PREFACE

Vector-borne diseases such as malaria, filariasis, Japanese encephalitis, dengue and many other arboviral diseases are emerging and resurfing as serious public health problems and cause a huge medical, financial burden and social disarray in developing and under-developed countries (Sathe, 2011). This is due to drastic demographic changes, poor sanitary condition as a consequence of rapid unplanned urbanization, change in agricultural practices, failure to maintain previously effective control measures, absolute control strategies, progressive spread of drug resistance and lack of identification of epidemic risk indicators (Das and Amalraj, 1997).

Chemical pesticides and insecticides failed to give sustained control of vector population and their overuse resulted in development of resistance, elimination of natural enemies with subsequent imbalance in the ecosystem. To rationalize the use of insecticides with minimum impact on the environment it is now advocated to suppress the target population through integrated approach including the use of bio-control agents. Mosquitoes can live on almost every continent and habitat. There are 3,500 described species of mosquitoes in the world (Sathe and Tingare, 2010). Biological control as a management tool dates back over 1,000 years when ancient Chinese citrus growers used ants to control caterpillar larvae infesting their trees. It is one of the safest methods of control since it is not toxic, pathogenic or injurious to humans (Muthupandi et al., 2014). Biocontrol is the least expensive and most sustainable of the pest control options which makes it worthwhile to learn how and when to use it in a pest management
program (Bean, 2012). Management of mosquito immatures through biological
control is being tried world over (Kumar and Hwang, 2006; Manilal et al., 2011).
The sub orders, Zygoptera (damselflies) and Anisoptera (dragonflies) come under
the order Odonata, the two interesting groups of insects as their larvae are fully
aquatic while the adults are terrestrial (Corbet, 1999). Nymphal odonates are
voracious predators of mosquito larvae and occupy a great diversity of aquatic
habitats but are generally most abundant in lowland streams and ponds. The
predatory nymphs are an important part of aquatic food webs and the aquatic
stages of mosquitoes comprise a significant part of the diet of many immature
odonates (Ward, 1992, Westfall and Tennesen, 1996). Indeed, odonates were one
of the first arthropods to be examined as biological control agents (Legner, 1995).

Since the Odonate larvae are hardy they can survive almost all over the
world in varied ecological niches extending from the sea level to over 3,600 meter
altitude and from brackish, marshy area to desert lands. The larvae are critical in
regard to water quality and aquatic habitat morphology such as bottom substrate
and they are an easy-to-study group and are useful for monitoring the overall
biodiversity of aquatic habitats and have been identified as good indicators of
environmental health.

Biological control of mosquito larvae using Gambusia officinalis and
Poecilia reticulata is effective but they required repeated stocking and mass
production that limited their utility. The other mosquito predators such as Ranatra,
Cyclops, Gerrissp., and Diplonychus have been found to be voracious mosquito
predators but only a few have been evaluated in the field is very successful.
Among the Odonate larvae, Bradynopyga geminata, comes under the sub order
Anisoptera, can be found in fresh water habitats like ponds, irrigation tanks, and canals prefer to prey on mosquito immatures. They possess many desirable attributes as good biological control agents such as high reproductive potential, competitive ability, efficient searching, adaptability and synchronization with available host. The functional response studies on B. geminata proved their feeding efficiency against mosquito larvae in the laboratory and so they can be used as very good biocontrol agents to control mosquito immatures.
GENERAL INTRODUCTION

Management of mosquito larvae is a priority area of research in developing countries, including India, where epidemics like malaria, chikungunya, yellow fever, filariasis and dengue fever are rampant due to the outbreak of mosquito populations even though use of chemicals and botanicals are effective in the management of mosquito larvae. Repeated use of synthetic insecticides for mosquito control has disrupted natural biological control systems and lead to resurgences in mosquito populations. It has also resulted in the development of insecticide resistance in mosquitoes and undesirable effects on non-target organisms and fostered environmental and human health concern, initiating a search for alternative control measures.

Biological control is generally defined as the use of natural enemies including pathogens, parasites and predators in reducing pest populations in natural habitats. The incorporation of biological measures in an integrated mosquito control program requires a careful selection of the antagonistic organism, so that the human protection is achieved without affecting the biodiversity and without inducing ecological problems. Use of predatory aquatic larvae belonging to a higher trophic level to feed upon mosquito larvae would be an ideal option since this exploits the natural trophic level relationships without employing chemical pesticides.

Experimental studies over the last century revealed a great diversity of living organisms, including microbes, fungi, protozoa, nematodes, invertebrate and vertebrate predators, as promising mosquito control agents. Weiser (1991)
discussed extensively all groups of organisms that have been tested as potential biological control agents. Introduction of predators which can breed in the environment may provide a continuous control. Vector-borne disease control strategies which were emphasized on eliminating preimaginal stages are more effective as compared to adult control which is not very effective (Kumar and Hwang, 2006).

Usually mosquito populations are controlled by means of variable agents, which apart from the commonly used synthetic chemical insecticides (Rodriguez et al., 2001; Kelly-Hope et al., 2005) include plant products like essential oils derived from leaf and bark of Cryptomeria japonica (Isman, 1999), Coriandrum sativum (Mangalat et al., 2004), Ferula asaftida and the extracts of Murrayakoenigii (Das et al., 2007), Gliricidia sepium (Nazli et al., 2008), Piper nigrum, P. aduncum (Misni et al., 2009), Clausena excavata (Cheng, 2009), Trigonella foenumgraceum (Fallata, 2010), azadiractin, the active ingredient of neem (Rehimi et al., 2011) and are found to have insecticidal and larvicidal activity against Aedes aegypti and Culex larvae.

Microbial insecticides (Park et al., 2001; Darboux et al. 2001; Wirth et al. 2005) that include microbial pathogens of mosquitoes like viruses (Becnel, 2006; Becnel and White, 2007), bacteria (Chansang et al., 2004; Su and Mulla, 2005), protozoans (Dhas, 2003), nematodes (Perez-Pacheco Flores 2005., Kumar and Hwang, 2006) and microsporidia and fungal pathogens, (Becker, 2000; Scholte et al., 2004; Kumar and Hwang, 2006), aquatic beetles (Insects, Coleoptera several families (Lundkvist et al., 2003), and backswimmers (Notonecta sp., Hemiptera, Heteroptera, Notonectidae), (Chesson 1984; Blaustein et al. 1995; Blaustein 1998;
predatory insects such as the belostomid bugs, Diplonychus annulatus and D. rusticus (Aditya et al., 2004, 2005; Pramanik and Raut 2005), crustaceans such as Triops newberjii (Su and Mulla, 2002), and Predatory fishes such as Poecilia reticulata, (Manna et al., 2008), Gambusia affinis (Kumar and Hwang, 2006), Fundulus zebrinus (Chandra et al., 2008), Alburnus alburnus, Phoxinus phoxinus (Medlock and Vaux, 2011), Cyprinus carpio (Gosh et al., 2005), Gobio gobio, Perca fluviatilis, Rutilus rutilus and Tinca tinca (Medlock and Snow, 2008) with particularly adequate life history characteristics and meta population structure (Briers and Warren 2000) have all been used as biocontrol agents to control mosquito populations, but feedback on the effectiveness of these agents is only anecdotal. Some mosquito species have developed resistance to microbial control agents (Rajkumar and Jebanesan, 2007; Manilal et al., 2011). It is therefore time to find out alternative, effective and ecofriendly biocontrol agents to control mosquito populations.

Odonate larvae are voracious and important predators of mosquito larvae in freshwater ecosystems (Sathe and Bhusnar, 2010; Venkatesh and Tyagi, 2013; Varshini et al., 2013). Their life cycle consists of three stages, egg, larva and imago or adult. The former two are aquatic in nature and their habitats are mainly ponds, rivers, streams, tanks and tree holes (Okogun, 2005). Dragonflies are true enemies of mosquitoes as larvae feed on mosquito larvae and adults feed on adult mosquitoes (Kumar and Hwang, 2006).

The natural feeding behaviour of nymphs is also innately effective. They detect their prey by compound eyes and mechanical receptors and capture them with their labium (Shaalan and Canyon, 2009). Odonate nymphs can be released.
into temporary pools or larger habitats where they can be a potential biological resource in regulating the larval population of vector and pest mosquitoes (Mandal et al., 2008). Bay (1974) reported that dragonfly larvae prey heavily on bottom-feeding Aedes larvae. Predatory capacity and prey selectivity of nymphs of the dragonfly Pantala hymenaea (Odonata, Family: Libellulidae) were evaluated on larvae of the mosquito Culex quinquefasciatus (Quiroz-Martínez et al., 2005). Chandra (2008) demonstrated that Brachytron pratense (Odonata) nymphs are dependable predators of mosquito larvae.

The physical and chemical properties of water immensely influence uses of a water body for the distribution and richness of biota (Unanam and Akpan, 2006). Each factor plays its own role but at the same time the final effect is the actual result of the interactions of all the factors. These factors serve as a basis for the richness or otherwise biological productivity of any aquatic environment. Odonates can be used as environmental quality indicators because of the complex requirements of habitat of each species, the presence of a vigorous and diverse fauna of these insects will always be a reliable indicator of stability, health, and integrity of an aquatic ecosystem (Chovanec, 1998, Foote and Hornung 2005). Others believe that the odonates are of minor or irregular value as bioindicators, except in specialized habitats (Carchini and Rota 1985). Nevertheless, odonate communities have become an increasingly important tool in studies on the ecological evaluation of aquatic systems (Schmidt 1985, Osborn 2005).

The functional response of a predator is a key factor in the population dynamics of predator-prey systems. The functional response can determine if a predator is able to regulate the density of its prey (Murdoch and Oaten 1975). The
functional response show density dependence, that was the predator must respond to higher prey densities by consuming an increasing proportion of the available prey over a range of prey densities. So the functional response studies on odonate nymphs predict the feeding efficiency of odonate larvae and that knowledge helped in the mosquito control programme using dragonfly nymph as a biocontrol agent,
OBJECTIVES

- To collect different odonate larvae in three different stations in Kanyakumari District.
- To assess the biodiversity of Odonate larvae in three different stations in Kanyakumari District.
- To calculate the abundance of different odonate larvae in all the three study stations.
- To study the physico-chemical parameters of water collected from three different stations, for 24 months.
- To assess the ability of Bradynopyga geminata naiads to tolerate the toxic effect of an insecticide Chlorpyriphos, Surfactant, Alkyl Benzene Sulphonate and a disinfectant, Sodium hypochlorite under laboratory condition.
- To compare the feeding efficiency of Bradynopyga geminate larvae with ten different genera of odonate larvae.
- To study the functional response of Bradynopyga geminata larvae against mosquito larvae.
REVIEW OF LITERATURE

Review of literature presents the investigations made in different parts of the world, on the Biodiversity of Odonate larvae, Toxicity studies of three different chemicals on the aquatic insects and the test animal Bradynopyga geminata and Functional response of different insects to predict their feeding efficiency.

Ward and Stanford (1982) reviewed the thermal heterogeneity that has shaped temperature response patterns of aquatic insects and analysed the influence of temperature on distribution patterns, life cycle phenomena, behavioural responses and trophic relationships and related patterns of temperature to biotic diversity. Buskirk and Sherman (1985) predicted the oviposition behaviour of dragonflies with respect to its microhabitat and spatial distribution of eggs.


Greenway et al. (2003) shown that the presence of mosquito larvae can be minimised by increasing macroinvertebrate biodiversity like larval stages of dragonflies (Epiproctomorpha), damselflies (Zygoptera), Caddish flies (Trichoptera) and pond snails. Schindler and chovanec (2003) observed dragonfly associations in relation to habitat variables and a multivariate approach. Mikdajewski and Johansson (2004) examined the relationship between...
antipredator behaviour and morphological defence in larvae of three closely related dragonfly species within the genus *Leucorrhinia*.

Catling (2005) explained the extent to which dragonflies have a potential use in evaluating the efficiency of sewage lagoon systems. McCauley (2005) assessed the habitat distribution of the three species of dragonfly, *Anax junius* (Drury, 1773), *Libellula pulchella* (Drury, 1773) and *Libellula luctuosa* (Burmeister, 1839) and examined the relationship between species distribution, larval growth rates, and growth rate plasticity. Foote et al. (2005) analysed the odonates as biological indicators of grazing effects on Canadian prairie wetlands.

Landwer and Sites 2006 used morphometric analysis of mensural characters and qualitative analysis to distinguish larvae of two species of Odonata. Laurie et al. (2006) studied the life History phenology and sediment size association of the Dragonfly Cordulegaster dorsalis (Odonata: Cordulegastridae) in an ephemeral habitat in South Western British Columbia. Mitra (2006) prepared a checklist of Odonata of Bhutan by collecting specimens of dragonflies from Trashiyangtse and Pemagatshel districts of eastern Bhutan and four among these were new records for Bhutan. Yeh et al. (2006) reported three dragonfly species namely Sinolestes edita Needham (Synlestidae), Zyxomma obtusm Albarda (Libellulidae), and Macromidia ishidae Asuhina (Corduliidae) from Taiwan for the first time.

Dmitriew et al. (2007) studied effects of early resource-limiting conditions on patterns of growth, growth efficiency, and immune function at emergence in a damselfly. Marczak et al. (2007) tested whether larval instars were distributed
randomly or if they occupied different sediment microhabitats and observed high density of odonate larvae in small, shrinking pools during late summer. They also found smaller larvae appeared to be associated with finer sediments while medium-sized and large larvae were most abundant in gravel and stones respectively. Englind et al. (2007) attempted the various integrating factors that appear to be presently limiting the distribution of native aquatic insects in Hawaii. Yasuoka and Levins (2007) analysed correlatios between several climatic factors and mosquito density, and how these factors affect mosquito oviposition, propagation and survival and suggested that concerving aquatic insect species could be effective in controlling mosquito vectors in the study site.


Remsburg and Turner (2009) made a survey of larval Odonates at a variety of lake and site conditions and field experiments. Chase et al. (2010) suggested that habitat isolation can strongly influence the abundance, richness and composition of species at multiple trophic levels through direct effects of isolation on the species themselves, as well as effects mediated through the modification of top-down control in the food web. Arulprakash and Gunathilagaraj (2010) studied the abundance and diversity of Odonata in temporary water bodies of Coimbatore and Salem districts in Tamil Nadu. Aly et al. (2010) aimed to study the diversity of Odonatous adults and naiads species encountered in the River Nile current throughout Upper Egypt.

Harabis and Dolny (2010) identified the important determinants of dragonfly density and distribution based on the regional distribution of dragonflies in the Czech Republic. Mohamed et al. (2010) studied diversity of some aquatic and aerial odonatous dwellers of the River Nile in upper Egypt. Sathe and Bhusnar (2010) studied the Biodiversity of mosquitovorous dragonflies (Order: Odonata) from Kolhapur district including Western Ghats.

Anaya et al. (2011) studied diversity and distribution of Odonata larvae along an altitudinal gradient in Coalcoman mountains, Michoacan, Mexico. Anderson et al. (2011) observed the direct and indirect effects of temperature on a
predator-prey relationship evaluated the diversity of Odonata larval assemblages from the Coalcoman Mountains. Lambertz et al. (2011) identified Odonates from a Caldera Lake of an active Galapagos Volcano. Dolny et al. (2011) sampled the different species of Odonates at Sungai WalnProtectio forest, East Kalimantan, Indonesia. Remsburg (2011) demonstrated that locations with higher densities of Odonates in the water also have higher densities of Odonates on land.

Manwar et al. (2012) explored the diversity and abundance of dragonflies and damselflies of Chatri lake region. Rudolf (2012) suggested that the relationship between predator diversity and prey suppression depends on variation in predator traits such as body size which strongly influences the type and strength of species interactions. May (2012) reviewed on the migration of dragonflies (Odonata: Anisoptera) on North America. Das et al. (2012) observed Odonates diversity in buffer area of Similipal Biosphere Reserve. Balzan (2012) investigated how Odonatae assemblage structure and diversity are associated with habitat variables of local breeding habitats and the surrounding agricultural landscape.

Tang et al. (2013) collected and described about an endemic and endangered new Sympetrum antouensis from the subtropical area of Taiwan. Dijkstra et al. (2013) classified the biodiversity of dragonflies and damselflies (Odonata). Abhijna et al. (2013) documented the diversity of aquatic entamofauna in Vellayanilake, Kerala and also emphasized the impacts of pollution by using bio-indicators of water quality. Paul and Kakkassery (2013) examined the characters of Odonate nymphs by using their exuviae having all the larval characters. Din et al. (2013) conducted a thorough survey of Potohar Plateau to
explore Odonata naiads fauna of this versatile plateau of Punjab in Pakistan. Majumder et al. (2013) carried out a study to identify the aquatic entomofauna, their diversity and distribution in three urban fresh water lakes of Tripura.

VarunPrasath and Daniel (2010) evaluated the physicochemical parameter of river Bhavani by using standard method, which enables the common man to understand the quality of water. Lawson (2011) conducted a study on physicochemical parameters and heavy metal contents of water from the mangrove swamps of Lagos lagoon. Shelly et al. (2011) conducted a study to compare the physicochemical factors and macroinvertebrate fauna of Chashma Barrage and Mangla Dam wetland areas due to the differences in capacities, locations, altitude latitude and anthropogenic activities. Srivastava et al. (2011) determined physicochemical parameters of Ramganga River at different sampling sites at Moradabad districts and assumed the present water quality of Ramganga River, through analysis of some selected water quality parameters. Wahizatul et al. (2011) showed that distribution of aquatic insect communities could be useful bioindicators of the biomonitoring approach in relation to water physicochemical parameters to assess, classify and compare the water quality of freshwater streams in Malaysia.

Shah et al. (2012) determine the physicochemical characteristics of water samples in order to assess the water quality status of Wular Lake, the largest freshwater lake in Indian subcontinent. Khalik et al. (2012) aimed to assess present status of Bertam River water quality in different localities of anthropogenic impacts as well as to determine seasonal variation such as atmospheric precipitations influences on aquatic ecosystems. Shetty et al. (2012) undertook a
survey to know the seasonal variation in nutrient content and physicochemical parameters of water along the upstream of the river Tungabhadra, Western Ghats, India. Sahni and Yadav (2012) dealt with the seasonal variations in some important Physicochemical parameters of Bhara was pond, district Rewari and observed that the pollutant receiving water body appears as an aquatic desert which is most unsuitable for aquatic biota and for aquaculture.

Asarpira et al. (2013) assessed the potential of aquatic macrophytes to improve the physicochemical characteristics of waste water. Abdar (2013) investigated the physicochemical characteristics and phytoplankton composition of the Morna Lake, Shirala, India. Balakrishna et al. (2013) attempted to investigate the physicochemical parameters and composition of the zooplankton community in Ghanapur Lake, Warangal, A.P., India. Jena et al. (2013) monitored Kharoon River water quality at Raipur by physicochemical Parameters analysis and the analyzed data were compared with standard values recommended by WHO. Shrivastava and Kanugo (2013) analyzed water quality in terms of physicochemical parameters of pond water near 10 village of Surguja, District Chhattisgarh State. Findik (2013) assessed metal concentrations and physicochemical parameters in the water of Beyler Reservoir (Kastamonu, Turkey) and detected that the reservoir has considerably high quality water and can be used as potable water in terms of these parameters.

Lodhi et al. (2014) evaluated the physicochemical status of Dihailalake at Karera as a primary data for sustainable management. Khalid et al. (2014) organized a study to explore the primary productivity and physicochemical properties of Keenjhar Lake. Roy et al. (2014) researched on the hydrobiological

Uyom et al. (2014) worked on the physicochemical parameters of AkpaYafe River water. Salahuddin et al. (2014) ascertained the magnitude of seasonal dial variation in physicochemical and biological variants with reference to phytoplankton, zooplankton and primary productivity at newly formed reservoir of Narmada. Shrame et al. (2014) focussed a study on the physicochemical status of pond water. Ahmad et al. (2014) undertook a study to assess variation in water quality with time variation of Wullar Lake, Srinagar, Kashmir. Patel et al. (2014) dealt with the seasonal effect of physicochemical parameter of Beehar River, Rewa District. Physicochemical parameters and nutritional loads of major rivers and streams were monitored by Omaka et al. (2014).Mishra et al. (2014) investigated the water quality of the ponds at Varanasi City under anthropogenic influences.

Tanwar and Tyor (2014) demonstrated the physicochemical parameters of recreational lake Tilyar in the summer and monsoon months. Shanmugasundaram et al. (2014) analysed the physicochemical parameters of drinking water from different sources in Coimbatore. Nithyavathy and Balasingh (2014) analysed the physicochemical status of four fresh water charophyte harbouring stations of Kanyakumari district. Jacob et al. (2014) studied the physicochemical
characteristics of River Jameson, which is one of the prominent fresh water rivers used for drinking and domestic purposes in this region of Delta state, Nigeria. Ghannam et al. (2014) assessed the physicochemical parameters and heavy metals seasonally from El-Bahr El-Pharaony drain, Egypt from summer to spring. Okomoda et al. (2014) evaluated the chemical and Biological parameters of Potable water in Kogi State metropolis of Nigeria.

Chlorpyrifos is an organophosphorous compound, very toxic to fish, and moderately to very highly toxic to amphibia and aquaticinvertebrates. It can have significant effects on aquatic community structure. Evaluation of LD50 values (mg/kg) indicated that aquatic insects might be more sensitive than terrestrial insects (Siegfried, 1993). Chlorpyrifos is primarily used to kill mosquitoes in the immature larval stages of development. It is generally considered to be non-persistent in the environment (Sharom et al., 1980). Technical grade chlorpyrifos generally appears to be of similar or greater toxicity than controlled release or emulsifiable concentrate formulations with lower LC50 values (Jarvinen and Tanner, 1982).

Maki et al., (1975) compared toxicity of larval lampricide (TMF, 3-trifluoromethyl-4-nitrophenol) to selected benthic macroinvertebrates. Hilsenhoff (1988) made a rapid field assessment of organic pollution with a family-level biotic index. Plafkin et al., (1989) suggested rapid bio-assessment protocols for use in streams and rivers on benthic macro-invertebrates and fish. According to Mace and Woodburnt (1995) the predominant determinant of chlorpyrifos toxicity to fish appears to be the test species, but toxicity may be influenced by exposure conditions, formulation, source and size of fish and water quality. Water hardness
and pH do not appear to influence toxicity in laboratory tests because chlorpyrifos is nonpolar and non-ionizable. However, pH and temperature can affect the dissipation rate in water, which may influence environmental exposures (Racke, 1993). Size of fish has been reported to influence toxicity in static tests (El-Refai et al., 1976), possibly because absorption by the fish decreases the exposure concentration (Barron et al., 1993).

Wallace and Webster (1996) studied the role of macroinvertebrates in stream ecosystem function. Stuijfzand et al. (2000) reported different variables in determining the impact of diazinon on aquatic insects such as taxon, developmental stage, and exposure time. Charvet et al. (1998) suggested biomonitoring through biological traits of benthic macroinvertebrates as a general tool in stream management. Boudou et al. (1991) studied the fundamental roles of biological barriers in mercury accumulation and transfer in freshwater ecosystems.

The studies regarding detergent toxicity started as early as 1970. The toxicity was monitored at first at the level of behavioural, physiological and histological changes. The blocking effects of cationic and anionic (ABS) compounds were noted on the olfactory epithelium of Atlantic salmon at 1 ppm (Sutterlin et al., 1971). The most commonly studied detergents were branched alkyl benzene sulphonate (ABS) and linear alkyl benzene sulphonate (LAS or LABS) which were used extensively in commercial products mainly cleaners (Abel, 1974).

The effects of linear alkyl benzene sulphonate on fish Tilapia mossambica, plankton Diaptomus forbesi and the worm Branchiura were studied by Konar and Chattopadhyay (1985). The feeding rates were decreased at 0.25, 0.38 and 1.1
ppm. Respiration was largely affected in presence of surfactants. The respiratory rate was increased in Lepomismachrochirus at concentrations above 1.56 ppm when exposed to alkyl ethoxylates (Maki, 1979). The detergent exposure (oil spill dispersants) was found to induce conditions similar to hypoxia. There was an increase in heart rate and ventilation cunner fish exposed to non-ionics viz. Triton X-100, Tween 20 and the anionic sodium lauryl sulfate. All the surfactants tested produced the same response differing only in the threshold concentrations.

Data regarding surfactant toxicity are also available for invertebrates like sea urchins, sponge, star fish etc. (Swedmark et al., 1971; Hidu, 1965; Vailati et al., 1975 and Moffet and Grosch, 1967). Marchetti (1965) and Pickering (1966) stated that developmental stages of fishes were especially sensitive to surfactants. Holman and Macek (1980) found that there was a reduction in the survival rate of fish larvae at 0.5 ppm of linear alkyl benzene sulphonate (LABS). The survival of the first generation of larvae was significantly reduced at 0.25 ppm of linear alkyl benzene sulphonate and also there was a reduction in spawning. Hidu (1966) also reported stunted growth and decreased survival rates of veliger larvae of clams and oysters in presence of low concentrations of surfactants.

Hara and Thompson (1978) reported that sodium lauryl sulphate (SLS) at 0.1 ppm depressed the olfactory senses in the white fish Coregonus lupeaformis. SLS was also found to cause a decrease in shell weight of the snails (Tarazona) at 0.61 ppm and alkyl benzene sulfonate interfered with the uptake of calcium (Misra et al., 1984).

Sprague and Drury (1969) observed avoidance reaction of salmonids at very low concentrations of alkyl benzene sulphonate. It was also observed that the
avoidance reaction was more pronounced in case of exposure to anionic surfactants. Swedmark et al. (1971) have studied the responses of fish, mussels, clams and crustaceans on exposure to various anionic and non-ionic surfactants. The swimming activity was affected in case of fishes and it was observed that more reactive fish species were affected the most. Swimming of the nauplius larvae of Balanus and zoea of Hya were also seriously affected on exposure to surfactants.

Avoidance reactions for anionic surfactants were studied on a large scale by many workers. Concentrations between 0.002-0.011 ppm of linear alkyl benzene sulfonate and alkyl sulfates elicited avoidance reactions (Tatuskawa and Hidaka, 1978) in Pleco glossus. In case of medaka, the concentration required was 0.007-0.027 ppm (Hidaka et al., 1978). For alkyl benzene sulfonate the concentration eliciting the avoidance reaction was 0.001 for Salmo gairdneri and 0.02 ppm for Gadus morrhua. A higher concentration of non-ionic surfactants was required for eliciting avoidance reactions. For C9 alkyl phenol 10 ethoxylates it was 2-4 ppm (Hoglund, 1976). The responses to the surfactants were erratic in most of the cases. Swimming and feeding responses were affected at higher concentrations.

sludge used on agricultural soil. Hrenovic, and Ivankovic (2007) investigated the
harmful effects of surfactants and their potential toxicity in a pure culture of
Acinetobacter junii, a phosphate (P)-accumulating bacterium.

Stefanoni and Abessa (2008) evaluated the effects of the Linear
Alkylbenzene Sulphonate (LAS) on the mussel Pernaperna (Linnaeus, 1758),
using a cellular level biomarker. Nwamba et al. (2009) presented the results of the
study of the exposure of Dutch Clarias gariepinus juveniles to different
concentrations of crude oil products and Detergents and their effect on the alkaline
phosphatase.

Ogeleka et al. (2010) estimated the short-term toxicity of two commonly
used chemicals, to fish (Tilapia guineensis); shrimp (Desmoscaris tripinsosa) and
earthworms (Aporrectodea longa). Flores et al. (2010) determined the effect of
linear alkylbenzene sulfonate (LAS), anthracene and a LAS-anthracene mixture on
the growth of a microbial consortium isolated from polluted sediment. Mandel et
al. (2010) studied the effect of surfactants on phosphatase level of fresh water fish
Labeorohita and found maximum increase in the liver followed by muscle and gill.

Buschini et al. (2004) evaluated the genotoxic potential of the world wide
used disinfectants sodium hypochlorite and chlorine dioxide in human leukocytes
by the Comet assay and in Saccharomyces cerevisiae strain D7. Sodium
hypochlorite was first registered for use as pesticides in 1957. Many studies have
detected the presence of mutagens in drinking water, due not only to different
pollution sources but also to disinfection treatment (Kraybill, 1981; Miller et al.,
1986; Meier, 1988; Vartiainen et al., 1988; Monarca and Pasquini, 1989; Peters et
Al., 1990; Suzuki and Nakanishi, 1990; Kusamram et al., 1994; Filipic et al., 1995; Zia'ee, 1995; Rehena et al., 1996; Cantor, 1997 and Hofer and Shukes, 2000).

It is known that chlorine reacts with organic matter (humic and fulvic acids derived from plant decomposition) present in untreated surface water to give disinfection by-products (Kruithof, 1985; Monarca et al., 1985; Cognet et al., 1986; Kowbel et al., 1986; Fielding and Horth, 1986; Richardson et al., 1994; De Marini et al., 1995; Lee et al., 2001 and Woo et al., 2002).

Chlorine provides very effective protection against waterborne infectious disease, but there are some epidemiological reports of a cancer risk associated with chlorinated water (Meier, 1988; Flaten, 1992; Morris, 1995). The genotoxic activity and carcinogenic action of chlorinated drinking water are also considered to be due to OCI itself (Whiteman et al., 1999; Ohnishi et al., 2002).

IARC (1991) considered NaClO is non-classifiable for carcinogenicity by the (group 3), although it was shown to give positive results. In some short-term mutagenicity tests: Escherichia coli and Salmonella typhimurium (point mutation), Chinese hamster (chromosome aberration), human broblasts (sister chromatid exchange) and mouse (sperm morphology) (Meier et al., 1985; Wlodkowski and Rosenkranz, 1975; Ishidate et al., 1984; Ishidate, 1988). Furthermore, OCl was shown to directly induce different kinds of DNA damage in relation to the cellular content (Patton et al., 1972; Winterbourn, 1985; Whiteman et al., 1997, 1999; Ohnishi et al., 2002).

Sodium hypochlorite is low in toxicity to avian wildlife, but highly toxic to freshwater fish and invertebrates (U.S. EPA, 1991). Thirty-three freshwater species in 28 genera have been exposed to sodium hypochlorite, and the acute LC50 values

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for total residual chlorine (sum of the free and combined chlorine) range from 28 pg/L for *Daphnia magna* to 710 pg/L for three spine stickleback (U.S. EPA, 1986a). Necrosis, chlorosis and leaf abscission have been noted when sodium hypochlorite is applied directly to plants (Chase and Osborne, 1984).


Relyea and Hoverman (2008) examined how a range of concentrations of a globally common insecticide affected freshwater communities containing a diversity of phytoplankton, periphyton, and 27 species of animals (zooplankton, snails, larval amphibians and predatory insects). Echols et al., (2009) described preliminary results of laboratory toxicity tests with the mayfly, *Isonychia bicolor* (Ephemeroptera: Isonychiidae) for development as a standard test organism for evaluating streams in the Appalachian coalfields of Virginia and West Virginia.

Davoodi and Abdi (2012) did a comparative study on the acute toxicity of synthetic pesticide, Permethrin 25% and Monocrotophos 36%, and Neem-Based Pesticide, Neem Gold EC 0.03%, to Juvenile *Cyprinus carpio* Linn. Majumdar and Gupta (2012) attempted to investigate the acute toxicity of copper sulphate on the third instar larvae of *Chironomous ramosus*, as well as the effects on sublethal
endpoints such as growth, emergence, pupation, ventilation movement and tube construction.

Haro et al., (2013) used burrowing dragonfly larvae as biosentinels of methylmercury in freshwater food webs and provided guidance on the application of burrowing gomphids as biosentinels of MeHg contamination, which can extend the bioassessment of MeHg to fishless fresh waters. Tennekesa and Sanchez-Bayob (2013) studied the molecular basis of simple relationships between exposure concentration and toxic effects with time and made some suggestions for new risk assessment procedures. In all cases, mortality increased with exposure time.

Real (1979) reported that when foods are changed from randomly dispersed to clumped in the habitat, the predation of the predators increase with their total resource utilization but decrease with their learning and half saturation. Because all organisms require food to survive and reproduce, feeding efficiency should be an important component of fitness (Sih, 1982). Miura and Takahashi (1988) did the laboratory study of predation by damselfly nymphs, Enallagma civile, upon mosquito larvae. Sebastian et al., (1990) studied the suppression of Aedes aegypti (Diptera: Culicidae) using augmentative release of dragonfly larvae (Odonata: Libellulidae) with community participation in Yangon, Myanmar.

Soluk (1993) studied multiple predator effects, predicting combined functional response of stream fish and invertebrate predators. Van der Meer and Ens (1997) reported the feeding rate can influence the distribution of predators through space. O’Donoghue et al., (1997) studied numerical response of coyotes and lynx to the snowshoe hare cycle and found that food is not limiting for coyotes
lynx at high hare density but at low hare density, food does become a limiting factor. A numerical response can be defined as an increase in predator numbers with a rise in prey density. This response may be in the form of aggregation, increased reproduction, or both (Marc et al., 1999).


Skalski and Gillium (2001) reported when predator feeding rate becomes independent of predator density at high prey density, predator feeding rate is decreased by higher predation density even when prey density is high. Predator recognition of patches of high prey density and the concentration of foraging acclivity in these areas can lead to stabilization, since predation pressure will be high where prey numbers are high and low where prey numbers are low. In the field, dragonflies do inhabit areas where prey are abundant and will migrate from patches of decreasing prey density to patches of higher prey density (Hamood et al., 2001). Jeschke et al. (2002) analysed the Predator’s functional responses discriminating between handling and digesting the prey. Pitt and Ritchie (2002) said that foreaging success or the ability of predators to find and consume prey, is of great importance in understanding population dynamics and interaction between species.
Sabo and Power (2002) studied numerical response of lizards (*Sceloporus occidentalis*) to aquatic insects and short-term consequences for terrestrial prey and predicted that lizard density would be higher in areas with higher aquatic resource input and that increased lizard density in these areas would lead to stronger depletion of in situ prey. Schenk and Bacher (2002) studied functional response of a generalist insect predator to one of its prey species in the field. Generalist predator assemblages were found to reduce pest numbers significantly in 79% of the 52 studies reviewed by Symondson et al. (2002).

Johnson et al. (2003) studied the potential of prey size and type to affect foraging asymmetries in tiger salamander larvae. Omkar and Srivastava (2003) investigated the predation and searching efficiency of fourth instar of predatory *Coccinellaseptem punctata* at various densities of mustard aphid, *Lipaphis erysimi* (Kaltenbach) under laboratory conditions. Rocha and Redaelli (2003) said that one of the fundamental aspects of a predator and prey interaction is the relationship between prey density and predator consumption.

Singh et al. (2003) studied the biocontrol potential of dragonfly nymph, *Brachythemis contaminata* Fabricius against the larvae of *Anopheles stephensi*, *Culex quinquefasciatus* and *Aedes aegypti* under laboratory conditions, found that dragonfly nymph had highest predation efficacy against *An. stephensi* followed by *Cx. quinquefasciatus* and *Ae. Aegypti*, feeding rate increased with decrease in prey size/stage and indicated that dragonfly nymphs have good predatory potential and can be used as a biological control agent for control of mosquito breeding.

Lester et al. (2005) examined the functional response of the acarine predator Amblyseius fallacis (German, 1948) feeding on Pononychus ulmi (Koch, 1839). Pervez and Omkar (2005) compared functional responses of three Coccinellids, Cheilomenes sexa maculata, Propylea dissecta and Coccinetta transvesalis (Coleoptera: Coccinellidae) on two aphid species Aphis craccivora Koch and Myzus persicae. Mucaulcy (2005) assessed the relationship between habitat distribution growth rate, and plasticity in congeneric larval dragonflies and studied larval growth rate and the degree if growth plasticity in the presence and absence of predator.

Gilg (2006) studied functional and numerical responses of four lemming predators in high Arctic Greenland and reported the functional and numerical responses of all the four predator species in summer and provided a basis for understanding the role of predation in the dynamics of the cyclic collared lemming population in Northeast Greenland. Krivan and Eisner (2006) assumed that consumers behave as optimal foragers and consumer switching promotes species
coexistence without stabilizing population dynamics. Preisser et al. (2007) analysed the predator hunting mode and habitat domain alter non consumptive effects in predator - prey interactions. Sohraby and Shishehbor (2007) quantified the effect of spider mite density on prey consumption and egg production of S. gilvifrons for improving the understanding of prey - predator interaction.


Anand et al.,(2010) made an attempt to assess the eco-friendly technology for the management of brinjal pest by studying the prey consumption in relation to prey density (functional response) of reduvid predators Rhynocoris fuscipes (Fabricius) and Endocus inornatus (Stal) on Pterophorus lienigianus - the pest of Solanum melongena Linn (brinjal). Smout et al. (2010) studied the functional response of a generalist predator and showed how one type of multispecies functional response can be fitted to field data on the consumption by a generalist predator of its three important prey species at 11 different combinations of prey densities.
Gosh and Chandra (2011) evaluated the predatory efficiency and functional response of the *Laccotrephes griseus* (Hemiptera: Nepidae) on immature stages of *Cx. Quinquefasciatus* (Diptera: Culicidae) as prey in the context of their presence in the same guild in their natural habitat. Sabaghi et al., (2011) studied functional and numerical responses of *Scymnus syriacus* Marseul (Coleoptera: Coccinellidae) to the black bean Aphid, *Aphis fabae* Scopoli (Hemiptera: Aphidae) under laboratory conditions and evaluated functional responses of female and male, numerical responses of the female *Scymnus syriacus* lady beetle to different densities of *A. fabae* as prey, and the efficiency of the female’s conversion of ingested food. Tian and Xu (2011) studied Global dynamics of a predator-prey system with Holling type II functional response and proved that the predator extinction equilibrium is globally asymptotically stable when the co-existence equilibrium is not feasible and sufficient conditions are derived for the global stability on the co-existence equilibrium.

Morozov et al. (2012) reviewed the implementation of the functional response framework for modelling the grazing of herbivorous zooplanktons made some general conclusions about the applicability of the functional response framework in plankton modelling. Harborne (2012) concluded that the proportion of prey eaten by individual predators may vary depending on prey density. Garay et al. (2012) found that under Holling type II functional response, the omnivore-prey system has a unique equilibrium and Holling type III, they obtained by stable co-existence. Rahman et al. (2012) studied functional and numerical responses of the predatory mite, *Neoseiulus longispinosus*, to the red spider mite, *Oligonychus coffeae*, infesting tea. SitiNurulhidayah and Norman (2012) evaluated the effect
density of predator of adults (males and females) and 5th nymphs of *S. dichotomus* and, (ii) the voracity of 5th nymphs and adults (males and females) of *Sycanus dichotomus* on *Tenebrio molitor*.

Feng (2013) analysed delayed, predator-prey model with ratio-dependent functional response and quadratic harvesting. Leeuwen et al. (2013) developed a theory and generalized functional response for the food intake of a predator that can switch between multiple prey species. Venkatesh and Tyagi (2013) explained the predatory potential of *Bradinopyga geminata* and *Ceriagrion coromandelianum* on dengue vector *Aedes aegypti* under controlled conditions (*Anisoptera; Libellulidae; Zygoptera: Coenagrionidae; Diptera: Culicidae*). Mary (2013) studied the ecology and predatory efficiency of Aquatic (Odonate) insect over the developmental stages of mosquito. Varshini et al. (2013) experimentally proved the biocontrol efficiency of *B. geminata* in the management of mosquito immatures. Jalalipour et al. (2014) evaluated the effect of different foraging periods on searching efficiency and functional responses *Aphidoletes aphidimyza* larvae at different densities of *Aphis craccivora* as prey.