

CHAPTER 2 LITERATURE REVIEW

Dragonflies and damselflies are ancient insects, belonging to the order Odonata - a name which refers to the large teeth-like mandibles of both larva and adult (Theischinger and Hawking, 2006). This group of insect contains species from tiny to large in size. Wingspans range from 19 mm in the Southeast Asian coenagrionid, *Agriocnemis nana*, to 191 mm in neotropical pseudostigmatid, *Megaloprepus caeluratus* (Tang *et al.*, 2010; Wilson, 2009). Dragonflies characteristically have two large well-developed compound eyes which cover most the rounded head. Between the front of the compound eyes, there are three small ocelli arranged in a triangle. Antennae are setaceous. The mouthparts are on the underside of the head and have chewing-type mandibles. Dorsum of synthorax (pterothorax) bears two pairs of hyaline wings. Caudal appendages, which are used to grasp the female, are extended from terminal abdominal segment. Secondary genitalia are located under abdominal segment 2 (Eak-Amnuay, 1996; Manolis, 2003; Ratanabhumma, 2007; Theischinger and Hawking, 2006).

2.1 Life cycle and general biology

Dragonflies and damselflies are hemimetabolous, in other words, the incomplete metamorphosis. They undergo gradual development in larva. They have three development stages; egg, larva, and adult (Fig.1). Egg and larval stages are aquatic but the adult is terrestrial.

Egg: The eggs of some dragonflies and most damselflies are elongate and are usually inserted into plant tissues. But other dragonflies have oval or round eggs, which are laid into the water. They take several days or weeks to hatch.

Larva: Odonate larva (sometimes referred to naiad or nymph) is unique. Overall coloration is dull and well camouflaged to the environment. They have a relative small abdomen, sometimes borne with spines or knobs on the sides. Wing pads are on the top front of abdomen and will appear in sixth, seventh, or eighth stage.

The larvae of damselflies are mostly long and slender with three long respiratory gills extended from the 10th abdominal segment. On the other hand, dragonfly larvae are more robust and have respiratory gills inside their rectal chamber and breathe through their anus. This allows the larvae to propel themselves by forcing water out of the anus under pressure.

Like adult, larvae are predator. They feed on aquatic invertebrates, for example, other odonate larvae, mosquito larvae, tadpoles, and small fish by thrusting their modified labium forward to the prey with high speed.

When larvae are fully grown, that is when wing pads are fully formed, they move onto exposed stone, log or plant on water surface. Then, they split their exoskeleton on thorax and adults emerge.

Adult: Newly emerged adults are teneral. They are usually soft, colorless and have glistening wings. Adults are predator and often prey on live insects, such as, midges, mosquito, and flies.

After coming to mature, they fly to aquatic resources and select and guard their territory while waiting for a female come by for mating. Copulation occurs when mature female accepts a male. The male grasps her occiput (in dragonflies) or prothorax (in damselflies) with his caudal appendages. This position is called ‘tandem’ position. Then, the female bends her abdomen to align her genital structures on eighth abdominal segment with male’s secondary genitalia. This forms ‘wheel’ position. The male transfer sperm to female’s storage sac. Then, the female use the sperm to fertilize the egg and lay them into plant tissues or into the water. The female of endophytic species produce 400–600 eggs, but the female of exophytic species produce between 800 and 2,000 eggs. Both sexes may mate several times in one day. The adults generally live for one to three months, but sometimes longer in warmer, drier areas (Manolis, 2003; Orr, 2003; Ratanabhumma, 2007; Theischinger and Hawking, 2006).

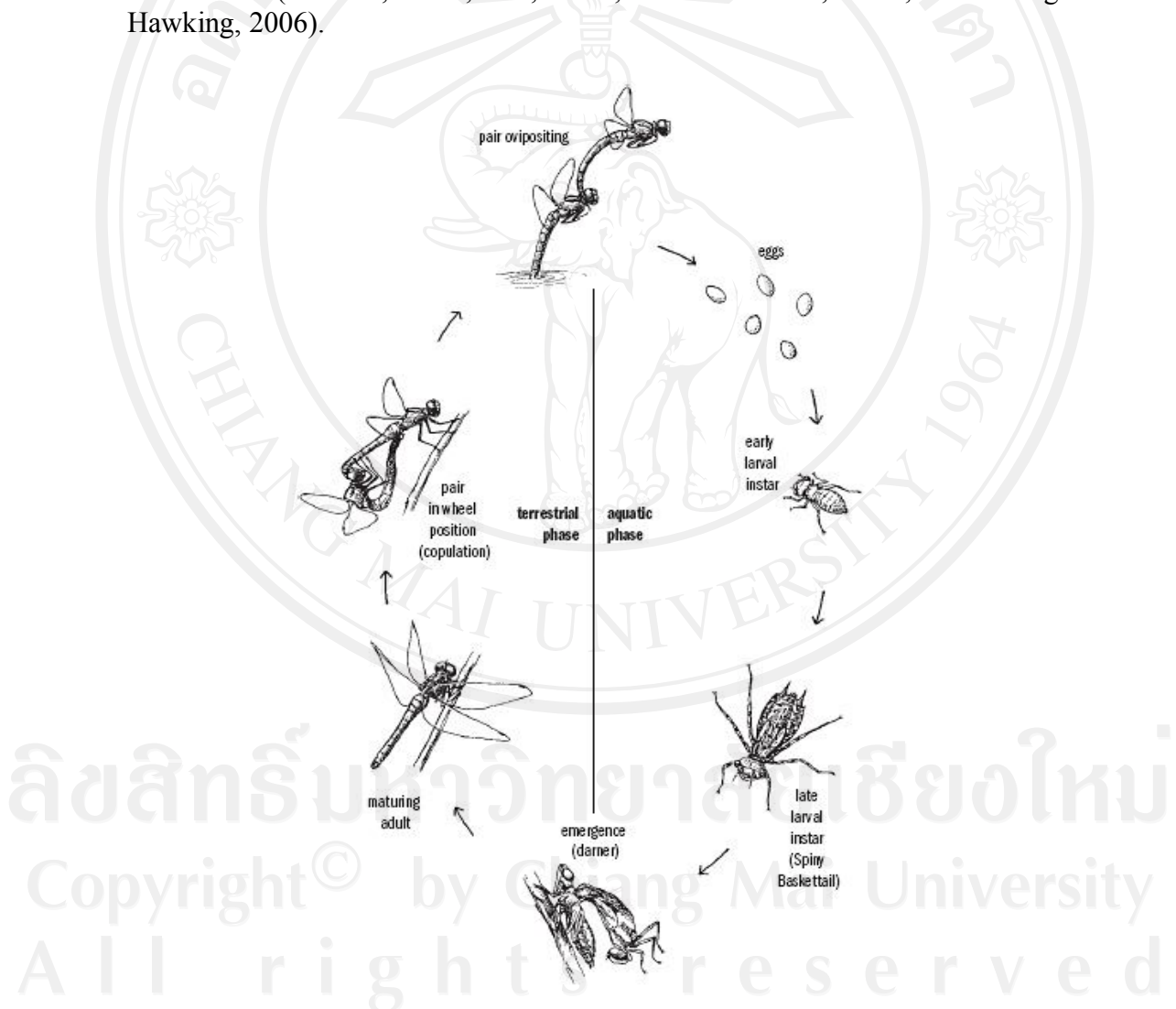


Fig. 1 Life cycle of a dragonfly (Manolis, 2003).

2.2 Ecology

All species of dragonflies and damselflies are voracious predators as both larvae and adults. Larvae feed on small aquatic organisms, such as mosquito larva, tadpole, or other odonate larva. Adults hunt small insects, for instance, midges, mosquitoes, bees, moths and other odonates for food (Eak-Amnuay, 1996; Ratanabhumma, 2007; Theischinger and Hawking, 2006).

Dragonflies are divided to 'opportunistic' and 'riverine' species. The opportunistic species live in still water or slow-running stream, for example, lakes, or temporary pond. The riverine species inhabit in river or stream. Larva development depends on water temperature. The opportunistic species take few months from eggs to adult, whereas the riverine species take more than a year to complete their life cycle (Theischinger and Hawking, 2006).

Most dragonflies and damselflies fly during the day (diurnal), but some active at dawn or dusk (crepuscular). Many species like to perch on rock or twig and fly only when they are feeding, mating, or disturbed. They are called 'perchers' including most damselflies, gomphids and libellulids. Whereas, some are on wing most of the time, cruising near the water surface. These 'fliers' include members of the families Aeshnidae, Corduliidae, Libellulidae (Orr, 2003; Theischinger and Hawking, 2006).

Odonates are frequently encountered near their breeding habitats. Their habitats are all type of freshwater. Few species live in brackish or highly saline waters. Eurytopic species are found in a broad range of habitats. They are common also in disturbed areas. In contrast, stenotopic species, they have offered a small distribution range. The specific requirements include matters related to need specific environment, topography, soil type, stream velocity, substrate, water chemistry, turbidity, water temperature, surrounding vegetations (forest type), rheophytic vegetation and degree of shading (Orr, 2003). Since many species, both as larvae and adults, live in specific environment, changes in structural habitat quality and amphibious habitat affected them (Clausnitzer *et al.*, 2009; Eak-Amnuay, 1996; Ferro *et al.*, 2009; Hilty and Merenlender, 2000; Kalkman *et al.*, 2008; Malithong, 2006, Ratanabhumma, 2007). They have shown to be useful for nature conservation and environment management and are often used as indicators of environment health (Clausnitzer *et al.*, 2009; Eak-Amnuay, 1996; Ferro *et al.*, 2009; Kalkman *et al.*, 2008; Ratanabhumma, 2007). Recently, Odonata became the first insect order to be used in a global assessment of biodiversity loss (Clausnitzer *et al.*, 2009).

2.3 Morphology

Like other insects, the body of dragonflies and damselflies consist of three parts; head, thorax, and abdomen. Head is relative small furnished with large well-developed compound eyes. Three ocelli are arranged in a triangle on front of head. The antennae are setaceous (hair-like), very short, usually with 6-7 segments. Below the eyes are mouthparts. Thorax is divided into prothorax and synthorax (pterothorax). Prothorax is small and short. Front pair of legs is in this part. Synthorax is the fusion of the second and third thoracic segments (meso- and metathorax), bearing the middle and hind legs, and wings. Synthorax is robust in Anisoptera (Fig.2A), but usually slim in Zygoptera (Fig.2B).

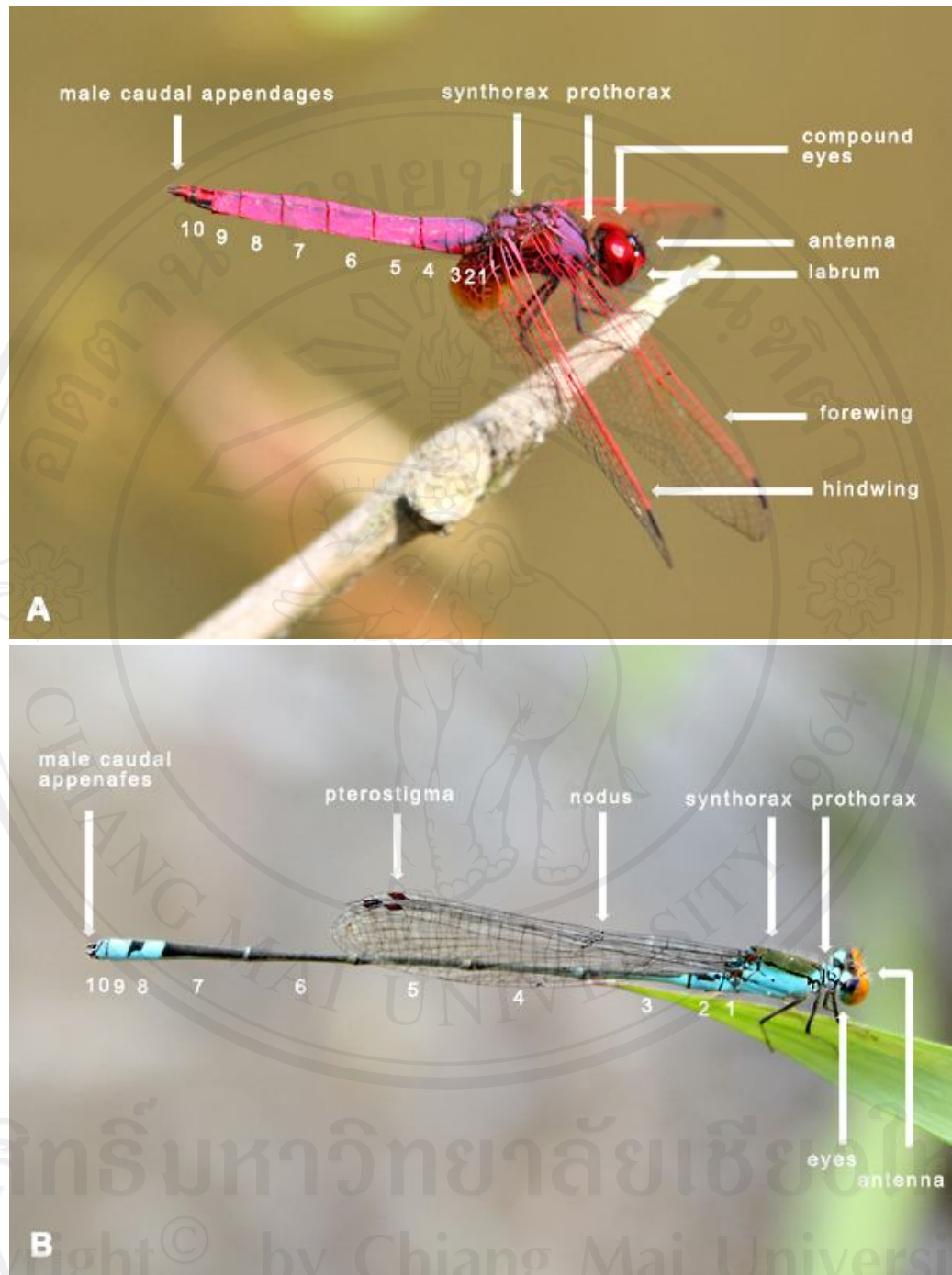


Fig. 2 General structure of Anisoptera and Zygoptera: **A.** male Anisoptera, *Trithemis aurora*; **B.** male Zygoptera, *Pseudagrion rubriceps rubriceps*.

Fore- and hindwings of Anisoptera are different (Fig.3A). Hindwings are broad at the base. The venation of both wings also differs substantially. Both wings of Zygoptera are similar in shape and venation (Fig.3B). The long abdomen consists of ten segments (S1-10). In male, the secondary genitalia organs are in the second

abdominal segments. At the tip of abdominal segment 10, two pairs of caudal appendages, superior (upper) and inferior (lower), are attached in the male Zygoptera. In male Anisoptera, there are two superior appendages and a fused inferior appendage (Fig. 2A-B). There are two small dorsal cerci in the female. In female of Zygoptera and the family Aeshnidae of Anisoptera there is an ovipositor in ventral side of eighth and ninth abdominal segments.

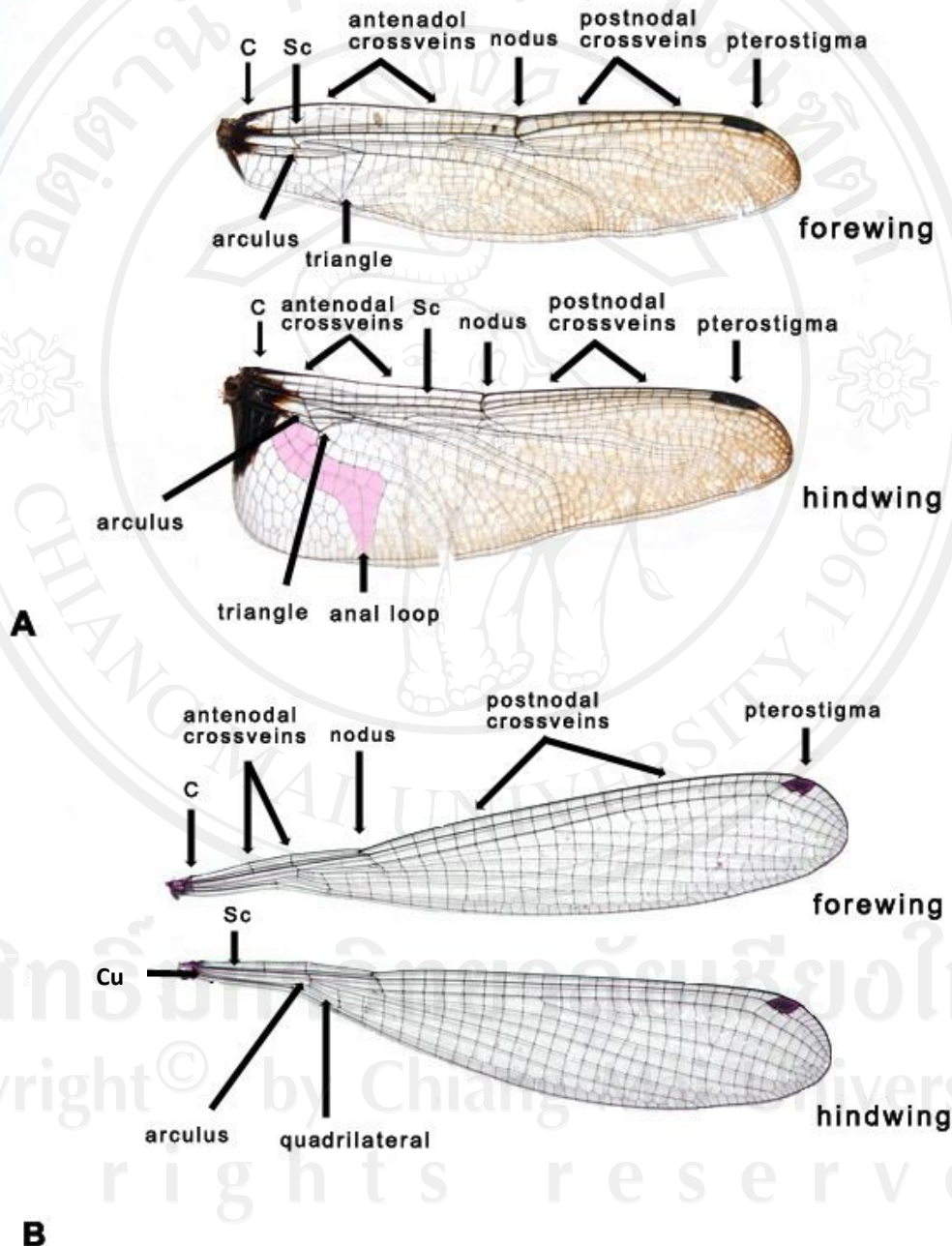


Fig. 3 Venation of fore- and hindwing: **A.** male Anisoptera, *Orthetrum triangulare* **B.** Zygoptera, *Coeliccia loogali*: A = anal vein; C = costa; Cu = cubitus; Sc = subcosta

2.4 Odonata in Thailand and in Doi Suthep-Pui National Park

The order Odonata has often been divided into three suborders, viz. Zygoptera, Anisoptera and Anisozygoptera (van Tol, 2010). However, suborder Anisoptera and Anisozygoptera are often included in Anisoptera or combined with a new name Epiprocta (Kalkman *et al.*, 2008). Recently, there are 5,747 recognized species around the world (van Tol, 2010). Kalkman *et al.* (2008) expected that the actual number of odonate species will be close to 7,000.

Stenobasis oscillans, presently known as *Archibasis oscillans*, is the first odonate species reported from Siam by Selys Longchamp in 1877. The first detailed collecting data on Thai Odonata were from two expeditions by W.L. Abbott. Part of his material was later studied by Williamson and Laidlaw (Hämäläinen and Pinratana, 1999). After that, the knowledge of Thai dragonflies increased gradually. Hämäläinen and Pinratana (1999) reported that 315 species in 18 families are found in Thailand. Recently, the number of known odonate species in Thailand has increased to 355 (Hämäläinen, pers. com.).

Odonata in the Doi Suthep-Pui National Park, Chiang Mai province, is fairly well known. The first dragonfly specimens from Doi Suthep, collected in 1923-1924 by local collectors for Sir Walter Williamson, were sent to F.C. Fraser for study (Hämäläinen and Pinratana, 1991). Until now, 126 species in 16 families were recorded (Hämäläinen and Pinratana, 1991, 2000; Hämäläinen, pers. com.; Hoess, 2002, 2007). The sixteen families are Calopterygidae, Chlorocyphidae, Chlorolestidae, Coenagrionidae, Euphaeidae, Lestidae, Megapodagrionidae, Philogangidae, Platycnemididae, Platystictidae, Protoneuridae, Aeshnidae, Chlorogomphidae, Corduliidae, Gomphidae, and Libellulidae. The description of the families was based mainly on Fraser (1933, 1934, 1936), Orr (2003) and Asahina (1993).

2.4.1 Family Calopterygidae (Fig. 4.1)

Medium sized species with long-legs. Males are usually strikingly colored, but females are often dull-colored. Antenodal crossveins numerous. Wings are not petiolated. Several crossveins in cubital space. Wings are broad and paddle-shaped. Abdominal segments have no pseudoauricles.

Seven genera are found in the park: *Caliphaea*, *Matrona*, *Mnais*, *Neurobasis*, *Noguchiphaea*, *Vestalis*, *Vestalaria*.

2.4.2 Family Chlorocyphidae (Fig. 4.2)

Small stout species. Front of head produced to form a large projecting rostrum or 'nose'. Wings are usually longer than abdomen and not stalked. Numerous antenodal crossveins. Male is often brightly colored with opaque markings on wings.

Three genera are found in this park: *Aristocypha*, *Heliocypha*, *Libellago*.

2.4.3 Family Chlorolestidae (Fig. 4.3)

Large robust metallic species. Wings are long, stalked at base. Two antenodal crossveins are present. R₄ arises at or just proximal to subnodus. The second cubital vein is strongly arched after leaving quadrilateral. Pterostigma is rhomboid or rectangular in shape. The species perch with wings spread.

One genus is found in the park: *Megalestes*.

2.4.4 Family Coenagrionidae (Fig. 4.4)

Tiny to large species. Wings are hyaline. Costal side of quadrilateral in forewings is two fifth or less length of anal side. Two antenodal crossveins are present. Anal vein is well-developed, extending at least two cells beyond distal end of quadrilateral. CuP vein meets wing margin at least half way along its length. Supplementary veins are absent from wings tip, or if present, only the depth of 1-2 cells. Short legs and hind tibia length is less than those of humeral band. Male inferior appendages are rarely as long as abdominal segment 10. Hind tibia has 4-8 short stout spines.

Seven genera are found in the park: *Aciagrion*, *Agriocnemis*, *Argiocnemis*, *Ischnura*, *Ceriagrion*, *Onychargia*, *Pseudagrion*.



Fig. 4 Family representatives of Zygoptera: 1. Calopterygidae; 2. Chlorocyphidae; 3. Chlorolestidae; 4. Coenagrionidae.

2.4.5 Family Euphaeidae (Fig. 5.1)

Robust species with short legs. Wings are not petiolated. Numerous antenodal crossveins in costal space. Only one crossveins in cubital basal space before arculus. Head, synthorax and abdomen are not bright metallic green.

Three genera are found in the park: *Anisopleura*, *Cryptophaea*, *Euphaea*.

2.4.6 Family Lestidae (Fig. 5.2)

Small to medium sized lightly built species, which keep their wings perching. Only two antenodal crossveins. Supplementary veins between the main veins from the distal wings margin to level of the pterostigma are numerous. Origin of IR_3 and R_{4+5} closer to arculus than nodus. The costal side of quadrilateral in forewing is very short, so the quadrilateral looks like triangle.

Two genera are found in the park: *Lestes*, *Orolestes*.

2.4.7 Family Megapodagrionidae (Fig. 5.3)

Fairly robust species which keeps their wings flat when perching (except *Burmagiolestes*). Two antenodal crossveins present. Numerous supplementary veins present between the main veins from the distal wings margin to level of the pterostigma. IR_3 and R_{4+5} origins are closer to subnodus than arculus. The costal side of forewing quadrilateral is nearly as long as anal side.

Two genera are found in the park: *Burmagiolestes*, *Rhinagrion*.

2.4.8 Family Philogangidae (Fig. 5.4)

Medium sized species. Wings are hyaline and strongly stalked. 5-8 antenodal crossveins are present.

One genus is found in the park: *Philoganga*.

2.4.9 Family Platycnemididae (Fig. 5.5)

Small to medium sized zygopteran. Wings hyaline. Two antenodal crossveins in costal space. Costal side of quadrilateral in forewing is at least half length of anal side. Anal vein is well-developed. CuP meets wing margin at least half way along its length. There are 1-2 cells of supplementary veins in wing tip. Hind tibia has 10-16 long filamentous spines. Male inferior appendages are thin, tapered, and longer than superiors and abdominal segment 10.

Three genera are found in the park: *Calicnemia*, *Coeliccia*, *Copera*.

2.4.10 Family Platystictidae (Fig. 5.6)

Small very fine built zygopterans. Two antenodal crossveins. Wings narrow and terminally falcate. There is a small sub-basal crossvein between CuP and wing margin. CuP meets wing margin less than halfway along its length. Sectors of arculus are fused basally to form a short stalk. Supplementary crossveins are absent from wing tip. Anal vein absent

Two genera are found in the park: *Drepanosticta*, *Protosticta*.

2.4.11 Family Protoneuridae (Fig. 5.7-8)

Small to medium sized zygopterans. Abdomen proportionally very long. Anal vein absent or reduced; CuP present or reduced, no cross vein in cubital-anal space at base of wing, Discoidal cell (Dc) a long regular rectangle, at least 3 times as long as wide, sub-Dc contiguous with posterior border of wing. Pterostigma short, trapezoidal.

One genus is found in the park: *Prodasineura*.



Fig. 5 Family representatives of Zygoptera: 1. Euphaeidae; 2. Lestidae; 3. Megapodagrionidae; 4. Philogangidae; 5. Platycnemididae; 6. Platystictidae; 7-8. Protoneuridae.

2.4.12 Family Aeshnidae (Fig. 6.1)

Large to very large anisopteran species. Eyes are broadly contiguous. Triangles are similar in both wings; elongate along the wing axis with costal side much longer than basal side. Auricles are absent in male. Female has a well-developed ovipositor.

Five genera are found in the park: *Anax*, *Gynacantha*, *Heliaeshna*, *Planaeshna*, *Tetracanthagyna*.

2.4.13 Family Chlorogomphidae

Large sized, black and yellow species. Eyes are close to each other but not quite touching. Median space of hindwings has two or more crossveins.

One genus is found in the park: *Chlorogomphus*.

2.4.14 Family Corduliidae (Fig. 6.2)

Small to large sized species. Synthorax is dull color. Abdomen is almost always metallic green. Most species have well-defined projection on the hind margin of the compound eyes. Male of most species have auricles laterally on abdominal segment 2. Anal angle of hindwings is angulated. Male tibiae are keeled at least in fore- and hind legs.

Four genera are found in the park: *Epophthalmia*, *Idionyx*, *Macromidia*, *Macromia*.



Fig. 6 Family representatives of Anisoptera: **1**, Aeshnidae; **2**, Corduliidae; **3**, Gomphidae; **4**, Libellulidae.

2.4.15 Family Gomphidae (Fig. 63)

Small to large species. Eyes are widely separated. Body is generally black with yellow or green coloration. Median space of hindwings lacks crossveins. Auricles are present on abdominal segment 2 in males. Females without ovipositor.

Thirteen genera are found in the park: *Amphigomphus*, *Anisogomphus*, *Asiagomphus*, *Burmagomphus*, *Heliogomphus*, *Leptogomphus*, *Macrogomphus*, *Onychogomphus*, *Orientogomphus*, *Paragomphus*, *Phaeandrogomphus*, *Gomphicdictinus*, *Ictinogomphus*.

2.4.16 Family Libellulidae (Fig. 6.4)

Tiny to large sized species. Body is often short and stout. Synthorax is mostly non-metallic and abdomen is only very rarely metallic. Old males are often pruinosed. Anal angle of hindwings are always rounded. Triangles are dissimilar in fore- and hindwings. Tibiae are not keeled. Auricles are not present in male. Female is lacking an ovipositor.

Twenty genera are found in the park: *Aethriamanta*, *Brachydiplax*, *Brachythemis*, *Camacinia*, *Crocothemis*, *Diplacodes*, *Hydrobasileus*, *Indothemis*, *Neurothemis*, *Onychothemis*, *Orthetrum*, *Pantala*, *Pseudothemis*, *Rhodothemis*, *Rhyothemis*, *Tetrathemis*, *Tholymis*, *Trithemis*, *Urothemis*, *Zygonyx*.