## Ecological and Economic Importance of Trichoptera (Aquatic Insect)

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## Abstract

Caddisfly insects, order Trichoptera, are one of the most common aquatic invertebrates occurring around the world in rivers, streams, and lakes. They are almost exclusively aquatic in their larval stages and metamorphose to the adult stage in the terrestrial habitat. The aquatic larvae use silk to construct cases in which they reside or to spin silken nets to capture food suspended in the water column. Some caddisfly larvae are caseless. The adults, with their body and wings covered with fine hairs, are crepuscular and resemble small moths. Larvae are important components of aquatic food webs. Most are intolerant of pollution and serve as biological indicators of water quality. They have great advantages and disadvantages in economic terms. The economic benefits obtained from caddisflies include uses such as water quality indicators, nutrition in the human diet, jewelry, and forensic entomology. Even though caddisflies provide many positive ecological and economic benefits, a few species have negative effects. They cause damage to rice crops, pose traffic hazards, and cause allergic reactions. This review provides an overview of the ecological and economic importance of aquatic insects of the Trichoptera order. In addition, research on the Trichoptera order in Thailand are presented.

Key words: Ecology and Economic Important, Aquatic Insect Order Trichoptera

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#### 1. Introduction to the aquatic insect order Trichoptera

The order Trichoptera, or caddisflies, is one of the major aquatic insect orders, which comprises a group of holometabolous insects closely related to the order Lepidoptera, together with the two orders from the superorder Amphiesmenoptera. The scientific name of the caddisflies (Trichos = hair, ptera = wing) refers to the covering of unmodified setae over the wing surfaces of most species. Adult caddisflies are moth-like insects with wings that are covered by fine hairs. The antennae are long and filiform, and the wings are folded tent-like over the abdomen. Typically, adult caddisflies are dull colored, but a few tropical taxa (such as the Macronematinae) may be boldly marked in yellow or white and black (Fig. 1B). The adults ingest liquid only, such as nectar (Nozaki & Shimada, 1997), although some of the mouthparts, the labial and maxillary palps, are well developed. They live for around a month although this varies among species. Most are nocturnal and crepuscular, but some brightly colored Macronematinae (among others) are diurnal. Mating follows swarming or courtship behavior (which can involve sex pheromones), and may take place among riparian vegetation or on the ground. Eggs are laid in or immediately above the water. Larvae can be found in almost any type of freshwater habitat, and are a major component of the stream benthos (Fig. 1A). There are generally five larval instars. Many species are univoltine although bivoltine and trivoltine life histories can occur. Pupation invariably occurs under water, and the pupae are enclosed inside a cocoon within a pupal case that was built by the larva and affixed to the substrate. The pupae have large mandibles which are used to free the emerging pharate adult, which is cloaked within the pupal integument. It nevertheless swims to the surface and moults to the winged adult stage. The pupal case is usually a modification of a moveable larval case or fixed shelter, and the ability of caddisfly larvae to build such structures out of organic or inorganic materials has been a source of fascination for many observers (Dudgeon, 1999). The larval and pupal stages of Trichoptera are, with a few exceptions, entirely dependent on an aquatic environment and are usually abundant in all freshwater ecosystems, from spring sources, mountain streams, large rivers, the splash zones of waterfalls, marshy wetlands, along shorelines and in the depths of lakes, to temporary waters. Certain species are tolerant to high salinities and the species in the Chathamiidae family have managed to colonise tidal pools along the sea shore in New Zealand and eastern Australia. Some species inhabit the brackish inshore waters of the Baltic and White seas (Williams & Feltmate, 1992).



Fig. 1 General life cycle of Trichoptera (A) and some of Macronematinae *Macrostemum midas* (B)

The world catalogue of caddisflies was produced by Fischer (1960-1973) and recorded 5,546 species. The recently published work of Morse (2017) reported that the caddisflies contain approximately 15,000 described species found on all continents except Antarctica. New species continue to be described at a considerable rate, particularly from ongoing studies in the Neotropics, Madagascar, humid regions of Africa, South-east Asia, China and the Philippines. The predictions of Schmid (1984) and Flint et al. (1999), although considered an overestimates by Malicky (1993), suggest that there are in excess of 50,000 species and may be closer to the actual figure (de Moor & Ivanov, 2008). Out of 14,291 species discovered, more than half of these known species were recorded from only two regions, the Oriental and Neotropical Regions (de Moor & Ivanov, 2008). The highest species diversity is recorded in the Oriental region. With more than 3,700 species, it

contains more than double the recorded species for each of the other regions, except the Neotropics (de Moor & Ivanov, 2008). In Thailand the Trichoptera order is represented by 28 families, containing 998 species under 109 genera (Malicky, 2010).

#### 2. Importance of Trichoptera in aquatic ecosystems

Trichoptera are abundant in all types of natural aquatic ecosystems. They are apneustic and rely on dissolved oxygen for respiration. With a high diversity of species having both case and shelter constructing larvae, they are useful indicators of organic pollution. Trichoptera have been used extensively in biomonitoring assays as indicator species, selected communities or assemblages of species or more broadly based family level identification of species being used to assess the health status of aquatic ecosystems (Hannaford & Resh, 1995; Hewlett, 2000; de Moor, 2002). Trichoptera are important processors of organic matter and provide a keystone taxon in the development of the river continuum concept (RCC) (Vannote et al., 1980). As processors of organic matter, collectively known as the functional feeding groups (FFG) of animals, they display the full array of feeding modes (Cummins, 1973). In lotic water filter feeding, shelter constructing species are important predators of blackfly larvae and help to keep population levels of pest species at acceptable level (de Moor, 1992).

The caddisflies are an important component in the diet of freshwater fish. The benthic larvae of Trichoptera are one of the food sources of bottom-feeding fish in various freshwater bodies (Lepneva, 1964; Hickin, 1967). Certain predatory young fish sometimes also feed on Trichoptera larvae and adults. The most useful food for the fish is the macro-caddisfly which appears in great numbers such as various species of Limnephilinae (Lepneva, 1964). Caddisflies are food of terrestrial and wild aquatic birds, some mammals, especially when they fly in great numbers. Some of the amphibians such as frogs and reptiles such as snakes, lizards and even mammals like bears feed on these insects when they are at rest on trees and stones (Lepneva, 1964; Hickin, 1967).

The larval stage of caddisflies play an important role in cleaning up their aquatic environment. The case-making caddisflies, cut up vegetation for the construction of their cases, thus indirectly clearing organic debris found in the habitats and the niche they occupy. They feed on almost all forms of organic matter, living or dead, found in the water bodies. The herbivorous species feed on vegetation only, while the carnivorous species feed on a wide range of freshwater animals and also show cannibalism among their own species (Wissinger et al., 2004).

#### 2.1 Potential use of Trichoptera as water quality indicator

Caddisflies have the potential to be used as water pollution indicator as they are represented by a large and diversified group (Wiggins, 1996). Although caddisfly larvae occur mainly in cool and lotic habitats, they can be found in warm and lentic conditions too. They are site specific and certain groups have the ability to adapt to a harsher environment. Through these adaptations, the available niche in the habitats can be exploited more efficiently.

Caddisfly larvae are known for their ability to construct nets, retreats and portable tubes or cases. These case making behaviors are closely related to their diverse roles in the surrounding environment. Besides serving as shelter, the cases also assist the larvae to capture or obtain food particles from the current through the nets. Portable cases enable the larvae to travel from one place to another for food and they also increase the efficiency of the larvae's respiration through artificial current created by the larvae rather than depending on natural current (Wiggins, 1996). It is common that caddisflies are found to be more abundant in species and biologically more diversified in any given habitat. Therefore, through the adaptation on different types of habitats and case making abilities, the caddisfly larvae have the potential to become one of the most reliable water pollution indicators (Dohet, 2002).

#### 2.2 Trichoptera as forensic entomology

In forensic entomology, the casing of caddisflies can also be used to determine how long a body had been in water (e.g. to answer the question when it was dumped in the water). In a case from the 1950s, a caddisfly casing (most likely of *Limnophilus flavicornis*) contained the fibers of the red socks that were worn by the deceased. However, the fibers were only found at the very top and the very bottom of the casing, which meant that the caddisflies had, for the most part, already built their casing and then finished it at the corpse (fiber on top), and after that and attached it to the red sock (fiber on bottom). Because the attachment procedure takes at least a few days, it was estimated that the body has been in the water for at least one week (Benecke, 2004).

Although few indicators of time since death for corpses found in aquatic ecosystems are comparable in precision to the insect indicators used in terrestrial cases, there are observations that can be useful in suggesting or ruling out an approximate PMSI (postmortem submersion interval). For example, the time intervals required for certain growth phases of aquatic insects, such as caddisflies, that may attach themselves to the submerged remains can be used to estimate a minimum PMSI. A case study in which portions of a body from an adult male were discovered in a south central Michigan stream. The body was dismembered and portions were recovered from two bags floating and submerged in the stream. Insect specimens collected from mesh and plastic bags consisted of one fly larva belonging to the family Muscidae, and caddisfly larvae belonging to two families: the Limnephilidae, (case-makers) and the Hydropsychidae, (net spinners). The unique case-building behaviors of the limnephilid caddisflies were found on the remains to elucidate a PMSI range consistent with the disappearance of the victim. It is important for forensic investigators to understand that although some precision is lost in estimating a PMSI with aquatic insects, these organisms should not be ignored in gathering evidence from aquatic crime scenes, and in fact, they can provide valuable details in estimating a PMSI (Wallace et al. 2008).

However, many species of limnephilid caddisflies construct portable cases made of sticks, leaf pieces, small stones, sand grains, and other inorganic and organic objects. Because of case material type, the size of mineral pieces used in case construction, and the size of the stream from where they were collected, we were able to differentiate between two different species of larval limnephilid caddisflies from the remains, *Pycnopsyche lepida* (stone case) and *Pycnopsyche guttifer* (primarily stick case) (Fig. 2).



Fig. 2 Pycnopsyche guttifer (primarily stick case) (upper) and Pycnopsyche lepida (stone case) (lower) (adapted from Wallace et al., 2008)

A case study from a south central Michigan stream revealed the use of Limnephilidae and Hydropsychidae larvae to determine postmortem submersion interval (Wallace et al., 2008). Investigators used the varying case making behaviors to determine the overlap between time of immersion and time of disappearance of the victim (Wallace et al., 2008).

## 3. Global focus on the economic importance of Trichoptera

#### 3.1 Trichoptera as jewelry

Freshwater insects are also used in decoration, but typically as images rather than actual specimens. For example, dragonflies are a common motif in jewelry, textiles, and tattoos. It may be that these insects (along with butterflies) provide bilateral symmetry when their wings are at rest, and consequently have aesthetic and artistic appeal. There is, however, at least one use of aquatic insects in jewelry: the West Virginia-based firm Wildscape produces caddisfly case pendants from the cases of emerged *Pycnopsche* caddisflies that are reared at large scales in their laboratory (Fig. 3 and Fig. 4) (Resh & Rosenberg, 2015)



Fig. 3 The Wonderful Caddis Worm: Sculptural Work in Collaboration with Trichoptera. [online]. Available http://www.mitpress2.mis.edu/ejournals/Leonado/isast/ duprat.html. [7 October 2005]. (Duprat & Besson, 1997)



Fig. 4 The Wonderful Caddis Worm: Sculptural Work in Collaboration with Trichoptera. [online]. Available http://www.mitpress2.mis.edu/ejournals/Leonado/isast/ duprat.html. [7 October 2005]. (Duprat & Besson, 1997)

#### 3.2 Trichoptera as human diet

Despite the potential of caddisflies to be used in the human diet, by virtue of their accessibility and the size of their larvae, there are few records of entomophagy. It is practiced, however, in Japan where the larvae are boiled and then sautéed in soya sauce and sugar. This is a delicacy known as Zaza-mushi ('zaza' meaning 'the sound of rushing water', and 'mushi' meaning 'insect') (Williams & Williams, 2017). The most commonly eaten species are *Stenopsyche griseipennis, Parastenopsyche sauteri*, and *Cheumatopsyche brevilineata*, and those collected from the pristine Tenryu River are particularly prized. The high production of larvae in this river is due to a high nutrient load carried down from an upstream lake (Césard et al., 2015). There are also anecdotal records of caddisflies being eaten in Mexico and Southern Asia (Pakistan to Nepal to Sri Lanka) (Deutsch & Murakhver, 2012).



Figure 5. A. Processing zazamushi: the catch is spread on the first sieve of the grader (left), the catch is composed of mixture of insects, debris and detritus (right). B. Processing zazamushi: after boiling and cleaning, the insects are spread to be sorted a final time by size and quality (left), the insects still contain small debris and detritus (right). C. Zazamushi are cooked with sugar and soy sauce and packaged. A glass bottle contains approximately 30 g of insects (Adapted from Césard, 2015).

## 4. Nuisance of Trichoptera

Mass emergences of some aquatic insect species (e.g., Trichoptera, Ephemeroptera, and Diptera) can deface human property, result in economic losses to businesses, pose traffic hazards, and cause allergic reactions. Perhaps the most common human response is repulsion at the aesthetic mess, including the smell of rotting carcasses, created by such mass emergences (Rosenberg & Resh, 2015).

Of the approximately 7000 known species of caddisfly, all but a few live in freshwater lotic or lentic habitats. Within these, they have become adapted to a wide range of conditions and, where favorable, their larvae can occur at high densities. Consequently, the adults often emerge synchronously and in large numbers, and are strongly attracted to lights. These mass emergences can be a nuisance around urban rivers and lakes (e.g., the 'shad-fly' emergences that occur annually, in May and June, from the St. Lawrence, Winnipeg, and Niagara rivers in Canada (Resh & Rosenberg, 2015). However, such events provide opportunities for harvesting—although, again, there are few records of this happening. A particular habitat that promotes very high larval densities of net-spinning families (e.g., the Hydropsychidae) is the fast water flowing over flat concrete surfaces at dam outflows or around hydroelectric generation stations (Stiege, 2004). In a manner similar to that described above for blackflies, concrete slabs or slates inserted into suitable rivers can replicate such habitats from which late-instar larvae and pupae can be gathered. An alternative artificial substrate is sheets of artificial turf ('astro-turf') to which net-spinning larvae readily attach. There is also the potential for larger, lentic species to be raised in tank or small artificial ponds, especially those that emulate vernal woodland pools.

The canal's walls of reservoirs and hydroelectric power stations provide new habitats to some species of Hydropsychidae. These species have been recorded to settle on the walls of canals, where larval cases, nets and pupal shelter are built. The larval and pupal shelters, which consist of solidly glued sand grains and gravel, form scaling and thus, narrowing the canal and often reducing the output of the power stations by 10-20%. In order to prevent thickening of scale on the wall, periodic scraping of the canal wall or other methods such as using cuprous oxide paint are recommended but all these will lead to higher maintenance cost (Lepneva, 1964). Caddisflies are often found in extraordinary large numbers, yet they are usually go unnoticed. They are hardly regarded as pests and only occasionally they caused considerably minute economic damages to the local community. In the larval stage, the species *Limnephilus lunatus* and some other species, cause damage to some of the water plants such as watercress beds by chewing the stalks and shoots for food and to construct their retreats. A few species have been recorded as pests in the rice fields as they cause damage to the newly transplanted rice plant (Hickin, 1967). During the nuptial flight, caddisflies shed their pupal exuviae. These

exuviae float on the water and may eventually, lead to clogging of filters of municipal water pipes (Hickin, 1967).

## 5. Research on Trichoptera in Thailand

### 5.1 Previous taxonomic research in Thailand

Caddisflies in Thailand have been researched since 1931 by Martynov (Dudgeon, 1999), who reported on a collection of Trichoptera from Siam and China, and described a new species, *Stenopsyche siamensis*. In 1987, Malicky started to collect caddisflies near streams on Doi-Suthep mountain which was his first paper on caddisflies in Thailand. Later, his research cooperated with Dr. Porntip Chantaramongkol and produced a series of 36 papers, which provided descriptions and illustrations of adult caddisflies. The most recent synopsis of Thai caddisflies reported 491 species and the minimum estimation of 700 species (Malicky & Chantaramongkol, 1999). Consequently, over 998 species of adult caddisflies have been reported (Malicky, 2010).

Various studies (Dohet, 2002; Lenat & Resh, 2001; Resh, 1992) have noted that the need for diagnostic keys to identify immature stages of caddisflies has become increasingly important with regard to understanding their potential as water quality indicators. Larval association and descriptions of species of Hydropsychidae have been improved and made available over the last few decades. Studies on caddisfly larval taxonomy are not only important for the realization of their potential as water quality indicator organisms, but are also vital for a number of other reasons. Firstly, such studies may be used as a starting point from which natural history and a wide spectrum of ecological investigations may be based. Any such studies hinge on correct species determination. Secondly and most importantly, from the trichopterologist's point of view, such studies give a new dimension of characteristics (the larva) from which diagnostic and phylogenetic data may be gleaned. Knowledge of the immature stages may enable a greater understanding of the systematics and phylogenetic relationship within Trichoptera. Ultimately, these may give rise to a better understanding of the entire order Trichoptera (Schuster & Etnier, 1978). Unfortunately, our taxonomic understanding of the immature stages of caddisflies in Thailand remains very poor.

Studies on Thai caddisflies have been confined mainly to descriptions of the adult stage, and relatively few larvae have been characterized adequately. Descriptions of

several Thai caddisfly larvae were given in papers by Malicky & Chantaramongkol (1991; Trichomacronema paniae (Malicky & Chantaramongkol, 1991), Malicky (1999; Ugandatrichia maliwan Malicky & Chantaramongkol 1991), and Thamsenanupap et al. (2005; Arctopsyche hynreck Malicky & Chantaramongkol 1991; Arctopsyche variabilis Schmid 1968; Eoneureclipsis sp.; Psilotreta trimeresuri (Malicky 1989), as Inthanopsyche trimeresuri Malicky 1989; Himalopsyche acharai Malicky & Chantaramongkol 1989). Descriptions of additional hydropsychid larvae were recently published, including in Prommi et al. (2006a; Hydromanicus adonis Malicky and Chantaramongkol, 1996 and Hydromanicus klanklini Malicky and Chantaramongkol, 1993), Prommi et al. (2006b; Pseudoleptonema quinquefasciatum Martynov 1935 and Pseudoleptonema supalak Malicky and Chantaramongkol 1998) and Prommi et al. (2006c; Potamyia phaidra Malicky and Chantaramongkol, 1997), Laudee (2008; Ugandatrichia spp.), Permvarunyoo & Prommi (2013; Amphipsyche gratiosa Navás 1922) and (A. meridian Ulmer 1902), Prommi & Permkam (2015; Hydromanicus malayanus Banks 1931), (H. abuid Malicky & Chantaramongkol 1993), and (H. inferior Chantaramongkol & Malicky 1995), Laudee & Prommi (2016; Cheumatopsyche lucida Ulmer 1907). Recently, the final larval instar of four species of Hydropsyche (H. dolosa Banks 1939, H. brontes Malicky & Chantaramongkol 2000, H. camillus Malicky & Chantaramongkol 2000, and H. napaea Mey 1996) from Thailand have been described and figured. Some notes on the biology, distribution and habitat of the species are provided (Prommi, 2016).

#### 5.2 The use of Trichoptera as water quality indicators in Thailand

Water pollution is one of the most serious environmental problems facing Thailand today. Most sewage enters waterways without adequate treatment, degrading the quality of Thailand's freshwater supply. The traditional water quality monitoring approach has been collecting stream water samples and analyzing them in a laboratory for suspected physical and chemical pollutants. Unfortunately, sampling and analysis methods are expensive and concentrations of pollutants vary greatly with time and location. Physical and chemical monitoring alone often cannot indicate nonpoint source pollution problems. In contrast, biological monitoring gives an indication of past conditions as well as current conditions (Resh et al., 1996). It is very important to develop efficient, fast, and inexpensive techniques to diagnose and monitor negative perturbations to aquatic ecosystems.

One of the most important biological indicator taxa for water quality is Trichoptera. This group of insects is ideal because it is high in biodiversity, inhabits many ecological niches, and is abundant (Dohet, 2002; Wiggins, 1996). However, many caddisfly species are known for their intolerance of habitat sedimentation and organic pollution (Dohet, 2002), so their numbers may strongly diminish downstream of habitat disturbances (Berlin & Thiele, 2002). In contrast, some species are more tolerant of organic pollution and may increase in abundance downstream of such disturbances (Dohet, 2002). Adult Trichoptera that emerge from streams live in the nearby riparian zone where they may select streamside trees as preferred sites to rest while awaiting proper swarming time, to feed in order to increase egg production, or to mate (Jackson & Resh, 1991). Provision of suitable habitat for adult aquatic insects, both in terms of its quality and quantity, is an important consideration as the adult stage can be critical in regulating population numbers of aquatic larvae, and adults can play an important role in terrestrial food webs (Ormerod & Tyler, 1991). Caddisflies of the family Hydropsychidae are some of the most abundant and common species in Asian freshwater (Dudgeon, 1999), especially in medium-size lowland and upland rivers and large lowland rivers. This is the reason why they often are treated as potential indicators of water pollution.

Documentation for the use of adult caddisflies as bioindicators of water quality in Thailand has been given in the papers of Chiabu (2000); Laudee (2002); Cheunbarn (2002); Prommi & Thani (2014); Prommi et al. (2014); Prommi (2015); Prommi et al. (2016). Caddisflies were chosen for this study because they are usually more diverse than other aquatic insect orders (Wiggins, 1996). Adults have been studied widely because they are easily collected by light traps and can be used as a useful tool for bioassessment (Greenwood et al., 2001; de Moor 1999). Chantaramongkol (1983) recommended light trapping for assessing water quality in large rivers. Knowledge of the taxonomy and ecology of the species has proven valuable in biomonitoring programs because of differences in susceptibilities of the various species to pollutants and other types of environmental disturbances. Genus- or species-level identifications of adult caddisflies are possible and clearly produce more accurate results than family-level identification, thereby giving better ability to assess changes of water quality.

# 5.3 Hydropsychid gill morphology (Insecta: Trichoptera: Hydropsychidae) association with water quality parameters

The gills of an aquatic macroinvertebrate are one of the most impacted structures on the body of the organism when the environment in which it lives is altered. They are especially sensitive due to their large surface area and their ability to accumulate compounds and gases (Laporte et al. 2002). Heavy metals, especially mercury and its methylated form, and acidic pH are two factors that are often present in streams due to the burning of fossil fuels elsewhere (EPA, 2001).

The caddisfly family Hydropsychidae have been increasingly utilized in biomonitoring and impact assessment of pollutants in rivers for several reasons (Vuori, 1994; 1995; Vuori & Kukkonen, 1996). First, hydropsychid larvae are widely distributed and abundant in many types of running waters. Second, they respond to variations in water quality and their autecology is well known enough for the impact of pollutants to be distinguished. Third, due to their robust body, hydropsychid larvae are easily handled and observed for morphological abnormalities. Fourth, the abnormalities in the hydropsychid tracheal gills, the ion-regulatory organ and the anal papillae can be attributed to a disruption of the respiratory and ion regulation functions. Fifth, the relatively large size facilitates sampling and analysis of the concentrations of chemicals in the larvae. Finally, the hydropsychid larvae as facultative filter feeders are more exposed to pollutants in seston, flowing water and the organic matter accumulated in riffle microhabitats. The gills of hydropsychid larvae are one of the most impacted structures on the body of the organism when the environment is altered. They are particularly sensitive due to their large surface area, which increase the accumulation of compounds and gases (Skinner & Bennett, 2007). Direct effluent discharges and agricultural runoff water mostly contain complex mixtures of contaminants that may produce new compounds due to breakdown and transformation processes and hence contribute to the complexity of the total toxin burden. By the employment of chemical and physical measurements only, the synergistic effect of pollution on its biotic community may not be fully and easily assessed (Resh & Jackson, 1993). In general, biological indicators provide a potential for direct observation of the overall effect of environmental contaminants by virtue of their role in aquatic ecosystems (Warwick, 1988). Research work on the use of individual gill morphology alterations in hydropsychid larvae and possible impacts of water quality parameters (e.g.,

dissolved oxygen (DO), pH, water temperature, conductivity, total dissolved solids (TDS), sulfate, nutrients, and some heavy metals on gills morphological structure were investigated on gill abnormalities in populations of hydropsychid larvae in Kanchanaburi Province, western Thailand. The results showed heavily darkened, malformed and/or reduced single gill tufts. The gill pigmentation was obvious, starting from either basal or distal ends and amounted to 69.51% and 74.19% as we observed in the populations at Huai Pakkok. Completely dissolved solids, alkalinity, and orthophosphate concentration were negatively correlated with gill abnormalities at p<0.05, p<0.01, whereas the pH and Cu concentration parameters were positively correlated (p<0.05) (Prommi, 2011; Prommi & Thamsenanupap, 2013).



**Fig. 6** Hydropsychidae gills abnormalities in *Amphipsyche meridiana* (A), *Amphipsyche gratiosa* (B) and *Macrostemum floridum* (C) (Prommi, 2011; Prommi & Thamsenanupap, 2013).

As mentioned about the economic importance of caddisfly in Thailand, a few cases were reported by Seetapan (unpublished data), who used black spinel for case construction of *Marilia sumatrana* (Odontoceridae) (Fig. 7) in an aquarium tank. This work will be used for jewelry industrial in the future.



Fig. 7 Odontoceridae case (Seetapan, unpublished data)

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