Insecta: Hemiptera, Heteroptera

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INTRODUCTION

All Hemiptera associated with aquatic habitats belong to the suborder Heteroptera (true bugs). They can roughly be grouped according to their habitats. Most Gerromorpha (semiaquatic bugs) live on the water surface, most Nepomorpha (aquatic bugs) live submerged in fresh water and most Leptopodomorpha (shore bugs) live at the margins of water bodies. Their habitats include moist soil, ponds, streams, rivers, rockpools, phytotelmata (small pools of water held by living plants), water-splashed rocks, hot springs, brackish water, intertidal coral reef flats and even the open ocean. The true bugs are among the most common and widespread insects found in these habitats. They range in length from less than 1 mm to about 110 mm. Most species are brown or black, sometimes with darker or lighter stripes. Only a few genera are brightly coloured, e.g. the orange-red *Perittopus* and the metallic-blue *Enithares.*

Hemiptera have a specialized beak-like rostrum used for piercing and sucking (Fig. 1B). The suborder Heteroptera is characterized by the possession of the typical fore-wings and scent glands. The fore-wing (hemelytra or hemielytra) is usually hard and leathery at the basal half and membranous at the distal part. There are two types of scent glands, both primarily used for defence. The nymphs possess abdominal scent glands (sometimes remaining active in the adults) and the adults possess metathoracic (= metasternal) scent glands (overview: see Staddon 1979). The fore-legs of some families are raptorial (water scorpions), the middle legs are sometimes used for rowing on the water surface (water striders) and the oar-like hind-legs are used for swimming (water bugs). Useful general works that cover a broad spectrum of morphology, biology, ecology, taxonomy and phylogeny include Cheng and Fernando (1969), Menke (1979), Anderson (1982a), Schuh and Slater (1995).

The economic importance of the aquatic and semiaquatic bugs was recently discussed by Keffer (2000), Papácek (2000), Spence and Andersen (2000), Sites (2000) and Venkatesan (2000). Some species can indicate the water quality, others

may be useful as biological control agents (Miura and Takahashi 1987), because they feed on the larvae of mosquitoes or other Diptera which are sometimes vectors of diseases. Larger aquatic bugs are at times of concern to fisheries, because they may be harmful to juvenile fish. Corixidae are sometimes very abundant in ponds and lakes and can be an important food source for fishes or other animals. In some regions they are dried and used as food for aquarium fishes or caged birds. Species of Gerridae, Nepidae, Notonectidae and Belostomatidae are consumed as food by

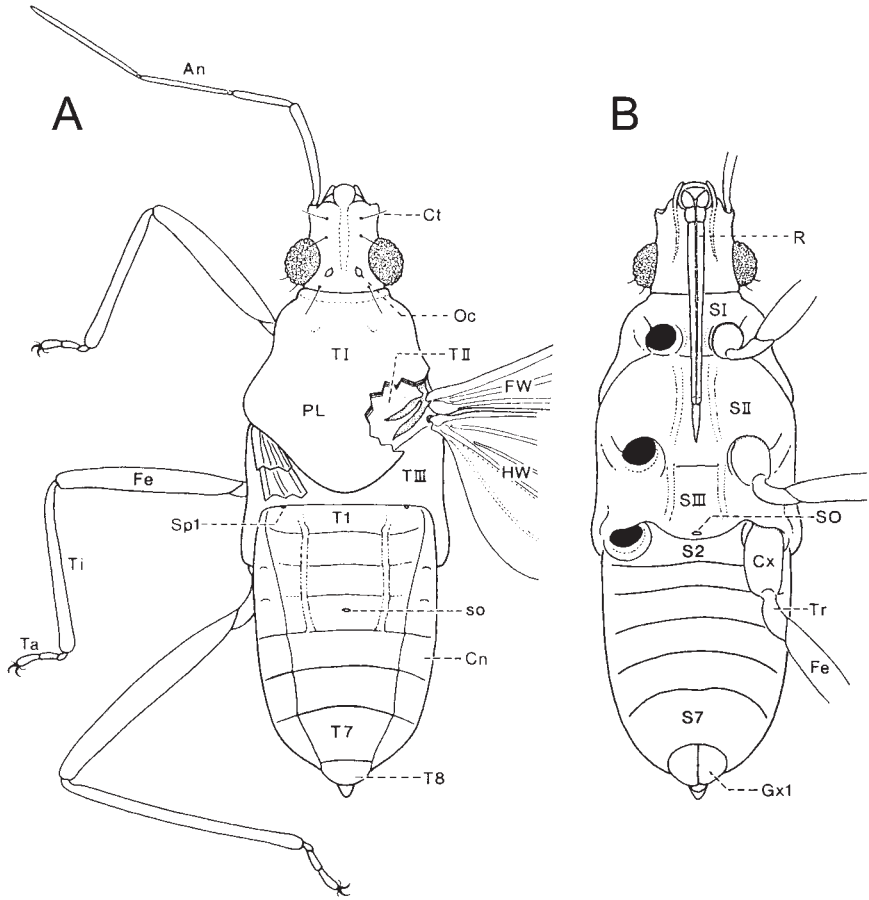

Figure 1. Diagram of a gerromorphan bug. A– dorsal view with part of the pronotal lobe removed to show the articulation of the wings; B - ventral view with part of legs removed. Abbreviations: An, antenna; Cn, connexivum; Ct, cephalic trichobothria; Cx, coxa; Fe, femur; FW, fore-wing; Gx1, first gonocoxa; HW, hind-wing; Oc, ocellus; PL, pronotal lobe; R, rostrum; SI, prosternopleura; SII, mesosternopleura; SIII, metasternopleura; S2,S7, abdominal sterna; SO, metathoracic scent orifice; Sp 1, abdominal spiracle; T I, T II, T III, pro-, meso-, and metanota; T1,T7, T8, abdominal terga; Ta, tarsus; Ti, tibia; Tr, trochanter. (Source: from Andersen 1982a)

local people in Thailand, Cambodia and China (Chen *et al*. 1998; Handboonsong *et al*. 2000). The giant water bug *Lethocerus indicus* is the most popular edible insect in Thailand for flavouring foods because males secrete a pungent substance in their metathoracic scent gland (Chen *et al.* 1998).

GENERAL BIOLOGY

Terrestrial true bugs are predominantly phytophagous, but the aquatic and semiaquatic bugs are predators or scavengers, feeding mainly upon other insects. Only some species of Corixidae feed on algae or detritus. Species of Belostomatidae, Nepidae, Naucoridae and Aphelocheiridae are known to attack and immobilize prey many times their own size such as tadpoles, frogs, juvenile fish, molluscs and other invertebrates (Keffer 2000; Polhemus and Polhemus 1988). These water bugs can inflict painful bites when handled carelessly. Feeding is initiated by harpooning the prey with the mandibular stylets or by grasping the prey with the raptorial legs. Their feeding apparatus consists of highly serrated maxillary stylets, which protrude from the rostrum tip during feeding. Through the rostrum, the bug injects digestive enzymes and sometimes toxic saliva into the prey's body and then sucks out the liquefied fluids until the prey is completely emptied (Cheng 1966a; Andersen 1982a).

Many species of semiaquatic and aquatic bugs have a pronounced sexual dimorphism. The males are often smaller than the females and their genital segments are more conspicuous. The fore-legs, hind-legs or even the antennae of some gerromorphan males are modified to hold the females in a firm grip during copulation. For sexual communication some gerrids use water surface waves. For example, the males of *Rhagadotarsus kraepelini* produce calling signals by movements of the middle and hind-legs (Wilcox 1972). In some aquatic bugs acoustic signals are used for sexual communication. The sound is produced by rubbing two ridged or roughened surfaces of the body against each other (= stridulation). The stridulatory structures are usually composed of a movable plectrum (for example, the fore-femur) and a stationary strigil or stridulatrum (for example, the head). Stridulation is well known in the Corixidae (Jansson 1972, 1989), but it also occurs in other Nepomorpha, some Gerromorpha (Veliidae, Gerridae) and Leptopodomorpha (Saldidae, Leptopodidae) (overview in Aiken 1985; Polhemus 1994).

Gerromorpha, Nepomorpha and Leptopodomorpha colonize new habitats by flight and many species are attracted to light at night (Fernando 1959, 1961). However, in some groups of Gerromorpha and Nepomorpha some or all of the adults, especially the females, are wingless. Thus, a population may be composed of both flying and flightless individuals showing different degrees of wing development: macropterous (long-winged), brachypterous (short-winged) or apterous (wingless) (Andersen 1982a). Populations living in unstable habitats like temporary pools usually consist of macropterous forms, which frequently colonize new habitats and tend to belong to

widely distributed species (e.g. *Limnogonus fossarum, Micronecta* spp.). In stable habitats such as rivers or marine environments the populations are often brachypterous or apterous (e.g. Aphelocheiridae and most marine bugs). One possible advantage of the wing loss is that it allows the female to divert energy from the wing and wing muscle development to the production of eggs. Another phenomenon involving the loss of wings is autotomy (self-mutilation), i.e., the bugs actively break off their wings with their hind-legs. This behaviour occurs mainly in Veliidae and Gerridae (e.g. *Rhagovelia, Metrocoris*) and its function is not well understood (Andersen 1982a).

In most insect orders with aquatic species only the larvae are aquatic. However, in aquatic Heteroptera and most aquatic Coleoptera the adult stage is also adapted to an aquatic mode of life. The adaptations involve, for example, locomotion (flattened hind-legs with swimming hairs), development of hydrostatic organs (e.g. in Nepidae, three pairs of oval structures on connexiva, for spatial orientation), grooming or respiration.

In most of the nepomorphan bugs, their bodies are covered by long and flexible hydrofuge hairs. When submerged, these hairs trap an air bubble, which serves as a store of oxygen and also has a hydrostatic function. Bugs possessing such air bubbles can stay submerged for a prolonged period of time, because the bubble serves as a physical gill, i.e., oxygen dissolved in the water diffuses into the bubble and partly replenishes the oxygen used up by respiration of the bug. When the oxygen is used up, the bugs swim or float upwards and replenish the oxygen by bringing the tip of the abdomen into contact with the air. In Aphelocheiridae, some Naucoridae and Helotrephidae the hydrofuge hairs are extremely short and stiff. They enclose a very thin air layer called a plastron (Thorpe and Crisp 1947; Thorpe 1950). Plastron breathers live in fast-flowing water and do not need to replenish their air supply at the water surface. Nepids usually stay close to the water surface and use siphons for breathing. The nymphs of some aquatic bugs have ventral air bubbles, or in some cases the younger stages breathe by absorbing dissolved oxygen through their soft cuticles.

In terrestrial and semiaquatic bugs metathoracic scent gland substances have a toxic or repellent effect on other arthropods (Aldrich 1988). However, in the aquatic habitat secretions are probably not very effective, due to the fast dilution in the water. Therefore, many aquatic bugs have reduced their metathoracic scent glands (Staddon and Thorne 1979). Some use the secretions of metathoracic scent glands on land as a defence against microorganisms. When the water temperature increases, some pleids, corixids, naucorids, etc climb out of the water and spread their metathoracic scent gland secretions over their respiratory hydrofuge hairs (= secretion-grooming: Kovac and Maschwitz 1989; Kovac 1993). These secretions contain substances such as hydrogen peroxide, which prevent the contamination of the hydrofuge hairs by killing attached micro-organisms. Contamination with micro-organisms could lead to wetting of the hydrofuge hairs, resulting in loss of the respiratory bubble and drowning (Kovac and Maschwitz 1989).

Aquatic and semiaquatic bugs are preyed upon by other insects (e.g. dragonfly nymphs), spiders, fishes, frogs and water birds (Fernando 1959; Leong 1962; Bullock 1966; Andersen 1982a; Morin *et al*. 1988; Papácek 2000). Adaptations against these predators include cryptic colouration and special structural features (e.g. the long, stalk-like body shape in *Hydrometra*), rapid rhythmical raising and lowering of the body which tends to obscure the outline of the insect (e.g. *Hydrometra*), death-feigning or gregarious behaviour. Fast escape is probably the most effective antipredator behaviour in water striders. A peculiar escape method is used by some veliids: they spread a detergent on the water surface, probably their saliva, which lowers the water surface tension and the veliids are thereby propelled on the water surface without walking (= expansion skating: Linsenmair and Jander 1963).

Life cycle

Few studies have been carried out on the life history of tropical aquatic bugs, and most of these have been under laboratory conditions. The eggs are usually glued to rocks and plants. There are five or sometimes four juvenile stages, called nymphs. The nymphs are morphologically similar to the adults and live in similar habitats. They can be distinguished from the adults by their paler and soft-bodied structure, the lack of wings (wing-pads develop in the 4th and 5th instars), genitalia and ocelli and by having one less tarsal segment than the adults. In the tropics most species do not have definite reproductive seasonality and they generally breed all year round. The entire life cycle from the egg to the adult stage may take 2–3 months (Cheng 1966b; Leong 1962). Developmental time of each stage depends on the availability of food and on temperature.

REGIONAL TAXA

About 4000 species of semiaquatic and aquatic bugs are known worldwide (Spence and Andersen 1994; Dudgeon 1999). The Oriental Region is particularly rich in the number of species and the diversity of life styles. In Peninsular Malaysia, Fernando and Cheng (1974) listed 102 species belonging to 12 families. Since then many other species have been described or recorded. Some 167 freshwater species belonging to 64 genera and 18 families are presently known from Peninsular Malaysia and Singapore (Cheng *et al*. 2001a; Andersen *et al*. 2002b; Nieser 2002b). Many of them are common and widespread in the Malaysian region while some are endemic. The aquatic Heteroptera fauna of Borneo contains about 80 endemic species. The zoogeography of the aquatic Heteroptera of the Malay Archipelago was discussed by Polhemus and Polhemus (1990). They indicated that the fauna of the Archipelago is mainly influenced by the fauna of continental Asia (see Fig. 2). There is relatively little influence from New Guinea or Australia.

The family and generic keys provided here are modified from different sources dealing with the fauna of the Malaysian region. They are only applicable to adults. Identification keys at the species level are available for the Gerridae (Cheng *et al.* 2001b), Veliidae (Andersen *et al.* 2002a,b), Corixidae (Nieser 2002a,b) and other groups (see family sections). The nymphs are difficult to distinguish at the species level. A key to the nymphs of Heteroptera at the family level was provided by Yonke (1991). Other recent references relating to the aquatic and semiaquatic bugs of the region include Andersen (1982a), Dudgeon (1999), Polhemus (1999), Shuh and Slater (1995) and Spence and Andersen (1994).

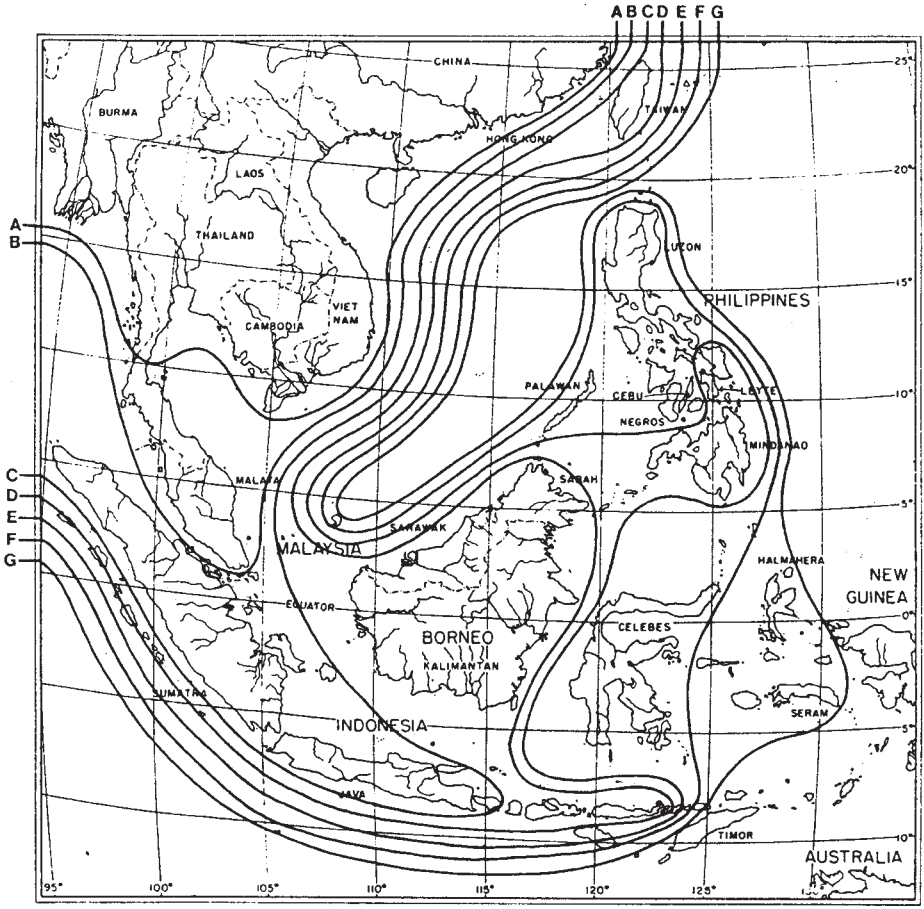

Figure 2. Ranges of various genera of aquatic Heteroptera in the Malay Archipelago. A – *Gestroiella* (Naucoridae); B – *Onychotrechus* (Gerridae); C – *Hyrcanus* (Hebridae); D – *Timasius* (Hebridae); E – *Heleocoris* (Naucoridae); F – *Metrocoris* (Gerridae); G – *Pseudovelia* (Veliidae). (Source: from Polhemus and Polhemus 1990)

KEY TO FAMILIES OF AQUATIC HETEROPTERA

(modified from Cheng *et al*. 2001a)

1. Antennae exposed and longer than head. (Mostly living on water surface, hygropetric zones around rocks in streams, intertidal rocks, or along water margins) 2
- Antennae shorter than head, inserted beneath eyes, with at most only the tips visible from above. (Living in water, except for two littoral families, Ochteridae and Gelastocoridae) .... Nepomorpha ..7

2. Long-winged, short-winged and apterous forms may be present. Hind-coxae small, cylindrical or conical; coxal cavity socket-like. (Living on water surface, along water margins, in springs, hygropetric zones, or waterfall splash zones) ..... Gerromorpha…3
- Always long-winged. Hind-coxae large, transverse; coxal cavity broad. (Living on shores, hygropetric zones, among intertidal rocks or large stones) ..... Leptopodomorpha…16

3. Head distinctly prolonged; eyes situated halfway along the head. (On quiet water surfaces or adjacent shores) (Fig. 3A) ..... HYDROMETRIDAE
- Head not distinctly prolonged; eyes situated at base of head 4

4. In long-winged forms, scutellum (Fig. 3C) exposed, forming subtriangular, rounded or transverse plate behind pronotal lobe; apterous or short-winged forms with abdominal scent gland on tergum IV 5
- In long-winged forms, scutellum not visible, hidden by pronotal lobe; apterous or short-winged forms lacking abdominal scent gland 6

5. Antenna 4-jointed (may appear 5-jointed due to membranous zone on fourth segment); bucculae well developed, reaching base of head; tarsi 2-segmented. (Margins of ponds and streams, intertidal, some species amphibious or even permanently submerged) (Fig. 3C) ..... HEBRIDAE
- Antenna clearly 4-jointed; bucculae absent or poorly developed; tarsi 3-segmented. (Margins of ponds and streams, also intertidal) (Fig. 3B) ..... MESOVELIIDAE

6. Head with median longitudinal groove on dorsal surface (Fig. 4B); male fore-tibiae usually with a comb of short spines along inner margin; middle femora scarcely or not extending beyond tip of abdomen; hind-femora usually stouter than middle femora. (Standing water, streams, phytotelmata, freshwater or marine) (Fig. 4A-E) ..... VELIIDAE
- Head without median groove on dorsal surface; male fore-tibiae without comb; middle femora usually extending well beyond tip of abdomen; hind-femora usually more slender than middle femora. (Standing or running waters, freshwater or marine) (Fig. 5A–H) ..... GERRIDAE

7. Apex of abdomen with paired respiratory processes 8
- Apex of abdomen without paired respiratory processes 9

8. Respiratory processes cylindrical, rigid and non-retractable, usually long and filiform; body either cylindrical or ovoid and flat. (Standing waters, or margins of streams) (Fig. 6D,F) ..... NEPIDAE
- Respiratory processes cylindrical, strap-like and retractable; body never cylindrical, always ovoid and flat (Standing waters or slow-flowing streams) (Fig. 6E) ..... BELOSTOMATIDAE

9. Ocelli present. (Littoral) 15
- Ocelli absent. (Living in water) 10

10. Body and fore-wings with transverse dark lines. Rostrum broadly triangular, non-segmented, transversely striate, appearing as apex of head. Fore-tarsi with a single segment, spoon- or scoop-like, fringed with long stiff setae ventrally. (Standing waters or slow-flowing streams, freshwater or saline) (Fig. 7A) ..... CORIXIDAE

- Body colouration never as above. Rostrum cylindrical, short to long, obviously segmented, not transversely striate. Fore-tarsi segmented or not, not scoop-like or fringed with long stiff setae 11

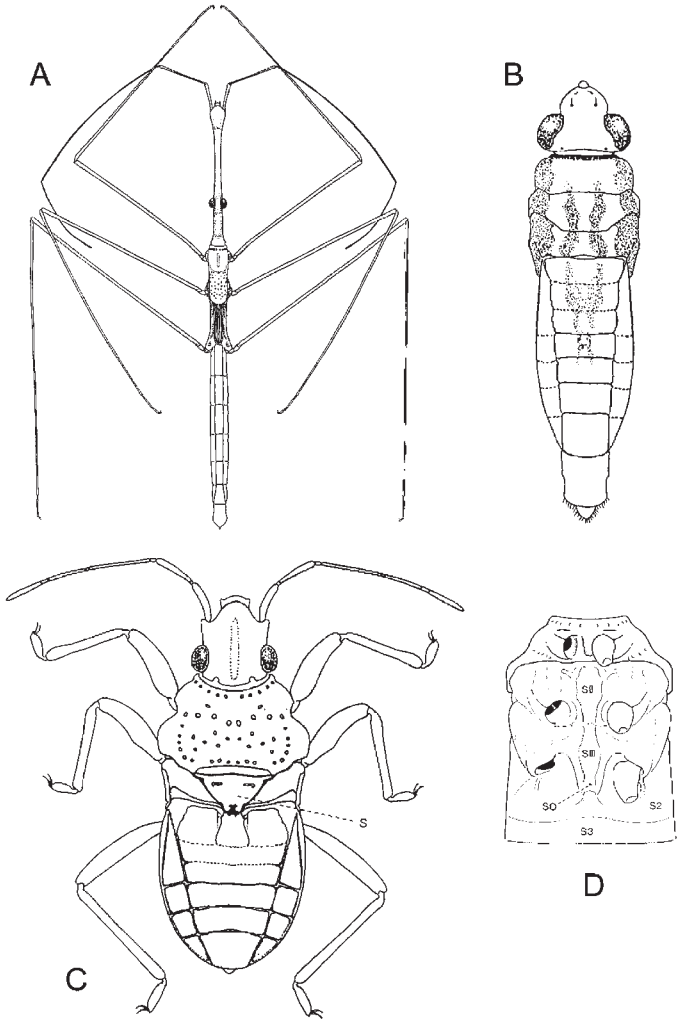

Figure 3. A – *Hydrometra longicapitis*, male, Hydrometridae; B – *Mesovelia horvathi*, male, Mesoveliidae; C – *Hebrus nereis*, male, Hebridae. S, scutellum; D – *Timasius* sp., Hebridae, thoracic venter showing the longitudinal carinae and the rostral groove. SII, SIII, meso- and metasterna. S2,S3, abdominal sterna 2 and 3. SO, metathoracic scent orifice. (Source: D, from Andersen 1982a)

11. Fore-legs not raptorial. Dorsum usually strongly convex or inversely boat-shaped; cephalonotal sulcus (head-pronotal boundary) sometimes incomplete. (Swim on their backs) 12
- Fore-legs raptorial. Dorsum usually flat; head and prothorax never fused. (Swim with dorsal surface uppermost) 14

12. Body elongate, wedge-shaped, usually over 4 mm long; hind-legs elongate, oar-shaped, with two reduced and inconspicuous claws. (Standing water or slow-flowing streams) (Fig. 7C) .... NOTONECTIDAE
- Body oval, robust, less than 3.5 mm long; hind-legs not oar-shaped, usually with two distinct claws 13

13. Antenna 3-jointed; head and pronotum separate, cephalonotal sulcus straight, complete, and distinct. (Standing water) (Fig. 6G) ..... PLEIDAE
- Antenna 1- or 2-jointed; head and pronotum fused, cephalonotal sulcus not straight, incomplete, often indistinct. (Standing water or fast-flowing streams) (Fig. 6H,I) ..... HELOTREPHIDAE

14. Head much wider than long, only slightly produced in front of eyes. Antenna short. Rostrum cylindrical, short and thick, not surpassing prosternum. (Standing water or fast-flowing streams) (Fig. 6A-C) ..... NAUCORIDAE
- Head usually longer than wide and produced in front of eyes. Antenna long, extending beyond lateral margin of head. Rostrum long, slender, extending at least to middle of mesosternum. (Among gravel or stones in fast-flowing streams) (Fig. 7F,G) ..... APHELOCHEIRIDAE

15. Head much wider than long. Tarsal formula 2:2:2; antennae concealed in pits beneath eyes; fore-femora incrassate (= thickened, rather suddenly swollen at some one point, especially near tip). (Stream banks, riparian) (Fig. 8B) ..... GELASTOCORIDAE
- Head more or less rounded. Tarsal formula 2:2:3; antennae not concealed in pits; fore-femora not incrassate. (Ponds or stream shores) (Fig. 8A) ..... OCHTERIDAE

16. Antennae shorter than body. Rostrum long, tapering, reaching base of hind-coxae or beyond. (Margins of ponds and streams, also intertidal) (Fig. 8D)… ..... SALDIDAE
- Antennae as long as or longer than body. Rostrum much shorter, reaching at most to apex of fore-coxae, often only to base of fore-coxae. (On surfaces of wet rocks in streams or entirely terrestrial.) (Fig. 8C) ..... LEPTOPODIDAE

INFRAORDER GERROMORPHA: semiaquatic bugs

The Gerromorpha are usually slender bugs ranging in size from about 1 to 36 mm. The 4-segmented antennae are usually longer than the head. In most families the head is elongate, more or less cylindrical, and protruding distinctly anterior to the eyes. A characteristic of the Gerromorpha is three pairs of sensory setae (= cephalic trichobothria) inserted in deep cuticular pits on the head. In the winged adult the posterior margin of the pronotum is usually extended as a large pronotal lobe covering the mesonotum and a part of the metanotum (Fig. 1). The body and the legs are covered by dense layers of hydrofuge hairs. The most comprehensive book on all biological aspects of Gerromorpha is that of Andersen (1982a).

Semiaquatic bugs live on the surface of standing or flowing waters or on wet surfaces at the margins of various aquatic habitats. Six families are known from the Malaysian region: Mesoveliidae, Hebridae, Hydrometridae, Hermatobatidae, Veliidae and Gerridae. One genus (*Nieserius*) in the Hebridae is truly aquatic, and lives submerged in fast-flowing streams (Zettel 1999b; DK observations). About 140 freshwater species are known from Peninsular Malaysia and Borneo. Several freshwater species have been able to colonize brackish water, such as *Aquarius adelaides, Rhagadotarsus kraepelini, Ventidius modulatus, Mesovelia horvathi, M. vittigera* and *Hydrometra maidli* (Andersen and Foster 1992; Murphy 1990; Yang *et al*. 1997b). Hermatobatidae and some genera of Veliidae and Gerridae are exclusively marine and not treated here.

FAMILY MESOVELIIDAE – water treaders (Fig. 3B)

Members of this family are small (2–4 mm long) and have an elongated head distinctly prolonged in front of the eyes. The scutellum is exposed in winged forms. Because of the head structure and strongly developed ovipositor this family is considered to be the most primitive of all semiaquatic bugs (Andersen 1982a). The family is represented by two genera, *Mesovelia* and *Nereivelia* in the Malaysian region. The wingless *Nereivelia* is found in mangrove swamps (Polhemus and Polhemus 1989). The greenish or brownish *Mesovelia* is common at the margins of ponds and streams, usually associated with some form of aquatic vegetation. It can run extremely fast across floating vegetation and the water surface when disturbed. Only two species are found in the region, *M. vittigera* and *M. horvathi* (Fig. 3B*)*. The former has rows of strong spines on the middle femora, while the latter has only 1 or 2 spines. Both apterous and macropterous forms are common and widespread. The winged form is often caught in light traps. Females are much bigger than males.

Mesovelia is a cosmopolitan genus, but the distributions of the other genera of this family are not well known. The discovery of a tiny, almost eye-less mesoveliid, *Cryptovelia stysi,* from moist soil litter in a Sarawak forest, far from the site in Brazil where the first species (*C.terrestris*) was found, suggests that the zoogeography of the Mesoveliidae is incompletely known (Andersen 1999).

FAMILY HEBRIDAE – velvet water bugs (Fig. 3C)

This is a family of small bugs (1.0–3.7 mm long) found among vegetation, mosses, shady rock surfaces of flowing streams, or in ponds. The brownish to black body is usually short and stout, and is covered with dense hairs. The antennae are 4-segmented, but in *Timasius* and *Hebrus* the 4th segment is divided by a membranous zone and the antenna appears to consist of 5 segments (Fig. 3C). Three genera (*Hyrcanus, Hebrus* and *Timasius*) with about eight freshwater species are known from Peninsular Malaysia (Andersen 1981b; Zettel 1999a). A fourth genus,

Merragata, has been included in the key, since it was recorded from Thailand and Java and may also occur in Malaysia.

Oriental species of *Hebrus* are hygropetric or ripicolous, while some are also found at the margins of stagnant waters. Two of the four known species of *Hebrus* were found in crevices of decaying logs in mangrove swamps (Polhemus and Polhemus 1989). They feed on springtails and other small invertebrates at the receding tide. *Merragata* inhabits the edges of large stagnant waters. *Timasius* species live in the zone of wet rocks in streams or torrents. *Hyrcanus* occur among leaf litter or on rocks in the wet zone of streams and waterfalls. At least some species are amphibious, i.e. can remain submerged in water for a long period of time (personal observations). One genus from Indochina and Nepal, *Nieserius*, is truly aquatic (Zettel 1999b).

Key to genera of Hebridae (after Andersen 1981b and Zettel 1999a)

1. Antennal segments stout, antenna shorter than greatest width of pronotum, clearly 4-segmented 2
- Antennal segments long and slender, antenna at least subequal to greatest width of pronotum, appearing 5-segmented 3

2. Larger species (longer than 2.1 mm), head longer and pointed ..... *Hyrcanus*
- Smaller species (less than 1.8 mm), head short and broad ..... *Merragata*

3. Rostral groove between longitudinal carinae on venter narrow, with carinae converging to a point in front of metasternal scent gland opening (Fig. 3D) ..... *Timasius*
- Rostral groove between longitudinal carinae on venter with parallel sides, not converging to a point (Fig. 3C) ..... *Hebrus*

FAMILY HYDROMETRIDAE – marsh treaders or water measurers (Fig. 3A)

This family occurs worldwide. Only two genera occur in this region: *Hydrometra* and *Heterocleptes*. The species of the common and widespread genus *Hydrometra* are usually brownish or blackish, with elongated bodies, 8–17 mm long. The head is extremely long, about 1/3 of body length, with eyes near the middle. The antennae are about half the body length. The legs are long and thread-like. The other genus, *Heterocleptes*, is much shorter (3 mm). It is a primitive hydrometrid originally known only from Africa, but a female specimen of *H. spinosus* was reported from Sabah by Andersen (1982b).

Hydrometra species are usually found at the margins of vegetated standing waters, or on shores or surfaces of slow-flowing streams. When motionless on vegetation or debris they can be easily mistaken for twigs. There are 18 species of *Hydrometra* widespread from Indochina to New Guinea (Polhemus and Polhemus 1995b). Six of the 13 Malaysian species are known from Singapore (Yang *et al.* 1997a). *H. maidli*, *H. longicapitalis*, *H. orientalis*, *H. gilloglyi* and *H. jaczewskii*

are the more common species found in both Borneo and the peninsula. *H. maidli* is commonly encountered in both temporary and permanent water of swamps, ponds, pools, slow-flowing streams, both forested and open country, and mangrove swamps. It is characterized by having a fringe of long hairs along the posterior margin of the male hind-femur. *H. longicapitalis* is a larger species (14 mm long) common in lowland swamp forests as well as forested highlands. Some females possess a finger-like tubercle on the posterior part of the thorax, a polymorphic feature found only in this species (Andersen 1992; Polhemus and Polhemus 1995b).

FAMILY VELIIDAE – broad-shouldered water striders or riffle bugs (Fig. 4A–E)

This is the second-largest family of semiaquatic Heteroptera, with 26 freshwater species known from Peninsular Malaysia (Andersen *et al*. 2002b). Many species are small and common, but some have secretive habits and are easily overlooked. The head is rather short and broad, with a longitudinal dorsal groove (Fig. 4B). The femora of some veliids are strongly incrassate or modified (e.g. *Rhagovelia*, *Tetraripis* and *Lathriovelia*). The male fore-tibia of certain genera usually bears a grasping comb of short and stout spines (e.g. *Microvelia, Angilia*). The middle tarsus of *Rhagovelia* (Fig. 4A) and *Tetraripis* has a deep cleft and a plumose swimming fan which facilitates locomotion in torrents and fast moving water. The swimming fan is folded into the tarsal cleft when the legs are lifted off the water surface but expands in the water during the thrust stroke (Andersen 1982a).

Most veliids are small, 1–4 mm in body length (e.g. *Microvelia*, *Rhagovelia*, *Strongylovelia*, *Entomovelia* and *Pseudovelia*). *Microvelia* is the most diverse genus, having about 180 species worldwide, with more than 10 species recorded from the Malaysian region (Andersen *et al.* 2002a,b). They are the most abundant and widespread veliids. They occur in nearshore regions of standing water, in permanent or temporary pools and in side pools of streams. Most of them are small and similar in body shape. *Microvelia leveillei* (previously known as *M. diluta*) is common in open pools, while *M. douglasi, M. cameron* and *M. albolineolata* are commonly found in forest habitats. *M. cameron* is easily distinguished from other species by the large hairy tumose pad on the male abdominal venter. *Perittopus* is often encountered in the puddles or side pools of forest streams. It is easily recognized by the showy orange to reddish colour on the back and by its black wings. Two species, *P. asiaticus* and *P. webbi*, are known from Peninsular Malaysia and *P. borneensis* was recorded from Sabah (Zettel 2001). *Rhagovelia* is commonly found on ripples of forest streams, from slow-flowing to swift rocky streams, where they often form loose schools. *Rhagovelia* species found in the peninsula are smaller (2–3 mm) and usually black (except *R. rudischuhi*), while many of the Borneo species are bigger (3–4 mm) with strongly incrassate hind-femora, and tend to be predominantly orange-coloured at higher elevations. This genus is very diverse in

Borneo, with more than 14 species, many of which are endemic (Polhemus and Polhemus 1988). *R. sumatrensis* is the most abundant and widespread species in the region (Yang and Polhemus 1994). *Strongylovelia*, *Entomovelia*, and *Xiphovelia* occur at the margins of slow forest streams, and *Pseudovelia* in narrow ripple zones in streams and along lake shores (Andersen 1983; Lansbury and Zettel 1997).

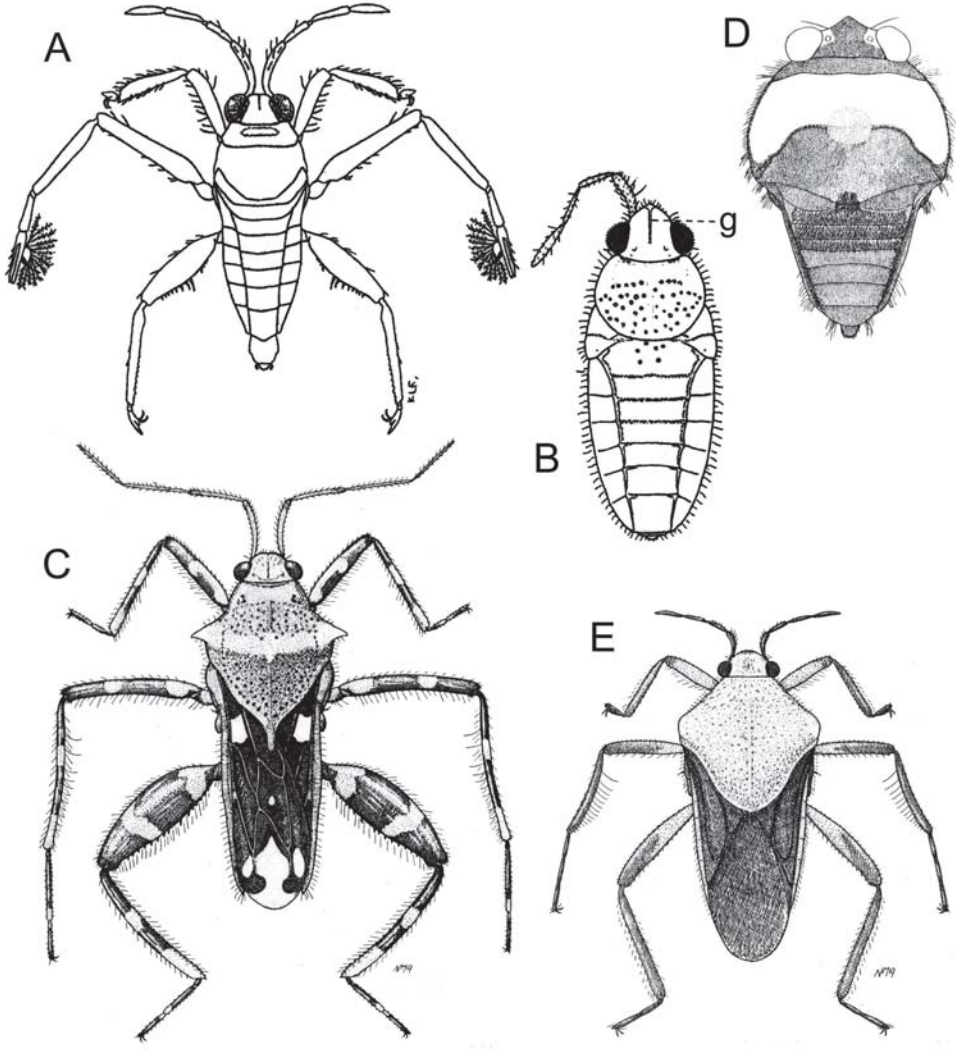

Figure 4. Veliidae. A – *Rhagovelia singaporensis*, male; B – *Pseudovelia sexualis*, male, median longitudinal groove (g); C – *Angilia bispinosa*, macropterous male; D – *Strongylovelia esakii*, female; E – *Perittopus* sp., macropterous female. (Sources: B, from Andersen 1983; C, E, from Andersen 1982a; D, from Lansbury and Zettel 1997)

Species of *Angilia, Tetraripis* and *Lathriovelia* are among the bigger veliids (4–7 mm long). They are less common or rarely collected, because of their cryptic and secluded habitats, such as moist soil close to the edges of forest streams, under overhanging tree roots or rocks of stream banks (Andersen 1981a, 1989; Andersen *et al*. 2002b). Species of *Angilia* and *Tetraripis* of Southeast Asia have been recently revised (Zettel and Hecher 1998, Polhemus and Polhemus 1999a; Andersen 2000; Zettel and Yang 2002). *Lathriovelia* is found in water-filled internodes of tall bamboo culms, and occurs as high as 18 metres above the ground. Macropterous *Lathriovelia* colonize bamboo internodes through holes made by beetles or woodpeckers, and feed on small arthropods on the water surface (Kovac and Streit 1996; Kovac and Yang 2000). The medium-sized *Baptista* is also cryptic and uncommon, with only two species known from Peninsular Malaysia (Andersen 1989). *Baptista* and *Neoalardus* are continental Asian genera and have not been reported from Borneo.

Marine veliids inhabiting the intertidal zone of coral reefs or tidal streams in mangrove swamps are not included in the key.

Key to genera of Veliidae (modified from Andersen *et al*. 2002b)

1. Last segment of middle tarsi deeply cleft, with leaf-like claws and plumose or setose swimming fan arising from base of cleft (Fig. 4A) 2
- Last segment of middle tarsi not deeply cleft, without plumose or setose swimming fan 3

2. Last segment of mid- and hind-tarsi deeply cleft, each segment with setose swimming fan arising from base of cleft. Apterous form with long pronotum ..... *Tetraripis*
- Only last segment of middle tarsi deeply cleft, with plumose swimming fan arising from base of cleft. Apterous form with short pronotum (Fig. 4A) ..... *Rhagovelia*

3. Middle tarsi with three segments (basal segment sometimes very small) 4
- Middle tarsi with two segments 6

4. Fore-tarsi with two segments, basal segment very short. First segment of middle tarsi subequal in length to segment 2 and 3 together. Fore-wings divided into proximal coriaceus part and distal membranous part (without veins) (Fig. 4E) ..... *Perittopus*
- All tarsi with three segments (basal segments of fore- and hind-tarsi sometimes very short). Fore-wing structure not as above, with four closed cells 5

5. Both male and female with stridulatory devices on connexival margins of sterna 2 and 3 and on hind-femora. Head moderately deflected in front of eyes. Fore-tibia of female without grasping comb ..... *Angilovelia*
- Without stridulatory devices. Head distinctly deflected in front of eyes. Fore-tibia of both male and female with long grasping comb (Fig. 4C) ..... *Angilia*

6. All tarsi with two segments (basal segment of fore-tarsi very short). Middle tarsi three or more times the length of hind-tarsi 7
- Fore-tarsi with only one segment. Mid- and hind-tarsi with two segments. Middle tarsi rarely more than twice as long as hind-tarsi 8

7. Second antennal segment shorter than first segment. First hind-tarsal segment about half as long as second segment. Body with dense pilosity, but without pale markings (except on pronotum) ..... *Entomovelia*
- Second antennal segment longer than or subequal to first segment. Hind-tarsal segments subequal in length. Body with pale markings and without dense pilosity (Fig. 4D) ..... *Strongylovelia*

8. Head posteriorly produced, extending well behind hind margin of eyes; anterior margin of pronotum deeply notched. Body usually elongate and relatively slender 9
- Head not produced as above; anterior margin of pronotum straight or only slightly concave. Body usually shorter and stouter (except in *Microvelia albolineolata*) 11

9. Fore-tibia of male without grasping comb. Fore- and middle femora of male simple .... *Neoalardus*
- Fore-tibia of male with grasping comb. Fore- and middle femora of male usually modified on posterior margin 10

10. Eyes distinctly apart from anterior margin of pronotum ..... *Lathriovelia*
- Eyes close to anterior margin of pronotum ..... *Baptista*

11. First antennal segment incrassate, extending more than two-thirds of its length beyond apex of head. Distal cells of fore-wings reduced (Fig. 4B) ..... *Pseudovelia*
- First antennal segment more slender and usually much shorter, extending less than two-thirds of its length beyond apex of head. Distal cells of fore-wings not reduced 12

12. Middle tarsi with three apical leaf-like structures (claws and ventral arolium). Pronotum of apterous form very short ..... *Xiphovelia*
- Middle tarsi not modified as above. Pronotum of apterous form usually long ..... *Microvelia*

FAMILY GERRIDAE – water striders, water skaters or pond skaters (Fig. 5A–H)

This is the largest family of aquatic bugs in our region. It is represented by 18 genera with about 43 known freshwater species from Peninsular Malaysia and Singapore (Cheng and Fernando 1969; Cheng *et al.* 2001b). Their body shapes vary from short and broad (Fig. 5G,H) to long and thin (Fig. 5D), but all have long middle and hind-legs which enable them to skate over the water surface. The male fore-femora are more or less modified in some genera. These are some of our most conspicuous water bugs. The largest pond skaters may measure 2 cm in body length, with a leg-span of almost 4 cm. Most species are brown or yellowish in ground colour, with various dark brown or black spots or stripes forming striking patterns. Most species are sensitive to waves propagated in the surface film, which may be employed for detecting prey, predators, or potential mates. Ripple communication for prey location and courtship has been demonstrated in *Rhagadotarsus* and certain other species (Wilcox and Spence 1986; Murphy 1990; Gogola 1996).

Gerrids are found in a variety of aquatic habitats and can be divided roughly into four groups:

1. Those found on open standing waters, temporary or permanent pools, ponds, reservoirs or lakes. These tend to be of medium size (about 1 cm long), and winged forms are very common. The most common and widespread species are *Aquarius adelaides*, *Limnogonus fossarum* (Fig. 5E) and *Rhagadotarsus kraepelini* (Fig. 5A).
2. Those found on quiet or slow moving waters, e.g. peat forest swamps, or slow-flowing forest streams. Some of our smallest gerrids (*Cryptobates*, *Esakia*, *Ventidius*, *Naboandelus*) belong to this group. Winged forms of *Cryptobates* (Fig. 5G) and *Naboandelus* are rare and their distribu tions are rather local. The somewhat larger species of *Amemboa* (Fig. 5B), *Tenagogonus* and *Limnometra* are more common.
3. Those found on fast-flowing streams or near waterfalls. These include some of our largest gerrids. The long middle legs of males are generally lined with dense hairs for skating on fast moving water (e.g. *Ptilomera* (Fig. 5F), *Potamometropsis*, *Pleciobates*, *Rheumatogonus*). *Cylindrostethus* and *Metrocoris* (Fig. 5D,H) are commonly encountered on smoothly flowing water.
4. Those found typically in rocky splash zones of waterfalls. Some are hygropetric or semi-terrestrial (e.g. *Onychotrechus* spp.) and are found jumping and climbing on wet rock surfaces, sometimes far from waterfalls.

Onychotrechus is the least known gerrid genus and in need of a revision. The first three groups of water skaters are more common and many genera have been recently revised, such as *Amemboa* (Polhemus and Andersen 1984; Zettel 1995), *Ptilomera*, *Cylindrostethus*, *Cryptobates*, *Gnomobates*, and *Naboandelus* (Polhemus 1994, 2001; Polhemus and Polhemus 1994, 1995a), *Metrocoris* (Polhemus 1990; Chen and Nieser 1993a,b), *Potamometropsis* (Polhemus and Zettel 1997), *Limnometra* (Nieser and Chen 1992), *Rhagadotarsus* (Polhemus and Karunaratne 1993), *Ventidius* (Chen and Zettel 1998). A list of species known from Peninsular Malaysia is given in Cheng *et al.* (2001b). Most common species are found in Borneo and Peninsular Malaysia, while a few genera and many species are regionally endemic. *Aquarius*, *Pleciobates* and *Onychotrechus* are distributed in continental Southeast Asia but have not been reported from Borneo, while *Potamometropsis* is distributed in Borneo, Philippines and Sumatra.

Other genera which inhabit the various marine environments, especially the coastal areas in habitats with strong intertidal influence are not included here. A few fresh-water species are known to occur in saline or brackish water habitats.

Key to genera of Gerridae (modified from Cheng *et al.* 2001b, and Ptilomerinae from Polhemus and Zettel 1997)

1. First abdominal sternite visible. Tip of abdomen produced to a rod-like point (Fig. 5A) .... *Rhagadotarsus*

- First abdominal sternite not visible. Abdomen not produced 2

2. Middle femora stout, distinctly shorter than middle tibiae and usually shorter than hind-femora 3

- Middle femora slender, usually distinctly longer than middle tibiae 5

3. Third antennal segment as long as or shorter than second and distinctly shorter than the first. Lateral margins of male proctiger with long, slender processes, directed anterolaterally .... *Naboandelus*

- Third antennal segment more than twice as long as second and distinctly longer than the first. Lateral margins of male proctiger (genital segment 10) not modified 4

4. Third antennal segment three times the length of second segment. Male fore-femora curved . ..... *Gnomobates*

- Third antennal segment about twice the length of second segment. Male fore-femora straight. (Fig. 5G) ..... *Cryptobates*

5. Metasternum with lateral evaporative channels leading to metacetabula. Body at least four times as long as broad (Fig. 5D) ..... *Cylindrostethus*

- Metasternum not as above. Body less than four times as long as broad 6

6. Fore-tarsi very long, at least half length of tibiae. Middle femora usually longer than body 7

- Fore-tarsi shorter, middle femora usually shorter or subequal to body length 10

7. Large species, over 15 mm in body length. Each hind-coxa with a dorsal spine. Posterior half of male middle femora lined with woolly hairs (Fig. 5F) ..... *Ptilomera*

- Smaller species, body length less than 10 mm. Hind-coxa without spine. Male middle femora without hair fringe 8

8. Anterior margin of head rounded. First antennal segment shorter than the 3 other segments together. Males distinctly smaller than females ..... *Rheumatogonus*

- Anterior margin of head not rounded. First antennal segment subequal or longer than the 3 other segments together. Males not or only slightly smaller than females 9

9. Middle and hind-tarsi with distinct claws. First antennal segment longer than the 3 other segments together. Female abdomen long and with a pair of long and thin spinous processes on segment 6 ..... *Pleciobates*

- Middle and hind-tarsi without distinct claws. Fist antennal segment subequal to 3 other segments together. Female abdomen short and not as above ..... *Potamometropsis*

10. Metasternum well developed. Body relatively long and slender, length : width ratio usually more than 3.0; if not, then first antennal segment with 4–6 dark spinous hairs 11

- Metasternum reduced, usually represented only by a short triangular plate enclosing the scent gland orifice. Body relatively broad and short, length:width ratio less than 3.0 17

11. Pronotum in apterous specimens not prolonged posteriorly. First antennal segment with 4–6 dark spinous hairs. Pretarsal arolia present, arising between the claws (Fig. 5C) 12

- Pronotum in apterous specimens prolonged posteriorly; if reduced in length, then dorsal head and thorax generally dark and pretarsal arolia missing. First antennal segment without dark spinous hairs 13

12. Hind-legs distinctly shorter than middle legs. 1st mid-tarsal segment longer than 2nd (Fig. 5B) ..... *Amemboa*

- Hind-legs subequal in length to middle legs. 1st mid-tarsal segment shorter than 2nd .... *Onychotrechus*

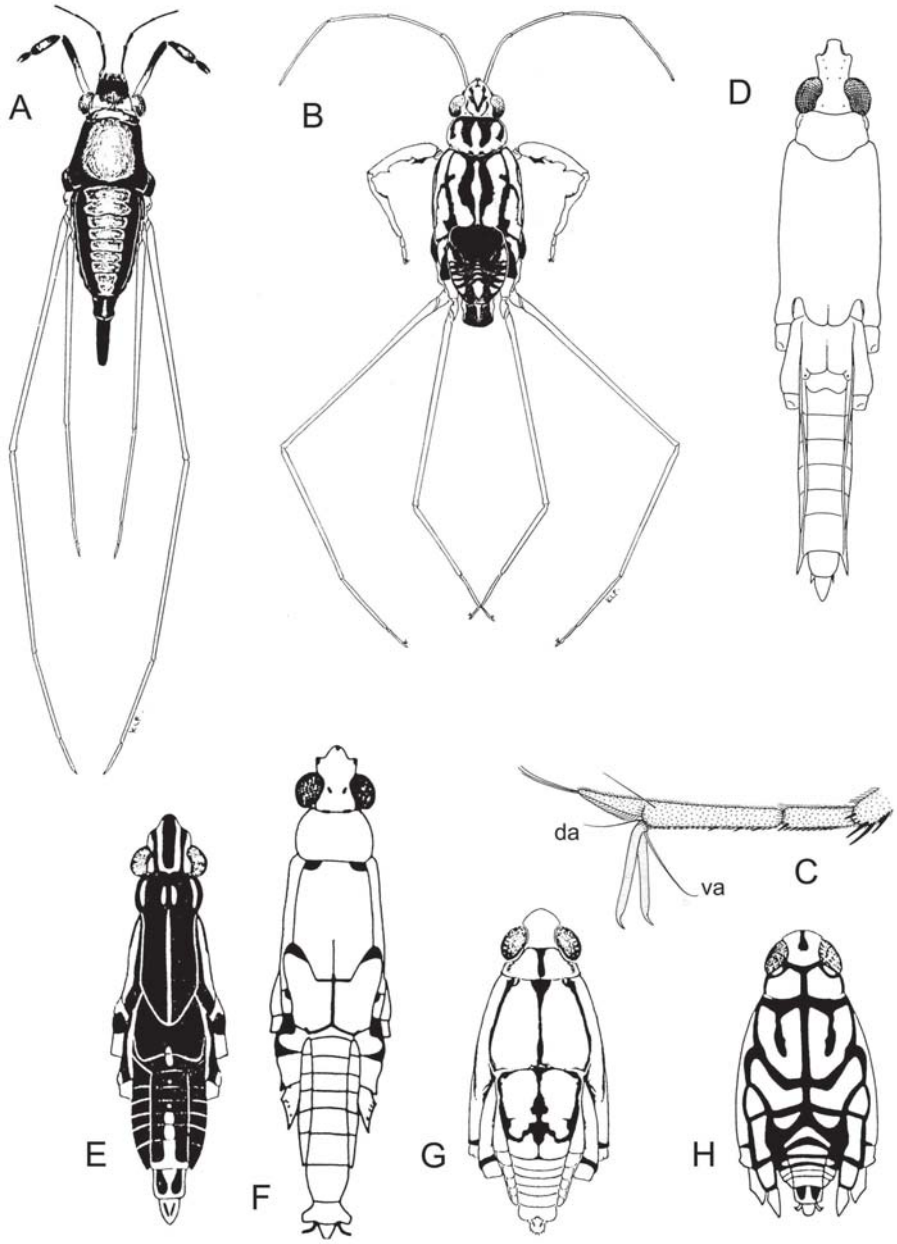

Figure 5. Gerridae. A – *Rhagadotarsus kraepelini*, male; B – *Amemboa lyra*, male; C – *Onychotrechus sakuntala*, left middle tarsus, da, dorsal arolium; va, ventral arolium; D – *Cylindrostethus scrutator*; E – *Limnogonus fossarum*, male; F – *Ptilomera tigrina*, male; G – *Cryptobates johorensis*, male; H **–** *Metrocoris tenuicornis*, male. (Source: C, D, from Andersen 1982a)

13. Antennae usually subequal to or longer than body length. Pronotal lobe usually pale with longitudinal median dark stripe 14
- Antennae much shorter than body. Pronotal lobe dark with or without longitudinal median pale stripe 15

14. Connexival spines well developed. Body relatively elongated ..... *Limnometra*
- Connexival spines not distinct. Body relatively short ..... *Tenagogonus*

15. Dorsal surface of head almost uniformly dark. Venter generally dark. First antennal segment subequal to or longer than segments 2+3 ..... *Aquarius*
- Dorsal surface of head with orange spots, or with two pale longitudinal stripes or elongate spots. Venter generally pale. First antennal segment shorter than segments 2+3 16

16. Pronotal lobe dark with a pale median stripe; if uniformly dark, anterior part with a pair of elongate pale spots (Fig. 5E) ..... *Limnogonus*
- Pronotal lobe dark, with a single median pale spot on the anterior part, sometimes shortened in apterous form ..... *Neogerris*

17. Male third antennal segment expanded laterally, with stiff hairs on margin ..... *Esakia*
- Male third antennal segment not expanded laterally 18

18. Eyes overlapping anterolateral angles of mesonotum. Fore-femora of male usually slender .... *Ventidius*
- Eyes not overlapping anterolateral angles of mesonotum. Fore-femora of male often robust and incrassate (Fig. 5H) ..... *Metrocoris*

INFRAORDER NEPOMORPHA: true aquatic bugs

Most Nepomorpha are stout bugs with streamlined bodies. In Peninsular Malaysia they range in size from 1 mm to 70 mm. The antennae are usually shorter than the head and concealed below the eyes. The eyes are very large, occupying nearly the entire sides of the head. Cephalic trichobothria are always absent. The fore-legs are generally raptorial, the middle and hind-legs flattened and fringed with swimming hairs. In many families the venter is covered by hydrofuge hairs, which trap air and function as a plastron when the insect is submerged. Menke (1979) and Schuh *et al.* (1987) published an overview of the Nepomorpha.

There are 10 families of Nepomorpha in the Malaysian Region: Belostomatidae, Nepidae, Gelastocoridae, Ochteridae, Corixidae, Naucoridae, Aphelocheiridae, Pleidae, Helotrephidae and Notonectidae. The adults and nymphs live in standing or flowing water, remaining submerged throughout their lives except during dispersal. Only Gelastocoridae and Ochteridae are riparian, occurring along the shores and margins of ponds and streams. About 70 species of Nepomorpha are known from Peninsular Malaysia. Many can inject painful bites when carelessly handled. Most members of the true aquatic bugs are predaceous and of economic importance, because they feed on harmful blood-sucking flies (Keffer 2000; Papácek 2000; Sites 2000; Venkatesan 2000).

FAMILY BELOSTOMATIDAE – giant water bugs (Fig. 6E)

The belostomatids include the largest of all heteropterans. The body shape is like that of the naucorids – flattened and oval, with strong fore-legs. The airstraps of the adults, derived from abdominal tergum 8, are their most distinctive feature. Only two genera are known in the region, *Lethocerus* and *Diplonychus*, each represented by one species. Adults of *Lethocerus* (=*Belostoma*) *indicus* may measure more than 60 mm in body length. *Diplonychus* (=*Sphaerodema*) *rusticus* is much smaller, less then 25 mm. The males of *Diplonychus rusticus* are known to carry eggs on their backs until they hatch. The eggs of *Lethocerus* are laid on vegetation. Belostomatids are efficient hunters and have been known to prey on small fish or tadpoles. They often hide among vegetation in standing water of lakes, ponds and paddy fields. *Lethocerus indicus* (Fig. 6E) is also known as the "Electric Light Bug" because adults leave the water and are attracted to bright lights at night. They are thus caught in large numbers and sold as food in Thailand, Vietnam and Cambodia. The males of giant water bugs have well-developed metathoracic scent glands, which produce a strong smell and are used for flavouring food in Thailand (Chen *et al*. 1998). *Diplonychus* lacks metathoracic scent glands. *Lethocerus* has not been seen in southern Peninsular Malaysia in the last 30 years, but *Diplonychus* is common and widespread.

FAMILY NEPIDAE – water stick-insects and water scorpions (Fig. 6D,F)

Nepids are some of the region's more conspicuous aquatic insects, remarkable by possessing a pair of long, respiratory siphons at the posterior end of the body. These elongate, ovoid to cylindrical water bugs range from 20 to 50 mm in body length (excluding the siphon). Three genera are known from Peninsular Malaysia: *Cercotmetus*, *Laccotrephes* and *Ranatra* (Lansbury 1972a; 1973). The water scorpion has strong, grasping fore-legs, and a dorso-ventrally flattened, and leaf-like body, looking somewhat like a terrestrial scorpion. *Laccotrephes pfeiferiae* (previously misidentified as *L. robustus*) (Polhemus and Keffer 1999) (Fig. 6D) is the largest species, commonly found in puddles or shallow pools in forests. Another genus of water scorpions, *Telmatotrephes*, may occur on the peninsula as it has recently been reported from central Thailand and Brunei (Sites and Polhemus 2000). It can be distinguished from the *Laccotrephes* by the broader body and very short siphons. The bodies of *Cercotmetus* and *Ranatra* (Fig. 6F) are more cylindrical and stick-like. The uniformly dark coloured water stick-insect *Cercotmetus asiaticus* is the most abundant and widespread nepid in Southeast Asia. The body length reaches 50 mm. Species of *Ranatra* are smaller, with long siphons. They are usually brown with some markings on body and legs. All nepids prefer still waters or slow-flowing streams, where they hang head down in vegetation with the tips of their respiratory siphons protruding through the water surface. They stay motionless like a twig,

waiting for their prey, and have been known to catch even tadpoles, frogs or small fish bigger than themselves. Although adults are winged they have rarely been caught at light.

Key to genera of Nepidae (after Lansbury 1972b and Fernando and Cheng 1974)

1. Body dorso-ventrally flattened, leaf-like (Fig. 6D) 2
- Body more or less cylindrical 3

2 Long siphon, more than two thirds the length of the inner margin of the elytra from the apex of scutellum to the membrane (Fig. 6D) ..... *Laccotrephes*
- Short siphon, never more than half as long as the distance from the apex of the scutellum to the membrane along the inner margin of the elytra ..... *Telmatotrephes*

3. Respiratory siphons relatively short and rigid, fore-femur shorter than pronotum.... *Cercotmetus*
- Respiratory siphons long and flexible, fore-femur longer than pronotum (Fig. 6F) ... *Ranatra*

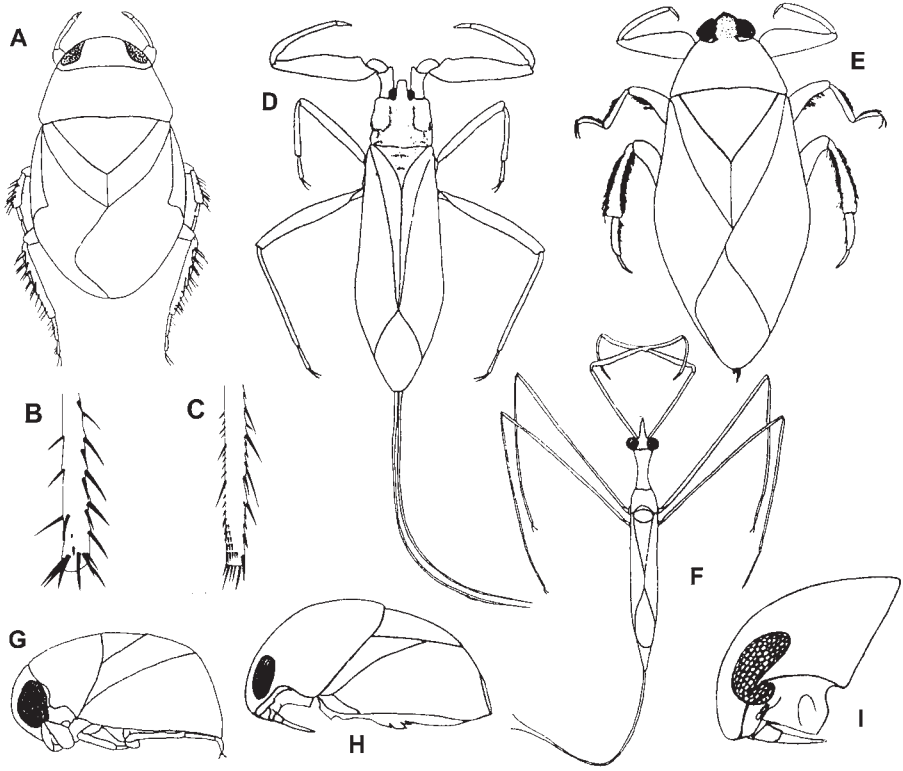

Figure 6. A – *Ctenipocoris asiaticus*. Naucoridae; B, C – Distal end of hind-tibia of Naucoridae, B – *Ctenipocoris* sp; C – *Heleocoris* sp.; D – *Laccotrephes pfeiferiae*, Nepidae; E – *Lethocerus indicus*, Belostomatidae; F – *Ranatra* sp., Nepidae; G – *Paraplea* sp., Pleidae; H, I – Helotrephidae, H – *Hydrotrephes* sp.; I **–** *Idiotrephes* sp. (Sources: B,C, from Sites *et al.* 1997; H, I, from Zettel 1998)

FAMILY GELASTOCORIDAE – toad-bugs (Fig. 8B)

These bugs are commonly known as toad-bugs because of their somewhat squat, warty bodies which resemble miniature toads and because of their tendency to jump when disturbed. In this region, only one species has been reported, *Nerthra lobata*. They have short, raptorial fore-legs. They are found near banks of streams or ponds, but are difficult to detect because of their dorso-ventrally flattened body (5 mm long) and dull, mottled appearance. Their biology is poorly known. Eggs are laid in sand or in mud beneath stones near water. Females may stay close to their eggs until they hatch (Menke 1979).

FAMILY OCHTERIDAE – velvety shore bugs (Fig. 8A)

These bugs are elongate-oval in shape, with a depressed body, and are rather small (3-7 mm long). They are usually dark brown or grey, with white markings on the dorsal surface. The eyes are large and the legs are slender and not modified. These bugs live along the shores of streams. Although they can jump or fly rather fast when disturbed, they rarely fly for long distances. The species reported from Peninsular Malaysia and Singapore is *Ochterus marginatus.*

FAMILY CORIXIDAE – water-boatmen (Fig. 7A)

Most water-boatmen are small to medium-sized bugs (2.5–8.5 mm long). They have oblong bodies and a flat dorsum. The broadly triangular rostrum is fused to the head and usually has transverse grooves. The fore-tibia is short and the single tarsal segment (= pala) is spoon-shaped and fringed with long setae. It is used for food gathering. The long and slender middle legs and long claws are used for clinging to vegetation. The oar-like, hair-fringed legs make the corixids very fast swimmers.

One or both sexes of many Corixidae are known to stridulate. In the subfamily Corixinae both sexes stridulate by rubbing a patch of pegs on the inner surface of the anterior femur against the sharp keels on the sides of the head (Jansson 1972). In the subfamily Micronectinae the males make a loud noise by rotating the genital capsule so that the right paramere is rubbed against ridges on the 8th abdominal segment (Jansson 1989). King (1999a,b) found that acoustic signals produced by nine species of Australian *Micronecta* were species-specific, females being attracted by signals of conspecific males. Two other structures were wrongly supposed to be stridulatory, the strigil and a row of pegs on the pala in the males. The strigil (Fig. 7B) is a small, ridged structure on the right side of the 6th abdominal tergite. Its true function is not well understood, but it seems to form a conduit between the air bubbles of copulating male and female, so that the female, held beneath the male, can replenish her air supply. The row of pegs on the pala of Corixinae males serves to aid in gripping the sides of the female's hemelytra.

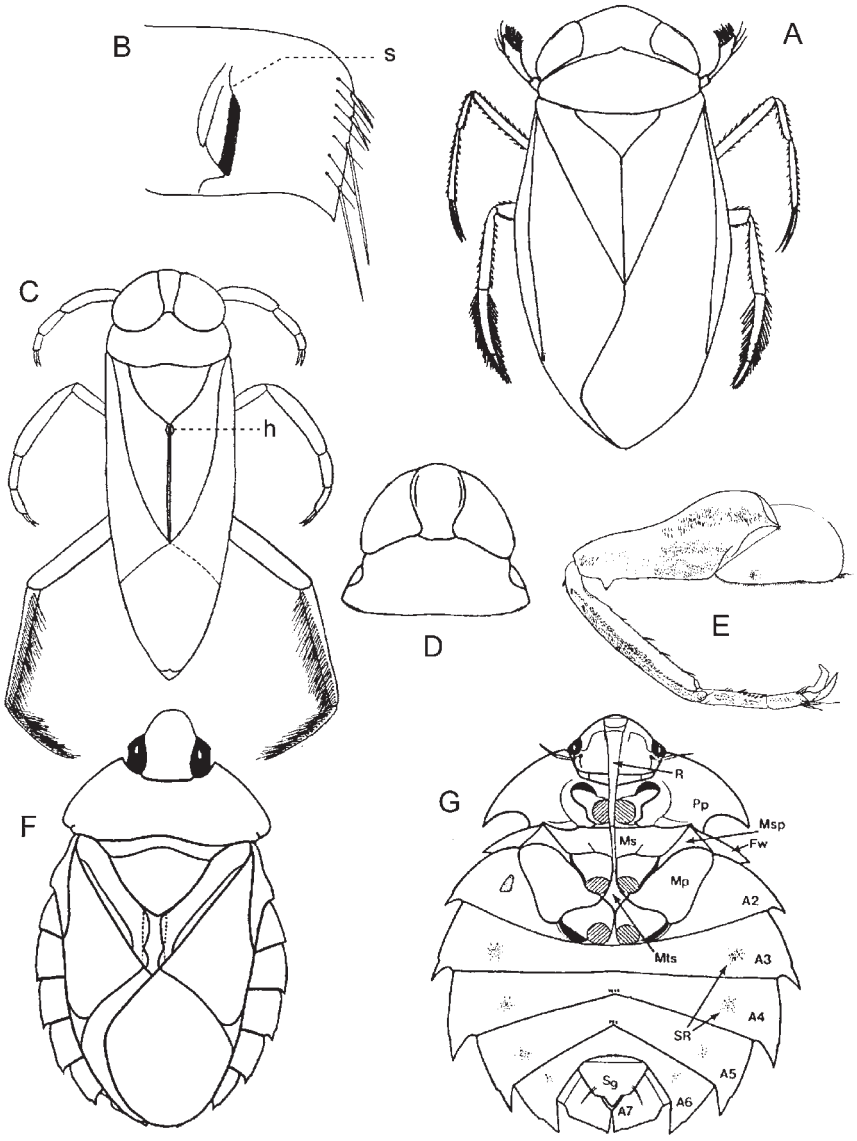

Figure 7. A–B, Corixidae, A – *Micronecta quadristrigata*, male; B – *Micronecta charakta*, male right part of abdominal tergite VI showing strigil (s); C – *Anisops* sp., Notonectidae, hair line pit (h). D,E - *Enithares mandalayensis*, Notonectidae, D – head and pronotum; E – middle leg showing protuberance on male fore-femur. F, G – Aphelocheiridae, F – *Aphelocheirus malayensis*, macropterous female; G – *Aphelocheirus nawae* (South Korea), female, ventral view. Abbreviations: A2–A7, abdominal segment 2–7; FW, fore-wing; Mp, metapleuron; Ms, mesosternum; Mts, metasternum; Pp, propleuron; R, rostrum; Sg, female subgenital plate; SR, spiracular rosettes. (Sources: A,B, from Nieser 2002a,b; C, from Leong 1962; D,E, from Lansbury 1968; F,G, from Polhemus and Polhemus 1988)

Corixids are widespread and found in many aquatic habitats of the region, being most common in ponds and lakes. They are omnivorous, feeding on algae, detritus and larvae of mosquitoes and chironomids. Most Corixinae use their palae to sift food items from the sediment that accumulates at the bottom of water bodies. They use a ventral air bubble as a physical gill. In Corixinae, secretion-grooming occurs

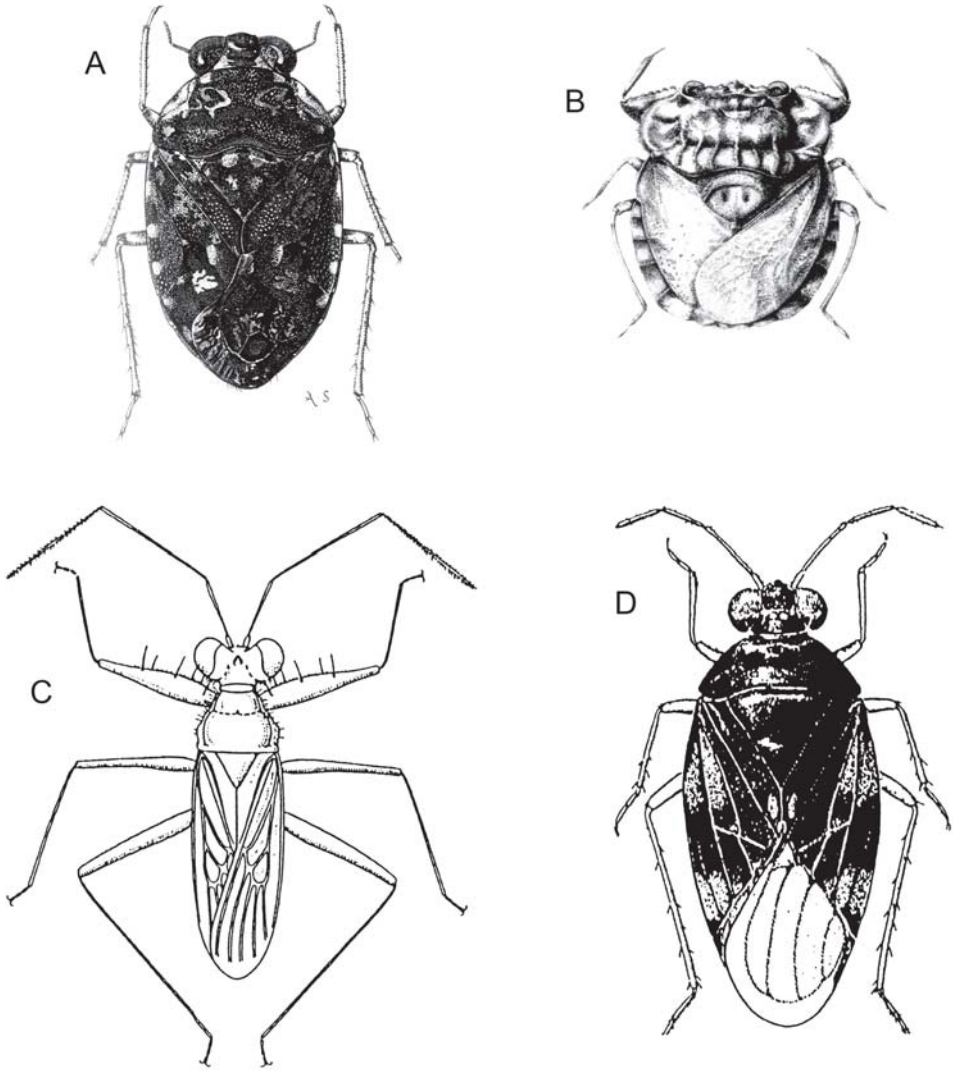

Figure 8. A – *Ochterus s*p., Ochteridae; B – N*erthra* sp., Gelastocoridae; C – *Valleriola* sp., Leptopodidae; D – *Saldula* sp., Saldidae. (Sources: A, from Usinger 1956; B, from Schuh and Slater 1995; C, D, from Polhemus and Polhemus 1999b)

on the water surface, while Micronectinae lack metathoracic glands and do not groom outside the water (Kovac and Maschwitz 1991). Flight polymorphism is widespread in the family. Flying adults are common and often abundant in light catches, and may land in swimming pools in fairly large numbers. In some lakes, population densities can be high, so that they have been harvested as food for human as well as for caged birds and aquarium fishes (Hutchinson 1993).

The Corixidae of Peninsular Malaysia and Singapore have recently been revised by Nieser (2002a,b). Four genera are known: *Micronecta*, *Synaptonecta* (Micronectinae), *Agraptocorixa* and *Sigara* (Corixinae). Most species are widespread in Asia and also occur in Africa, Arabia and Australia. Nieser (2002b) recorded 18 species of *Micronecta* from Peninsular Malaysia. *Agraptocorixa hyalinipennis* is the largest corixid (6.0–8.5 mm long) found in the region. It can be recognized easily by its size and the lack of yellowish transverse marks on the pronotum and hemelytra. One species in each of the genera *Sigara* and *Synaptonecta* has been recorded. Both *Sigara paivai* and *Synaptonecta issa* are widespread in Asia.

Key to genera of Corixidae (modified from Nieser 2002b)

1. Vertex with a depression, male fore-tibia and tarsus fused ..... *Synaptonecta*
- Vertex convex, male fore-tibia and tarsus separated 2

2. Scutellum exposed, covered by pronotum only at the anterior margin (Fig. 7A)....*Micronecta*
- Scutellum covered by hemelytra 3

3. Pronotum and hemelytra concolourous. Large and stout species, length 6.0-8.5 mm .... *Agraptocorixa*
- Pronotum and hemelytra with alternating transverse yellow and dark lines. Smaller species, length less than 6.0 mm ..... *Sigara*

FAMILY NAUCORIDAE – creeping water bugs (Fig. 6A–C)

The naucorids are dorso-ventrally flattened and oval bodied. The fore-legs, modified for grasping the prey, have enlarged femur and a sickle-like tibia and tarsus. The middle and hind-legs are fringed with swimming hairs or thorny spines. Four genera with five species are known from Peninsular Malaysia: *Ctenipocoris*, *Laccocoris*, *Heleocoris* and *Naucoris*. *Ctenipocoris asiaticus* (Fig. 6A) and *Naucoris* species live in standing water or along quiet margins of streams. *Laccocoris* and *Heleocoris* are found along the edges of slow to fast-flowing streams among gravel or vegetation. An additional genus, *Gestroiella*, is included in the key because it occurs in Yunnan, Indochina and South Thailand, close to the Malaysian border (Sites *et al.* 1997). *Gestroiella* lives in the gravel and rocky substrates of fast-flowing streams or in pools at waterfalls. Naucorids are among the least known aquatic Heteroptera, and the family is in need of a revision.

Key to genera of Naucoridae (after Nieser and Chen 1991 and Sites *et al.* 1997)

1. Labium arising from a deep excavation on underside of head ..... *Gestroiella*
- Labium not arising from an excavation of head 2

2. Fore-leg pretarsus with one minute claw ..... *Naucoris*
- Fore-leg pretarsus with two claws 3

3. Distal end of hind-tibia with a circlet of stout spines, not arranged in rows (Fig. 6B) .... *Ctenipocoris*
- Distal end of hind-tibia with rows of parallel spines, arranged in rows (Fig. 6C) 4

4. Labrum more or less equilateral with an acute tip ..... *Laccocoris*
- Labrum with sides shorter than base and tip broadly rounded ..... *Heleocoris*

FAMILY APHELOCHEIRIDAE (Fig. 7F,G)

This family is represented by only one genus, *Aphelocheirus*, previously included in the Naucoridae. It can be distinguished from the naucorids by the rather long rostrum and antennae and by the rosettes (part of the respiratory system, Fig. 7G) surrounding the ventral abdominal spiracles. Wingless specimens are common. Aphelocheirids are medium-sized bugs (6–8 mm long) with dorso-ventrally flattened bodies, found in fast-flowing streams, under rocks or stones. They are basically restricted to rocky upland streams with gravelly riffles and rapids where dissolved oxygen is high. They have a unique plastron respiration system (Thorpe and Crisp 1947) as well as special pressure receptors (Thorpe 1947). Aphelocheirids are predators and can attack prey many times their own size. Their nasty bite is painful to humans and may become sore and swollen. Polhemus and Polhemus (1988) reported several bites to fingers causing temporary loss of muscular function in the area. They documented 35 species of *Aphelocheirus* from tropical Asia, but only three are known from Peninsular Malaysia, two from Borneo and several from Indochina.

FAMILY NOTONECTIDAE – back-swimmers (Fig. 7C–E)

Notonectids or back-swimmers characteristically swim with their ventral side uppermost. Their body is boat-shaped. The fore- and middle legs are adapted for grasping prey, while the hind-legs are oar-like, fringed with long setae and used for swimming. The abdomen has a median keel, and heavy fringes of setae form air chambers. They are generally found in shallow standing waters, while some are found in slow-flowing streams, usually close to the surface. Most are winged. Some may be found in swimming pools during migration or dispersal. Four genera are known: *Enithares, Aphelonecta, Anisops* and *Nychia* (Lansbury 1966, 1968).

The genus *Enithares* contains some of the region's largest back-swimmers, measuring more than 10 mm in body length. They are usually metallic blue or green on the dorsal surface but rather dull on the ventral side. Adults and nymphs are

often seen hanging head-down beneath the water surface film, waiting for prey to fall into the water. They should be handled with care since they can inflict quite a nasty bite. *Anisops* (Fig. 7C) species are pale and appear somewhat pinkish brown in preserved samples, because of the haemoglobin in their cells. The haemoglobin functions in controlling buoyancy, allowing the insects to remain at a constant level in the water column (Wells *et al*. 1981). The males can produce sound using stridulatory organs on the fore-legs. *Nychia* and *Aphelonecta* are smaller, less well known, and represented in our region only by one species in each genus (*N. sappho* and *A. gavini*).

Key to genera of Notonectidae (after Nieser 1998)

1. Hemelytral commissure with a definite hair-lined pit at anterior end (Fig. 7C) ..... *Anisops*
- Hemelytral commissure without a definite hair-lined pit 2

2. Middle femur with pointed protuberance near distal end (Fig. 7E) ..... *Enithares*
- Middle femur without pointed protuberance 3

3. Basal halves of eyes meet in the middle ..... *Nychia*
- Eyes widely separated at base ..... *Aphelonecta*

FAMILY PLEIDAE and FAMILY HELOTREPHIDAE – pygmy back-swimmers (Fig. 6G–I)

Both pleids and helotrephids are small bugs (1–3.5 mm long), usually with strongly convex dorsum, brownish body and red eyes. Like the Notonectidae, they usually swim in the inverted position. The family Helotrephidae (Fig. 6H,I) is distinguished from the Pleidae (Fig. 6G) by the fusion of the head and pronotum into a cephalonotum. However, there is usually a curved, finely impressed demarcation line between the head and pronotum (cephalonotal sulcus). In the Pleidae the antennae are 3-segmented, in the Helotrephidae they are 1- or 2-segmented (always 2-segmented in the Oriental species).

The family Pleidae has only one genus, *Paraplea* (Fig. 6G), with two species known in Peninsular Malaysia. Pleids inhabit vegetated areas in lentic habitats like ponds. The metathoracic scent gland secretes hydrogen peroxide and is used for secretion-grooming (Kovac and Maschwitz 1989; Kovac 1993).

The Helotrephidae are more diverse than the Pleidae and inhabit a wide variety of habitats. Eight species belonging to five genera are known from Peninsular Malaysia. Two additional genera, *Hydrotrephes* (Fig. 6H) and *Trephotomas*, may occur in Peninsular Malaysia, since they are known from Indochina and Borneo. *Fischerotrephes* and *Trephotomas* are plastron breathers and occur in the middle of streams. They prefer a bottom covered with pebbles, gravel or sand. *Helotrephes* and *Hydrotrephes* inhabit running waters, but prefer to stay in slow-flowing, vegetated areas along the river bank. *Distotrephes* species are confined to brooks

and streams with stone or gravel sediments, among accumulated plant material or submerged rootlets of trees. Species of *Idiotrephes* (Fig. 6I) invade lentic areas of streams or rivers, stagnant waters including temporary lithotelmata as well as artificial bodies of water (ceramic bowls, tanks) or tiny pools on seeping rocks at waterfalls. *Tiphotrephes* occurs in ponds, lakes and in very slow-flowing streams. Recent papers on Peninsular Malaysian Helotrephidae include Kovac and Papácek (2000), Papácek and Kovac (2001), Papácek and Zettel (2000), Zettel (1994) and Zettel and Polhemus (1998). In Borneo, more than 20 helotrephid species have been recorded, and many genera and species there are endemic (Zettel 2000).

Key to genera of Helotrephidae (modified after Zettel 1998)

1. Tarsal formula 3-3-3, dorsum flat. Body less than 1.6 mm long ..... *Fischerotrephes*
- Tarsal formula 2-2-3 or 1-1-2, dorsum usually strongly convex. Larger species 2

2. Tarsal formula 2-2-3 ..... *Trephotomas*
- Tarsal formula 1-1-2 3

3. Body length at least 2.5 mm, postero-lateral margins of cephalonotum not reaching the eyes (Fig. 6H) 4
- Body length less than 2.0 mm, postero-lateral margins of cephalonotum reaching the eyes (Fig. 6I) 5

4. Sternite 4 (or 4 and 5) with median keel ..... *Helotrephes*
- Sternite 4 and 5 without median keel (Fig. 6H) ..... *Hydrotrephes*

5. Eyes divided into two parts by the lateral margins of cephalonotum ..... *Distotrephes*
- Eyes not divided into two parts 6

6. Lateral margins of cephalonotum clearly extending onto eye surface, deeply indenting posterior margins of the eyes (Fig. 6I) ..... *Idiotrephes*
- Lateral margins of cephalonotum not extending onto eye surface, or slightly indenting the posterior margins of eyes ..... *Tiphotrephes*

INFRAORDER LEPTOPODOMORPHA – shore bugs

The Leptopodomorpha have flattened and ovoid or elongate and parallel-sided bodies, 2–7 mm long. The antennae are longer than the head and exposed. The head is usually short and broad, the eyes are large, protruding laterally and occupying nearly the entire sides of the head. At least three pairs of cephalic trichobothria are present, but in contrast to the Gerromorpha they do not arise from pit-like depressions in the cuticle. The bugs of this group are rarely represented in museum collections, and their biology is not well known. They are not easy to collect, because some species have no apparent association with water and they are extremely agile by jumping and flying. A catalogue and bibliography for the world Leptopodomorpha was published by Schuh *et al.* (1987), while an overview of the Leptopodomorpha of Thailand and the adjacent regions was given by Polhemus and Polhemus (1999b).

Three families of Leptopodomorpha are known in the Malaysian region: Saldidae, Leptopodidae and Omaniidae. They inhabit damp areas near water or along the margins of streams, lakes, ponds and intertidal zones. Some are found far away from aquatic habitats. The Omaniidae (not treated here) are small marine bugs found exclusively in intertidal zones, where they stay in cavities among coral rubble during high tide, apparently using trapped air as a source of oxygen. Only four species of freshwater Saldidae and Leptopodidae have been recorded from Peninsular Malaysia, but probably several more remain to be found.

FAMILY SALDIDAE – shore bugs (Fig. 8D)

The saldids are small, oval bugs with large eyes which protrude laterally. The coxa of each hind-leg is modified into a flattened plate fused to the thorax. The adults are always winged and readily take flight when disturbed. They prefer bare ground for hunting, and are commonly found on damp sandy shores of lakes, ponds or stream banks. This is the largest and commonest of the region's shore bug families, with four known genera: *Saldula*, *Saldoida*, *Pentacora* and *Salduncula*. Species of *Saldula* (Fig. 8D) and *Saldoida* are found on shores of streams, lakes or ponds, or on rock surfaces near waterfalls, and some species occur in saline or intertidal habitats. *Pentacora* is found in salt marshes or muddy seashores and *Salduncula* is strictly intertidal (Polhemus 1991; Polhemus and Polhemus 1999b). A world overview of the biology, taxonomy and phylogeny of Saldidae was published by Polhemus (1985).

Key to genera of Saldidae (after Polhemus and Polhemus 1999b)

1. Pronotum strongly narrowed anteriorly, with 2 prominent conical tubercles on anterior lobe ..... *Saldoida*
- Pronotum not strongly narrowed anteriorly, without prominent tubercles on anterior lobe. (Fig. 8D) ..... *Saldula*

FAMILY LEPTOPODIDAE – spiny shore bugs (Fig. 8C)

The body and legs of these bugs are always covered with spines or long setae. This family is represented by two genera, *Leotichius* and *Valleriola*, each with one species (*L. speluncarum and V. javanica*). *Leotichius* has eyes dorsally chitinous, opaque and apparently non-functional, while *Valleriola* (Fig. 8C) has normally functioning eyes set with ommatidia. *Leotichius* has been found in a cave entrance on completely dry, sheltered earth associated with ant-lion larvae (Polhemus and Polhemus 1999b). *Valleriola* occurs on vertical rock or boulder surfaces in streams or waterfalls.

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