THE GENUS GOMPHUS.—The nymphs of this genus live in the mud or sand on the bottom of the Mississippi and its tributaries, and thus far none of them has been found in any of the fishponds. There is no reason, however, why pond species like *graslinellus* and *submedianus* should not be found there, as they probably will be in the future. They burrow into the mud and débris, leaving only the tip of the abdomen exposed for respiration, and lie in wait for their prey. They are both rapacious and omnivorous and will eat anything and everything small enough to be caught and held by their powerful jaws. They may be recognized by their thick and hairy, four-jointed antennæ, which are usually inclined inward toward each other, by a flat labium simply folded beneath the chin, with strong grasping arms like mandibles and not extending up over the face in a

mask, and by the absence of dorsal spines along the midline of the abdomen. Their legs are stout and adapted for burrowing, the two front pairs directed forward and the posterior pair directed backward, and all three pairs armed at the tips with strong burrowing claws. Their color is similar to that of the débris in which they live, and the furry hairs covering their bodies and legs quickly gather a coating of mud which still further obscures them. When ready to transform they crawl up on some board surface like a floating barge, the side of a boat, the bark of a tree, or more commonly a flat mud surface close to the water. In suitable locations the mud will be found thickly incrusted with their nymph skins, and it is not uncommon to find two or more skins one on the top of another, those coming out last crawling up on the others.

The imagoes scatter quickly as soon as they are able to fly and often entirely disappear from the vicinity where they leave their nymph skins. In general, the females retire inland, while the males remain along the water front.

Their habits are very different from those of the Libellulidæ, the imagoes usually alighting flat on the ground or close to it, or on the surface of a log, and squatting or flattening the body down until the wings almost touch the ground, all ready to spring upon their prey. They almost never alight on twigs or grass stems, like the Libellulidæ. From this flattened position they dart out over the water, skimming close to the surface and going toward the center of the river or stream, and then return again to the bank. Their motion is more similar to the ordinary aeroplane than that of most Libellulids, and they often hover over one spot for some time. They pluck much of their prey off the surface of the water, and some species actually dive beneath the surface, entirely disappearing under the water.

Although two of the species, *externus* and *vastus*, are common about the ponds, they have never yet been observed hunting their prey over the pond surface. They do catch numbers of teneral dragonflies and damselflies, however, in the vegetation around the margins of the ponds.

The imagoes are so nearly alike in color pattern, wing venation, and even in habits, that it is very difficult for anyone but an expert to distinguish the various species, but the nymphs afford much plainer distinctive characters.

The pairing of the sexes occurs toward evening, and if one goes out just before sunset there is a good chance of obtaining the two sexes together. The male does not accompany the female while ovipositing, and the sexes never fly about together after the manner of some of the Libellulidæ.

GOMPHUS PLAGIATUS Selys.

Gomphus plagiatus Selys, Bull. Acad. Belgique, 1854, vol. 21, p. 57.

In the Proceedings of the Indiana Academy of Science for 1901, page 123, Williamson said: "The why, whence, and whither of imago Gomphi is a puzzle." And to no species of the genus apparently does it apply any more forcibly than to the present. The nymph skins of this species were by far the most abundant of any found along the river bank, and over 1,000 were collected during the summer. But the only imagoes caught or seen were two tenerals captured as they were emerging. The imagoes must depart as soon as they can fly at all, and apparently they remain in the place to which they go. Consequently this species can hardly be said to have any part at all in the ecology of the fishponds although such large numbers of them are transformed within a few hundred feet of the ponds.

Emergence takes place early in the season, usually during the night, so that by the next morning the imago can fly fairly well.

GOMPHUS VASTUS Walsh.

Gomphus vastus Walsh, Proc. Acad. Nat. Sci., Phila., 1862, p. 391.

This species was third in abundance, judging by the number of skins obtained, and it takes an active part in the odonate life around the ponds.

While the imagoes emerge along the river bank, and while many of them remain there, others migrate to the vicinity of the ponds. Most of these migrants are females, although there is a respectable sprinkling of males. And yet none of them ever deposits eggs in the ponds; they all return to the river. Hence the part which they play is strictly confined to the imagoes, and consists wholly in the consumption of various insects and the teneral imagos of smaller dragonflies.

GOMPHUS EXTERNUS Hagen.

Gomphus externus Hagen, Monogr. Gomphidæ, 1857, p. 411.

This species was second in abundance, as shown by the skins collected. The sexes seemed fairly well divided, and specimens could nearly always be seen along the cinder road to the north of the ponds or in the vegetation on the embankments. They are active and restless hunters and voracious eaters. One female was observed July 18 eating an *Argia putrida* imago and was so intent upon her meal that she allowed an approach to within 2 feet. She chewed and swallowed every scrap of the large damselfly except the wings and had no sooner finished than she caught another and ate it similarly. Such gormandizing must of necessity play an important part in the ecology of the ponds. Like *vastus*, this species returns to the river for ovipositing, and its nymphs are never found in the ponds.

Like *plagiatus*, emergence takes place during the night, and many tenerals were found early in the morning at the season of transformation, which seems to last through June and July.

GOMPHUS SUBMEDIANUS Williamson.

Gomphus submedianus Williamson, Entomol. News, 1914, vol. 25, p. 54.

This species was found only at Patterson Lake and Sunfish Lake, on the Illinois side of the Mississippi River, just above Fairport. The males were plentiful along the banks of the lakes, while the females were found in swampy places some distance back in the woods. Specimens were sent to E. B. Williamson, the founder of the species, and he very kindly confirmed their identification. The males usually fly close to the surface of the water and have the habit of hovering for a short time over one spot after the manner of some of the other Gomphids. They also frequently alight upon floating logs, bushes, or some water plant. While hovering, the seventh, eighth, and ninth abdominal segments have a decided reddish tinge when the sunlight strikes them just right.

GOMPHUS AMNICOLA Walsh.

Gomphus amnicola Walsh, Proc. Acad. Nat. Sci., Phila., 1862, p. 396.

This species was especially abundant along the banks of the river just above the ponds in series B and was occasionally captured around the fishponds. While the exuviæ collected give us the best idea of the actual number of imagoes of the various species, the apparent abundance does not always correspond. The present species was seen and captured as often as any other single species, but in the number of exuviæ it was far behind most of the other Gomphids. Evidently these imagoes do not migrate after their emergence, but stay around in the immediate vicinity.

This dragonfly frequents the thick grass and underbrush a little back from the water's edge and can be captured with comparative ease.

The nymphs and nymph skins were all obtained from the river, and none was found in any of the ponds.

GOMPHUS NOTATUS Rambur.

Gomphus notatus Rambur, Ins. Neur., 1842, p. 162.

This dragonfly is a little larger than *amnicola*, but has similar habits; it stays out in the open rather more, but is occasionally found in the thick grass. Its favorite haunt is along the river's bank, whence it makes long flights out over the water, returning again to nearly the same place. The nymphs frequent the shallower portions of the river, and none are ever found in the ponds.

NASIÆSCHNA PENTACANTHA (Rambur).

Aeschna pentacantha Rambur, Ins. Neur., 1842, p. 208.

This species is said to have a wide geographical range, but not to occur anywhere in abundance. It was found quite plentifully around Patterson Lake and the slew leading up to it from the river. Its habits are like those of other Æschnines; it patrols the banks, flying back and forth over a limited area and frequently alighting and clinging to the underside of twigs and branches, its body hanging vertically and its wings drooping. In this position it is not very difficult to catch. No old nymphs or nymph skins could be found, although careful and continued search was made for them, but newly hatched nymphs were obtained in August, 1917.

ANAX JUNIUS (Drury).

Libellula junia Drury, Illust. Exot. Entomol., vol. 1, 1773, p. 112.

According to Kellicott, this species is the first to appear in the spring and almost the last to disappear in the fall. During June the imagos were not very plentiful around the ponds, but they increased greatly in actual numbers and still more in relative abundance as the season advanced, and by the last of August they were surpassed only by *Libellula luctuosa*. This is one of the most powerful fliers and almost never alights except for ovipositing. At such times the two sexes fly about together and, alighting upon some water plant at or near the surface of the water, the male assists the female as she inserts her eggs in the tissue of the plant stem. Both sexes often have a regular beat which they patrol back and forth for a long time; they also fly later at night than any other species, sometimes high in the air, catching the numerous small insects which they find there.

Nymphs were found in all the ponds, but especially in 4 and 9, where they were not much disturbed by the fish. This nymph is probably better known and more often figured than that of any other dragonfly. It shows a great variety in its color pattern at different ages, as well as the usual differences according to the nearness of the next molt. When very small, it is a uniform greyish green; as it grows larger it becomes banded transversely with black and white, while the mature nymphs are bright grass-green, with a beautiful and intricate color pattern of cinnamon brown. Two medium-sized nymphs were taken in pond 4 that were snow white throughout and so transparent that the dark breathing tracheæ around the posterior intestine showed through plainly.

The nymphs are most abundant in waters filled with vegetation, and may be found even in small ditches and pools, and there are sometimes two broods in a year. They expel the water from their rectum with a noise like that made in ejecting saliva, and such spitting served to locate most of them in pond 4 when the water was drawn. When those that were left in this pond transformed, they seemed to find the screen across the outlet peculiarly attractive, and it was covered with bunches of skins. Two of these bunches are shown in Plate LXVIII, figure 1, the right-hand one containing six skins in a row, each fastened to the one in front of it.

ÆSCNHA CONSTRICTA Say.

Æschna constricta Say, Jour. Acad. Nat. Sci., Phila., vol. 8, 1839, p. 11.

Nymphs were found in all the ponds associated with those of Anax; they do not transform until midsummer or later, and hence no imagos are seen until then. The imagos frequently enter houses or other buildings and may often be captured there. They wander afar in the fields and are seldom seen around the ponds, preferring some small brook among the hills. They feed on flies as well as mosquitoes and often catch house flies and stable flies around our dwellings.

MACROMIA TÆNIOLATA Rambur.

Macromia tæniolata Rambur, Ins. Neur., 1842, p. 139.

This and the following species were only found in the slews along the Mississippi River. None have ever been seen around the fishponds, nor have any nymphs or nymph skins been found there. Patterson Lake is a favorite resort of the imagos, but careful search in its waters failed to reveal any nymphs.

MACROMIA ILLINOIENSIS Walsh.

Macromia illinoiensis Walsh, Proc. Acad. Nat. Sci., Phila., 1862, p. 397.

Like the preceding species this one is never found around the ponds, but may be seen frequently along the river bank and at sunset in the cornfields flying back and forth between the rows. At night both species congregate in favorite places upon low bushes and hang by their legs from the under side of the branches like Nasiæschna.

EPICORDULIA PRINCEPS (Hagen).

Epitheca princeps Hagen, Synop. Neuropt. of N. A., 1861, p. 134.

This species is easily recognized by its large size, by the brown blotches on its wings at the nodus and stigma, and by the fact that there are never any white areas connected with these blotches as in *L. pulchella*.

The males have regular areas which they patrol incessantly hour after hour, hawking the varied insect life they may find.

The nymphs are common in all the ponds; but the imagos scatter after emerging, and only a few are seen about the ponds at any one time. The nymph is large and sprawling and can not cling well to grass stems, preferring a broad surface like a board, a stump, or even the side of a bank. Most of those taken at the ponds were found on a hard mud bank beside the cinder road. The two sexes do not fasten together during oviposition, but the female drops her eggs alone into deep water.

The imago emerges early in the morning and is one of those that consequently falls a prey to the birds, since it is helpless during the first forenoon. Some of the wings of this species were found with those of *L. luctuosa* already noted (p. 222).

PANTALA FLAVESCENS (Fabricius).

Libellula flavescens Frabricius, Entomol. System. Supple., 1798, p. 285.

This species was found more plentifully upon the Illinois side of the river, but was occasionally taken around the fishponds. Nymphs were found in ponds 4 and 8, and skins were obtained along the shores of ponds 1, 2, and 3.

The imagos are rapid flyers and very difficult to capture while on the wing; they congregate in open places near the river bank, where they may be recognized by their reddish-yellow color and strong flight.

Apparently they never become really numerous anywhere in the vicinity of the station, but are one of the rarer species.

PANTALA HYMENÆA (Say).

Libellula hymenæa Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 18.

Similar to *flavescens*, but with a distinct fuscous spot at the base of the posterior wings; common along the river bank just above the ponds in series B. Like *flavescens* they are rapid flyers and difficult to capture while on the wing, but, unlike that species, they frequently alight upon the under side of a twig of some bush or tree like Macromia and Nasiæschna, and can then be captured easily.

Nymphs were taken in ponds 3 and 4, but no skins were found in any of the counts made. Neither imagos nor nymphs occur in sufficient numbers to affect the ecology of the ponds.

TRAMEA LACERATA Hagen.

Tramea lacerata Hagen, Synop. Neurop. N. A., 1861, p. 145.

This species can be readily recognized even when flying by the large black blotches at the bases of the posterior wings. The male accompanies the female while ovipositing, and the two may frequently be seen flying tandem over the ponds. Early in the season, June and the first of July, the species is comparatively rare, but later they become more numerous and by the last of August they share with Anax the honors of first place. Nymphs were found in all the ponds, and skins were obtained in every count made, those in August being especially numerous.

TRAMEA ONUSTA Hagen.

Tramea onusta Hagen, Synop. Neurop. N. A., 1861, p. 144.

A single male of this species was captured on pond 8D in July, 1917, and others were seen later about several of the ponds. It can be readily distinguished from lacerata by the reddish color of the blotches at the bases of the wings. Neither nymphs nor skins were secured.

PERITHEMIS DOMITIA (Drury).

Libellula domitia Drury, Illust. Exot. Entomol., vol. 2, 1773, p. 83.

This is the smallest of the dragonflies and may be distinguished from the others here mentioned by its diminutive size and its amber-tinted wings. The imagos are as common about the ponds as elsewhere, but are not very abundant anywhere. It is a slow and clumsy flyer, approaching more nearly to the damsels than to the other dragons. Its small size gives it very little confidence and it keeps well out of the way of other species, flying close to the surface of the water.

The female is usually found in the fields some distance away from the ponds, and she deposits her eggs unattended by the male.

The nymphs are found sparingly in all the ponds and were also obtained from Patterson Lake on the river; they are cleaner, as well as smaller, than most other species. The skins are always found close to the water's edge, often over the water, apparently on the first suitable stem that the nymph met with.

CELITHEMIS EPONINA (Drury).

Libellula eponina Drury, Illust. Exot. Entomol., vol. 2, 1773, p. 86.

These dragonflies can be recognized by their heavily spotted wings and by their habit of balancing upon the very tip of some convenient grass or weed stem. When disturbed they return again to the same spot, and this makes them easy to capture. Their flight is slow, and in the position and movement of the wings bears more resemblance to that of a butterfly than of other dragonflies. They are seen paired and flying tandem more often than other species, and in spite of their slow flight they are more in evidence on windy days.

The nymphs are found in all the ponds, while the skins are found close to the water's edge, like those of Perithemis. The small size and scarcity of both species gives them but little influence in the ecology of the ponds.

CELITHEMIS ELISA (Hagen).

Diplax elisa Hagen, Synop. Neurop. N. A., 1861, p. 182.

This species was first seen around the fishponds in the summer of 1917. One or two were seen in 1918, but none was captured. A male and female were secured on July 1, 1919, near ponds 4 and 8 of series D.

LEUCORRHINIA INTACTA (Hagen).

Diplax intacta Hagen, Synop. Neurop. N. A., 1861, p. 179.

This is another small species familiarly known as "Johnny Whiteface"; it may be recognized by its diminutive size and its snow-white face combined with a dark body and clear wings. The two sexes do not fasten together during ovipositing, but spend much of their time perched separately on some convenient object near the water. They fly only short distances from one resting place to another, but forage continuously all summer long. Their nymphs are found in all the ponds and much resemble those of Celithemis and Perithemis, but are shorter and generally show a definite color pattern of dark brown on a greenish background. They are lively and clamber about on the submerged vegetation with considerable agility.

SYMPETRUM RUBICUNDULUM (Say).

Libellula rubicundula Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 26.

This species appears early in the season and remains until after the frosts of October. At first the adults are very soft and seem to remain teneral a long time, but later they become firmer and by September are as rigid as any of the smaller species.

The imagos are found in large numbers around the ponds, but stick to the vegetation and do not fly out over the water. The nymphs were found in all of the ponds; and nymph skins were present in all the counts.

SYMPETRUM CORRUPTUM (Hagen).

Mesothemis corrupta Hagen, Synop. Neurop. N. A., 1861, p. 171.

Appears early in the season and is common around the ponds; then diminishes gradually and by the middle of August entirely disappears.

Nymphs were found in all the ponds, and nymph skins occurred in the first two counts. It is the largest species of the genus and the strongest flyer, going out, like other dragonflies, over the water, but never in numbers, and remaining but a short time.

ERYTHEMIS SIMPLICICOLLIS (Say).

Libellula simplicicollis Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 28.

Second in abundance at the ponds, sticking close to the grass and weeds and never taking long flights. It does not perch on the sides of the grass stems like *L. luctuosa*, but prefers a horizontal blade of grass and settles down flat upon it. The females hunt almost exclusively in the grass and feed upon diptera, small butterflies and moths, and damselflies, especially teneral *Enallagmas* and *Lestes* (Pl. LXIX, fig. 2.)

Williamson (1899, p. 326) has noted a peculiar habit of the males. Two of them hover over the surface of the pond close to the water, one a few inches above and in front of the other. The lower one then rises in a curve over the back of the upper one, which at the same time moves in a curve downward, backward, and then upward, so that the positions of the two are exactly reversed. The two keep this up for several minutes and then separate; such movements may be witnessed on any clear day by watching for it.

The two sexes never fly about together, but the female oviposits alone, hovering close to the water and repeatedly dipping the tip of the abdomen beneath the surface. Both sexes alight on the floating algæ and other water plants, unlike most dragon flies.

The nymphs never crawl far from the water to transform, and many of the skins are found upon rush stems standing in the water. They showed a curious preference for *Carex stricta* and *Homalocenchrus oryzoides*, and but very few skins were found on other plants. Such a preference was probably due more to the position of the plants than to any other factor. The two sexes are shown in Plate LXIX, figure 1.

PACHYDIPLAX LONGIPENNIS (Burmeister).

Libellula longipennis Burmeister, Handb. Entomol., vol. 2, 1839, p. 850.

Not very common around the ponds, although a few can be found there all through the season. The matured, pruinose males are more in evidence than the females; both sexes have the habit of drooping the wings and elevating the abdomen when they alight. Nymphs were more abundant in ponds 2 and 3, and nymph skins more numerous in July and August.

LIBELLULA LUCTUOSA Burmeister.

Libellula luctuosa Burmeister, Handb. Entomol., vol. 2. 1839, p. 861.

This is by far the most common species at Fairport and can be recognized by the broad, black bands across the wings, with chalky white spots outside of them in the male. It is very energetic and active, but alights often upon the grass and sedges and sometimes remains at rest a long time. It does not hover after the manner of some species and does not hunt late at night, being rarely seen actively flying about after sunset. It roosts in the tall grass up in the fields, holding onto the grass stem well down out of sight, and sometimes in the vegetation alongside of the ponds. Its characteristic attitude is to grasp the stem with all six legs, the longer hind legs holding the body inclined at an angle of about 45° with the stem, as shown in Plate LXVIII, figure 2. It gets thoroughly wet with the dew during the night and does not start flying in the morning until the dew has dried off.

The two sexes do not fly about together after the manner of Anax, Tramea, and Celithemis, but the female oviposits alone, dropping her eggs loosely in the water, and not inserting them in the tissue of any water plant.

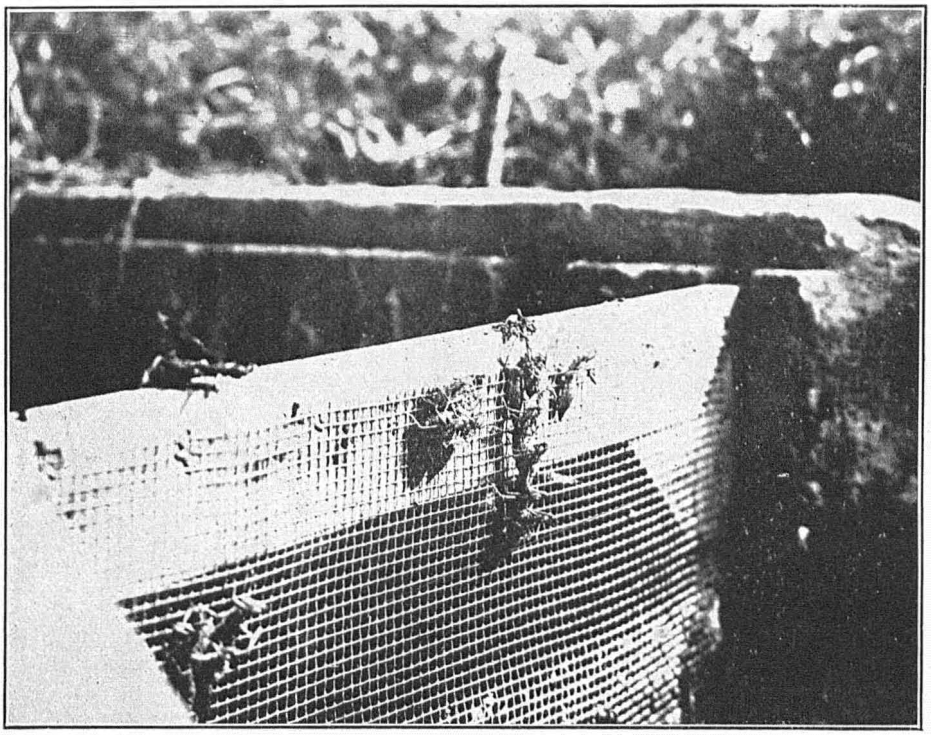


FIG. 1.—Skins of nymphs of *Anax junius* left on the screen of the outlet of pond No. 4.

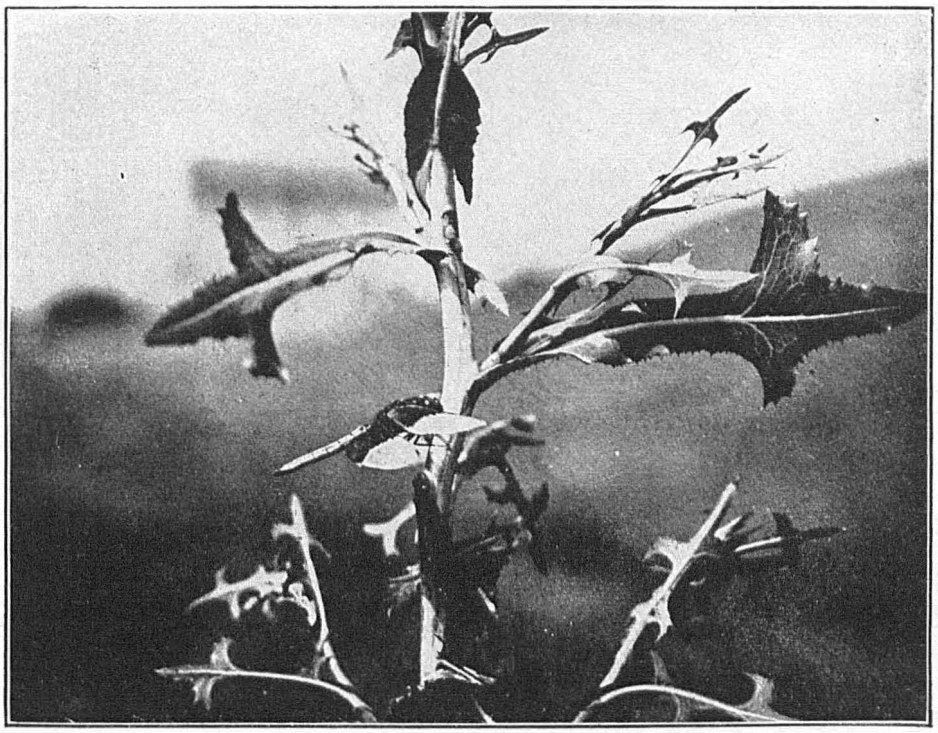


FIG. 2.—Male of *Libellula luctuosa* in characteristic attitude on the stem of a plant.

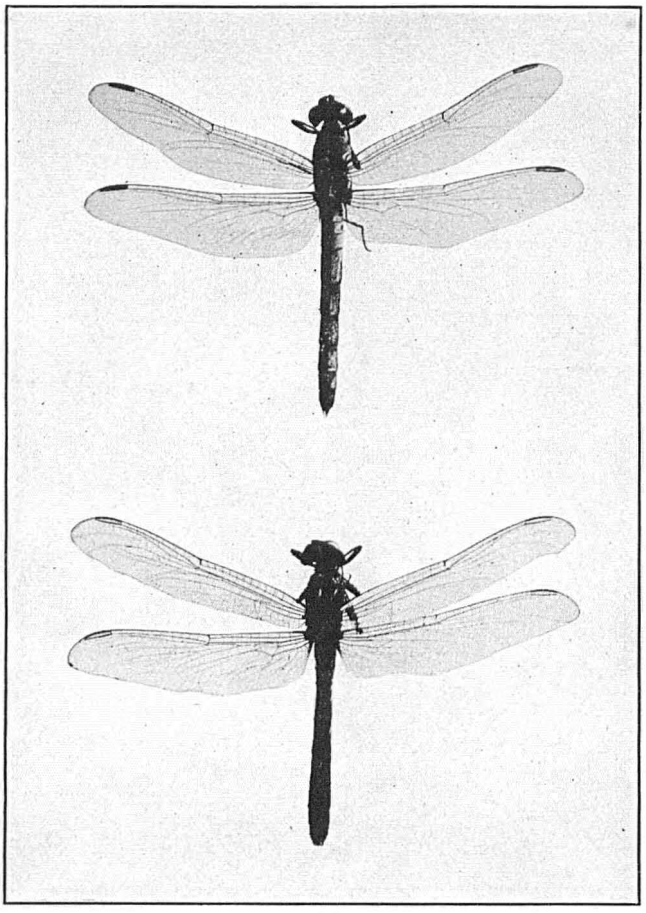


FIG. 1.—Male (upper) and female (lower) of *Erythemis simplicicollis*.

FIG. 2.— A favorite resort of *Erythemis simplicicollis* beside pond No. 2.

The males frequently come hawking around the laboratory building toward night, alight on the screens, and fly up and down the sides of the building, catching house flies, mayflies, and midges. They also have a curious habit of congregating around straw stacks in the open fields, probably attracted by the insects that frequent the sunny side of the stacks.

Over the ponds they do not keep to a definite beat or patrol, but wander about indiscriminately, the males frequently clashing with one another. So far as observed, the imagos do not eat other dragonflies or any of the larger insects. Large numbers of them while teneral fall victims to English sparrows and red-winged blackbirds.

The nymphs are found in all the ponds, but most plentifully in ponds 3, 4, and 7. These nymphs are always dirty and without a color pattern, but the dorsal hooks on the abdominal segments are always visible.

Sometimes they crawl long distances from the water, but most of the skins were found in the fringe of Carex close to the ponds. A few live in the Mississippi River, and these climb the willow trees on the bank and leave their skins attached to the bark.

LIBELLULA PULCHELLA Drury.

Libellula pulchella Drury, Illust. Exot. Entomol., vol. 1, 1773, p. 115.

Common around all the ponds, but seeming to prefer those nearest the railroad and the ditch along the railroad track. It goes much farther from the water than the preceding species and is often found along the country roads and in the farmyards, industriously hunting the insects which occur there. Nymphs were found in all the ponds, and skins were obtained in every count, but were most abundant the last of July; they are among the largest of the Libellulid nymphs and make excellent fish food.

PLATHEMIS LYDIA (Drury).

Libellula lydia Drury, Illust. Exot. Entomol., vol. 1, 1773, p. 112.

Like *pulchella*, this species prefers the ponds and the ditch along the railroad track; the nymphs were abundant in the ditch, but rare in the ponds. The male is easily recognized by his white pruinose body and black wings; the female has spotted wings and might be mistaken for *pulchella*, but is considerably smaller, and the triangle of the front wings is entirely free from color. This species is a persistent hunter, and the males have regular beats which they patrol almost constantly.

DAMSELFLIES.—The habits of the various damselflies in ovipositing and the habits and relations of the nymphs to the fish life in the ponds are so similar that a general statement will cover them all, with the exception of a few peculiarities, which may be noted under the separate species.

When ovipositing, the male grasps the female by the prothorax and flies about with her. She does not dip her abdomen beneath the surface and wash off the eggs after the manner of some dragonflies, but alights on some convenient water plant, floating algæ, pond-lily leaf, or rush stem, or upon a floating twig or piece of wood, and places her eggs in position beneath the water, the male retaining his hold and assisting her out after she has finished. Often the male holds his body erect in the air, and floating objects are sometimes covered with the females busily ovipositing, while the males stand up from the surface like small twigs or moss stems. In some genera like Lestes, Argia, and Enallagma the female descends into the water and often draws the male in with her. The females of *Argia putrida* sometimes descend 9 inches beneath the surface, the female clinging to some water plant, the male holding his body erect, with the wings spread. After placing her eggs, the female releases her hold and the two rise to the surface, their buoyancy lifting the male into the air until his wings are free. He immediately begins to fly and lifts the female out of the water, and the two then go to another place and repeat the process.

However they may be laid, the eggs hatch quickly, and the ponds are swarming during the summer time with nymphs of all sizes and kinds. These nymphs have long masks which fold back beneath the head and thorax, like those of the dragonfly nymphs. But in place of the rectal respiratory apparatus of the latter, they carry three external tracheal gills at the posterior end of the abdomen. These are flattened laterally and are usually about half the length of the abdomen, their size and shape furnishing one means of identifying the species.

Their food is similar to that of the dragon nymphs, but contains a larger percentage of small animals, as would be expected (table, p. 201). One such nymph was seen by Williamson (1899, p. 234) clinging to a dead catfish and evidently feeding on its flesh.

ARGIA APICALIS (Say).

Agrion apicalis Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 40.

The male imagos of this species never become pruinose like *putrida;* one was secured from pond 5, in which the blue of segment 8 was W-shaped and restricted to the base of the segment, like that in *translata.*

The imagos were observed by Needham (1903, p. 242) at Galesburg, Ill., "feeding voraciously on adult Chironomids." The nymphs were not found at all in the ponds, but were fairly common in the river. They do not travel far when ready for transformation, but the skins are always found within a few inches of the water's edge.

ARGIA MŒSTA PUTRIDA (Hagen).

Agrion putridum Hagen, Synop. Neurop. N. A., 1861, p. 96.

The largest species of the genus; does not breed commonly in the ponds, but is very plentiful along the river. The imagos eat large numbers of mayflies, and when the latter are emerging almost every Argia, male and female, may be found munching one. The males quickly become pruinose, fading into a uniform bluish gray, but the colors are usually restored on immersion in alcohol.

The nymphs are numerous in the river, but only one or two were found in the ponds, and but few imagos were seen around the ponds. When ready for transformation the nymphs often go long distances from the water and even climb rough-barked trees. Ten skins were taken from the trunk of a large willow tree 60 feet from the water, and with them were found half a dozen skins of *Libellula luctuosa.*

AGRION (CALOPTERYX) MACULATUM (Beauvois).

Agrion maculata Beauvois, Ins. Afr. Amer., 1805, p. 85.

This beautiful damselfly is restricted to shady running water and is found only along a small brook one-fourth of a mile above the station. It sticks close to its haunts, although a male was seen one day fluttering along the shores of the ponds. Such visits, however, are only accidental, and the species does not enter into the life of the ponds to any appreciable degree.

THE GENUS ENALLAGMA.—Enallagma and Ischnura females, after inserting 8 or 10 eggs into the tissue of some plant, have a habit of stopping and straightening out the abdomen and stretching it, much as one stretches his fingers after prolonged writing. Evidently it requires considerable effort to thrust the ovipositor into the plant tissue, and since the abdomen is curved during the process it relieves the strain to straighten and stretch it.

Two Enallagma females were observed on July 26 depositing their eggs. During the process each came in contact with a partially drowned damselfly floating in the water and tossed about by the waves, which they seized, pulled out of the water and ate.

Here in the fishponds the Enallagma females seem to prefer the leaves of the carex grass as tissue in which to deposit their eggs. When the leaves break and fall over into the water, the part distal to the break dies and becomes apparently of just the right consistency to suit these damselflies, and nearly every such leaf contains eggs.

A pair of *Enallagma civile* was observed upon a bullrush stem in pond 1D July 20, 1917. The female backed down the stem into the water for the purpose of laying her eggs. When the water reached the male and he became half submerged, he released his hold and perched on the stem above the water. But the female continued backing down the stem until she was at least 6 inches beneath the surface. Here she remained for ten and a half minutes actively ovipositing. Then a small sunfish, *Lepomis euryorus*, caught sight of her and snapped her up instantly.

The female Enallagma often gets stranded on the surface of the water with her wings wet and unable to fly. When he catches sight of her in such a predicament, a male will fasten to her and try to pull her out. Such a rescue was witnessed in pond 2D; four different males fastened to this female, but the adhesion of the water was too strong for them. They could merely tow her along on the surface, each in turn giving way when he became exhausted. But together they pulled her far enough to reach some floating algæ, onto which she crawled. Such chivalry deserved a far better reward than it received; a small cricket frog seized and swallowed her while she was drying her wings.

ENALLAGMA ANTENNATUM (Say).

Agrion antennata Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 39.

This species is rare about the ponds, and only a few specimens were secured; elsewhere it is often found in large numbers and becomes the dominant species, as noted by Williamson (1899, p. 275).

ENALLAGMA CALVERTI Morse.

Enallagma calverti Morse, Psyche, 1895, p. 208.

Only a single pair was secured from pond 4, the male of which could be recognized by the excellent figures given by Williamson (1900, pl. 1).

ENALLAGMA CIVILE (Hagen).

Agrion civile Hagen, Synop. Neurop. N. A., 1861, p. 88.

This is one of the two most common species of the genus about the ponds, and its nymphs are found in every pond. In 1915 this species and *Ischnura verticalis* constituted the bulk of the damsel fauna of the ponds, but in 1916 there were fully as many of the species *hageni* as of *civile*.

Williamson stated (1899, p. 270) that old individuals of *civile* often have the wings milky or gray and the pterostigma bluish or pruinose, and this was noted in several specimens collected in September, 1915. Both the imagos and the nymphs take an active part in the life of the ponds, serving as food for fish and dragonflies.

ENALLAGMA EBRIUM (Hagen).

Agrion ebrium Hagen, Synop. Neurop. N. A., 1861, p. 89.

Moderately abundant around the ponds and found in company with other species of the genus, which it very much resembles in habits and appearance. The nymphs were more abundant than the imagos and were found especially in ponds 1, 2, 3, and 4. They are just the right size to furnish good food for young fishes.

ENALLAGMA GEMINATUM Kellicott.

Enallagma geminatum Kellicott, Etom. News, vol. 6, 1895, p. 239.

This is the smallest and most slender of the genus that frequents the ponds, but is also the most active, flying about restlessly over the water, often a long distance from the shore. It has the habit of sticking close to the surface of the water and alighting only on floating algæ, which renders it difficult to capture.

ENALLAGMA HAGENI (Walsh).

Agrion hageni Walsh, Proc. Entomol. Soc., Phila., vol. 2, 1863, p. 234.

This species, with *civile* and *Ischnura verticalis*, makes up 90 per cent of the damselfly life in and around the ponds. They are found everywhere in the vegetation near the ponds and often wander long

distances into the fields and woods. They are quiet and remain well concealed, so that often when none can be seen a sweep of the net through the vegetation will reveal them.

ENALLAGMA SIGNATUM (Hagen).

Agrion signatum Hagen, Snyop. Neurop. N. A., 1861, p. 84.

This is the only orange-colored species of the genus found about the ponds, and this makes it conspicuous while flying, as well as at rest. The males and the two sexes when paired frequent the lily pads and similar water vegetation, sometimes long distances from shore. It is nearly as active and restless as *geminatum* and, like the latter, flies close to the water, making it difficult to catch. The species is common along the slews of the river as well as around the ponds and probably plays an important part in the life of those localities.

HETÆRINA AMERICANA (Fabricius).

Agrion americana Fabricius, Ent. Syst. Suppl., 1798, p. 287.

This species frequents the neighborhood of flowing water, and hence is never found around the quiet ponds, but only on the river where the current runs swiftly. It is not very common anywhere near Fairport.

ISCHNURA VERTICALIS (Say).

Agrion verticalis Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 37.

This is the most common damselfly around the ponds, appearing first in the spring and disappearing last in the fall. It frequents the thick grass and other vegetation to quite a distance from the margins of the ponds. The females are dimorphic; that is, of two different colors, and the black and the orange are about equally numerous. Both sexes are weak fliers and can be caught easily in the hands. The nymphs are abundant in all the ponds, and the stem of nearly every water plant projecting above the surface is covered with their skins. The species can be raised with little trouble if suitable aquaria are provided with the stems of rushes or similar water plants projecting above the surface. As the tables show, the nymphs are eaten not only by the fish but also by the larger dragonfly nymphs. There are probably a number of overlapping broods every season.

LESTES EURINUS Say.

Lestes eurinus Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 36.

This is a large and stout species and has been found thus far only at the eastern end of the ponds; its nymphs have been taken in ponds 4 and 8, but not elsewhere. The imagos are associated with those of *rectangularis* and *unguiculatus*, and late in the afternoon the three species can sometimes be obtained in one sweep of the net. In spite of its size this species is a weak flier, but is an omnivorous eater. Two females were captured with partly eaten, brown moths in their mandibles; others were found eating butterflies, small caterpillars, and even teneral Enallagmas and Ischnuras.

LESTES RECTANGULARIS Say.

Lestes rectangularis Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 34.

This is a very long and slender species and may be recognized by these characters. It is the most common species around the ponds and was taken also along the river and at both Sunfish Lake and Patterson Lake on the Illinois side. It is rather more of a woodland species, but is found as well in the open, especially where there is rank vegetation to furnish shelter. It is not as omnivorous as the preceding species, but feeds largely on gnats and midges.

LESTES UNGUICULATUS Hagen.

Lestes unguiculatus Hagen, Synop. Neurop. N. A., 1861, p. 70.

The smallest of the Lestes species and found along only the eastern end of pond 4, where it is fairly common. No nymph that could be identified with this species was found in any of the ponds, although it is probable that the imagos referred to deposit their eggs in the ponds.

LESTES UNCATUS Kirby.

Lestes uncatus Kirby, Synonymic Cat., 1890, p. 160.

A single male of this species was captured in one of the runs that stretch back onto the prairie August 10, 1917. The species can not be at all common in this vicinity, since this is the only specimen secured during four years of collecting.

ISCHNURA (NEHALENNIA) POSITA (Hagen).

Agrion positum Hagen, Synop. Neurop. N. A., 1861, p. 77.

Needham (1903, p. 260) places this species in the genus Ischnura "chiefly because of the form of the abdominal appendages in the male and the small round postocular spots." Like *verticalis*, it appears early in the spring and continues until late in the fall, and its nymphs are associated with those of *verticalis* in the ponds. In habits and in their relation to the fish life of the ponds the two species may be treated as one.

NEHALENNIA IRENE (Hagen).

Agrion irene Hagen, Synop. Neurop. N. A., 1861, p. 74.

This tiny species is associated with Lestes, frequenting the grass and vegetation in damp places. Like Ischnura, it feeds upon gnats and midges. Neither the imagos nor the nymphs occur in sufficient numbers to affect the life of the ponds.

AMPHIAGRION SAUCIUM (Burmeister).

Agrion saucium Burmeister, Handb. Entomol., vol. II, 1839, p. 819.

A male and two females of this species were captured around the ponds below the railroad track July 26, 1917; none had ever been seen near the ponds in series D. However, this species is sometimes found in great numbers, and it may be that once obtaining a start here they will increase sufficiently to rank alongside the Enallagma species.

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