SECOND LARVAL INSTARS OF FLORIDA ANISOPTERA (ODONATA)

By

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Chairman: Minter J. Westfall, Jr.
Major Department: Entomology and Nematology

Descriptions and identification keys are provided for Florida anisopteran second instars, including all of the families, 78% of the genera, and 62% of the 109 species breeding within the state. Comparative and supplementary data on 28 non-Florida species are also given. A list of all previously published illustrations of anisopteran first and second instars of the world is included. Methods of obtaining and hatching Anisoptera eggs are discussed, along with methods of preparing specimens of second larval instars for examination. The only known mid-ventral thoracic and abdominal spines in larval Anisoptera were found in Arigomphus, evidence that this group should be considered a genus instead of a subgenus. Epicranial tubercles, or horns, were found in 25 to 100% of the genera studied in Aeshnidae, Gomphidae, Macromiidae, Corduliidae, and Libellulidae. Horns have

evolved independently many times in the Anisoptera and are probably primarily sensory. The behavior of anisopteran second instars and the use of characters of second instars in solving taxonomic problems are discussed. Partial life histories for species of Cordulegastridae and Macromiidae are the first to be described for these families.

INTRODUCTION

The suborder Anisoptera of the insect order Odonata contains approximately 287 species breeding in the continental United States and Canada. The immature stages of these insects live in fresh water or rarely on wet soil or in salt water. Anisoptera or dragonfly immatures have recently shown increasing potential as indicator organisms in assessing environmental water quality. Existing keys for the identification of Nearctic species of immature Anisoptera, such as Needham and Westfall (1955), work only for well grown specimens. The present study was undertaken primarily to develop a key to the youngest mobile immature stage of Florida Anisoptera. I hope that by using both the keys presented here and keys to older immatures that most of the specimens in any sample of immature Florida Anisoptera can be identified. Another objective of this study was to provide data bearing on taxonomic problems. The newly hatched immatures show some different characters from fully grown individuals, and these characters have not been used previously to assess phylogenetic relationships.

Before proceeding further, the usage of certain terms in the following text must be explained. Immature Anisoptera are variously known as nymphs, naiads, or larvae. I use larva to emphasize the differences from the adults rather than the similarities to the adults implied by nymph or naiad. The larva which hatches from the

egg resembles the embryo and has been regarded by many authors as a separate stage, the pronymph or prolarva. However, it molts its cuticle in the same way as later larval stages and is best considered as the first larval instar. An instar is the insect body between successive molts. The first larval instar cannot walk or eat, and the stadium lasts only a few seconds to about 2 hours in different species. The second larval instar, which exists between the first and second molts, is the earliest mobile feeding stage. Thus my usage of second larval instar corresponds with that of many recent authors such as Corbet (1963). An anisopteran second instar is meant when discussing any species throughout the following text, unless stated otherwise. How to distinguish an anisopteran second instar from those in other insect orders, the suborder Zygoptera, and other instars is given at the beginning of the morphology section. The authors of most species names are given in Tables 1 and 2; the authors of species not in the tables are given at their first usage.

Scope of Species Coverage

About 109 species of Anisoptera breed in Florida waters. Anax amazili (Burmeister), Brachymesia herbida (Gundlach), Tauriphila australis (Hagen), and Tramea walkeri Whitehouse have been collected in Florida but most likely are vagrants to the state. I was able to hatch eggs from 65 species of Florida Anisoptera, listed in Table I. Second larval instars of 3 other species have been described in the literature, namely Epicordulia princeps (Hagen), Libellula

Table 1. Species of larval anisopteran second instars examined. The number of females from which larvae were preserved, and the general locality where the females were collected are given in the right hand columns. An H after the species name indicates that the second instar bears epicranial tubercles or horns on the head.

Species	Number of Broods	Geographic Area
Florida Species		
PETALURIDAE		
Tachopteryx thoreyi (Hagen)	1	Florida
AESHNIDAE		
Anax junius (Drury)	7	Florida
A. longipes Hagen	1	Florida
Coryphaeschna ingens (Rambur)	2	Florida
Epiaeschna heros (Fabricius) H	5	Florida
Gomphaeschna furcillata (Say)	1	Florida
Nasiaeschna pentacantha (Rambur) H	1	Florida
GOMPHIDAE		
Aphylla williamsoni (Gloyd) H	5	Florida
Arigomphus pallidus (Rambur) H	4	Florida
Gomphus (Gomphus) australis Needham	1	Florida
G. cavillaris Needham	3	Florida
G. diminutus Needham	1	Florida
G. exilis Selys	1	Georgia
G. lividus Selys	1	Georgia
G. minutus Rambur	6	Florida
Gomphus (Stylurus) laurae Williamson	1	Florida
G. plagiatus Selys	1	Florida
G. townesi Gloyd	1	Florida
Hagenius brevistylus Selys H	1	Quebec
Progomphus obscurus (Rambur)	2	Florida
CORDULEGASTRIDAE		
Cordulegaster sayi Selys	1	Florida
MACROMIIDAE		
Macromia taeniolata Rambur H	1	Florida

Table 1--continued.

Species		Number of Broods	Geographic Area
Florida Species--continued.			
CORDULIIDAE			
Helocordulia selysii (Hagen)	H	2	Florida, South Carolina
Neurocordulia virginiensis Davis	H	2	Florida
Somatochlora calverti Williamson and Gloyd		1	Florida
S. filosa (Hagen)		2	Florida
S. linearis (Hagen)		5	Florida
S. provocans Calvert		1	Florida
S. tenebrosa (Say)		1	Florida
Tetragoneuria cynosura (Say)	H	6	Florida, Georgia
T. sepia Gloyd	H	1	Florida
T. stella Williamson	H	1	Florida
LIBELLULIDAE			
Brachymesia furcata (Hagen)	H	2	Mexico
B. gravida (Calvert)	H	4	Florida
Celithemis amanda (Hagen)	H	2	Florida
C. bertha Williamson	H	5	Florida
C. elisa (Hagen)	H	2	Florida
C. eponina (Drury)	H	2	Florida
C. fasciata Kirby	H	1	Florida
C. ornata (Rambur)	H	4	Florida
Dythemis velox Hagen		3	Florida
Erythemis simplicicollis (Say)		6	Florida
Erythrodiplax berenice (Drury)		4	Florida, Georgia
E. minuscula (Rambur)		5	Florida
Ladona deplanata (Rambur)		2	Florida
Lepthemis vesiculosa (Fabricius)		1	Mexico
Libellula auripennis Burmeister		6	Florida
L. axilena Westwood		4	Florida
L. flavida Rambur		4	Florida
L. incesta Hagen		5	Florida
L. needhami Westfall		1	Florida
L. semifasciata Burmeister		1	Florida
L. vibrans Fabricius		6	Florida
Miathyria marcella (Selys)		3	Florida
Nannothemis bella (Uhler)		1	Florida
Orthemis ferruginea (Fabricius)		5	Florida

Table 1--continued.

Species	Number of Broods	Geographic Area
Florida Species--continued.		
Pachydiplax longipennis (Burmeister)	5	Florida
Pantala flavescens (Fabricius)	2	Florida
P. hymenaea (Say)	2	Florida, Mexico
Perithemis tenera (Say) H	5	Florida
Plathemis lydia (Drury)	1	Florida
Sympetrum corruptum (Hagen)	1	California
S. vicinum (Hagen) H	1	Georgia
Tramea carolina (Linnaeus)	5	Florida
T. lacerata Hagen	4	Florida, California
Non-Florida Species		
AESHNIDAE		
Aeshna multicolor Hagen	1	California
GOMPHIDAE		
Gomphus (Gomphus) kurilis Hagen)	1	California
G. militaris Hagen	2	Texas
Gomphus (Gomphurus) consanguis Selys	1	Georgia
G. rogersi Gloyd	1	Georgia
Octogomphus specularis (Hagen)	1	California
CORDULIIDAE		
Neocordulia n. sp.	1	Panama
Tetragoneuria semiaquea (Burmeister) H	2	South Carolina
LIBELLULIDAE		
Belonia croceipennis (Selys)	1	Texas
B. saturata (Uhler)	1	California
Dythemis nigrescens Calvert	1	Mexico
Erythemis collocata (Hagen)	1	California
Erythrodiplax connata (Burmeister)	1	Mexico
E. funerea (Hagen)	2	Mexico
Leucorrhinia frigida Hagen H	1	Quebec
Libellula cyanea Fabricius	2	Georgia
L. quadrimaculata Linnaeus	1	California
Micrathyria didyma (Selys)	1	Mexico
M. hageni Kirby	2	Mexico

Table 1--continued.

Species	Number of Broods	Geographic Area
Non-Florida Species--continued.		
Orthemis levis Calvert	1	Mexico
Paltothemis lineatipes Karsh	1	California
Perithemis intensa Kirby H	3	Mexico
P. domitia (Drury) H	1	Mexico
Pseudoleon superbus (Hagen)	1	Mexico
Sympetrum illotum (Hagen)	1	California
S. internum Montgomery	1	Quebec
S. obtrusum (Hagen)	4	Quebec
S. semicinctum (Say)	3	Quebec

pulchella Drury, and Sympetrum ambiguum (Rambur). Of the 109 Florida resident species, 27 are restricted to the panhandle, 11 are restricted to the tip of the peninsula south of Lake Okeechobee, and 71 occur in the northern 2/3 of the peninsula. Thus this study includes 68/109 or 62% of the species of Florida Anisoptera, which incorporates all 7 families and 35/45 or 78% of the genera. The coverage of northern peninsula species is better——52/71 or 73% of the species and 31/37 or 84% of the genera.

I also inspected 28 species not found in Florida to obtain a better idea of the range of morphological variation possible. These species also are listed in Table 1 and are discussed in a separate section.

With caution, the results of this study can be applied to the non-mountainous parts of the southeastern coastal states from Louisiana to South Carolina. The coverage of species for this area is 70/120 or 58%, encompassing 35/45 or 78% of the genera.

Scope of Morphological Knowledge of Anisopteran Second Instars

All of the figures of anisopteran second instars which I could locate in the literature are listed in Table 2. For the sake of completeness figures of larval first instars also are listed. Some references may have been overlooked, primarily because titles often do not indicate that early instars are described. No larval second instars of the Cordulegastridae or of the Australian Synthemidae have been illustrated. All of the instars have not been described

Table 2. References to illustrations of anisopteran first and second instars. In the Structure Illustrated column, a ? to the left of the name of the structure means that there is some doubt about the species, a ? to the right of the name indicates some doubt about the instar. Figures of the first instar and its parts are listed first under each species. In the Figure Type column, L = line drawing, B&W = black and white photograph, C = color photograph. In the Page or Plate column, the page number of the illustration is given where possible, plate numbers are preceded by Pl. An H after the species name indicates that the second instar bears epicranial tubercles or horns.

Species	Structure Illustrated	Figure Type	Page or Plate	Reference
PETALURIDAE				
Tanypteryx hageni Selys	Second	L	227	Svihla (1959)
T. pryeri Selys	First	L	71	Ando (1962)
	First	L	2	Ando and
	Second	L	3	Miyakawa (1969)
	Leg	L	3	
	Antenna	L	3	
	Labium	L	3	
Uropetala carovei White	First	L	250,253	Wolfe (1953)
	Second	L	256	
	Labium	L	256	
AESHNIDAE				
Aeshna isosceles (Muller)	First	L	99	Robert (1936)
	First	L	Pl 15	Robert (1958)
A. mixta Latrielle	First	L	80	Robert (1958)
	Second	L	230	Munchberg (1930)
	Second	L	135	Gardner (1950a)
	Trident Setae	L	135	
	Labium	L	135	
	Second	L	80	Robert (1958)
	Second?	B&W	14,15	Sonehara (1968b)
	Second	B&W	Pl 28	Ishida (1976)

Table 2--continued.

Species	Structure Illustrated	Figure Type	Page or Plate	Reference
Aeshna viridis Eversmann H	Second	L	229	Munchberg (1930)
	Second	L	42	Schiemenz (1953)
	Second	L	182	Schiemenz (1954)
Anax imperator Leach	First	L	51	Robert (1939)
	First	L	Pl 15	Robert (1958)
	Second	L	Pl 1	Portmann (1921)
	Second	L	51	Robert (1939)
	Labium	L	51	
	Second	L	199	Corbet (1955)
	Head	L	200	
	Labium	L	202	
	Palp	L	203	
	Second	L	Pl 1,15	Robert (1958)
	Head	L	61	Corbet (1963)
A. junius (Drury)	First Labium	L	Pl 4	Butler (1904)
	Second	L	471	Needham and Betten (1901)
	Labium	L	Pl 4	Butler (1904)
	Head	L	Pl 1	Calvert (1934)
	Ligula	L	Pl 1	
	Palp	L	Pl 2	
A. parthenope (Selys)	First Eye	L	179	Ando (1957)
	First	L	67	Ando (1962)
	First	L	Pl 15	Robert (1958)
	Second	L	76	Munchberg (1932c)
	?Second	C	4	Inoue (1979a)
A. strenuus Hagen	First Exuviae	L	279	Williams (1936)
	Second	L	279	
Basiaeschna janata (Say)	Second Labium?	L	Pl 4	Butler (1904)
Brachytron pratense (Muller)H	Second	L	229	Munchberg (1930)
	Second	L	42	Schiemenz (1953)
	Second	L	182	Schiemenz (1954)

Table 2--continued.

Species	Structure Illustrated	Figure Type	Page or Plate	Reference
Gomphaeschna furcillata (Say)	First	L	316	Kennedy (1936)
	Egg Burster	L	316	
	Second	L	318	
	Mandible	L	320	
	Maxilla	L	320	
	Labium	L	320	
	Abdomen 10	L	320	
Hemianax papuensis (Burmeister)	First	L	68	Tillyard (1917)
	First	L	242	Tillyard (1968)
	Second	L	68	Tillyard (1917)
	Second	L	242	Tillyard (1968)
Polycanthagyna melanictera Selys	First	L	71	Ando (1962)
GOMPHIDAE				
Gomphus (Gomphus) graslinellus Walsh	Second	L	34	Needham and Heywood (1929)
	Labium	L	34	
	Second	L	31	Needham and Westfall (1955)
	Labium	L	31	
G. spicatus Hagen	Second Labium	L	Pl 2	Butler (1904)
G. (Stylurus) annulatus Dyanokov	Second	L	35	Inoue (1979b)
Lestinogomphus africanus (Fraser)	Second	L	15	Gambles and Gardner (1960)
	Labium	L	15	
Ophiogomphus serpentinus (Charpentier)	Second?	L	731	Munchberg (1932b)
MACROMIIDAE				
Epophthalmia vittata sundana Lieftinck H	Second	L	76	Lieftinck (1931)
	Head	L	78	
	Palp	L	78	
	Second	L	76	Corbet (1963)
	Head	L	77	
	Thorax Seta	L	77	

Table 2--continued.

Species	Structure Illustrated	Figure Type	Page or Plate	Reference
CORDULIIDAE				
Epicordulia princeps (Hagen) H	Second	L	244	Wilson (1917)
	Labium	L	244	
Epitheca bimaculata (Charpentier) H	First	L	Pl 1	Heymons (1896)
	First	L	95	Robert (1936)
	First	L	Pl 33	Robert (1958)
	Labium	L	Pl 33	
	Second?	L	Pl 1	Heymons (1896)
	Labium?	L	Pl 2	
	Second	L	95	Robert (1936)
	Second	L	Pl 33	Robert (1958)
	Labium	L	Pl 33	
	Second	B&W	34	Sonehara (1968a)
E. marginata (Selys) H	Second	B&W	23	Sonehara (1972)
	Second	C	Pl 33	Ishida (1976)
Oxygastra curtisii (Dale)	Second?	L	35	Fraser (1951)
	Labium?	L	39	
Somatochlora kennedyi Walker	Second	L	Pl 17	Walker (1925)
	Antenna	L	Pl 17	
	Palp	L	Pl 17	
S. metallica (Van der Linden)	Second	L	281	Munchberg (1932a)
S. viridiaenea Uhler H	Second	L	33	Miyakawa (1971)
	Antenna	L	33	
	Palp	L	33	
	Tibia	L	33	
	Tarsus	L	33	
Tetragoneuria canis McLachlan H	Second Head	L	95	Kormondy (1955)
	Labium	L	95	
	Head	L	43	Kormondy (1959)
	Labium	L	43	
T. spinigera Selys H	First	L	93	Kormondy (1955)
	First	L	43	Kormondy (1959)

Table 2--continued.

Species	Structure Illustrated	Figure Type	Page or Plate	Reference
LIBELLULIDAE				
Diplacodes haematodes Burmeister	Second	L	72	Tillyard (1917)
Erythemis simplicicollis (Say)	Second	L	241	Wilson (1917)
	Labium	L	241	
	?Head	L	35	Needham and
	?Anal Append.	L	35	Heywood (1929)
	Head	L	216	Bick (1941)
	Abdomen 9+10	L	216	
Leucorrhinia dubia (Van der Linden)	First	L	58	Gardner (1953a)
	Second Labium	L	296	Prenn (1929)
	Anal Append.	L	296	
	Second	L	59	Gardner (1953a)
	Labium	L	59	
	Palp	L	59	
L. intacta (Hagen)	Second	L	242	Wilson (1917)
	Labium	L	242	
Libellula depressa Linnaeus	First	L	195	Gardner (1953b)
	Second	L	Pl 2	Portmann (1921)
	Second	L	195	Gardner (1953b)
	Labium	L	195	
	Metatibia	L	195	
L. fulva Muller	First	L	Pl 15	Robert (1958)
L. luctuosa Burmeister	Second	L	239	Wilson (1917)
	Labium	L	239	
L. pulchella Drury	Second	L	240	Wilson (1917)
	Labium	L	240	
L. luctuosa X L. pulchella	Second	L	241	Wilson (1917)
Lyriothemis pachygastra Selys	Second Labium	L	244	Miyakawa (1970)
	Antenna	L	243	
Nesogonia blackburni (McLachlan)	Second	L	291	Williams (1936)

Table 2--continued.

Species	Structure Illustrated	Figure Type	Page or Plate	Reference
Orthetrum albistylum (Selys)	Second Eye	L	179	Ando (1957)
	Second	L	34	Bilek (1962)
	Labium	L	35	
O. cancellatum (Linnaeus)	First	L	Pl 15	Robert (1958)
O. poecilops Ris	Second	B&W	5	Sawano (1966)
Pachydiplax longipennis (Burmeister)	First	L	193	Wilson (1917)
	Second	L	193	
Pantala flavescens (Fabricius)	Second	L	313	Lamb (1925)
	Head	L	313	
	Labium	L	313	
	Abdomen 10	L	313	
Plathemis lydia (Drury)	Second	L	243	Wilson (1917)
	Labium	L	243	
Pseudothemis zonata (Burmeister) H	Second	L	412	Miyakawa (1969)
	Abdomen 9+10	L	411	
Sympetrum danae (Sulzer)	Second	L	115	Gardner (1951a)
	Labium	L	115	
S. fonscolombii Selys	Second	L	63	Gardner (1951b)
	Labium	L	63	
	Tibial Comb	L	63	
S. frequens Selys	Second Eye	L	179	Ando (1957)
S. meridionale (Selys)	First Exuviae	L	171	Aguesse (1959)
	Labium	L	171	
	Claw	L	171	
	First Exuviae	L	22	Aguesse (1968)
	Second	L	172	Aguesse (1959)
	Labium	L	170	
S. nigrifemur (Selys)	Second	L	80	Gardner (1962)
	Labium	L	80	

Table 2--continued.

Species	Structure Illustrated	Figure Type	Page or Plate	Reference
Sympetrum obtrusum (Hagen)	First	L	222	Tai (1967)
	Second Labium	L	222	
	Antenna	L	222	
	Labium	L	458	Trottier (1969)
S. rubicundulum (Say)	Second Labium	L	458	Trottier (1969)
S. sanguineum Muller	Second	L	24	Gardner (1950b)
S. striolatum (Charpentier)	First	L	57	Gardner (1950c)
	Labium	L	290	Corbet (1951)
	First	L	41	Schiemenz (1953)
	First	L	181	Schiemenz (1954)
	Second	L	18	Lucas (1899)
	Second	L	57	Gardner (1950c)
	Labium	L	57	
	Labium	L	290	Corbet (1951)
	Second	L	41	Schiemenz (1953)
	Second	L	125	Gardner (1954)
	Second	L	181	Schiemenz (1954)
S. vicinum (Hagen) H	First Labium	L	224	Tai (1967)
	Second Head	L	224	
	Horn	L	224	
	Antenna	L	224	
	Labium	L	224	
	Labium	L	458	Trottier (1969)
Tramea lacerata Hagen	Second Ligula	L	301	Bick (1951)
	Palp	L	301	
Trithemis annulata scortecii Nielsen	Second Palp	L	83	El Rayah and El Din Abu Shama (1978)
Zyxomma petiolatum Rambur H	Second	L	78	Corbet (1963)

for any species in these families or for any species of Gomphidae or Macromiidae. All or part of the second larval instar of 22 of the Nearctic species have been illustrated. Second larval instars of 6 other Nearctic species have been described but not illustrated. These are Aeshna juncea (Linneaus) described by Robert (1958), A. tuberculifera Walker by Lincoln (1940), Somatochlora filosa by Dunkle (1977), Tetragoneuria cynosura by Kormondy (1955,1959), Sympetrum ambiguum by Tai (1967), and S. semicinctum by Tai (1967). Thus 28/287 or 10% of the Nearctic species have had the second instar characterized in some degree. Only 14/287 or 5% of the Nearctic species have had all the instars described. These are Aeshna juncea described by Robert (1958), A. tuberculifera by Lincoln (1940), Anax junius by Calvert (1934) and Macklin (1963b), Somatochlora filosa by Dunkle (1977), Tetragoneuria cynosura and T. spinigera by Kormondy (1955,1959), Erythemis simplicicollis by Bick (1941), Pantala flavescens by Lamb (1925,1929), Sympetrum danae by Gardner (1951a) and Robert (1958), S. vicinum by Nevin (1929) and Tai (1967), and S. ambiguum, S. obtrusum, S. rubicundulum, and S. semicinctum by Tai (1967). Three other Nearctic species have been reared from egg to adult but the instars were not described. These are Gynacantha nervosa Rambur reared by Williams (1937), Nannothemis bella by Calvert (1929), and Pachydiplax longipennis by Macklin (1963a). Of the 109 Florida species, 15 or 14% have had the second instar partially or fully described, and 7/109 or 6% have had all the instars delineated. These species are mentioned in the descriptions section of this study. I have reared or partially reared a number of other species from the egg which are also mentioned in the species description section.

METHODS

Obtaining Fertile Anisoptera Eggs

Anisoptera eggs are fertilized with stored sperm released from the female's spermatheca as the eggs are laid. No parthenogenetic or ovoviviparous species are known. All of my many attempts to fertilize Anisoptera eggs dissected from a female with sperm from the same or a different species *in vitro* were failures. The major problem with these experiments seemed to be lack of sperm motility. F. C. Johnson (personal communication) observed motility in sperm taken from *Perithemis tenera*, yet eggs fertilized with these sperm did not complete embryonic development.

Various methods of obtaining eggs from endophytic Anisoptera, the Aeshnidae and Petaluridae, have been mentioned in the literature. Needham and Westfall (1955) proposed placing a fresh *Typha* stem at a slant and a little in front of a patch of erect emergent stems, and changing the stalk every day. A problem with this method is that one might not be sure of which species oviposited in the stem. Another method is to watch a female oviposit, then collect the object or soil sample containing the eggs. One disadvantage of this method is that some other female of the same or a different species may have previously oviposited at that spot. Another disadvantage is that a large amount of time is sometimes needed to find the eggs in the collected material.

Gardner and MacNeill (1952) and Ando (1962) allowed endophytic species to oviposit in soft stems in a container in the laboratory. The former used a 100 watt incandescent lamp to warm the container. I have found white, wet, paper toweling on the floor of a container more convenient because the eggs can easily be seen. The sides of the container, and for some species, the top, should be slippery so that the female must rest on the wet toweling. I used a 4 liter plastic jug with one side cut out and loosely covered with a plastic bag or netting. This is a modification of a method developed by Wilbur (1945). Some endophytic species will not oviposit under these conditions, even if the female is captured while ovipositing, for example Coryphaeschna ingens. Other species were reluctant to oviposit but finally did so after several females were tried, for example Tachopteryx thoreyi. Anax oviposits readily in captivity and Obana and Inoue (1972) have a photograph of A. panybeus Hagen ovipositing in a piece of paper held in the hand. Kubota (1978) used a 10 volt 60 cycle electric current to induce the release of more than 5 eggs in 70% of the Zygoptera he worked with, but I was unable to obtain anisopteran eggs by using this method. No method has been found to induce Cordulegastridae to oviposit in captivity.

Exophytic species generally release eggs readily into a container of water if the female was caught while ovipositing, and the abdomen is tapped to the water surface. Often more eggs are released if only one pair of wings is held above the back of the dragonfly and the other pair allowed to move. Lieftinck (1933) obtained more eggs by loosely

holding a female's thorax between his fingers and allowing both pairs of wings to move. Gentle squeezing of the abdomen often starts a female ovipositing, and Gardner and MacNeill (1952) suggested stroking the dorsal surface of the abdomen with a brush. As with the endophytic species, some exophytic Anisoptera are very reluctant to release eggs when captured, for example Aphylla and the Macromiidae. Aphylla williamsoni released eggs only after considerable squeezing of the abdomen. One Macromia taeniolata female oviposited after I employed the platform method of Gardner and MacNeill (1952). This method involves pinning the female's wings to a platform over a dish of water so that her abdomen dips into the water as she struggles. It should be mentioned that Lieftinck (1931) easily obtained eggs from the macromiid Epophthalmia vittata by capturing an ovipositing female, loosely holding the insect's thorax, and regularly stripping the end of its abdomen against a piece of soft carton in a bottle of water. Armstrong (1958) obtained eggs from Hemicordulia australiae (Rambur) by merely providing a petri dish of water in the bottom of a 38 X 38 cm cage. It is interesting to speculate that some of the exophytic Anisoptera may voluntarily release eggs, perhaps as a "squirt," with each tap to the water surface. Someone should examine the internal anatomy of these species to determine if such a muscular mechanism exists.

Hatching Anisoptera Eggs

In my experience, eggs hatched best when oviposited into aged tap water. When water from the wild was used the eggs were much more likely to mold, especially if many unfertilized eggs were present. Krull (1929) also found that eggs hatched best in clean water, but Tillyard (1917) got better results in very dirty water. Perhaps if enough of a grazing fauna is present, the growth of mold can be kept in check, but it is certainly more convenient for observation if clean water is used. I did not find it necessary to aerate the water during incubation, even for stream species. Obana and Inoue (1972) aerated the water with the floating liverwort Riccia, but presumably green plants used in this way should be continuously illuminated.

Anisoptera eggs hatch in 5-50 days, depending on species and temperature, unless diapause intervenes. Egg diapause is known in Aeshna, Somatochlora, and Sympetrum. The longest hatching time known to me is 221 days in Aeshna nigroflava Martin (Ando,1962).

Preserving and Preparing Specimens

Larval second instars should be allowed to age for about a day to develop their color pattern and harden the exoskeleton. Since alcohol fades the color pattern, the color pattern should be described before placing specimens in alcohol. I found that 83% ethyl alcohol preserved specimens much better than 70% isopropyl alcohol. Larvae should be preserved at 1 or 2 days of age after hatching to avoid their becoming pharate third instars, which obscures the second instar characteristics.

The following procedure is recommended for rapid examination of anisopteran second instars. If the investigator wishes, he or she may examine the specimens under a dissecting microscope, or in a depression slide under a compound microscope, until he/she finds that removal of the labium is necessary.

1. Describe the color pattern before preservation. Alternating light and dark backgrounds under the specimen allows different parts of the color pattern to be seen more clearly under a dissecting microscope.
2. Measure head width and total body length, using an ocular micrometer in a dissecting microscope.
3. Look for horns, dorsal abdominal spines, and ventral abdominal spines while rolling the specimen on its side in a dish of alcohol under the high magnification of a dissecting microscope. Note whether the palps of the labium cup dorsally in front of the face or lie in the same plane as the prementum.
4. Arrange the specimen on its side in a drop of alcohol on a microscope slide with labium extended and legs and antennae pulled away from the labium. An eyedropper of alcohol should be ready to add alcohol if the specimen begins to dry out.
5. Cut the labium through the postmentum, using the tip of a small, sharp scalpel.

6. Arrange the labium in the center of the slide, dorsal side up. Arrange the body dorsal side up near the labium, with legs and antennae extended.
7. Flow a fresh drop of alcohol onto the slide from the side of the specimen. Quickly place one edge of a coverslip near the specimen, and lower it gradually to force out air bubbles. Centering the specimen under the coverslip and centering the coverslip on the slide allow the specimen to be located more easily under the compound microscope. The body of the specimen will be somewhat wrinkled and distorted, but the labial parts, antennae, and legs are in one plane for accurate observation and measurement.
8. Blot away excess alcohol from the edge of the coverslip, and seal the edges of the coverslip with a permanent mounting medium. Some of the mounting medium should overlap onto the top of the coverslip along its entire margin. The slide should be handled and stored horizontally until the mounting medium has hardened for several days. The result is a semi-permanent slide which dries out in a few days or weeks. Thus observations should be made soon after preparation. Some features can be seen on a dry specimen, however, and a slide can be partially or entirely restored by scraping away some of the mounting medium, and allowing fresh alcohol to flow under the coverslip.

9. Label the slide.
10. The specimen is most easily located under a compound microscope if the objective lens is swung out of the way, the specimen centered in the hole of the stage, and the objective lens then clicked back into position.

RESULTS

Morphology of Anisopteran Second Instars

In order to use the keys given later, one must ascertain that the specimen to be identified is actually an anisopteran second instar. Anisopterans are insects which have 2 antennae, 3 major body divisions, and 6 legs. As members of the order Odonata, they are distinguished from all other insects by the enlarged, grasping labium of the larvae, shown in Figure 1. Larvae of the odonate suborder Anisoptera have 3 pointed appendages at the tip of the abdomen. The length of these appendages is less than or equal to the combined length of the posterior 3 abdominal segments. In the suborder Zygoptera, these appendages are nearly as long, or longer, than the abdomen. The anisopteran first instar has all of its appendages directed posteriorly, and is not able to walk. The anisopteran second instar is about 1-2 mm long in the exophytic families, 2-3 mm long in the Petaluridae and Aeshnidae. With some possible exceptions to be discussed later, anisopteran second instars have 3-segmented antennae, 1-segmented tarsi, no wing pads, no cerci, a maximum of 1 major palpal seta on each palp, and no major premental setae. Anisopteran third instars are about 26% larger than the second instar (Calvert,1929), and often have more antennal segments, tarsal segments, and major palpal setae.

The ways in which certain structures of some species change with growth are given in Table 3 and the species descriptions.

Antennae. The 3 segments of the antennae are known from the base toward the tip as the scape, pedicel, and flagellum. The pedicel is generally longer than the scape, and the flagellum is longer than the other 2 segments taken together. The scape has an enlarged seta on the medial side in all the families except Gomphidae.

Fraser (1951) reported that Oxygastra curtisii had 4-segmented antennae, but his figures also show 2- or 3-segmented tarsi, 2 major palpal setae, and 2 major premental setae. If one compares these numbers with the growth changes of other Corduliidae in Table 3, it appears that Fraser was describing instar 4 when he thought he had instar 2. Lamb (1925) stated that Pantala flavescens had 4-segmented antennae, but all specimens of this species I have seen had 3-segmented antennae. Lamb may have seen the pharate third instar within the exuviae of the second. Gardner and MacNeill (1952) recommended examining the exuviae of an instar to correctly determine the number of antennal and tarsal segments. Munchberg (1932b) claimed that the antennae of Ophiogomphus serpentinus and Gomphus flavipes (Charpentier) were 2-segmented. I suspect that the antennae of these species are actually 3-segmented, because in Gomphidae the antennae slope ventrally, the scape is short, and the scape may be partly telescoped into the head. The dark stripes Munchberg described on the dorsal thorax and abdomen of O. serpentinus are probably thick setae, indicating that he did not examine this species in lateral view. Wilson (1917) in his descriptions of several Corduliidae and Libellulidae thought that the tip of the

Table 3. Changes in the number of antennal and tarsal segments, and the number of major labial setae, during instars 2 to 4 of some Florida Anisoptera. SWD refers to data from the present study.

Species	Antennae	Tarsi	Major Palpal Setae	Major Premental Setae	Reference
	2 3 4	2 3 4	2 3 4	2 3 4	
PETALURIDAE					
Tachopteryx thoreyi	3 3 4-5	1 2 2			SWD
AESHNIDAE					
Gomphaeschna furcillata	3 4 4	1 1 1-2			Kennedy (1936), SWD
Nasiaeschna pentacantha	3 3 4	1 2 2			SWD
Epiaeschna heros	3 3 4	1 2 2			SWD
Coryphaeschna ingens	3 3 4	1 2 2			SWD
Anax junius	3 4 4	1 2 2			Calvert (1934)
A. longipes	3 3 3-4	1 2 2			SWD
GOMPHIDAE					
Arigomphus pallidus	3 4 4	1 1 1			SWD
Gomphus minutus	3 4 4	1 1 1			SWD
Progomphus obscurus	3 4 4	1 1 1			SWD
CORDULEGASTRIDAE					
Cordulegaster sayi	3 3 5	1 2 2	0 1 2	0 1 3	SWD
MACROMIIDAE					
Macromia taeniolata	3 3 3	1 1 1	1 1 2	0 1 3	SWD
CORDULIIDAE					
Helocordulia selysii	3 3 5	1 1 2	1 1 2	0 1 3	SWD
Somatochlora calverti	3 3 3-4	1 1 1	1 1 2	0 1 3	SWD
S. filosa	3 3 4	1 1 1	0-1 1 2-3	0 1 2-4	Dunkle (1977)
S. provocans	3 3 3-4	1 1 1	1 1 2	0 1 2	SWD
Neurocordulia virginiensis	3 3 5	1 1 2	1 1 2	0 1 1	SWD
Tetragoneuria cynosura	3 3 4-5	1 1 2	1 1 2	0 1 3	Kormondy (1955,1959)

Table 3--continued.

Species	Antennae			Tarsi			Major Palpal Setae			Major Premental Setae			Reference
	2	3	4	2	3	4	2	3	4	2	3	4	
LIBELLULIDAE													
Brachymesia gravida	3	3	4	1	1	1	1	1	2	0	1	2	SWD
Erythemis simplicicollis	3	3	4	1	1	1	1	1	2	0	1	3	Bick (1941)
Ladona deplanata	3	3	4	1	1	1	1	1	2	0	1	3	SWD
Orthemis ferruginea	3	3	4	1	1	1	1	1	2	0	1	3	SWD
Pantala flavescens	3	3	4-5	1	1	1	0-1	1	4	0	2	4	Lamb (1925), Miyakawa (1977)
Sympetrum ambiguum	3	3	4	1	1	1	1	2	3	0	1	4	Tai (1967), Trottier (1969)
S. vicinum	3	3	4	1	1	1	1	1	2	0	1	3-4	Tai (1967)
Tramea lacerata	3	3	4	1	1	1	1	1	2	0-1	1	3-4	Bick (1951)

antennal flagellum was the third segment. Thus his second "joint" or segment is the proximal part of the flagellum, his "first joint" or "basal joint" is the pedicel, and his "base" is the scape.

Labium. The terminology used for labial parts is shown in Figure 1. Minor Palpal Setae numbers 1 and 2 were present in nearly all species I examined, but showed little variation that could be used as key characters. Minor Premental Setae 6,7, and 8 were constantly present in the Macromiidae, Corduliidae, and Libellulidae, and some species of other families. These setae showed differences in position, but the differences seemed to depend at least in part on how the labium was flattened on a slide. The other Minor Palpal Setae and Minor Premental Setae often required extremely critical focus and lighting to see, and were not constantly present. The Ligular Setae also demanded critical focusing to observe. The Dorsal Ligular Setae are usually lateral as well as dorsal to the Ventral Ligular Setae, but the relative positions of the 2 pairs of Ligular Setae appeared to be determined by how the labium was flattened on a slide. The best taxonomic characters displayed by the labium were the palpal teeth and the condition of the ligula. The Ligula is a convenient term for the antero-medial area of the prementum. It may have an anterior projection or an open or closed medial cleft.

The numbers of labial setae and ligular teeth in the remainder of the text refer to the number on either the right or left side unless stated otherwise. Petaluridae, Aeshnidae, and Gomphidae have a flat labium with no major labial setae in any instar. Macromiidae, Corduliidae,

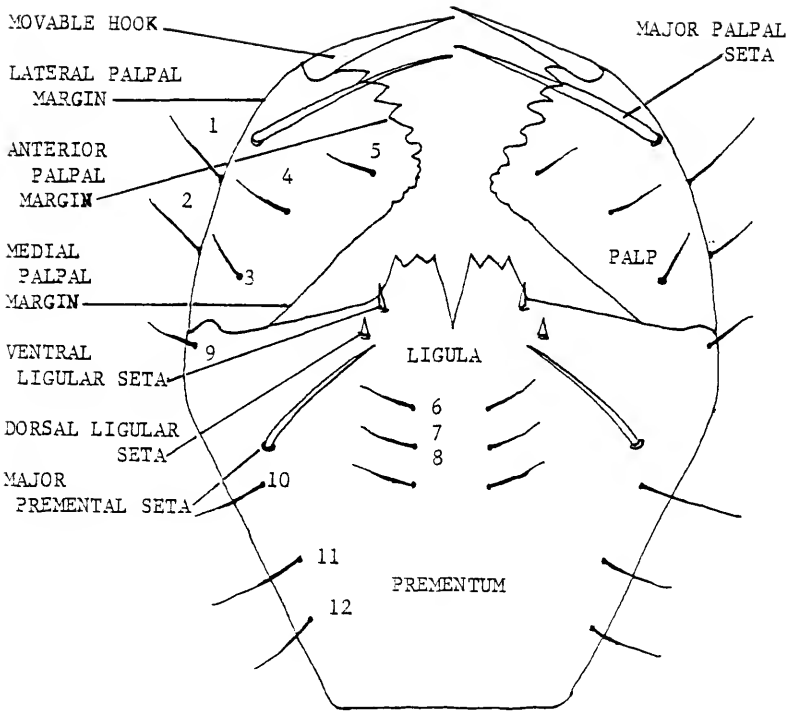

Figure 1. Composite labium of anisopteran second instars, identifying terms used in the text. No single species has all the features shown and few if any species normally have Major Premental Setae in the second instar. Numbers 1-5 identify Minor Palpal Setae; numbers 6-12 identify Minor Premental Setae. The Palps shown have 3 pointed teeth, 2 rounded teeth, and a crenate antero-medial corner. The Ligula has a Ligular Projection with 3 teeth on each side, and both the Ligular Projection and the Ligula have an open cleft.

and Libellulidae have a cupped labium with usually 1 major palpal seta in the second instar, more major palpal setae plus major premental setae in later instars. Cordulegastridae have a cupped labium without major labial setae in the second instar, both major palpal setae and major premental setae in later instars.

A few authors have recorded the presence of major premental setae in the second instar. Gardner (1951b) stated that Sympetrum fonscolombii has 1 major premental seta. Bick (1951) stated that Tramea lacerata sometimes has 1 major premental seta in the second instar, but all the specimens I examined lacked major premental setae. Lieftinck (1933,p 413) said that second instars of Procordulia artemis Lieftinck have a "Labium with two mental setae, the outermost much shorter than the inner, the latter vestigial. . . ." This may mean that the setae he saw were not major setae.

Several writers, for example Lamb (1925), have noted that major palpal setae may be lacking from 1 or both palps in individuals of species that normally have a major palpal seta on each palp. The characteristic labia are shown for 5 families of Anisoptera in Figure 2. The labia of Corduliidae and Libellulidae are like the labium of Macromiidae.

Eyes. Anisopteran second instars lack ocelli but have a pair of compound eyes. Ando (1957,1962) found that the number of ommatidia in each compound eye of the 22 species he examined was constant within a species. The numbers of ommatidia he found within families were 7 in Petaluridae, 170-270 in Aeshnidae, 7 in Gomphidae,

7 in Cordulegastridae, 7 in Macromiidae, 7-10 in Corduliidae, and 7-19 in Libellulidae. Unfortunately I was unable to accurately count the ommatidia in my specimens with either bright field or phase contrast microscopy, and so could not use ommatidial number as a key character.

Epicranial Tubercles or Horns. Some species of Anisoptera have 1 or 2 pairs of outgrowths of the head exoskeleton which have the position, but of course not the structure, of mammalian horns. For simplicity, these outgrowths are referred to as horns if they are as long or longer than their width at the base, or as tubercles if they are shorter than their basal width. The distribution of horns within the Anisoptera is discussed in a later section.

Thorax. The thorax, as in other insects, has 3 segments, which are from anterior to posterior the prothorax, mesothorax, and metathorax. A pair of setae on 1 or more of these segments may be enlarged and be a useful taxonomic character. The legs consist of 6 segments, which from the base distally are the coxa, proximal trochanter, distal trochanter, femur, tibia, and tarsus. The tarsus becomes 3-segmented in later instars. The tip of the tarsus always bears 2 equal claws, unless these are lost by accident.

The setae on the underside of the distal end of the tibiae are spiniform digging setae in the Petaluridae, Cordulegastridae, and some Gomphidae. These setae are branched in one plane with 3-7 divisions, forming tibial combs, in the Aeshnidae, Macromiidae, Corduliidae, and Libellulidae. The number of comb setae is best seen in ventral view. Some setae on the underside of the tarsi in

the Aeshnidae are branched, and some are serrated along the most ventral side, forming tarsal combs. MacNeill (1967) discussed tibial and tarsal combs of several anisopteran families.

Abdomen. The abdomen consists of 10 segments in all instars, numbered from the base toward the posterior end as segments 1 to 10. Posterior to segment 10 are 3 short, pointed, anal appendages. These comprise a dorsal epiproct and 2 ventral paraprocts. The 2 cerci, lateral in position, do not appear until several instars have passed. Medial to the anal appendages are 2 flap-like anal valves which may be as long as the paraprocts in the second instar, but become hidden by the anal appendages in later instars.

The dorsal and lateral abdominal spines, so useful in the taxonomy of late instars, are generally lacking in the second instar. Aeshnidae and Gomphidae have lateral abdominal spines. Dorsal abdominal spines are known to occur only in some species of Gomphidae. Arigomphus pallidus has ventral thoracic and abdominal spines, and to my knowledge, it is the only anisopteran to possess such spines.

A large mass of yolk fills the midgut. This is often enough to sustain the larvae to the third instar. According to Johannsen and Butt (1941), the midgut lumen is not open in Plathemis lydia until the end of the second instar, and food eaten before that time accumulates in the posterior end of the foregut. The rectal gills form an opague mass in the posterior end of the abdomen.

Size. Body size is not generally a useful character for separating species or genera of anisopteran second instars, but size is useful in separating instars. Total length is measured in dorsal

view from the base of the labrum to the tip of the epiproct, and thus excludes the antennae. Head width is the maximum width, usually across the eyes, and excludes lateral horns. Head width is more reliable than total length because the abdominal segments can telescope. Specimens in alcohol are extended, and thus longer than living specimens. The measurements given in this study are taken from specimens in alcohol.

Keys to Florida Anisopteran Second Instars

In the following keys, I have used the characters which are easiest to see first. In many cases, identifications are possible without detaching the labium. Where color pattern is used, I have also tried to include one or more structural characters. Major qualifications in the use of the keys are stated at the beginning of each key, or at the appropriate place within the key. Number of structures given is the number on the left or right side unless otherwise stated. Left margin numbers in parentheses indicate the previous couplet choice which led to that point and allow the user to verify the characters of a group by quickly backtracking through the key.

Key to Families

1A. Mid-dorsal or mid-ventral spines present on some segments of the abdomen (Figures 6A,6B) ..... Gomphidae in part

1B. No mid-dorsal or mid-ventral abdominal spines present 2

2A. (1B) Lateral spines present at least on abdominal segment 9, labial palps lie in nearly the same plane as the prementum .. 3

2B. No lateral abdominal spines present, labial palps flared dorsally (except in Petaluridae) to lie nearly perpendicular to the plane of the prementum 4

3A. (2A) Body with a conspicuous color pattern; eyes usually large, covering about half of the sides of the head (1/3 in Gomphaeschna); tibial and tarsal combs present; ligular cleft present but closed (Figure 2C)..... Aeshnidae

3B. Body uniformly gray or brown; eyes small, covering about 1/3 of the sides of the head; no tibial combs, tarsal combs, or ligular cleft present (Figure 2D) ..... Gomphidae in part

4A. (2B) Labial palps lie in nearly the same plane as the prementum; 4 flat, lanceolate, digging setae on the underside of the distal end of each tibia (Figure 6C); local, in spring seepages in deciduous forest in north Florida .....
Petaluridae

4B. Labial palps nearly perpendicular to plane of prementum, tibial combs or tapered setae present on distal ends of tibiae (Figure 6D); various habitats 5

5A. (4B) No tibial combs and no major palpal setae present in the second instar; ligula projecting anteriorly, the projection widely V-cleft (Figure 2B); habitat streams in north Florida (head shown in Figure 7B) ..... Cordulegastridae

5B. Tibial combs and 1 major palpal seta present; ligular projection if present small and bifid (Figure 2E); habitats various....6

6A. (5B) Head with a pair of large horns, each tipped with a flat, scale-like seta (Figure 6G); sides of the thorax with a short, robust seta above each leg base ..... Macromiidae

6B. Horns, if present, tipped with a tapered or brush-like seta (Figure 6H); setae above leg bases, if present, are tapered...7

7A. (6B) Palps with antero-medial corner crenate, ligula with a bifid-notched projection (Figure 3) ..... Corduliidae
For the convenience of the user, some genera of Corduliidae and Libellulidae may be identified without removing the labium by going directly to the combined key to these families from this point.

7B. Palps with antero-medial corner slightly if at all crenulate; ligula without a projection, but 1-3 teeth are sometimes present (Figure 3) ..... Libellulidae

Key to Aeshnidae

Genera Not Examined:

Basiaeschna janata -- streams in the Florida panhandle

Boyeria vinosa -- streams

Gynacantha nervosa -- Florida peninsula, temporary forest ponds

Triacanthagyna trifida (Rambur) -- Florida peninsula, probably temporary forest ponds

1A. Head with a pair of long, lateral horns behind the eyes which extend laterally farther than the eyes; vertex with a second pair of short, forward-slanting horns; beginning with the third instar dorsal abdominal spines are present (Figure 7A)... Nasiaeschna pentacantha

1B. Head with only one pair of horns, or no horns; never any dorsal abdominal spines 2

2A.(1B) Head with one pair of postero-lateral conical horns which are about as high as wide at the base .. Epiaeschna heros

2B. No horns on head 3

3A. (2B) Lateral spines on abdominal segment 9 only; antennae as long as head; eyes small, covering about 1/3 of the sides of the head ..... Gomphaeschna

3B. Lateral abdominal spines on segments 7-9; antennae shorter than head; eyes large, covering about 1/2 of the sides of the head 4

4A. (3B) Mid-dorsal red stripe from prothorax to posterior edge of abdominal segment 4; antennae pale, with distal half of flagellum bent laterally, narrowed, and darkened; frons with a lengthwise ridge; abdominal segment 7 gray, with a mid-dorsal and lateral pale spots ..... Coryphaeschna ingens

4B. No red markings; antennae not as above; frons bulging but not ridged; abdominal segment 7 without pale spots 5

5A. (4B) Large pale mid-dorsal spot on abdominal segment 8; pale + mark on head, with posterior arm of + mark narrow and nearly parallel sided; abdominal tergites pigmented to their anterior and posterior edges; medial palpal margin smooth; 5-6 ligular teeth on each side of midline; ligular setae no longer than ligular teeth ..... Anax junius

5B. No pale spot on 8; pale + mark on head, with posterior arm widely divergent rearward; abdominal tergites with yellow-brown anterior and posterior edges, giving abdomen a tiger-banded appearance; medial palpal margin crenate; 3-4 ligular teeth on each side with a gap in the row; a pair of ligular setae extend beyond ligular teeth ..... Anax longipes

Key to Gomphidae

Genera Not Examined:

Dromogomphus

Erpetogomphus designatus Hagen -- Apalachicola River

1A. Prominent dorsal abdominal spines present (Figure 6B) 2

1B. No dorsal abdominal spines present 4

2A.(1A) Dorsal abdominal spines present on 1 or 2 to 9; flagellum flattened, oval in dorsal view; head with 2 pairs of horns (Figure 7C) ..... *Hagenius brevistylus*

2B. Dorsal abdominal spines on 3 to 9 or on 8 and 9; flagellum cylindrical, pointed; head with 1 pair of horns or horns absent 3

3A. (2B) Head with a pair of backward slanting horns; dorsal abdominal spines on 3 to 9 (Figure 6B).... *Aphylla williamsoni*

3B. Head without horns; dorsal abdominal spines on 8 and 9 ..... *Progomphus*

4A.(1B) Head with a pair of horns, each tipped with a dark brown seta bulbous in its basal half (Figure 6F); mid-ventral spines present on mesothorax, metathorax, and abdominal segments 2 to 8 (Figure 6A) *Arigomphus pallidus*

4B. No horns on head; no ventral thoracic or abdominal spines ..... Genus *Gomphus* 5

5A.(4B) Setae on epiproct minute or absent; either pairs of stout stubby setae dorsally on abdominal segments 2-9 or pairs of stout spike-like setae on each segment from mesothorax to abdominal segment 10 ..... Gomphus (Stylurus)

5B. Setae on epiproct robust; no stubby dorsal abdominal setae; dorsal spike-like setae, if present, on abdominal segments 1-9...6

6A.(5B) Abdominal segment 10 not well set off from rest of abdomen, mid-dorsal length of segment 10 47% or less of its maximum width; abdomen appears short, broad, and blunt in dorsal view; burrowing hooks on distal ends of pro- and mesotibiae moderately well developed .....Gomphus (Gomphurus) and probably Gomphus (Hylogomphus)

None of the Florida species of these subgenera were examined.

6B. Abdominal segment 10 set off from segment 9 as a breathing siphon, its mid-dorsal length 48% or more of its maximum width; tibial burrowing hooks poorly developed .....Gomphus (Gomphus)

Key to Gomphus (Stylurus)

Species Not Examined:

G. ivae Williamson--north Florida streams

G. potulentus Needham--panhandle streams

1A. Pairs of stout, pointed, spike-like setae dorsally on each segment from mesothorax to abdominal segment 10 .....G. townesi

1B. No stout setae on thorax or abdominal segments 1 and 10, but stout, blunt dorsal setae are present on abdominal segments 2-9 2

2A.(1B) Abdominal segments each with 3 pairs of dorsal setae, thus each of the stubby setae is flanked by a medial and a lateral hair-seta; a robust seta present above antennal bases; second instar about 1.46 mm long .....G. laurae

2B. Abdominal segments 2-8 each with 2 pairs of dorsal setae, no hair-setae medial to the stubby setae; no robust seta above antennal bases; second instar about 1.26 mm long .....G. plagiatus

Key to Gomphus (Gomphus)

Species Not Examined:

G. hodgesi Needham--panhandle streams

G. descriptus Banks--the Florida record from Chipola Dead Lake needs to be confirmed

1A. Head with thick blunt seta mounted on conical base nearly as tall as wide on each rear corner; mid-dorsal length of abdominal segment 10 68% of its basal width; habitat sand-bottom lakes.... G. australis

1B. Rear corner setae of head, if thickened, not blunt or mounted on a high conical base; mid-dorsal length of abdominal segment 10 usually 54% or less of its basal width (62% in G. minutus); various habitats 2

2A.(1B) Body brown; medial pairs of dorsal setae on abdominal segments 1-9 dark and thickened, appearing black at 50X; only 3 pairs of setae on head behind level of eyes ....G. lividus

2B. Body usually gray (brown in G. exilis); medial setae on abdomen may be thickened and darkened, but not enough to appear black at 50X; 4 or more pairs of setae on head behind level of eyes...3

3A.(2B) Mid-dorsal length of abdominal segment 10 62% of its basal width .....G. minutus

3B. Mid-dorsal length of abdominal segment 10 48-54% of its basal width 4

4A.(3B) Mid-dorsal length of abdominal segment 10 54% of its basal width, appearing cylindrical; body gray; western Florida panhandle ..... G. diminutus

4B. Mid-dorsal length of abdominal segment 10 48-50% of its basal width, flattened; body gray or brown; Florida panhandle or peninsula 5

5A.(4B) Body brown; slow streams and lakes in the western Florida panhandle; 6 anterior palpal teeth; 5-6 ligular teeth ..... G. exilis

5B. Body gray; sand-bottom lakes in both panhandle and peninsula; 8 anterior palpal teeth; 7 ligular teeth ..... G. cavillaris

Key to Corduliidae and Libellulidae

Genera Not Described:

Crocothemis servilia Drury -- south Florida

Idiataphe cubensis (Scudder) -- south Florida

Macrodiplax balteata (Hagen) -- primarily coastal, and marl ponds

Tauriphila australis (Hagen) -- south Florida, may not breed in Florida

1A. Dorsum of head with conspicuous horns 2

1B. No tubercles or horns on head 10

2A. (1A) Pairs of thick, inflated, cylindrical setae on occiput, each segment of thorax, and each of the first 9 abdominal segments (Figure 6I) ..... Perithemis tenera

2B. Setae on occiput, thorax, and abdomen may be thickened but are pointed, not inflated or cylindrical 3

3A. (2B) Horns tipped with a thick, brush-like seta (Figure 6H) or hooked posteriorly at the tip; 2 setae anterior to each horn..4

3B. Horns tipped with a thin, tapered seta, rarely a slightly brushy seta; 1 seta anterior to each horn (2 setae in Helocordulia and Neurocordulia) 5

4A. (3A) Horns tipped with a thick brush-seta; 6 anterior palpal teeth (Figure 3B) ..... Tetragoneuria

4B. Horns hooked posteriorly at the tip; 7-8 anterior palpal teeth ..... Epicordulia princeps

5A.(3B) Horns 2X as tall as width at base, or taller 6

5B. Horns as tall as wide, or shorter 7

6A.(5A) One thick seta posterior to each horn; midgut usually pigmented ..... Brachymesia

6B. Two thin setae posterior to each horn; midgut not pigmented ... Celithemis in part

7A.(5B) Palps with 6 pointed anterior teeth; ligula with a bifid projection (Figures 3A,3C); habitat streams 9

7B. Palps with 2-4 pointed anterior teeth (Figures 4C,4D); ligula without a projection, but sometimes 1-3 teeth present; habitat usually still water 8

8A.(7B) Horns divergent laterally; flagellum about 59% as long as width of head ..... Sympetrum vicinum

8B. Horns vertical; flagellum 62-70% as long as width of head ..... Celithemis in part

9A.(7A) Major palpal seta shorter than movable hook (Figure 3C); femora unbanded; midgut may be pigmented ..... Neurocordulia

9B. Major palpal seta longer than movable hook (Figure 3C); femora with dark bands at 1/4 and 3/4 of their length; midgut not pigmented ..... Helocordulia selysii

10A.(1B) Eyes large, occupying the anterior 1/2 to 2/3 of the lateral margin of the head (Figure 7D); body dark gray; habitat Sphagnum bogs ..... Nannothemis bella

10B. Eyes smaller, covering approximately the anterior 1/3 of the lateral head margin; color and habitat various..... 11

11A.(10B) Head dorsum with a large, conspicuous, pale, mid-dorsal mark which narrows anteriorly; femora unbanded or with one distal band 12

11B. Head dorsum without a conspicuous pale mark; femora often with 2 dark bands, but may be unbanded or have 1 dark band.. 14

12A.(11A) Pale mid-dorsal head mark is wedge-shaped; tip and base of flagellum dark; paraproct tip-seta about 44% as long as paraproct; habitat salt marsh ..... Erythrodiplax berenice

12B. Pale mid-dorsal head mark is violin-shaped; flagellum unbanded; paraproct tip-seta about 17-20% as long as paraproct; habitat not salt marsh 13

13A.(12B) Pale mid-dorsal stripe from labrum to abdominal segment 9; anterior palpal margin with 1-3 low, pointed teeth (Figure 4A); widespread distribution ..... Erythemis

13B. Pale mid-dorsal stripe not extending to the posterior abdomen; anterior palpal margin with 3-5 larger, pointed teeth (Figure 4F); south Florida ..... Lepthemis vesiculosa

14A.(11B) Femora with dark bands at 1/4 and 3/4 of their length ...15

14B. Femora unbanded, or with 1 dark distal band 21

15A. (14A) Head dorsum freckled with brown lateral to level of antennal bases; antennae unbanded; abdominal segments 1-4 and 8-9 dark brown dorsally; prementum short and wide, its mid-sagittal length about 55% of its width .....Miathyria marcella

15B. Color pattern not as above, head dorsum unpatterned; flagellum usually banded; abdomen usually concolorous medially along its length; premental length 65% or more of its width 16

16A. (15B) Basal halves of pedicel and scape darker than anterior halves .....Pachydiplax longipennis

16B. Pedicel and scape both concolorous 17

17A. (16B) Flagellum 59-64% as long as maximum width of head, tarsi mostly pale with brown distal tip, palpal teeth occupy nearly the entire anterior margin (Figure 3F) .....most Tramea

17B. Flagellum less than 56% as long as maximum width of head, tarsi usually without a darker distal tip, at least the medial 1/3 of the anterior palpal margin without teeth 18

18A. (17B) Anterior palpal margin with 2-4 low serrate teeth (Figure 4D), not common in Florida .....most Sympetrum

18B. Anterior palpal teeth not so low as to appear serrate, and often more than 4 teeth present; common species in Florida ...19

19A. (18B) Tip and base of tarsus darker than middle portion, dorsal head surface without longitudinal lines of fine points, 2 or 3 of the palpal teeth pointed .....Erythrodiplax minuscula

19B. Tarsus concolorous, gray; dorsal head surface with or without longitudinal lines of fine points, 2-5 of the palpal teeth pointed 20

20A.(19B) Distal ends of tibiae not pale, posterior head setae about 1.5X the thickness of the adjacent more anterior setae, dorsal surface of head without longitudinal lines of fine points .....Ladona deplanata

20B. Distal ends of tibiae pale, posterior head setae less than 1.5X the thickness of the adjacent more anterior setae, dorsal surface of head with longitudinal lines of fine points .....

Libellula

21A.(14B) Tip and base of flagella dark 22

21B. Flagella unbanded 25

22A.(21A) Flagella 59-64% as long as maximum width of head; tarsi mostly pale with brown distal tip ..... Tramea in part

22B. Flagella less than 56% as long as maximum width of head; tarsi without dark distal tip 23

23A.(22B) Dorsum of head marked with brown, a mid-dorsal, longitudinal, club-shaped mark on occiput; posterior pair of head setae about 1.5X as thick as the adjacent anterior pair; tibia with both proximal dark band and gray band at 2/3 of its length; anterior palpal margin toothed nearly to medial margin (Figure 5C) ..... Plathemis lydia

23B. Dorsum of head without distinct markings; head setae of about the same thickness; tibiae with only proximal dark band, or unbanded; more than half of anterior palpal margin without teeth 24

24A.(23B) Anterior palpal margin with 4 pointed teeth plus 2-3 square-ended teeth (Figure 5D); tibiae with dark proximal band ..... Orthemis ferruginea

24B. Anterior palpal margin with 2-4 low, pointed, serrate teeth (Figure 4D), no square-ended teeth; tibiae unbanded ..... Sympetrum in part

25A.(21B) Femur with a dark band at 2/3 of its length; foregut and midgut pigmented with dark granules; flagellum with long, transparent, acuminate tip about 20% of the length of the flagellum ..... Dythemis velox

25B. Femur unbanded; foregut and midgut not pigmented with dark granules; transparent flagellum tip, if present, less than 15% of the length of the flagellum 26

26A.(25B) Labium corduliid -- anterior palpal margin with 7-8 pointed teeth, antero-medial corner crenate, bifid ligular projection present (Figure 3D) ..... Somatochlora

26B. Labium libellulid -- anterior palpal margin with 2-4 of the teeth pointed; antero-medial corner may be slightly crenate; ligular teeth may be present, but are not formed into a bifid projection (Figures 4D,5H) 27

27A. (26B) Anterior palpal margin with 2-4 tall, pointed teeth plus 4-5 rounded teeth (Figure 5H) ..... Pantala

27B. Anterior palpal margin with 2-4 low, pointed teeth laterally, the rest of the margin smooth or slightly crenulated (Figure 4D) ..... Sympetrum in part

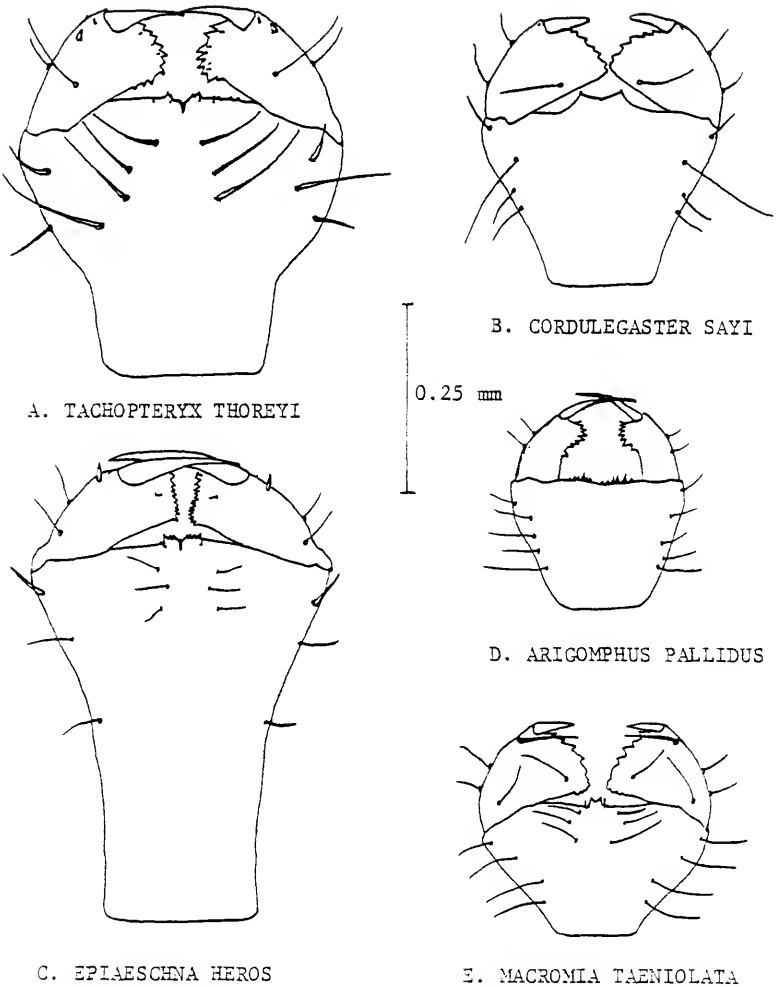

Figure 2. Prementum and palps of second larval instars of 5 families of Anisoptera, seen in dorsal view at 200X. A. Petaluridae, B. Cordulegastridae, C. Aeshnidae, D. Gomphidae, E. Macromiidae.

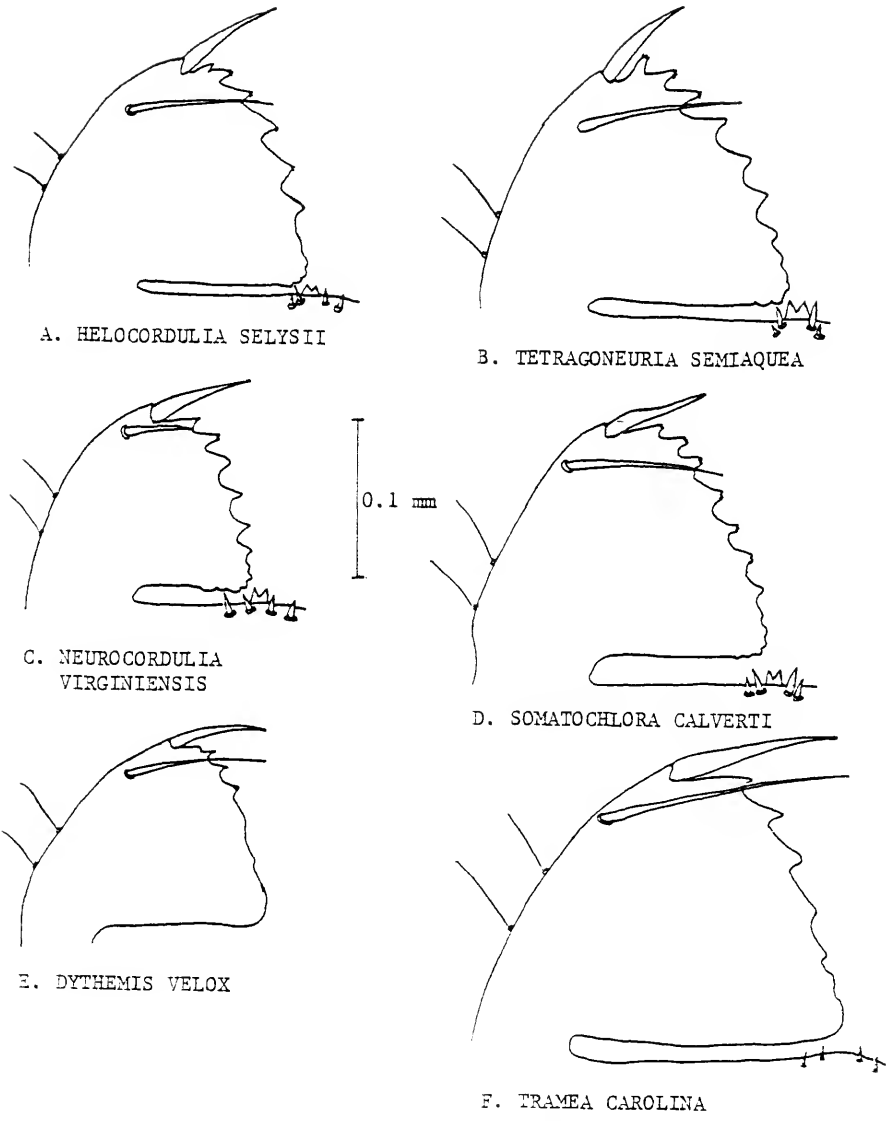

Figure 3. Left palp and anterior premental margin of Corduliidae and Libellulidae second instars in dorsal view at 430X. A-D Corduliidae, E-F Libellulidae.

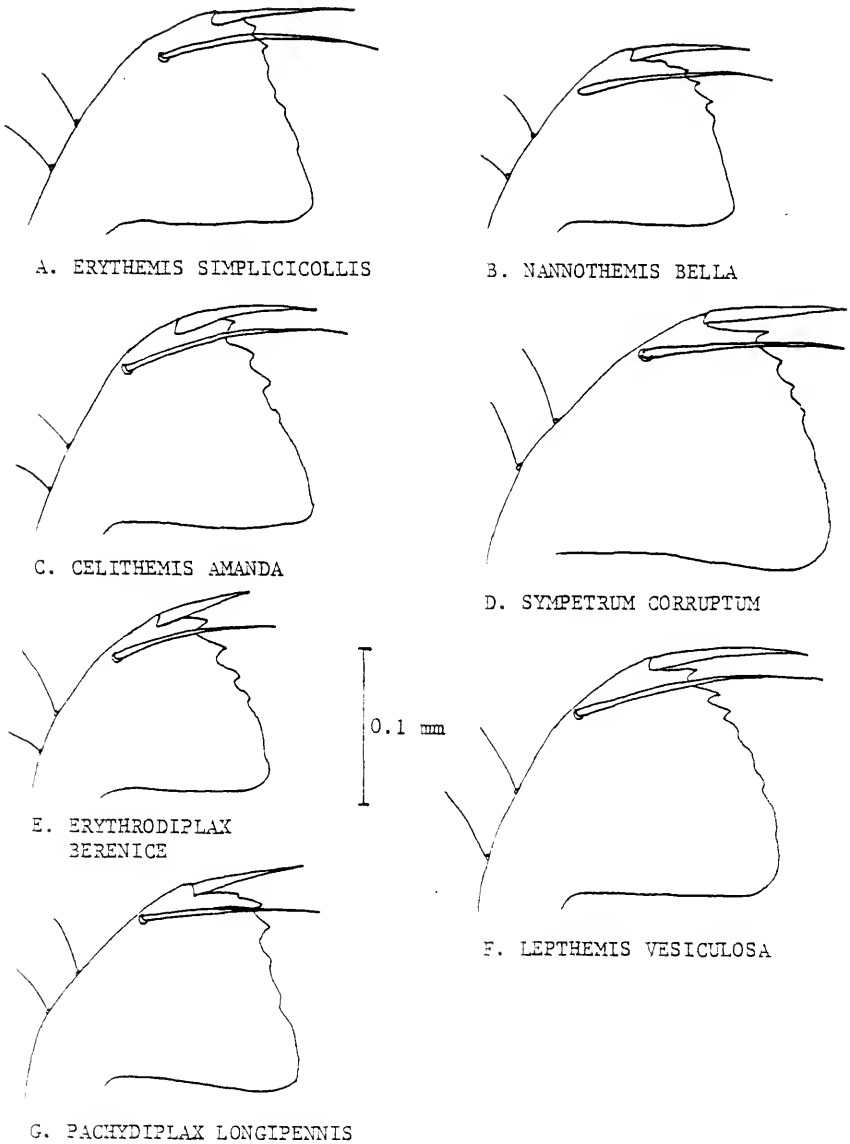

Figure 4. Left palp of Libellulidae second instars in dorsal view at 430X.

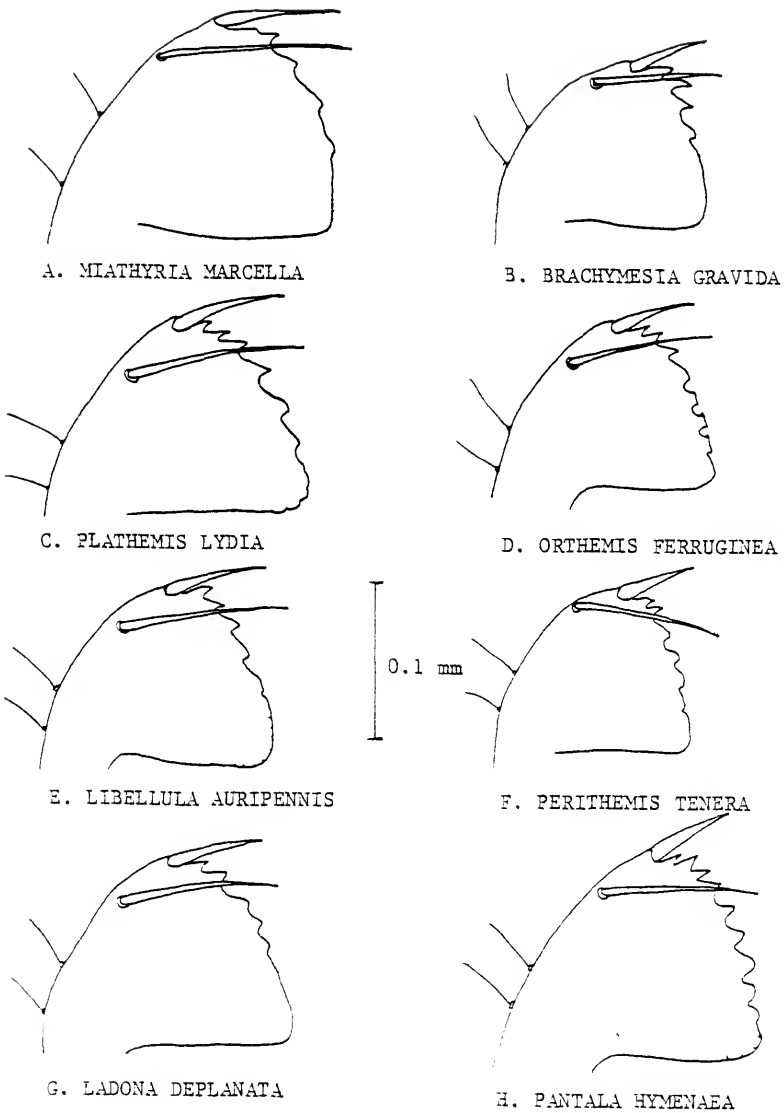

Figure 5. Left palp of Libellulidae second instars in dorsal view at 430X.

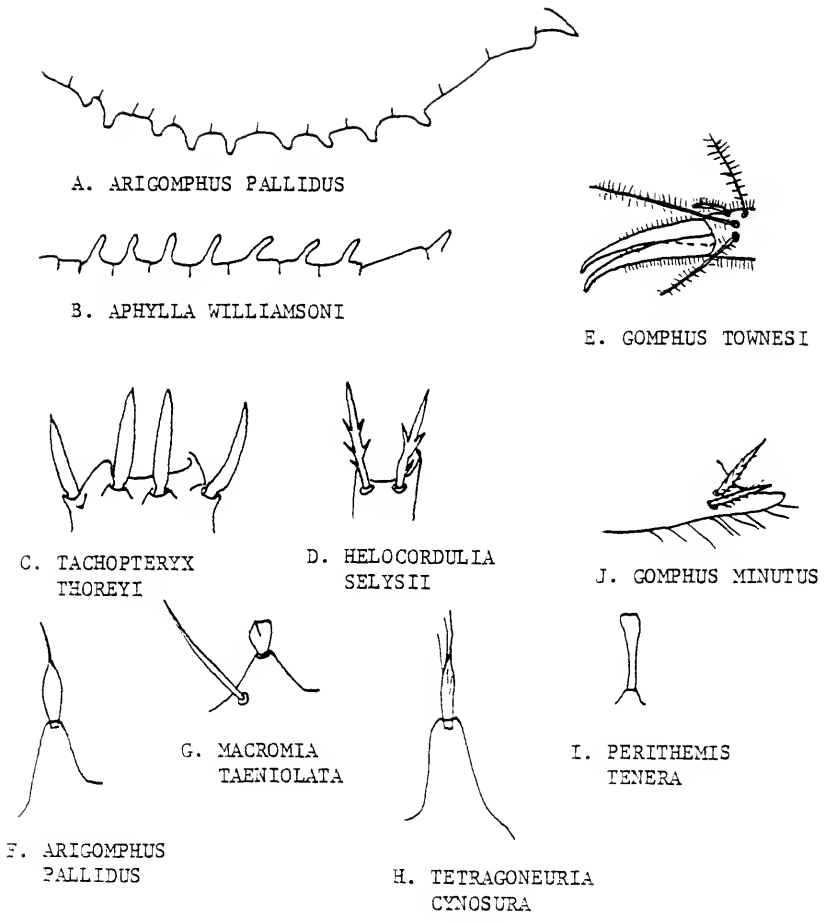

Figure 6. Spines and setae of anisopteran second instars. A and B at 100X, C-J at 430X. A. Left lateral view of ventral thoracic and abdominal spines, B. Left lateral view of dorsal abdominal spines, C. Ventral view of distal hind tibia showing digging setae, D. Ventral view of distal fore tibia showing tibial comb, E. Claws and distal end of fore tarsus, F-H. Horns as seen flattened by a cover slip, I. Occipital seta, J. Dorsal view of left paraproct showing bottle-brush setae.

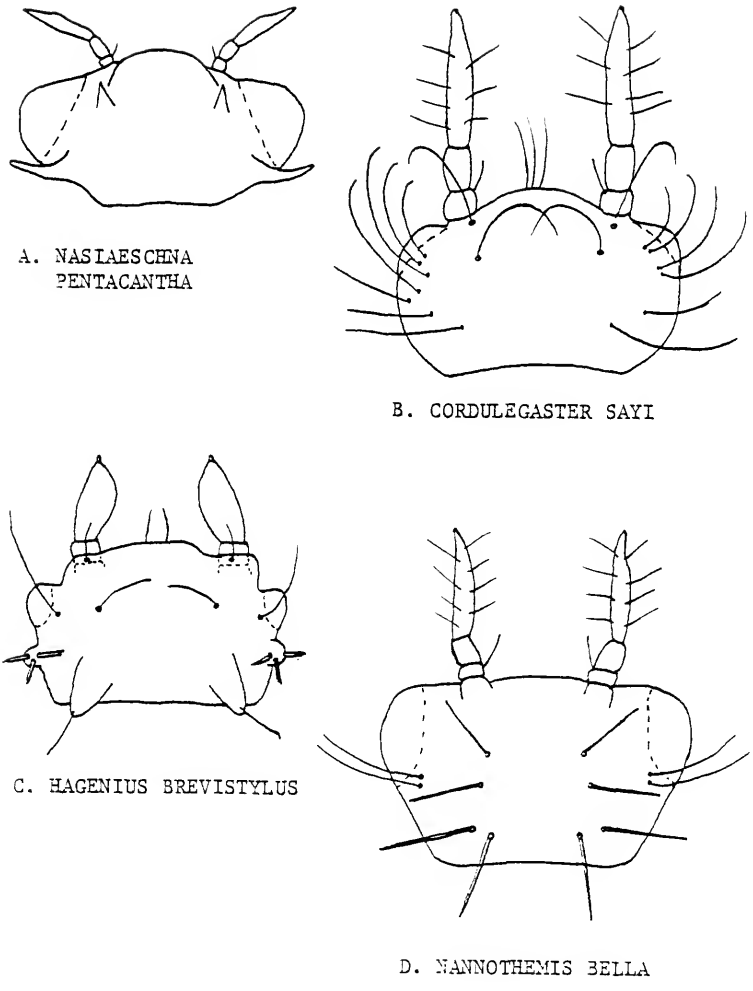

Figure 7. Heads of anisopteran second instars in dorsal view. A. at 100X, B-D. at 200X.

Diagnostic Descriptions

The descriptions in this section are not intended to be complete in every detail, but to supplement and confirm identifications made with the keys. Where possible, growth changes for the third and fourth instars are given so that the reader can separate those instars from the second instar, and as a step toward identifying all the instars of Florida Anisoptera. More instars are described for Macromiidae and Cordulegastridae because no life histories in these families have been published previously. Some growth changes are listed in Table 3 for ready comparison among species. The ommatidia of all species in life are dark red-brown to black. I did not note any differences more than individual variation between specimens from different broods, regardless of geographic origin.

Petaluridae. The only petalurid species in eastern North America is described below. It is a generally scarce and local insect whose habitat is hillside spring seepages in deciduous forest. No tibial or tarsal combs are present, and the palps lie in the plane of the prementum.

Tachopteryx thoreyi

Diagnosis: The general appearance is distinctive, due to the combination of large size, uniformly brown coloration, stout antennae, and stout legs. T. thoreyi has several features unique among the Anisoptera of Florida, including the ligula with an open cleft, the stout spine at the base of the movable hook, and the 4 stout setae at the distal end of the tibia.

Size: Total length 2.24-2.38 mm, head width 0.48-0.51 mm.

Color: Entirely pale brown in life; head, thorax, and abdominal segments 1-2 a little darker.

Head: About 2X as wide as long. Antennae stout, pedicel about as wide as long, ratio of segment lengths about 2:3:7.

Labium: Palps with 7-11 sharp teeth, the row extending well onto the medial border; a short, stout, spine at the base of the movable hook; ligula with an open V-shaped cleft flanked by a large triangular tooth and 2 short setae on each side (Figure 2A).

Thorax: Legs stout, 4 large digging setae at the distal end of each tibia (Figure 6C).

Abdomen: Many long hair-setae, no dorsal or lateral spines.

Growth Changes:

Instar 3: Total length 2.50 mm, head width 0.72 mm, tarsi 2-segmented, 6-7 equal ligular teeth, 11-13 palpal teeth.

Instar 4: Total length 3.30 mm , head width 0.88 mm, antennae 4-5 segmented, tarsi 2-segmented, 9 ligular teeth, 17 palpal teeth, small lateral spine on abdominal segment 9.

Remarks: Wilson (1917) found that the second instars of the Zygoptera Enallagma hageni (Walsh) and E. signatum (Hagen) had a spur at the base of the movable hook as in T. thoreyi. Possibly these spurs are homologous with the major palpal setae of other families of Anisoptera and Zygoptera.

Aeshnidae. Larvae of this family have a characteristic appearance in all instars, given by the large eyes, elongate subcylindrical abdomen, prominent color pattern, and general paucity of setae. A characteristic of aeshnids not found in other second instar larvae is the tarsal comb, composed of mixed branched and serrated setae on the ventral side of the tarsi. The tibial combs each consist of several branched setae, more than in other families. The labium (Figure 2C) has the palps truncate and lying in the same plane as the prementum. The palps have small teeth all along the anterior border. Near the base of the movable hook is a short but stout seta which is in the position of the major palpal setae of the Cordulegastridae, Macromiidae, Corduliidae, and Libellulidae. As Corbet (1955,p 194) said, "It is tempting to regard this as representing the homologue of the primary palpal seta . . . of the . . . Libellulidae." The ligula is cleft, but the cleft is closed, except in some cases for a minute anterior notch. All species examined had lateral abdominal spines on 7-9 except for Gomphaeschna furcillata which had lateral spines on 9 only. G. furcillata is also unique in having small eyes for an aeshnid, evidently compensated for by its exceptionally long antennae. All species examined lack dorsal abdominal spines in the second instar. Long tip setae are present on the paraprocts (except in Coryphaeschna) but there is no tip seta on the epiproct.

Genera Not Examined:

Basiaeschna janata

Boyeria vinosa

Gynacantha nervosa

Triacanthagyna trifida

Gomphaeschna

Species Not Examined:

G. antilope (Hagen)--known habitat is Sphagnum-Taxodium swamps

Gomphaeschna furcillata

Diagnosis: The general appearance is distinctive among aeshnids due to the long antennae, small eyes, color pattern, and lateral abdominal spines present only on 9.

Size: Total length 2.44 mm, head width 0.44 mm.

Color Pattern: Generally pale brown, distal half of flagellum pale, top of head with a large pentagonal pale spot, legs pale with dark band at 3/4 the length of the femur, abdomen darkens posteriorly to 9 but 10 and epiproct pale, paraprocts with wide median brown band.

Head: Eyes small for an aeshnid, occupying the anterior 1/3 of the lateral head margin; antennae as long as head, flagellum bulging distally beyond a slight constriction. Four pairs of setae dorsally, each pair thicker than the adjacent anterior pair; 2 eyelash setae.

Labium: A notched tooth and 2 short setae on each side of the ligular cleft, the latter slightly open anteriorly; palps with 9-11 anterior teeth, medial margin slightly serrate; minor premental setae 6-8 present.

Abdomen: Lateral spine only on 9.

Remarks: This species was reared to instar 4 from eggs obtained by Kennedy (1936). He described dark lateral spots on abdominal segments 3-7, and 2 bristles on each eye. The latter are actually above the eye, but appear at certain microscope focus planes to grow from the eye.

Growth Changes from Kennedy (1936), and original data:

Instar 3: Total length 2.5 mm; antennae 4-segmented; 4-6 ligular teeth, each with a seta lateral to it; lateral spines on abdominal segments 8-9.

Instar 4: Total length 3.0 mm; antennal segment 4 with black tip and base, segment 3 with black base, curved black spot medial to each eye; 5-6 ligular teeth. Tarsi 1- or 2-segmented and lateral abdominal spines on 8 and 9, 6-7 ligular teeth.

Nasiaeschna pentacantha

Diagnosis: Easily distinguished from other Florida aeshnids by the 2 pairs of horns on the head (Figure 7A).

Size: Total length 2.56 mm, head width 0.76 mm.

Color Pattern: Mostly dark brown, antennae pale except for dark tip and base of flagellum, anterior half of head pale, abdominal segments 1-4 mostly pale, the pale areas of head and abdomen

connected by a narrow pale mid-dorsal line on the thorax, femora pale with dark bands at 1/4 and 3/4 of their length, abdominal appendages pale.

Head: Rear corners with anteriorly curved horns which extend laterally beyond the level of the eyes, anterior vertex with a second pair of anteriorly slanted shorter horns.

Labium: Ligula with 4-5 pointed teeth and 2 short setae; palps with 9-10 pointed anterior teeth, medial margin serrate.

Abdomen: Minute lateral spine on 6, large divergent lateral spines on 7-9; no dorsal spines.

Growth Changes:

Instar 3: Mid-dorsal spines on abdominal segments 7-9. These remain to the last instar and are unique among Nearctic aeshnids. Tarsi 2-segmented, large lateral spines on abdominal segments 6-9.

Instar 4: Antennae 4-segmented, tarsi 2-segmented.

Remarks: Munchberg (1930) showed the European Brachytron pratense with similar but straighter lateral horns on the head, but B. pratense lacks vertex horns.

Epiaeschna heros

Diagnosis: Quickly recognized by color pattern and the 1 pair of short horns on the rear corners of the head.

Size: Total length 2.72 mm, head width 0.80 mm.

Color Pattern: In life mostly black; flagellum with white band around middle; anteclypeus with variable pale spots; posterior half of head dorsum with a large crescent-shaped pale mark;

labium gray, femora transparent with dark bands at 1/4 and 3/4 of their length; tibiae pale with dark proximal, central, and distal bands; tarsi and claws gray; abdominal segemnts 1-4, 10, and epiproct white; antero-lateral corners of abdominal segments 6-9 white; base and tip of paraprocts black.

Head: Each rear corner with a conical projection whose length equals its basal width.

Labium: Ligula with 3-5 pointed teeth and 1 short seta; 10-13 pointed palpal teeth (Figure 2C).

Abdomen: Short lateral spines on 7-9.

Growth Changes:

Instar 3: Tarsi 2-segmented; 13-14 palpal teeth; 9 ligular teeth, the sixth from the slightly open cleft the largest.

Instar 4: Tarsi 2-segmented; antennae 4-segmented; lateral spines on abdominal segments 6-9; 13-15 palpal teeth; 10-11 ligular teeth, the sixth the largest.

Coryphaeschna

Species Not Examined:

C. viriditas Calvert -- south Florida

Coryphaeschna ingens

Diagnosis: Easily recognized by the color pattern, particularly by the red mid-dorsal stripe on the thorax. The form of the antennae and the ridged frons are also distinctive.

Size: Total length 2.92 mm, head width 0.88 mm.

Color Pattern: Mostly brown, antennae pale, pale median spot on

anterior frons, pair of small pale spots on front of bulge of frons, pale crescent-shaped mark on head dorsum extends from eye to eye, pale mid-dorsal stripe extends from pale area of head to epiproct, this stripe wide on thorax and abdominal segments 1-4 and 7, but obscure on abdominal segments 5-6 and 8-10. A red mid-dorsal stripe within the pale stripe on thorax and abdominal segments 1-3. Epiproct brown, paraprocts pale. Legs pale with dark bands on femora at 1/4 and 3/4 of their length. Sides of abdominal tergite 7 pale. Palps at base of movable hook and prementum at base of palps brown, remainder pale.

Labium: Ligula with 4-5 teeth and 2 short setae; 12-13 anterior palpal teeth, medial palpal margin serrate.

Abdomen: Lateral spines on 7-9; paraprocts pointed, without tip-setae.

Growth Changes:

Instar 3: Tarsi 2-segmented, small lateral abdominal spine on 6, general body color pale with fine longitudinal green lines.

Instar 4: Antennae 4-segmented, rear corners of head angulate, suggesting the shelf-like occiput of later instars.

Remarks: This was the only species examined with a red marking.

Anax

The 2 regional species are similar in structure but differ in color pattern. Anax amazili (Burmeister) probably does not breed in the United States.

Diagnosis of Anax junius: Color pattern distinctive, pale + mark on top of head with posterior arm narrow; large mid-dorsal pale spot on abdominal segment 8.

Diagnosis of Anax longipes: Color pattern distinctive, pale + mark on top of head, with posterior arm widening posteriorly; abdomen with yellow-brown bands between the gray segments.

Size: Total length 2.80 mm, head width about 0.80 mm. Calvert (1934) said the total length of A. junius can be as short as 1.9 mm, and the head width ranges from 0.70-1.0 mm.

Color Pattern: Major differences between the 2 species are given above. Both are mostly gray-brown and have a pale spot on each rear corner of the head. A pale mid-dorsal line on the thorax continues and widens on abdominal segments 1-2 and narrows on segment 3. Legs paler than the body, and a pale epiproct. A. longipes has tergites 2-9 of the abdomen with anterior and posterior edges yellowish brown, creating narrow tiger-like bands.

Labium: Ligula with 4-6 teeth and 1 short seta, 12-13 anterior palpal teeth. A. longipes tends to have the medial palpal margin crenate, and the ligular setae longer than the ligular teeth.

Abdomen: Lateral spines on 7-9 in both species.

Growth Changes of A. junius from Calvert (1934) and Macklin (1963b):

Both authors described all the instars of this species.

Instar 3: Antennae 4-segmented; tarsi 2-segmented; segments 1, 2, and 8 of abdomen pale; head width 0.94-1.14 mm.

Instar 4: Like instar 3, but head width 1.00-1.31 mm.

Growth Changes of A. longipes:

Instar 3: Antennae 3- to 4-segmented, tarsi 2-segmented; total length of exuviae 3.16 mm, head width of exuviae 1.2 mm; small lateral abdominal spine on segment 6.

Instar 4: Like instar 3, but total length 4.20 mm, head width 1.48 mm.

Gomphidae. Larvae of this family are quickly recognized by their characteristic appearance produced by their short antennae, small eyes, short legs, lack of color pattern, and usually setose body. An incipient tiny fourth antennal segment is located at or near the tip of the flagellum, and the scape lacks the enlarged medial seta of the other families. Characteristic of gomphids are the burrowing hooks, which are projections of the postero-distal part of the fore- and mid-tibiae. The distal ends of the tibiae have 2 strong setae which are probably the homologues of the tibial comb setae of other families. Two "bottle-brush" setae are present on the medial side of each paraproct (Figure 6J), but these are

poorly developed in the subgenus Stylurus. The tip setae of the anal appendages are small or absent. Some species are the only Anisoptera known to have dorsal or ventral abdominal spines in the second instar. The labial palps lie in the same plane as the prementum and have large pointed teeth anteriorly (Figure 2D). The ligular margin has several teeth and 1 or 2 short setae on each side.

Genera and Subgenera Not Examined:

Dromogomphus armatus Selys -- streams

D. spinosus Selys -- streams

Erpetogomphus designatus -- Apalachicola River

Gomphus (Gomphurus) dilatatus Rambur -- streams

G. hybridus Williamson -- Apalachicola River

G. modestus Needham -- Yellow River

Gomphus (Hylogomphus) geminatus Carle -- panhandle streams

Hagenius brevistylus

Diagnosis: Easily distinguished from other gomphids by the 2 pairs of horns on the head and the oval flagellum.

Size: Total length 1.04-1.30 mm, head width 0.32 mm.

Color: Body gray-yellow, darker band around central part of femora.

Head: Flagellum oval in dorsal view; a pair of long posterior horns, each tipped with a slender seta; a second pair of horns as high as wide behind eyes, each with 3 cylindrical setae on its summit (Figure 7C).

Labium: Palps with 5 anterior teeth, 1-2 small medial teeth; ligula with 2 teeth and 1 short seta on each side.

Abdomen: Dorsal spines on 1 or 2-9, no lateral spines.

Aphylla williamsoni

Diagnosis: Readily recognized by the presence of 1 pair of horns on the head, and dorsal abdominal spines on 3-9.

Size: Total length 1.72 mm, head width 0.32 mm.

Color: Gray.

Head: Lateral edge of flagellum straight in dorsal view, a pair of horns slant posteriorly without summit setae, head as long as wide.

Labium: Palps with 5 fang-like distal teeth, 4 medial teeth; ligula with 6-7 teeth, approximately the fourth from the midline the longest.

Abdomen: High, slender, dorsal spines on 3-9 (Figure 6B); 10 nearly 2X as long as anal appendages.

Growth Changes: In a specimen 9 mm long, the dorsal spines on 3-9 are proportionately low, but dorsal spines have developed on 1 and 2 which remain to the final instar. The 9 mm larva has segment 10 already tubelike, and as long as segments 5-9 of the abdomen. Bick and Aycock (1950) and Hornuff (1950) have described some growth changes in this species from the eighth or ninth instar, which is 15 mm long, to the last instar.

Progomphus

Species Not Examined:

P. alachuensis Byers -- Florida peninsula

P. bellei Knopf and Tennessen -- Florida panhandle

Progomphus obscurus

Diagnosis: Quickly distinguished by its paucity of setae, and dorsal spines on abdominal segments 8 and 9.

Size: Total length 1.48 mm, head width 0.34 mm.

Color: Transparent in life, uniformly brown in alcohol.

Antennae: Flagellum with straight lateral edge in dorsal view, about 35% as long as head width.

Labium: Palps with 5-6 anterior teeth, 1-2 small medial teeth; prementum narrows anteriorly, widest at half its length; minor premental seta 9 points straight anteriorly; ligula slightly notched, with 4-6 teeth on each side.

Thorax: Protarsi short, about 35% as long as the head width.

Abdomen: Dorsal spines present on segments 8 and 9; nearly without setae.

Growth Changes:

Instar 3: Antennae with rudimentary fourth segment at the distal tip of the flagellum; total length 1.76 mm, head width 0.40 mm; rudiments of dorsal spines on abdominal segments 4-9.

Instar 4: Antennae 4-segmented, the fourth segment 1/5 as long as the third; total length 1.64 mm in life, head width 0.44 mm; rudiments of dorsal spines on

abdominal segments 1-9, no lateral abdominal spines; labrum with anterior medial bump; tarsi still 1-segmented.

Remarks: The thick cuticle, smooth body surface, and narrowed prementum seem to be adaptations for sand burrowing.

Arigomphus pallidus

Diagnosis: The ventral thoracic and abdominal spines (Figure 2A), and the bulbous setae tipping the horns (Figure 6F) are unique.

Size: Total length 1.60 mm, head width 0.34 mm.

Color: Transparent in life.

Head: Occiput with a pair of posteriorly slanting horns which also spread laterally, each horn tipped with a dark seta that is inflated proximally. Two setae are placed near the base of the antennae, and 2 more setae are placed medial to each horn.

Labium: Anterior palpal margin with 6 teeth, medial margin with 1-2 teeth; 5-7 ligular teeth (Figure 2D); minor premental seta 9 sometimes resembles a bottle-brush, like the setae on the paraprocts.

Abdomen: Unique mid-ventral spines on segments 2-8, each flanked by a seta on both sides. Lateral spines on 5-9, prominent on 6-9; a pair of dark, thick, dorsal setae mounted on tubercles on 1-9; segment 10 as long as wide.

Thorax: Unique mid-ventral spines on meso- and metathorax.

Growth Changes:

Instar 3: Head width 0.44 mm; total length 1.92 mm; antennae with tiny terminal fourth segment; setae on horns clavate, bulbous distally; palps with 5 anterior teeth and 3 medial teeth; ligula with 8-9 teeth on each side; prothorax with a dorsal pair of bulbous setae; lateral spines only on abdominal segments 7-9.

Instar 4: Head width 0.50-0.54 mm, total length 2.64-2.68 mm, 12 ligular teeth, small dorsal spine on abdominal segment 9, tarsi 1-segmented and ventral spines still present on thorax and abdomen. Larvae 10 mm long lack horns and ventral spines.

Gomphus (Gomphus)

Species Not Examined:

G. hodgesi

G. descriptus

The species in this subgenus are much alike. The key presented earlier must be considered somewhat tentative. This subgenus can be differentiated from other Floridae Gomphidae in that horns, dorsal abdominal spines, and specialized abdominal setae are all lacking, but well developed bottle brush setae are present on the paraprocts. The second instars are transparent in life. Abdominal segment 10 is developed to some extent as a respiratory siphon, 48% or more as long as wide. Tiny abdominal spines are present on the posterior abdominal segments, but it is often a subjective judgement

as to whether a particular segment does or does not have a spine. G. australis, G. cavillaris, and G. diminutus have the seta at the rear corner of the head thickened. This seta is exceptionally robust and mounted on a tubercle in G. australis. Two pairs of dorso-lateral setae are present on abdominal segments 2 to 9. The epiproct has 2 pairs of robust lateral setae. Knopf (1977) has synonymized G. brimleyi Muttkowski with G. cavillaris on the basis of identical electrophoretic patterns of 22 proteins.

Growth Changes of G. minutus:

Instar 3: Total length 1.76 mm, head width 0.42 mm, rudimentary fourth segment at distal end of antenna, lateral spines on abdominal segments 6-9, palps with 5-7 anterior teeth and 2-3 medial teeth, 8-9 ligular teeth of uneven length, 3 bottle-brush setae on each lateral margin of epiproct.

Instar 4: Total length 1.86 mm, head width 0.46 mm, antennae 4-segmented, lateral spines on abdominal segments 5-9, palps with 6 anterior teeth and 4 medial teeth, 11 ligular teeth, 4-5 bottle-brush setae on each lateral margin of epiproct, tarsi still 1-segmented.

Gomphus (Stylurus)

Of the 3 species of this subgenus examined, G. laurae and G. plagiatus are much alike, but G. townesi is so different as to seem to belong to another genus. All 3 species, however, have the following characters in common: Head as wide or wider behind the eyes as across the eyes, no tubercles on head, no abdominal spines

dorsally, no setae on the epiproct, and reduced development of the bottle-brush setae on the paraprocts. The claws of last larval instars of all 3 species are hairy, but only G. townesi of the anisopteran second instars examined had hairy claws.

Species Not Examined:

G. ivae

G. potulentus

Gomphus (Stylurus) laurae

Diagnosis: A pair of stubby dorsal setae on each of abdominal segments 2-8, each of the stub-setae flanked on both sides by hair-setae.

Size: Total length 1.46 mm, head width 0.34 mm.

Color: Gray.

Labium: Palps with 5-6 teeth anteriorly, 2-3 small medial teeth; 7-9 ligular teeth of even length but uneven thickness.

Thorax: Two pairs of dorso-lateral setae on prothorax, usually 1 pair on meso- and metathorax. Protarsi and mesotarsi short, length of protarsus 33% of head width.

Abdomen: A pair of stout, stubby, dorso-lateral setae on each of 2-9; becoming flattened and scale-like on 8-9; the stub-setae flanked by hair-setae medially and laterally on 2-8, laterally only on 9; lateral spines on 4-9, minute on 4-6, large and flat on 7-9.

Gomphus (Stylurus) plagiatus

Diagnosis: Like G. laurae, but stub-setae not flanked medially by hair-setae.

Size: Total length 1.06-1.26 mm, head width 0.30-0.32 mm.

Color: Gray.

Labium: Palps with 5-6 anterior teeth, 1-4 small medial teeth; 5-6 ligular teeth.

Thorax: Length of protarsus 32% of head width.

Abdomen: Stout, stubby, dorso-lateral setae on 2-9, flanked by hair-setae laterally but not medially; lateral spines on 5-9, large and flat on 7-9.

Gomphus (Stylurus) townesi

Diagnosis: Pairs of spike-setae on rear corners of head and every body segment except the prothorax, claws hairy (Figure 6E).

Size: Total length 1.56 mm, head width 0.34 mm.

Color: Gray.

Head: A stout spike-like seta at each rear corner.

Labium: Palps with 4-7 anterior teeth and 2-5 small medial teeth; 7-9 ligular teeth.

Thorax: Prothorax with 2 pairs of hair-setae dorsally; meso- and metathorax with a pair of dorsal, medial, thick, dark, spike-setae mounted on tall cone-shaped tubercles, each of the these flanked by a hair-seta laterally. Leg setae and claws are themselves finely hairy at 430X; protarsus 32% of head width; burrowing hooks prominent.

Abdomen: Pairs of dorsal, stout, dark, spike-setae mounted on tubercles on segments 1-9, similar but shorter setae not mounted on tubercles on 10; spike-setae flanked by medial hair-setae on 1-8 and by lateral hair-setae on 1-9; lateral spines on 4-9, large and divergent on 6-9.

Cordulegastridae. Only the genus Cordulegaster is found in North America. All of the species live in unpolluted spring seepages or streams. Judging from the single species available for examination, the second instars are in a less advanced growth stage than second instars of the remaining families, in that the second instar of C. sayi lacks major palpal setae and tibial combs. Both of these types of setae develop in the third instar.

Species Not Examined:

C. fasciata Rambur

C. maculata Selys

Cordulegaster sayi

Diagnosis: The widely cleft projecting ligula is distinctive (Figure 2B).

Size: Total length 1.68 mm, head width 0.34-0.36 mm.

Color: Gray-yellow.

Head: Eyes directed as much anteriorly as laterally; flagellum long, 3-4X length of pedicel (Figure 7B).

Labium: Entire ligula projecting anteriorly, the projection widely V-cleft in the midline; 4-5 sharp, separated, anterior palpal teeth of about equal length; no major palpal setae; movable hook short and blunted.

Thorax: No tibial combs, claws long and slender.

Abdomen: Numerous hair-setae, no dorsal or lateral spines.

Growth Changes:

Instar 3: Total length 2.30 mm, head width 0.44-0.48 mm; 1 major palpal seta, 1 major premental seta; anterior

palpal teeth large and interdigitating; tarsi 2-segmented; 3-5 stout spine-like setae on distal ends of tibiae, some of these branched; a pair of thick blunt setae dorsally on each thoracic segment and abdominal segments 4 and 5.

Instar 4: Two major palpal setae, 3 major premental setae, antennae 5-segmented, 3 blunt setae on dorsal surface of epiproct.

Instar 5: Four major premental setae, lateral abdominal spine on 9.

Instar 6: Three major palpal setae, 6 major premental setae.

Instar 7: Major premental setae 6-7, antennae 6-segmented, lateral abdominal spines on 8 and 9, protarsus 2-segmented, meso- and metatarsus 3-segmented, pairs of blunt setae on each segment of thorax and abdominal segments 1-5. Total length 5.44 mm, head width 1.05 mm.

Remarks: The blunt setae on the dorsum of thorax and abdomen look as if they could be depth sensors, informing the larva how deep it is buried in silt.

Macromiidae. The single species available for examination has a labium resembling that of the Corduliidae with the antero-medial corner of the palp crenate, and sometimes a bifid ligular projection (Figure 2E). The rostral horn so characteristic of the later instars is not present in any of the first 6 instars. The tibial combs are like those of the Corduliidae and Libellulidae, with 2 branched setae at the distal end of each tibia on the underside. The general appearance of the larva in late instars is distinctive with its long, gangling, legs, but in the second instar all the larvae of the Corduliidae and Libellulidae

resemble Macromiidae because they too have relatively long legs.

No dorsal or lateral abdominal spines are present.

Genus Not Examined:

Didymops floridensis Davis--sand-bottomed lakes

D. transversa (Say)

Macromia

Species Not Examined:

M. alleghaniensis Williamson--panhandle streams

M. georgina (Selys)

Macromia taeniolata

Diagnosis: The scale-like seta on the summit of each horn is unique (Figure 6G).

Size: Total length 1.28 mm, head width 0.30-0.34 mm.

Color: Gray-yellow.

Head: No rostral horn; a pair of tall, thick, horns on vertex, each tipped with a flat, scale-like seta; 3 setae are present anterior to each horn, the most posterior of these on the base of the horn.

Labium: Palps with 5-7 anterior teeth, the lateral 2-5 pointed; antero-medial corner of palp crenulate; ligula with a low triangular tooth and a short seta on each side, sometimes a bifid ligular projection. One major palpal seta present (Figure 2E).

Thorax: A short, robust seta on the side of the thorax above the base of each leg, claws long and slender.

Abdomen: Paraproct and epiproct tip-setae short and blunt, that of paraproct 15% of paraproct length excluding the seta.

Growth Changes:

Instar 3: No seta at tip of horn, 1 major premental seta, dagger-setae on several palpal teeth.

Instar 4: Two major palpal setae, 3 major premental setae.

Instar 5: Three major palpal setae, 4 major premental setae, tarsi 2-segmented, antennae 4-segmented.

Instar 6: Three or four major palpal setae, 6 major premental setae, tarsi 2-segmented, antennae 4-segmented, a black line connecting the eyes across the frons. Still no rostral horn, dorsal abdominal spines, or lateral abdominal spines.

Remarks: The only other macromiid second instar that has been described is the Oriental Epophthalmia vittata (Lieftinck,1931). This species has several unique features: 2-branched horns, cupped setae on the thorax, forked setae on abdominal segments 8-10, and a truncate epiproct with 2 equal setae at the apex. Lieftinck's Figure 27 represents the antero-medial corner of the palp as not crenulate.

Corduliidae. The larvae of this family and the Libellulidae are similar, but in the second instar Corduliidae can be usually differentiated by the presence of a small bifid-notched ligular projection and a crenate antero-medial palpal border. Representative labia of all the Florida corduliid genera examined are shown in Figure 3. Some Libellulidae have small ligular projections, but these are usually cleft to the base, forming separate teeth. Some species of Libellulidae

have the antero-medial palpal border slightly crenulate (Figures 5C, 5E, and 5H). The differences between these 2 families tend to disappear in the third and fourth instars because the ligular projection becomes relatively smaller in the Corduliidae, and the palpal margins become crenulate in the Libellulidae.

The labial palps are cupped dorsally, set in a plane nearly perpendicular to the prementum. One major palpal seta is present. The anterior palpal margin is variably toothed, with the largest teeth near the lateral border and diminishing to crenations near the medial border. The teeth are taller, occupy more of the anterior margin, and are of more nearly even length than in most Libellulidae. Both pairs of ligular setae and most or all of the minor labial setae shown in Figure 1 are present.

The top of the head typically has 4 pairs of setae and in most genera a pair of horns. On each segment of the thorax are 1 pair of robust setae dorsally and 1 or 2 small setae laterally. Most segments of the abdomen have 3 pairs of setae dorsally. Dorsal and lateral spines are absent. The legs are long and gangling with tibial combs of 2 branched setae on each tibia. Some species have distinctive color patterns.

Helocordulia selysii

Diagnosis: Diagnostic are the combination of a pair of short horns, the corduliid labium, banded femora, and only one dark band on the antennae, that around the base of the flagellum.

Size: Total length 0.98 mm, head width 0.38 mm.

Color Pattern: Mostly transparent in life with a gray band around the base of the flagellum, gray bands at 1/4 and 3/4 the length of the femur, and gray tarsi.

Head: A pair of postero-lateral conical horns, each as high as wide, and with a tapered seta at the summit. Two setae stand anterior to each horn.

Labium: Palps with 6 large, pointed, anterior teeth; antero-medial corner of palps crenate; bifid ligular projection deeply cleft; dorsal and ventral ligular setae about equal in size (Figure 3A).

Thorax: Each segment with a pair of thick dorso-lateral setae mounted on tubercles.

Abdomen: Paraprocts sometimes have bottle-brush setae, as in the Gomphidae.

Growth Changes:

Instar 3: No ligular projection, 1 major premental seta.

Instar 4: Two major palpal setae, 3 major premental setae, 5-segmented antennae, 2-segmented tarsi; horns twice as tall as wide, slanting posteriorly, without a summit seta.

Somatochlora

Species Not Examined:

S. georgiana Walker--western panhandle

Diagnosis: The combination of the corduliid labium with lack of horns is diagnostic in Florida.

Size: Total length 1.68-1.88 mm, head width 0.40 mm.

Color: Almost no color pattern. Body gray to pale brown with rusty-brown rectal gills. In life, S. linearis had dark gray tarsi, and S. provocans had the thorax and legs paler than the rest of the body.

Head: No horns present, but see Remarks below. S. filosa has a pair of low postero-lateral bumps present. Dorsally on the head are 4 pairs of setae, the postero-lateral pair the thickest.

Labium: Palps with 7-8 anterior teeth, with a minute seta on the most lateral tooth; antero-medial corner of palps crenate; ligula with a bifid tooth; ventral ligular setae larger than dorsal ligular setae (Figure 3D).

Thorax and Abdomen: Setal pattern like that of Tetragoneuria except that the setae are not on conical bases.

Remarks: Miyakawa (1971) stated that the Japanese S. viridiaenea Uhler has a pair of tubercles on the occiput, each tipped with a brush-seta as in Tetragoneuria. In the third instar a smaller tubercle develops at the base of the seta behind the eyes, and the brush-seta of the occipital tubercle is replaced by 4-5 hair-setae. Gardner (1954) also reported horns in second instar S. metallica.

Growth Changes: In S. calverti, S. filosa, and S. provocans, the ligular projection is not obvious in the third instar and is no larger than adjacent teeth in the fourth instar. For other growth changes in these three species, see Table 3. Growth changes of S. kennedyi are similar (Walker,1925) except that instar 4 has 5-segmented antennae.

Neurocordulia

Species Not Examined:

N. alabamensis Hodges -- streams

N. molesta (Walsh) -- Apalachicola River

N. obsoleta (Say) -- bald cypress (Taxodium) rimmed lakes in north Florida

Diagnosis : The short and robust major palpal seta, shorter than the movable hook, is unique (Figure 3C). The bottle-brush setae of the paraprocts are also not found in other regional larvae, except in the Gomphidae and some Helocordulia. The color pattern and pair of short horns are as in Helocordulia, except that the femora are unbanded.

Size: Total length 1.22-1.26 mm, head width 0.32-0.36 mm.

Color Pattern: In life, body nearly transparent with the internal parts of the head, thorax, and abdomen pale brown. Gray band at base of flagellum; legs gray with paler proximal trochanter, joints, and tips of the tarsi; abdomen darker gray along the lateral edges. Midgut pigmented in alcohol.

Head: A pair of short horns on the occiput about as high as wide, tipped with a thick seta. Two long setae anterior to horns, 1 short seta posterior to horns. Two eyelash setae above each eye.

Labium: Major palpal seta thickened for most of its length, shorter than movable hook. Anterior palpal margin with 6 pointed teeth, crenate antero-medial corner; bifid ligular projection

present; dorsal ligular setae larger than ventral ligular setae.

Thorax: A pair of long, thick, dark setae on each segment, mounted on conical bases.

Abdomen: Medial side of each paraproct with 2 bottle-brush setae.

Growth Changes of N. virginiensis:

Instar 3: One major premental seta, 1 major palpal seta a little longer than movable hook, 3 dagger-setae on anterior palpal margin, horns without a summit seta.

Instar 4: One major premental seta, 2 major palpal setae, antennae 5-segmented, tarsi 2-segmented, total length 1.56 mm in life, head width 0.56 mm, horns bright orange.

Tetragoneuria

Species Not Examined:

T. costalis (Selys)

T. spinosa (Hagen) -- Florida panhandle

As expected from adult and last larval instar morphology, second larval instars of the 3 Florida species examined are nearly identical. Second larval instars of T. sepia in the one brood available were dark brown, the other species gray to pale brown.

Diagnosis: The pair of tall horns on the head, tipped with brush-setae (Figure 6H), combined with the corduliid labium, and 6 anterior palpal teeth, are diagnostic.

Size: Total length about 1.0 mm, head width about 0.36 mm.

Color Pattern: Generally pale brown, T. cynosura in life had the tip and base of the flagellum gray, basal half of the pedicel gray,

scape gray, distal trochanter gray, femora with gray bands at 1/4 and 3/4 of their length, tibiae gray with pale distal end, tarsi gray with pale distal end, claws black, antero-lateral parts of abdominal tergites dark, tips of paraprocts black. Colors quickly lost in alcohol.

Head: A pair of tall horns on the vertex, each tipped with a thick seta which usually has the distal end divided and brush-like. Anterior to each horn are 2 setae, behind each horn on the occiput is a shorter, thicker seta. The antennae are longer than the head.

Labium: Labial palps with 6, or occasionally 7, anterior teeth and a crenate antero-medial corner; ligula with a bifid tooth, ventral ligular setae much larger than dorsal ligular setae (Figure 3B). Butler (1904) illustrated a trifid ligular tooth for T. cynosura.

Thorax: A pair of robust dorso-lateral setae on each segment, set on conical bases. Lateral to these are 1 small seta on the prothorax, 2 small setae on the meso- and metathorax.

Abdomen: Segments 5-9 with 5 pairs of setae dorsally, the second from the midline longest and thickest. The latter are set on conical bases in T. sepia and T. stella. The longitudinal tracheae may be pigmented in the base of the abdomen.

Remarks: Kormondy (1955,1959) did not find key differences among second instar larvae of T. canis, T. cynosura, and T. spinigera. In his Table 11 (1955), only 1 of 22 characters he measured

did not overlap in size. The shortest epiproct of T. cynosura was 0.01 mm longer than the longest epiproct of T. spinigera.

Growth Changes of T. cynosura from Kormondy (1955,1959):

Instar 3: One major premental seta, a 2-segmented tarsus in some specimens.

Instar 4: Antennae 4-5 segmented, tarsi 2-segmented, 2 major palpal setae, 3 major premental setae. The horns on the head increased in size to instar 6, remained unchanged to instar 8, and disappeared by instar 11.

Epicordulia princeps

The second instar of E. princeps, which the author considers synonymous with E. regina (Hagen), was described by Wilson (1917). The labium was studied by Butler (1904). The following data are from these sources.

Diagnosis: Similar to Tetragoneuria, but larger, with 7-8 anterior palpal teeth instead of 6. According to Wilson (1917) the tips of the horns are hooked posteriorly, but possibly the "hooks" are thick setae bent over posteriorly by a cover slip. Wilson also stated that the dark abdominal markings on the tergites are postero-lateral, rather than antero-lateral.

Size: Total length 1.25 mm.

Color: Mostly pale, basal half of flagellum black, basal half of pedicel black, abdomen with dark spots on the posterior margin at the lateral edge of each tergite.

Head: A pair of tall occipital horns with the tips hooked posteriorly.

Labium: Palps with 7-8 anterior teeth and a crenate antero-medial corner. A bifid ligular projection is present.

Remarks: Walker (1966) lumped Tetragoneuria and Epicordulia into the old world Epitheca. Also, some odonatologists consider Epicordulia princeps to be a separate species from E. regina. Both of these problems need more study.

Libellulidae. Most libellulid genera lack horns on the head, ligular projections, and crenations on the antero-medial palpal border. Otherwise, Libellulidae are nearly identical to Corduliidae. See the discussion of the Corduliidae for differences between these 2 families. Representative labia are shown for all the Florida genera examined in Figures 3, 4, and 5. The ligula of nearly all the Libellulidae examined looks like Figure 3F.

Genera Not Examined:

Crocothemis servilia

Idiataphe cubensis

Macrodiplax balteata

Tauriphila australis

Brachymesia

Both of the Florida species were examined, but no definite differences could be found between them. Brachymesia furcata occurs only in south Florida.

Diagnosis: A pair of tall, vertical horns on the vertex, each usually tipped with a hair-seta. A large, thick seta stands behind each horn, and the midgut is usually pigmented.

Size: Total length 1.12-1.14 mm, head width 0.30-0.32 mm.

Color Pattern of B. gravida: Mostly transparent in life; tip and base of flagellum gray, scape and pedicel gray; distal trochanter gray; femora with gray band at 1/4 and black band at 3/4 of their length, distal end white; femoro-tibial and tibio-tarsal joints pale; base of tibiae dark, obscure pale band at I/4 of their length, the remainder gray; abdominal tergites with antero-lateral corners dark, postero-lateral corners white; paraprocts with white base and dark tip. The color pattern of the available B. furcata specimens was lost in alcohol.

Head: A pair of tall, vertical horns 0.08 mm long on the vertex, each with a hair-seta at the summit. The summit seta is occasionally thickened with a few brush-like divisions, as in Tetragoneuria. A small seta is located anterior to each horn, and a large, thick seta posterior to each horn. Flagella about 55% as long as head width.

Labium: Palps with 3 pointed lateral teeth, and 1-3 medial blunt teeth on the anterior margin; the medial 1/4 of the anterior margin smooth (Figure 5B). Ligula often with a pair of pointed teeth between the ventral ligular setae, more often in B. gravida.

Thorax: Each segment with a pair of robust dorso-lateral setae mounted on small, conical tubercles. Since the eggs of B. furcata are

dark green, and the eggs of B. gravida range from yellow to green, the midgut is often pigmented with dark yolk granules.

Growth Changes in B. gravida:

Instar 3: One major premental seta, palps with antero-medial corner crenate, a dagger-like seta at antero-medial corner of palp.

Instar 4: Two major palpal setae, 1 major premental seta, antennae 4-segmented, no dorsal or lateral abdominal spines, 3 dagger-setae on anterior palpal margin, horns still tall and tipped with a seta, tarsi still 1-segmented.

Nannothemis bella

Diagnosis: Eyes relatively larger than in any other species seen except species of the Aeshnidae, covering the anterior 1/2 to 2/3 of the lateral head margin (Figure 7D); body dark gray; Florida panhandle in Sphagnum bogs.

Size: Total length 1.10 mm, head width 0.38-0.40 mm.

Color Pattern: Generally dark gray, distal half of the flagellum pale, femora with dark bands at 1/4 and 3/4 of their length, trochanter dark, obscure dark bands at proximal end of tibia and proximal end of tarsus. Longitudinal tracheal trunks pigmented full length, from head to hindgut.

Head: Eyes exceptionally large, spanning 1/2-2/3 of the lateral length of the head; 4 pairs of dorsal setae.

Labium: Distal margin of palps with 4-5 teeth, the lateral 2 or 3 pointed, the medial ones rounded, the medial 2/3 of the distal margin may be slightly crenulate (Figure 4B).

Thorax: Tarsi relatively short, about 34% as long as head width.

Perithemis tenera

Diagnosis: Immediately distinguished by the pair of tall, vertical horns on the vertex, with a thick, cylindrical seta standing behind each horn (Figure 6I).

Size: Total length 1.10 mm, head width 0.30 mm.

Color Pattern: In life, generally pale brown; black bands at tip and base of flagellum; wide pale mid-dorsal stripe on thorax; dark distal trochanter; dark bands at 1/4 and 3/4 the length of the femur; tibia dusky, with dark proximal band; tarsi dusky; lateral edges of tergites white posteriorly, black anteriorly; paraprocts black-tipped. Specimens become transparent in alcohol.

Head: A pair of tall vertical horns on vertex, each with a hair-seta at the tip. Posterior to each horn is a thick, inflated, cylindrical seta, mounted on a conical base. Anterior to each horn is a small seta, with another posterior to each inflated seta.

Labium: Anterior palpal margin with 5 teeth, the lateral 2 pointed, the others truncate or serrate with apices hooked medially; medial part of anterior margin smooth for a distance of 2 tooth-widths (Figure 5F).

Thorax and Abdomen: A pair of thick, inflated, cylindrical setae dorsally on each segment from the prothorax to abdominal segment 9.

Celithemis

No constant differences could be found among the 6 species examined.

Species Not Examined:

C. verna Pritchard -- south to Lake City

Diagnosis: A pair of vertical horns on the vertex 1-2X as high as their width at the base, each tipped with a hair-seta. There are 2 hair-setae behind each horn.

Size: Total length about 1.16 mm, head width about 0.34 mm.

Color Pattern: C. ornata in life had the tip and base of the flagellum dark, delimiting a white band around the middle; distal half of the pedicel white, basal half black; black band at 3/4 the length of the femur; white bands at both ends of the femur and distal end of the tibia; antero-lateral corners of abdominal tergites black. The only marking on alcohol specimens of all the 6 species examined was the dark femoral band. Also, the longitudinal tracheae were pigmented in the thorax and base of the abdomen.

Head: A pair of vertical horns on the vertex 1-2X as high as basal width, each horn with a hair-seta at the summit. One seta stands anteriorly to each horn, 2 setae behind each horn. Flagellum 62-70% as long as the head width.

Labium: Palps usually with 3-4 teeth laterally on the anterior margin. C. eponina has 2-3 teeth. The medial half of the anterior palpal margin is smooth (Figure 4C).

Remarks: C. eponina seems most different from the other species examined in that it has taller horns, and sometimes only 2 anterior palpal teeth.

Dythemis velox

Diagnosis: Recognized by the combination of a dark band at 2/3 the length of the femur, darkly pigmented foregut and midgut, and long transparent tip on the flagellum. Not found in the Florida peninsula.

Size: Total length 1.14 mm, head width 0.34 mm.

Color: Gray with a pigmented foregut and midgut, although the yolk is the usual pale yellow; faint brown bands at 2/3 the length of the femora.

Head: Flagellum with a clear acuminate tip 20% of flagellum length, flagellum 54% as long as head width; 3 or 4 pairs of setae on vertex.

Labium: Anterior palpal margin with 3 or 4 pointed teeth laterally, 1 blunt tooth medially, medial 1/3 of the anterior margin smooth (Figure 3E).

Erythemis

Species Not Examined:

E. plebeja (Burmeister)--south Florida

Erythemis simplicicollis

Diagnosis: E. simplicicollis has a distinctive color pattern. Body dark brown with a nearly full length pale mid-dorsal stripe from the labrum to segment 9 of the abdomen. The pale stripe is widened to 1/4 the width of the head on the occiput. Palps with only 1 or 2, occasionally 3, pointed anterior teeth.

Size: Total length 1.18 mm, head width 0.36 mm.

Color Pattern: In life dark brown with a cream-colored mid-dorsal stripe from labrum to abdominal segment 9, the stripe widened to about 1/4 the head width in a violin-shaped marking on the occiput. Femur pale with brown distal band, tibia pale with brown proximal band, the femoro-tibial joint pale. Tarsi and claws brown. Sides of thorax above coxae with small pale spots, and epiproct pale. In alcohol the legs become brown with pale joints.

Head: Vertex with 3 or 4 pairs of setae; eyes directed laterally and dorsally, not anteriorly.

Labium: Anterior palpal margin with 1-3 low pointed teeth laterally, with a few medial crenations; most of anterior border nearly smooth (Figure 4A).

Abdomen: Seta at tip of paraproct short, about 20% of paraproct length excluding the seta.

Growth Changes from Bick (1941), who described all the instars:

Instar 3: One major premental seta, anterior palpal margin with 3 dagger-like setae.

Instar 4: Three major premental setae, 2 major palpal setae, anterior palpal margin with 6 dagger-setae, antennae 4-segmented, tarsi still 1-segmented.

Remarks: The western Nearctic E. collocata has a pale mid-dorsal line which extends posteriorly only to abdominal segment 3, but the labium is like that of E. simplicicollis. The labium of both species is different from that of Lepthemis vesiculosa, which some odonatologists consider congeneric with Erythemis.

The figure of E. simplicicollis in Needham and Heywood(1929) is apparently some other species, since prominent horns on the vertex are shown.

Wilson (1917) and Bick (1941) have both described the second instar of E. simplicicollis. Bick questioned the existence of the minor labial setae figured by Wilson, and thought that Wilson indicated a cleft prementum in his figure. My specimens have the minor palpal and premental setae as shown by Wilson. Probably Wilson did not intend to show a cleft prementum, but rather folds or lines to demonstrate that the prementum is slightly cupped.

Lepthemis vesiculosa

Diagnosis: In Florida, restricted to the southern peninsula. Morphologically like Erythemis simplicicollis, as in the short paraproct tip-setae, but with 3-5 large pointed teeth on the anterior palpal margin instead of 1-3 small pointed teeth (Figure 4F). Color pattern unknown, probably similar to that of E. simplicicollis.

Size: Total length 1.30, head width 0.42 mm.

Color Pattern: Specimens in alcohol are pale brown with an obscure pale mid-dorsal line on the thorax.

Head: Dorsal surface with 4 pairs of setae.

Labium; Anterior palpal margin with 3-5 pointed teeth laterally, followed by 1 or 2 blunt teeth medially, then low crenations to a smooth antero-medial margin.

Abdomen: Setae at tips of paraprocts short and stout, about 17% as long as the paraprocts excluding the setae.

Erythrodiplax

Species Not Examined:

E. umbrata (Linnaeus) -- south Florida

Diagnosis for E. berenice: The color pattern is distinctive, and the habitat is salt marsh. Body brown with a large, pale, wedge-shaped mark on the top of the head; tip and base of the flagellum dark; color pattern superficially like Erythemis simplicicollis.

Diagnosis for E. minuscula: Color pattern markedly different from E. berenice. Color pattern similar to that of Libellula, except that the tip and base of the tarsi are darker than the central part.

Size: Total length 1.14-1.18 mm, head width 0.32-0.38 mm.

Color Pattern of E. berenice: Body brown with the following areas pale: a large wedge-shaped mark on the head dorsum, spreading posteriorly from a point on the frons; zones at the bases of the compound eyes; femoro-tibial joint; tibio-tarsal joint; mid-dorsal line on thorax; and segments 9 and 10 of the abdomen. The tip and base of the flagellum are dark.

Color Pattern of E. minuscula: Mostly translucent in life; tip and base of the flagellum black; distal trochanter gray; femora

with gray band at 1/4 and black band at 3/4 of their length, distal end white; tibiae with black proximal band and obscure pale band at 1/4 of their length; tarsi gray with base and tip darker; lateral edges of abdomen darker, postero-lateral corners of tergites white.

Head: Four pairs of setae on dorsum, these setae thin in E. berenice, thick and robust in E. minuscula. Flagellum of the antennae long, 52-56% as long as head width. Surface of head covered with curved lines of fine dark points in E. berenice, apparently not so in E. minuscula.

Labium: Anterior palpal margin with 4 teeth, the most lateral 2 or 3 pointed, the others rounded; medial half of the distal margin smooth. The pointed teeth are larger in E. berenice (Figure 4E).

Abdomen: Paraproct tip-seta exceptionally long and thin in E. berenice, about 44% of paraproct length, compared with about 33% in E. minuscula.

Remarks: Some odonatologists consider E. minuscula to be a subspecies of E. connata. No difference was noted between second instars of these two species or subspecies. The other species differences observed in this genus are relatively great for libellulids.

Libellula

L. pulchella was not examined in this study, but was described by Wilson (1917). No differences among the 8 Florida species were found on which to base a key.

Diagnosis: Color pattern like that of Ladona deplanata, Erythrodiplax minuscula, Pachydiplax longipennis, Perithemis tenera, and

Tetragoneuria, but distinguished by the combination of pale distal ends on the tibiae, lines of fine points on the surface of the top of the head, pale unbanded scape and pedicel, and lack of horns.

Size: Total length about 1.0 mm, head width 0.32-0.38 mm.

Color Pattern: In life, body mostly pale yellow-brown, with the following dark gray or black: tips and bases of flagella; proximal trochanter; bands at 1/4 and 3/4 the length of the femora; the tarsi, claws, anal valves, and the tips of paraprocts. Tibiae gray with pale distal ends and band at 1/4 of their length, the proximal end darker. Abdominal tergites with black antero-lateral corners, and white postero-lateral corners. The coxae and both ends of the femur are white.

Head: Dorsum with 4 pairs of setae, these becoming a little thicker posteriorly; dorsal surface with longitudinal lines of minute points.

Labium: Anterior palpal margin with 3, sometimes 4-5 pointed teeth laterally, and 1, sometimes 2, rounded teeth medially; medial 1/3-1/2 of anterior margin smooth (Figure 5E).

Abdomen: Terminal seta of paraprocts 2X as long as the terminal seta of the epiproct. Epiproct with 1 or 2 robust lateral setae on each side. Longitudinal tracheal trunks pigmented in basal part of abdomen.

Remarks: A northern species, L. quadrimaculata, has the body dark brown, and has no pale distal end on the tibiae.

Wilson (1917) described supposed hybrid second instars from a female L. luctuosa mated with a male L. pulchella. The hybrids differed from the parental species in having 1 or 2 fewer anterior palpal teeth, stouter abdominal setae, and the pedicel banded with gray at both ends.

Ladona deplanata

Diagnosis: Nearly identical with Libellula, differing in that the distal ends of the tibiae are not pale, lines of fine points on the head surface are lacking, and the posterior head setae are generally more robust. The most posterior head setae are up to 1.5X the thickness of the next most anterior pair. L. deplanata is likely to be found as small instars only in the spring, most species of Libellula occur as small instars throughout the summer and fall. The labium of L. deplanata is shown in Figure 5G.

Growth Changes:

Instar 3: One major premental seta present.

Instar 4: Three major premental setae, 2 major palpal setae, antennae 4-segmented. Still no dorsal or lateral abdominal spines, and tarsi 1-segmented.

Plathemis lydia

Diagnosis: A brown club-shaped marking on dorsum of head; basal half of femur gray; tibia with gray band at 2/3 of its length, then pale to distal end; posterior head setae thick; palps with 5-7 large teeth, occupying all but 2 tooth-widths of the anterior margin (Figure 5C).

Size: Total length 1.54 mm, head width 0.38 mm.

Color Pattern: Generally pale brown in life. Tip and base of flagellum black, enclosing a white band. A dark brown, mid-dorsal, longitudinal, club-shaped mark on dorsum of head with its narrow end anterior. Dark brown areas postero-lateral to each eye connected by a brown line across the vertex. Distal trochanter gray; femur with gray basal half, gray band at 3/4 of its length, and white distal end; tibia with black proximal band and gray band at 2/3 of its length, tarsi and claws gray. Abdomen darker along lateral edges with postero-lateral corners of tergites white, paraprocts gray-tipped, anal valves dark, longitudinal tracheae pigmented at base of abdomen. Specimens in alcohol become transparent with only the tips of the flagellum and paraprocts dark.

Head: Four pairs of dorsal setae, the most posterior setae 1.5X the thickness of the adjacent more anterior ones; dorsal surface with lines of fine dark points.

Labium: Anterior palpal margin with 4 pointed teeth laterally, 1-3 rounded teeth medially, most medial part of anterior margin smooth or slightly crenulate for about 2 tooth-widths. Wilson (1917) stated that there are 7 palpal teeth, but illustrated 5.

Remarks: Specimens from Iowa described by Wilson (1917) had the brown areas postero-lateral to the eyes extended posteriorly and curved a little medially, forming parentheses-like markings enclosing the the club-shaped marking on the head.

Orthemis ferruginea

Diagnosis: Anterior palpal margin with the most medial 2 or 3 teeth distinctively squared (Figure 5D). Body pale gray, with the only dark markings the tip and base of the flagellum and the proximal end of the tibia.

Size: Total length 1.30 mm, head width 0.34 mm.

Color Pattern: Generally pale gray, tip and base of flagellum dark, femora darker proximally, dark band at proximal end of tibia, tarsi darker gray.

Head: Flagellum about 42% as long as width of head, 4 pairs of setae on dorsum, dorsal surface with lines of fine dark points.

Labium: Anterior palpal margin with 4 pointed teeth laterally, and 2-3 square cornered, truncate teeth medially; medial part of anterior margin smooth for a distance of about 2 tooth-widths.

Growth Changes:

Instar 3: One major premental seta present, 3 dagger-setae on anterior palpal margin.

Instar 4: Three major premental setae, 2 major palpal setae, 5 dagger-setae on anterior palpal margin, antennae 4-segmented. Still no lateral abdominal spines, and tarsi 1-segmented.

Miathyria marcella

Diagnosis: Color pattern and labium distinctive; dorsal head surface freckled with brown spots lateral to level of antennal bases, prementum notably short and wide, anterior palpal margin with 4 widely spaced teeth (Figure 5A).

Size: Total length 0.82 mm, head width 0.36 mm.

Color Pattern: Generally pale brown; dorsum of head with small dark-brown spots lateral to level of antennal bases; femora with obscure darker bands at 1/4 and 3/4 of their length; tibiae with obscure dark band proximally; abdominal segments 1-4 and 8-9 dark brown dorsally.

Head: Four pairs of dorsal setae; flagellum long, about 53% as long as head width.

Labium: Prementum exceptionally short and wide, its mid-sagittal length 54-56% of its maximum width (measurements taken in ventral view, not on a flattened labium). Anterior palpal margin with 4 widely spaced teeth, the lateral 2 or 3 pointed, the others rounded, medial 1/4 of anterior margin smooth.

Pachydiplax longipennis

Diagnosis: This species differs from others with a similar color pattern, such as Libellula, by having the basal halves of the pedicel and scape gray.

Size: Total length 1.04 mm, head width 0.34 mm.

Color Pattern: Mostly gray in life; tip and basal half of flagellum, and basal halves of pedicel and scape dark gray; head with a transparent mid-dorsal stripe; distal trochanter dark; femora with dark bands at 1/4 and 3/4 of their length; pale tibio-tarsal joint; antero-lateral corners of abdominal tergites dark; abdominal tergites 5-6 paler, and 8-10 darker, than the rest of the abdomen; paraprocts dark-tipped. Longitudinal tracheae pigmented in segments 5 and 8-9 of the abdomen.

Head: Dorsum with 1 or 2 pairs of setae on vertex, 2 pairs on the occiput; longitudinal lines of fine points on dorsum.

Labium: Anterior palpal margin with 3 pointed teeth laterally, followed by 1-2 rounded teeth medially; medial half of anterior margin smooth (Figure 4G).

Pantala

No differences could be found between second larval instars of the 2 species of Pantala.

Diagnosis: The palp resembles that of the Corduliidae with 6-7 tall teeth (Figure 5H), but the ligula has 2 or 3 separate teeth, not a bifid projection.

Size: Total length 1.20-1.46 mm from Lamb (1925), head width 0.29-0.40 mm.

Color: Pale brown in alcohol.

Head: Four pairs of setae dorsally, the third from the anterior wider apart. Surface with lines of fine dark points.

Labium: Distal margin of palps with up to 9 teeth, 2-4 pointed teeth laterally followed by 4-5 tall rounded teeth medially; antero-medial corner crenulate. Ligular margin with 3, sometimes 2, pointed teeth between the ligular setae.

Abdomen: Setae at tips of paraprocts relatively short, 21% of the epiproct length excluding the seta.

Growth Changes of P. flavescens from Lamb (1925,1929), who reared this species from egg to final instar:

Instar 3: Antennae 4-segmented, 2 major premental setae, femur and tibia each with 2 gray rings.

Instar 4: Antennae 5-segmented, 4 major premental setae, 4 major palpal setae, tarsi still 1-segmented, small lateral spine on abdominal segment 9. Miyakawa (1977) found that the antennae were 3-segmented in the third instar, and 4-segmented in the fourth instar.

Sympetrum

S. ambiguum is scarce in the Florida peninsula, and S. corruptum is scarce all over the southeast. S. vicinum has not been found in the Florida peninsula. S. ambiguum was not examined in this study, but Tai (1967) described all its instars.

Diagnosis: S. vicinum is differentiated from other libellulids and the Corduliids by its short, divergent horns. The palpal teeth of all the species are notably low. This genus is keyed out at 4 points in the key, primarily because of uncertainty about the living color pattern.

Color Pattern: Pale brown in alcohol. S. vicinum has faint brown bands at 1/4 and 3/4 the length of the femora and at 1/4 the length of the tibiae. Nevin (1929) stated that the antennae of this species are also faintly banded in early instars. A northern species, S. semicinctum, examined in life, had a Libellula-like color pattern.

Head: Dorsum with 4 pairs of setae; in S. vicinum the second pair from anterior tips a pair of divergent horns, each about as tall as wide at the base. Flagellum about 59% as long as width of head in S. vicinum, about 48% in S. corruptum.

Labium: Anterior palpal teeth very low, the lateral 2-4 pointed; the remainder of the anterior margin and the anterior part of of the medial margin may be slightly crenulate (Figure 4D). S. corruptum may have a short tridentate ligular projection.

Growth Changes for S. ambiguum from Tai (1967), who describes all the instars:

Instar 3: Two major palpal setae and 1 major premental seta.

Instar 4: Three major palpal setae, 4 major premental setae, 4-segmented antennae, but still only 1-segmented tarsi.

Growth Changes for S. vicinum from Nevin (1929), Tai (1967), and Trottier (1969):

Instar 3: One major premental seta. Total length 1.40-2.17 mm, head width 0.43-0.67 mm.

Instar 4: Three or four major premental setae, 2 major palpal setae, 4 antennal segments, but still only 1-segmented tarsi. The horns become taller to instar 8, are reduced to a bump in instar 9, and are generally not present in instar 10. Total length of instar 4 1.70-2.33 mm, head width 0.60-0.83 mm. Nevin (1929) gave a key to all the instars, and Tai (1967) described all the instars.

Tramea

Species Not Examined:

T. abdominalis (Rambur)--south Florida

T. binotata (Rambur)--south Florida

T. onusta Hagen--south Florida

Diagnosis: This genus can usually be identified by the long flagella and the brown-tipped tarsi.

Size: Total length 1.18-1.32 mm, head width 0.38-0.42 mm.

Color Pattern: Generally brown. Tip and base of flagellum darker brown, with central part of flagellum, scape, and pedicel pale. Femora with obscure darker bands at 1/4 and 3/4 of their length; femoro-tibial joint pale; distal 2/3 of tarsi pale, except distal tip and claws brown.

Head: Four pairs of setae dorsally, plus 2 eyelash setae above each eye. Flagellum 59-64% as long as head width.

Labium: Anterior palpal teeth low, lateral 2 pointed, followed by 3-4 serrations to about 2 tooth-widths from the medial margin (Figure 3F).

Thorax and Abdomen: Longitudinal tracheae sometimes pigmented brown.

Remarks: Bick (1951) reared T. lacerata to instar 13 from eggs obtained in Louisiana. His description of the second instar differs from mine in some respects: 1. Some specimens had 1 major premental seta, 2. Ligular setae were absent, 3. Tibial combs had only 1 branched seta, 4. Femora had 3 dark bands, tibiae with a dark distal band, tarsi not dark-tipped.

Growth Changes for T. lacerata from Bick (1951):

Instar 3: One major premental seta, anterior margin of palps with 3 dagger-setae.

Instar 4: Four antennal segments, 2 major palpal setae, 3-4 major premental setae, anterior margin of palps with 8 dagger-setae, still only 1 tarsal segment.

Behavior

Behavior of second larval instars was not systematically studied, but the observations in this section are of interest, since practically nothing has been recorded on this subject.

Locomotion. Anisopteran late instars do not swim with the legs, but rather with jets of water from the rectum. A few species such as Tachopteryx thoreyi do not swim. Anisopteran second instars can be classified in 4 swimming categories: 1. Non-swimmers, 2. Jet propulsion plus running movements of the legs, 3. Jet propulsion only, 4. Running motions of the legs only. Tachopteryx and most Gomphidae were non-swimmers. When lifted by water currents, most gomphids held the legs

next to the body, curled the abdomen dorsally, and drifted back to the bottom. Aeshnidae swam by a combination of running motions of the legs and weak rectal jets. The only species noted swimming with strong rectal jets alone were Aphylla williamsoni and Progomphus obscurus. Macromiidae, Corduliidae, and Libellulidae swim with running motions of the legs only.

Taxes. When examining egg batches for hatching with a directed lamp, I noticed that some second larval instars exhibited positive or negative phototaxis. Tachopteryx and Aeshnidae did not show phototaxes, perhaps because a strong positive thigmotaxis overrides any phototaxes present. Gomphidae generally did not respond to light, but Gomphus minutus and Arigomphus pallidus had weak negative phototaxes, Gomphus laurae a strong positive phototaxis. A negative phototaxis might result in a larva moving toward a hiding place; a positive phototaxis could cause a larva to move toward open sky and thus into deeper water.

In the Corduliidae, Tetragoneuria cynosura had a weak positive phototaxis, Helocordulia selysii a negative phototaxis, and Neurocordulia virginiensis no phototaxes. The positive response of the lentic T. cynosura could cause the larvae to move to surface waters in weed beds where higher dissolved oxygen and temperature would speed growth. The lotic H. selysii merely needs a hiding place in a well aerated stream where the water column tends to be of even temperature. N. virginiensis clings to substrates, thus positive thigmotaxis probably overcomes any response to light in this species. Second instar N. virginiensis feign death like the late instars, by curling the legs and abdomen ventrally and remaining motionless.

Miyakawa (1969) noted that the libellulid Pseudothemis zonata showed a negative phototaxis, but Lyriothemis pachygastra (Miyakawa, 1970) had no phototaxes. I did not note any phototaxes in Belonia saturata, Brachymesia gravida, Celithemis amanda, Libellula auripennis, L. incesta, and Tramea carolina. Only Miathyria marcella showed a negative phototaxis. Species with a positive phototaxis were Erythrodiplax minuscula, Libellula flavida, Orthemis ferruginea, Pantala hymenaea, Perithemis tenera, Sympetrum corruptum, S. illotum, S. semicinctum, and Tramea lacerata. It is interesting that some species in a genus may have different phototaxes than others, as in Libellula and Tramea. Species with anomalous behavior, among others, are Miathyria marcella and Orthemis ferruginea. I would expect M. marcella to have a positive phototaxis, to cause the larvae to move to their habitat of water hyacinth (Eichornia) roots. O. ferruginea is a bottom dweller in shallow water and should not have a positive phototaxis to cause larvae to move to surface waters. Quite possibly phototactic responses change with age. Larvae from some egg batches of certain species demonstrated different phototactic responses than others. Some Erythrodiplax berenice had positive phototaxis, others no phototaxes, and the same was true for Pachydiplax longipennis. I would expect more species to show negative phototaxis, but one benefit of positive phototaxis could be dispersal in water currents as the larvae left sheltered areas and entered the water column.

Wilson (1917) noticed that newly hatched Libellula luctuosa swam to the surface of the water, a negative geotaxis. I noted that Brachymesia gravida, Miathyria marcella, Perithemis tenera, and Tramea carolina showed the same response when disturbed. These species then exhibited simultaneously their respective phototaxes.

DISCUSSION

Taxonomic Problems

Anisopteran second instars show considerable differences in structure and coloration from final larval instars. Some differences may be due to different adaptations useful to small insects, for example horns on the head and modified setae. Other differences might result from the general but not rigorous principle that ontogeny recapitulates phylogeny. That is, the second instar might exhibit characters present in more distant ancestors than does the last instar. At the least, characters of the second larval instar should be considered along with all other characters of a species or group when establishing taxonomic relationships. The following discussion includes some ways in which taxonomic relationships could be clarified by using features of the second larval instar.

Arigomphus. Needham (1897) had Arigomphus as a subgenus of Gomphus, but later (Needham,1948) stated that this group was worthy of generic rank. Needham and Westfall (1955) retained Arigomphus as a subgenus. Knopf (1977) found this group generically distinct from other Gomphus on the basis of electrophoretic analysis of 22 proteins, and concluded that Arigomphus should be considered a genus. The morphology of the second larval instar of A. pallidus abundantly supports Knopf's

proposal. Horns were not found in other Gomphus second instars, and the bulbous-based horn seta, ventral thoracic spines, and ventral abdominal spines are unique in all the known anisopteran second instars.

Gomphus (Stylurus) townesi. Since adults of this species seem similar to adults of the other Stylurus examined, the different appearance of the second larval instar is surprising. The hairy claws are unique in the known anisopteran second instars. The pairs of spike-setae on every body segment except the prothorax, but including the head, are different in degree from the other Anisoptera I examined. The egg of G. townesi is also different from those of other Anisoptera I have seen in that only the posterior half is covered with a thick layer of jelly. Knopf (1977) grouped this species closely with other Stylurus, however, as a result of his protein studies. The relationship between this species and other Stylurus warrants further study.

Libellula, Ladona, and Plathemis. Needham and Westfall (1955) regarded these 3 groups as separate genera but other recent authors such as Walker and Corbet (1975) considered Ladona and Plathemis as subgenera of Libellula. A preliminary electrophoretic analysis of 22 proteins by Knopf (1977) demonstrated that the genetic distance among Libellula, Plathemis, and Ladona was similar to the distance among aeshnid genera, implying that these libellulid groups should be considered as genera. Knopf placed Plathemis a little closer than Ladona to Libellula, but I observed just the opposite. I found the color pattern and morphology of 8 species of Libellula to be quite

uniform. Ladona deplanata was nearly identical to the Libellula species, but Plathemis lydia was generically different in both color pattern and palpal teeth. Gardner (1953b) described the second instar of the European Libellula depressa, the adults of which on morphological grounds are more similar to P. lydia than American "Libellula." However, Gardner's description indicated that the palpal teeth and femoral bands of L. depressa second instars are more like those of other Libellula, not P. lydia. The color pattern of the head is unlike either P. lydia or Florida Libellula. Clearly the relationships among Libellula, Ladona, and Plathemis need a good deal more study.

Basiaeschna. This genus includes only B. janata, rated as a primitive aeshnid on the basis of wing venation. B. janata was not seen in this study, but Butler (1904) examined the labium of the second instar and described the development of the labium in succeeding instars. The labium of the second instar had truncate palps like those of all other described aeshnid second instars and most aeshnid last instars. In later instars the palps of B. janata become pointed anteriorly. One implication is that the ancestors of B. janata had truncate larval palps, and its palps have evolved more rapidly than the palps of most other Nearctic aeshnids. A second implication is that the palps have evolved faster than the wing venation in B. janata. In his electrophoresis study Knopf (1977) grouped Basiaeshna with Coryphaeschna, the latter a highly evolved aeshnid on the basis of wing venation. Thus the palps and the proteins of Basiaeschna indicate that it is more highly evolved than wing venation alone would imply.

Non-Florida Species

The family and generic descriptions given for Florida species apply generally to the non-Florida species I examined, although not all extra-limital species will key out properly. Some of the more interesting features of the non-Florida species are given in this section, not complete descriptions.

The only non-Florida aeshnid examined was Aeshna multicolor. It had a color pattern similar to Anax and had no horns, but the rear corners of the head had 1-3 large setae with a small spine posterior to each seta.

Gomphus (Gomphurus) consanguis and G. rogersi were used to place Gomphurus in the key since no Florida species of this subgenus were available. The eggs of both of these species and infertile eggs of G. dilatatus Rambur had long sticky threads several times the length of the egg extending from the posterior pole. These threads function as holdfast devices and have been described in the literature only for 2 genera and 5 species of Old World Gomphidae, Ictinogomphus australis lieftincki (Schmidt) by Lieftinck (1978), I. ferox Rambur by Miller (1964), I. fraseri Kimmins by Corbet (1977), Lestinogomphus africanus (Fraser) by Gambles (1956), and L. minutus Gambles by Gambles (1968). Holdfast threads in Gomphurus would seem to be a generic character, because such threads were not noticed in any of the other Anisoptera I studied.

Gomphus (Gomphus) militaris is a typical Gomphus (Gomphus), but G. kurilis has robust, round-ended, dorsal setae resembling the stubby setae of Gomphus (Stylurus) plagiatus and G. laurae. Pairs of these

setae in G. kurilis are found on the rear corners of the head, each segment of the thorax, and abdominal segments 1-9. The setae of G. kurilis differ from Stylurus setae in that they are flattened and twisted, each seta twisting about 1/2 turn in its length.

Last instars of Octogomphus specularis have flattened antennal flagella similar to those of Hagenius brevistylus. The flagellum of second instar O. specularis was not flattened as it was in second instar H. brevistylus. The distal tibial setae of O. specularis had a few fine pinnate divisions forming a weakly developed tibial comb, which was not seen in other species of Gomphidae.

Tetragoneuria semiaquea was a typical Tetragoneuria. Neocordulia n. sp. from Panama had no horns and a typical corduliid palp, but the ligula had 2 separate teeth, as in some Macromia taeniolata. The medial side of each of the paraprocts had 2 bottle-brush setae, otherwise noted only in some Helocordulia and the Gomphidae.

Non-Florida species of Florida libellulid genera resembled their Florida counterparts, except that Erythrodiplax funerea had 5-7 palpal teeth instead of the 4 of other Erythrodiplax. Orthemis levis had square-ended palpal teeth like those of O. ferruginea, suggesting that this character is a generic one. Perithemis intensa and P. domitia had the inflated cylindrical setae of P. tenera, but had them developed on different patterns of body segments.

The most interesting of the non-Florida libellulid genera was Paltothemis, which had many of the same adaptations as Progomphus, namely a thick cuticle, sparse and short body setae, short tarsi, and short antennae. The tarsi are 40% as long as the head width, and the

antennal flagellum 31% as long as the head width. Body color of alcohol specimens was a uniform rich brown, as in alcohol specimens of Progomphus obscurus. Pseudoleon superbus also had sparse and short body setae. This species had only the posterior half of the eyes pigmented, evidently antecedent to the vertically striped eyes of the adult.

Leucorrhina frigida had an especially wide prementum, 2X as wide as long, and a pair of short horns on the vertex. Belonia resembled Libellula morphologically, but B. croceipennis did not have the strongly banded legs and alternately black and white lateral edges of the abdomen found in Libellula.

Epicranial Tubercles or Horns

One or 2 pairs of horns are present on the head of many species of anisopteran second instars. These either decrease in relative size in succeeding instars, or increase in relative size for a few instars before degenerating. By the last instar they have often become vestigial or absent. Of the Anisoptera listed in Tables 1 and 2, species of Petaluridae and Cordulegastridae lack horns. The fraction of genera in other families with horns was Aeshnidae 4/8 or 50%, Gomphidae 3/8 or 38%, Macromiidae 2/2 or 100%, Corduliidae 6/8 or 75%, and Libellulidae 7/28 or 25%. In the above calculations, Basiaeschna and Polycanthagyna were excluded because the presence or absence of horns was not stated in their respective literature sources. Somatochlora was counted as horned because S. viridiaenea and S. metallica have horns.

Horns seem to develop at the base of head setae, and large setae stand at least on a conical base or tubercle if not on a horn. Thus I suspect that horns are usually sensory, the horn accommodating an increased number of sensory cells, or perhaps lifting the seta away from debris on the head surface. Corbet (1963) suggested that horns may be either sensory, or used for holding debris as camouflage. Production of more setae would seem to be more economical of energy use than growing horns, if the primary goal was camouflage. Many species which are not horned, such as Cordulegaster sayi, are well covered with debris using head setae alone. Exceptions to the above are the horned Aeshnidae and Aphylla. These do not have a summit seta on the horns in the second instar, and the horns may have some other purpose.

Most species of Macromiidae, Corduliidae, and Libellulidae which I examined had 4 pairs of setae on the dorsal head surface. Horns have developed at the bases of different setae in each of these 3 families. In Macromia taeniolata, the horns are at the base of the most posterior or fourth pair of setae. In Neurocordulia virginiensis and Tetragoneuria, the horns are at the base of the third pair of setae from the anterior. Helocordulia selysii has 3 pairs of setae, the horns at the base of the most posterior pair. In this case, probably the fourth pair of setae posterior to the horns has been lost. The horns in Libellulidae are at the bases of the second pair of setae from the anterior in Celithemis, Leucorrhinia frigida, Perithemis, and Sympetrum vicinum. Brachymesia has 3 pairs of setae,

the horns at the bases of the middle pair. As in Helocordulia, probably the fourth or posterior pair of setae has been lost. It is interesting to note that some species in certain genera have horns while others do not, as in Aeshna, Somatochlora, Leucorrhinia, and Sympetrum. From this we may deduce that horns have evolved on many independent occasions in the Anisoptera.

The setae at the summit of the horns are often highly modified -- cup-shaped in Epophthalmia vittata, scale-like in Macromia taeniolata, bulbous-based in Arigomphus pallidus, brush-like in Tetragoneuria, and cylindrical in Hagenius brevistylus. One would expect such important-looking setae to be retained in succeeding instars, but in some cases they are lost in the third instar, as in Macromia taeniolata. The more ordinary tapered summit setae are lost in the third instar in Helocordulia selysii and Neurocordulia virginiensis.

The only anisopteran second instar known to have branched horns is Epophthalmia vittata. Nasiaeschna pentacantha and Hagenius brevistylus each have 2 pairs of horns. Perithemis and Zyxomma petiolatum each approach a condition of having 2 pairs of horns. This is accomplished in both genera in the same way, with the development of a pair of large cylindrical setae set on conical bases posterior to the pair of horns.

CONCLUSION

The major conclusion to be reached from this study is that anisopteran second instars can be identified -- at least to the generic level in a circumscribed area. Many more species need to be studied in the second instar, and still more species should be reared from egg to last larval instar. A major goal should be the ability to identify all the instars of every Nearctic species. Achieving this goal would also help to attain a much better understanding of the phylogeny and a more stable taxonomy of the Nearctic Anisoptera. Great possibilities are available in several related lines of research. Systematic studies of anisopteran egg morphology have not yet been done. The scanning electron microscope (SEM) offers a good technique for examining egg surfaces. The specialized setae of many anisopteran second instars would also be a good subject for SEM work, and the ommatidial studies by Ando (1957,1962) should be expanded, perhaps using the SEM. Internal characters can be used in anisopteran second instars without dissection, because their bodies are transparent or nearly so. Two good internal characters for taxonomic use are the tracheae and the abdominal ganglia. The tracheae are most easily seen when filled with gas in living specimens, while the abdominal ganglia are most easily detected as off-white blocks in alcohol specimens. An exciting field of study awaits an

investigator who can find a way to fertilize Anisoptera eggs in vitro. Determination of which species or groups within the Anisoptera are capable of hybridization would be of great value in elucidating the phylogeny of the suborder.

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Sidney Warren Dunkle was born on September 27, 1940, in Cleveland, Ohio. In 1958, after graduation from Medina Senior High School, he entered Baldwin-Wallace College, Berea, Ohio. In June of 1962 he received the degree of Bachelor of Science, with a major in biology and a minor in chemistry. From September 1962 to June 1965 he earned the degree of Master of Science from the University of Wyoming, Laramie, majoring in zoology. From 1966 to 1977 he was an instructor of biological subjects at Cuyahoga Community College, Cleveland, Ohio; Orange Coast College, Costa Mesa, California; Santa Fe Community College, Gainesville, Florida; and Fresno City College, Fresno, California. He has also been employed as a farmer, city park naturalist, national park ranger-naturalist, gas station attendant, and department store clerk. In 1965 he was a biologist for ecological studies of grizzly bear and elk in Yellowstone National Park. In 1975 and 1976 he was a biologist for behavioral studies of Beechey's jay at Mazatlan, Mexico. He has published 10 scientific papers on birds, dragonflies, and Strepsiptera. He has traveled in the United States, Canada, Mexico, Guyana, Jamaica, Haiti, England, Italy, Kenya, Tanzania, and South Africa. From the spring of 1978 to the

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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