INTRODUCTION

BIOSYSTEMATICS, DIVERSITY AND CONSERVATION OF MAYFLIES (INSECTA: EPHEMEROPTERA)
FROM CHOSEN RIVERINE REGIONS OF SOUTHERN WESTERN GHATS
The biosphere contains only 0.014% of Earth’s water, distributed among lakes (0.008%), soils (0.005%) and the atmosphere, rivers and biota (0.001%). An additional 2.58% of Earth’s water is fresh, occurring as ice (1.97%) or ground water (0.61%). The remainder of Earth’s water is saline (La Riviere, 1989). The countries of tropical Asia have extensive freshwater resources which are being used increasingly for developing purposes. Tropical Asian rivers drain these lands with a monsoonal climate which extend from west of the Indus eastward along the Himalaya to the China Sea at the mouth of the Yangtze. Six of the world’s longest rivers are Chang Jiang, Mekong, Indus, Brahmaputra, Ganges, and Irrawaddy situated in tropical Asia (Leeden, 1975). Individual Asian countries have a large number of rivers; for instance, Bangladesh has 50 rivers, India 400, Indonesia 200 and Thailand 10 (Jalal, 1987). India with unique geological history, highly variable physiography and monsoon climate is endowed with diverse fresh water habitats. There is a network of 14 major, 44 medium and 100 minor river systems in India (Rao, 1975). These rivers are responsible for the transport of over 80% of the sediments all over the world (Degens et al., 1991).

There are now probably no large, tropical Asian rivers in pristine condition (Hynes, 1970). Anthropogenic influence on tropical Asian rivers is pervasive. Among diverse human influences upon tropical Asian rivers, three threats are worth coming. Firstly, degradation of drainage basins particularly through deforestation and overgrazing leads to increased suspended sediment loads and extensive flooding. Excessive floodplain siltation alters habitats causing species decline or disappearance. The second threat, river regulation and control have been practiced widely in the region for centuries. Flow regulation reduces flood-season peaks, changing the magnitude and extent of floodplain inundation and land-water interactions. Fish breeding migrations may be disrupted, because dams block migration routes or changed flow regimes fail to stimulate reproduction. Thirdly, pollution occurs throughout the basins. Together, the three threats
have led to decline and range of constriction of aquatic animals and terrestrial species associated with riparian corridors and floodplains (Dudgeon, 1992).

The use of biological methods for monitoring (biomonitoring) the ecological quality of running waters is already a widespread approach. It provides information on water quality and ecology both before and during sampling, in contrast to chemical approaches which only characterize the water system during sampling. However, a combination of both approaches, physicochemical and biotic, has been shown to be the most appropriate method for pollution monitoring. Biomonitoring includes both sublethal changes at the cellular or tissue level and changes in community. The use of changes in community structure for monitoring freshwater pollution, commonly involves benthic macroinvertebrates (Metcalfe, 1989). Benthic macroinvertebrates are the animals that lack a backbone, occupy the bottom of water body and generally are visible with the naked eyes. Macroinvertebrates are the most diverse group of organisms which includes molluscs, crustaceans, annelids, nematodes and aquatic insects in freshwater ecosystems. Besides their role in ecosystem function of organic material dynamics and trophic energy transfer as important links in the food chain, they are good indicators of health of freshwater ecosystems and water quality. The macroinvertebrate population is very sensitive to environmental perturbation and is highly influenced by the physico-chemical characteristics of water, nature of substratum, food, predation and other factors (Negi and Malik, 2008). Benthic macroinvertebrates are the most appropriate biotic indicators for the following reasons: 1) these organisms are relatively sedentary and are therefore representative of local conditions 2) Macroinvertebrate communities are very heterogeneous, consisting of representatives of several phyla. The probability that at least some of these organisms will react to a particular change of environmental conditions, is therefore high. Other groups of organisms (fish, phytoplankton, etc) possess some, but not all, of these attributes. 3) Macroinvertebrates are differentially sensitive to pollutants of various types, and react to them quickly; also, their communities are capable of a gradient response to a broad spectrum of kinds and degrees of stress. 4) Their life spans are long enough to provide a record of environmental quality. 5) Macroinvertebrates are
ubiquitous, abundant and relatively easy to collect. Their identification and enumeration is not as tedious and difficult to as that of microorganisms and plankton (Dimitriadou, 2002).

The composition, abundance and distribution of benthic organisms over a period of time provide an index of the ecosystem. In recent years, there is a greater emphasis world over for better understanding of benthic environment, its communities and productivity and this has led to increased exploitation of many inland water bodies (Garg et al., 2009). Among the macroinvertebrates, insects are the most successful inhabitants of fresh water environment. This is demonstrated by their broad distribution and ability to exploit most types of aquatic habitats (Wallace and Anderson, 1996). Aquatic insects are a group of arthropods that live or spend part of their life cycle in water bodies (Pennak, 1978). They are of great importance to water bodies where they are found and their presence in water serve various purposes; some serve as food for fishes and other invertebrates, others acts as vectors through which disease causing pathogens are transmitted to both humans and animals (Foil, 1998; Chae et al., 2000). Most importantly, aquatic insects are very good indicators of water qualities since they have various environmental disturbances tolerant levels (Arimoro and Ikomi, 2008). Some are very vulnerable and sensitive to pollution, while others can live and proliferate in disturbed and extremely polluted waters (Merritt and Cummins, 1996; Popoola and Otalekor, 2011).

There are about thirteen orders of insects that have aquatic life. Aquatic insects of inland waters comprise some well known groups like mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), dragonflies and damselflies (Odonata), besides aquatic bugs (Heteroptera), aquatic beetles (Coleoptera) and aquatic flies (Diptera) (Selvakumar et al., 2012). With respect to biodiversity of invertebrates in Asian rivers has not been studied thoroughly. The general composition of the benthos of large Asian rivers appears similar to that of such habitats found worldwide and includes Tubificidae, Chironomidae (Chironominae), Gastropoda (Prosobranchia) and Bivalvia
(Hynes, 1970). Among the aquatic insects, the diversity of Plecopteran families is low in tropical Asian streams. The order is typically found in cooler, more northern latitudes, and is represented mainly by Perlidae (especially Neoperlinae), Nemouridae, Leuctridae, and Peltoperlidae. Odonata and Naucoridae (Hemiptera: Heteroptera) are conspicuous elements of the zoobenthos in many tropical Asian streams, and Lepidoptera (Pyralidae) may be diverse and abundant (Dudgeon, 2000). Although most invertebrate species are still undescribed, a high diversity is displayed by certain taxa. For example, Schmid (1984) estimated that India alone may support 4,000 species of caddisfly (Trichoptera), with perhaps 50,000 species in the Oriental Region as a whole and the single genus Chimarra (Phillobotamidae) may contain 500 Southeast Asian species (Malicky, 1989; Thani and Phalaraksh, 2008).

Globally, about 3000 species in 400 genera and 42 families are currently known from Ephemeroptera. Of these, 390 species in 84 genera and 20 families occur in the Oriental region. About 49% of the genera (41 genera) are endemic to the region. The Western Ghats-Sri Lanka biodiversity hotspot shows a high degree of endemism (Barber-James et al., 2008). The fauna of the Indian subregion is represented by four suborders, fifteen families, sixty genera and 204 species (Sivaramakrishnan et al., 2009a). The Ephemeroptera fauna of India is represented by 4 suborders, 12 families, 46 genera and 125 species (Sivaramakrishnan et al., 2009b) and the Western Ghats part of southern India alone constitute 49 species under 28 genera and 13 families (Dinakaran and Anbalagan, 2009) though around 41 genera in 14 families were recorded in recent surveys (Sivaramakrishnan and Subramanian, 2011). The abundance of morphologically unrecognized species, even in well known taxa suggests that there are more species than are currently recognized or estimated. The species diversity is likely to be 3-4 times higher.

Mayflies are very good indicators of water pollution, conservation importance and centres of endemicity. They can be used to identify significant localities at much smaller scale than those identified by studies on vertebrates.
The larval stage of mayflies is the dominant life history stage, which is always aquatic. The larvae undergo a series of moults as they grow, the precise number being variable within a species, depending on external factors, such as temperature, food availability and current velocity (Brittain and Sartori, 2003). Ranges from 10 to 50 instars have been reported (Ruffieux et al., 1996). Typically, larva have up to seven pairs of abdominal gills, usually three caudal filaments, and mouthparts generally adapted for collector/gatherer and deposit feeding. A few species are predaceous and some are scrapers. Certain groups are burrowers, and have variously developed mandibular tusks and frontal processes to loosen the substrate, and flattened legs for digging. Burrowers usually have feathery gills, which are folded over the abdomen and used to create a current through their burrow. Mayfly larvae colonize all types of freshwaters but are more diversified in running waters than in lakes or ponds. A couple of species can even be found in brackish waters. Mayflies undergo hemimetabolous metamorphosis, having a unique maturation stage between the larvae and adult, the subimago. Subimagos appear superficially similar to the adults, but are sexually immature. Their wings and abdomens are covered with small water-resistant microtrichia, which help them to leave the water after moulting from the final instar larva (Edmunds and McCafferty, 1988). Except for a few exceptions, such as female Polymitarcyidae and Palingeniidae (which are mature as subimagos), most adults have transparent wings and glossy abdomens, having shed the subimaginal cuticle, and males have extended forelegs for grasping the female during mating. Usually, mayfly adults live from a few hours to a few weeks depending on the species. Many species have male mating swarms forming at dawn or dusk. Females have various methods of oviposition and the number of eggs laid varies according to species and size of female and eggs (Sartori and Sartori-Fausel, 1991; Brittain and Sartori, 2003). Length and number of life cycles per year depend largely on geographic locality and size of the species, with large burrowers in temperate climates taking over 2 years to mature, while tropical species may have several generations in a year (Barber-James et al., 2008). Mayflies and other aquatic insects are also good indicators of human impact on freshwater ecosystems.
Biological monitoring methods using aquatic insects have been developed and reliably tested in both temperate and tropical aquatic systems (Resh, 1979; Armitage et al., 1983; Trivedi, 1991; Sivaramakrishnan et al., 1996a). Well known Indian Ichthyologist and Zoogeographer, Sunder Lal Hora highlighted the importance of current and substratum as major determinants of faunal distribution and morphology in torrential streams 80 years ago (Hora, 1923; 1927; 1936). Unfortunately, Hora’s work was not pursued further in tropical streams. Despite this early start, it took almost another 50 years to bring out a significant publication on Asian tropical streams. Bishop (1973) comprehensively studied the basic dynamics of the Malaysian river Sungai Gombak environment and its biotic communities providing details of community composition of aquatic insects including mayflies. Meanwhile, the biological communities of higher latitude streams were reviewed and summarized by Macan (1961), Illies and Botosaneanu (1963), Cummins (1966) and Hynes (1970). These studies have led to broad-scale comparisons with large temperate rivers and development of reliable biomonitoring methodologies (Resh, 1979; Armitage et al., 1983). Studies on tropical riverine ecosystems revived with the studies of Dudgeon (1982), which culminated in a comprehensive summary of tropical Asian stream ecology (Dudgeon, 1999). Simultaneously, studies of taxonomy and ecology of South Indian mayflies were carried out (Sivaramakrishnan, 1984; 1985a; Sivaramakrishnan and Peters, 1984; Sivaramakrishnan and Venkataraman, 1987a; 1990; Sivaramakrishnan et al., 1996b). This led to the resurgence of interest in biological communities of Indian riverine ecosystems and helped in developing a full-fledged project on the environment and biodiversity of the river Kaveri, in which the aquatic insect fauna including mayflies were inventoried and monitored in the entire Kaveri basin (Jayaram, 2000) and exploratory studies on the biodiversity of aquatic insects of the Western Ghats (Burton and Sivaramakrishnan, 1993; Sivaramakrishnan et al., 1995; Sivaramakrishnan et al., 2000).

These pioneering studies in Western Ghats streams were followed in the first decade of the present century by equally significant contributions by Subramanian and Sivaramakrishnan, 2005; Subramanian et al., 2005; Anbalagan and Dinakaran, 2006;
Dinakaran and Anbalagan 2007c). In this context, the present investigation aims at documenting the diversity of the Ephemeropteran (mayfly) fauna and improving the knowledge of its Systematics in the riverine ecosystems of southern Western Ghats at various scales. A preliminary attempt is also made to set conservation priorities for the riverine ecosystems of the Western Ghats in general. Habitat inventory and utilization of habitat by fishes were assessed in selected streams of KMTR by Johnson and Arunachalam (2010). This work along with related studies on freshwater molluscs (Madhyastha, 2000), freshwater fishes (Bhat, 2002; Esa and Shaji, 1997; Arunachalam and Sankaranarayanan, 1999a; 1999b; Arunachalam, 2000; Arunachalam et al., 2001), amphibians (Bhatta, 1997; Vasudevan et al., 2001; Biju, 2001), Myristica swamps (Chandran and Divakar, 2001) and Cumulative Impact Assessment of a dam (Ramachandra et al., 2001) have made valuable contributions towards understanding and conserving riverine biodiversity of the Western Ghats.