Abstract

DIVERSITY AND ECOLOGY OF AQUATIC HEMIPTERA (CLASS INSECTA) OF CACHAR DISTRICT, BARAK VALLEY, N. E. INDIA

A Thesis Submitted to Assam University for the Award of the Degree of

DOCTOR OF PHILOSOPHY IN ECOLOGY AND ENVIRONMENTAL SCIENCE

By

KANKANA DAS

UNDER THE SUPERVISION OF

Dr. SUSMITA GUPTA
Assistant Professor in Ecology and Environmental Science
ASSAM UNIVERSITY

DEPARTMENT OF ECOLOGY AND ENVIRONMENTAL SCIENCE
ASSAM UNIVERSITY, SILCHAR

2012
First chapter- General Introduction

Aquatic insects are one of the most important creatures of the world mostly live in water in their immature form and live their adult life on land. The aquatic and semi aquatic Hemipterans are paurometabolous, undergoing incomplete, gradual metamorphosis from egg to nymph to adult (Andersen, 1982). Adult and nymphal hemipterans are predaceous, having mouthparts specialized for piercing and sucking the contents of their prey. These insects are used for various purposes as bioindicator, as food of other aquatic organisms and as Biological Control Agent.

The true bugs Hemiptera appeared in the Permian period 245-285 million years ago. The super-families of the aquatic hemipteran infraorders Nepomorpha all appear in the fossil record in the Late Triassic (c. 210 Ma), while the earliest Gerromorpha (semi-aquatic water bugs of the super-family: Hydrometroidae) are known from the Early Cretaceous (Shcherbakov and Popov 2002). Fossils from the Santana formation of Brazil indicate that all modern families of Heteroptera had evolved by at least the Cretaceous (Polhemus, 2005). Most of the diversification of the Hemiptera started in the late Paleozoic (Upper Permian), and the major lineages diverged early in the Mesozoic (Triassic).

Aquatic Hemiptera of Barak Valley has not yet been well documented and hence there is a great scope of new records of some species. In the aforementioned context, the present study was carried out to investigate the composition and distribution of aquatic insects in the selected fresh water systems of Barak Valley.
Second Chapter- General Description of Study Area

The Barak Valley is bestowed with many large and small water bodies throughout the areas. These are of immense importance as a source of water for different uses. The climate of Barak valley is sub-tropical, warm and humid. The average rainfall is 3180 mm with average rainy days of 146 per annum. A total of ten sites have been selected for the study which includes oxbow lakes, temple ponds, flood plain lakes, agricultural fields and rain pools etc. The different sites are designated as S1, S2, S3, and so on. Site 1 to 4 are the oxbow lakes. The name of “Oxbow” refers to its shape, which is like a horseshoe or Oxbow. Oxbow Lakes are connected with the flood plain of the river by inlets and outlets. Site 1 is the Baskandi Anua (Oxbow lake) which is situated nearly 20 km away from the city (Silchar) (table 1). Site 2 is the Satkarakandi Anua. It is fully covered by vegetation. Sometimes the people dwelling nearby clean the water hyacinths, from their common fund for fishing (Image 2.2). The Site 3 (Image 3) is the Phulbari Anua, The Site 4 is Ramnagar Anua, which is situated very close to Silchar town. The system is fully covered by hydrophytes as water hyacinth, etc. Site 5 is a Temple pond (Bharam Baba), situated in the Silkuri area which is 10-11 km away from Silchar town. The one side of the pond is covered by different aquatic macrophytes such as *Salvinia cucullata* (Flame moss), *Azolla pinnata* (Feathered mosquito fern), *Trapa bispinosa* (Water chestnut), *Jussiaea repens* (Primrose willow) and *Cynodon dactylon* (Bermuda grass), *Nymphaea nouchali* (Blue water lily), *Nymphoides cristatum*, *N. indicum*, *Nelumbo nucifera* (water lotus) and *Hygrorhiza aristata* (Indian lotus). The Site 6 is another temple pond which is situated in Silchar town at the locality called Bilpar. The pond is about
200 hundred years old (Data collected from the priest of the temple and year of the establishment). The next site is the Site 7, which is about 12-13 km from the Silchar town. The name of the temple is Kachakanti (one of the forms of Goddess Kali) temple. Site 8 is the flood plain wet land near the Durgakona Area of Silchar town. The site 9, is the Agricultural wet land. The last study area is the temporary water covered area which is called rain pool, situated in the Silkuri area of Cachar district.

**Third Chapter- Physico-chemical Properties of Water of Study Sites**

Insects occupy a wide variety of niches in almost every kind of terrestrial and aquatic habitats. Fresh water environments, unlike the marine ones, are subjected to variations in the environmental factors such as temperature, dissolved oxygen, light penetration, turbidity, density, etc. These factors are responsible for distribution of organisms in different fresh water habitats according to their adaptations, which allow them to survive in that specific habitat (Jaffries and Mills, 1990). So to know the ecological conditions and other aquatic organisms, two years study (From March 2008 to February 2010) was conducted in ten different Lentic aquatic systems of Barak Valley, Assam, North East.

Water samples were collected seasonally from the selected sites for a period of two years from March 2008 to February 2010. Meteorological data as Total rainfall and Air temperature were obtained from Meteorological Department, Cachar College, Silchar. DO, free CO2, total alkalinity, TDS, TSS, EC, TR, Phosphate and Nitrate were estimated by standard methods.
On the basis of selected physico chemical parameters study in ten different sites during 2008-10, it has been concluded that air temperature showed much fluctuations, water temperature ranged from 19.66°C to 35.50°C in the first year and 20.9 to 34.09 °C in the second year. In the first year, maximum DO was recorded as 15.10mg/l in the winter in S1 and highest dissolved oxygen during winter could be attributed to the fact that in lower temperature oxygen carrying capacity of water increases (Wetzel, 1983) and minimum was estimated (1.13mg/l) in S9 in the pre-monsoon. Nitrate is the oxidized form of nitrogen and end product of aerobic decomposition of organic nitrogenous matter. The presence of nitrate in fresh water bodies depends mostly upon the activity of nitrifying bacteria, domestic and agricultural source. Nitrate content varied between 0.20 mg/l to 3.46mg/l throughout the study period. These changes are commonly associated with erosion and transportation of nitrogenous rich fertilizers, soil and local sources into the water. Phosphate is an important nutrient for the maintenance of the fertility of water body. During the present investigation the phosphate concentration fluctuated in different seasons due to water level fluctuation and pollution. pH is one of the important factors which have an impact on living organisms. During the study period, acidic pH was observed in agricultural field and alkaline pH was estimated in the oxbow lakes. The overall water quality of the study sites remained within the permissible limits of water quality standards throughout the study period, which showed that water of Barak valley is fit to support biodiversity except sites S9 and S7 which are affected by various fertilizers, wastes, bleaching powder and detergents.
Definitely more studies are required at different sites of this valley to compare the water quality at different places and at different times.

Fourth Chapter- Inventory and Diversity of Aquatic Hemiptera

The present members of the order Hemiptera were historically placed into two suborders, Homoptera and Heteroptera based on the differences in wing structure and the position of the rostrum. All aquatic and semiaquatic bugs belonged to the suborder Heteroptera which has three aquatic infraorders: Nepomorpha, Gerromorpha and Leptopodomorpha. However, little is known about aquatic and semi-aquatic bugs in North East India despite its potential as a biodiversity hotspot. Although some preliminary surveys have reported on the Water bugs from Assam, Manipur and Meghalaya but report from Barak Valley area is lacking.

The valley has nearly undisturbed ecosystems (natural forests with many fresh water systems and small people communities). Therefore the species diversity of the water bugs from this area, along with taxonomy and ecology were studied to expand the database for water bugs in Barak Valley, Assam, North East India. The insects were collected in pre-monsoon (March-May), monsoon (June-August), post-monsoon (Sept-November) and winter (December-February) by Kick method during 2008 March to 2010 February. The study revealed occurrence of 18 species, 15 genus and 9 families from the ten study sites during the two years study period. They were later identified using Dewinter Advance Stereozoom Microscope with the help of standard keys and experts from the zoological Survey of India, Kolkata (ZSI).
This study recorded 9 hemipteran species such as *Limnometra* sp., *Rhagadotarsus* sp., *Tenagogerris* sp., *Rhagovelia* sp., *Ranatra elongata*, *Diplonychus annulatus*, *Nychia sappo*, *Anisops lundbladiana*, *Paraplea* sp. belonging to the order Hemiptera for the first time in North-East India. No other previous study in this region has reported them.

The eighteen species recorded in the present investigation are *Limnogonus nitidus* (Mayr, 1865), *Neogerris parvula* (Stal, 1860), *Rhagadotarsus* sp., *Limnometra* sp. (family Gerridae); *Mesovelia vittigera* Horvath, 1843 (family Mesoveliidae); *Microvelia* sp. (family Veliidae), *Ranatra elongata* Fabricius, 1790 and *Ranatra varipes varipes* Stal, 1861 (family Nepidae); *Diplonychus annulatus* Fabricius, 1781, and *Diplonychus rusticus* Fabricius, 1781 (family Belostomatidae); *Micronecta scutellaris scutellaris* Stal, 1858, and *Micronecta haliploides* (family Corixidae); *Enithares ciliata* Fabricius, 1798, *Anisops lundbladiana* and *Nychia sappo* Kirkaldy, 1901 (family Notonectidae), *Paraplea* sp. (family Pleidae) and *Rhopalosiphum nymphaeae* Linnaeus (family Aphididae).

During 2008-09, the highest number of families (5) were recorded in S4 and S6 and lowest number of families (2) were recorded in S9 and S10. The families were Gerridae, Nepidae, Notonectidae, Belostomatidae, Corixidae, Mesoveliidae, Pleidae, Veliidae and Aphididae. Family Notonectidae was present in all the ten sites; Corixidae in eight sites; Mesoveliidae in five sites; Aphididae, Pleidae, Veliidae were only present in one site. The highest numbers of species (8) was present in S2 and S3 followed by 7 in S1 and lowest numbers of species (4) were present in S7 and S9. The species were *Limnogonus nitidus*, *Neogerris parvula*, *Rhagadotarsus* sp., *Limnometra* sp. (family: Gerridae); *Mesovelia*
vittigera, (family :Mesoveliidae); Rhagovelia sp. (family Veliidae), Ranatra elongata and Ranatra varipes varipes (family: Nepidae); Diplonychus annulatus and Diplonychus rusticus (family: Belostomatidae); Micronecta scutellaris scutellaris and Micronecta haliploides (family: Corixidae); Enithares ciliata, Anisops lundbladiana and Nychia sappo (family: Notonectidae), Paraplea sp. (family :Pleidae) and Rhopalosiphum nymphaeae (family: Aphididae). Micronecta scutellaris scutellaris, Micronecta haliploides and Anisops lundbladiana were present in all the eight sites out of ten study sites.

During 2009-10, four families were recorded in S1 to S5 and S8 and minimum numbers of families (2) present in S7. Family Belostomatidae was not recorded in this year in all the sites. The highest number of species was recorded from oxbow lakes in both the years could be due to the fact that oxbow lake, periodically supplied by river waters, especially during the strong currents of flood therefore they may support greater species diversity and create concealment conditions for numerous lacustrine organisms. Moreover, during the fluctuating water periods oxbows may also enrich the main river channel in nutrients (Kajak, 2001). Another important cause of diversity in oxbows is the degree of water permanence. Oxbow lakes of Barak valley are productive lakes rich in plankton, macro-invertebrates and macrophytes. The species diversity was followed by S6 which is a temple pond and closely followed by oxbow lakes. S6 on the other hand is a permanent pond and covered by hydrophytes. Vegetated zones are structurally much more complex than non-vegetated areas and owing to their heterogeneity, which is positively and strongly associated with varying degrees of
habitat complexity, such macrophyte-dominated zones often support more diverse and abundant organisms within various types of water bodies.

Shannon diversity index (Shannon H/) of Hemiptera of the study sites ranged from 0.502 – 1.77. The lowest value was in S9 in the post monsoon and highest was estimated in S6 in the monsoon season and in the second year, it ranged from 0.580-1.011. The highest diversity was recorded in S5 in the pre-monsoon and lowest was recorded in S9 in post-monsoon. The lowest diversity in S9 in both the years indicated the polluted nature of the system (AF) where pesticides are used throughout the year. Shannon Evenness Index estimated highest evenness in S7 and S5 in the first and second year respectively and lowest in S4 and S7 in both the years respectively. Margalef Diversity Index ranged from 2.502-8.763 and 0.035-9.187 in the first and second year respectively. The highest was recorded in S3 in the first year and S5 in the second year while lowest value was recorded in S9 in both the years. Berger-Parker Dominance Index showed the highest value in S4 and lowest in S3 in the first year and in the second year, the highest was in S10 and lowest was recorded in S6.

During the study period among all the sites the density of Hemiptera was found highest in the oxbow lakes in both the years. In all the oxbow lakes, the most abundant family was Notonectidae, whose SIGNAL sensitivity grade is just 1 followed by Corixidae having sensitive grade 2. The family Notonectidae was recorded from all the sites in two years of study period. SIGNAL (Stream Invertebrate Grade Number- Average Level) is a family-level water pollution index based on the known tolerances of aquatic macro-invertebrate families to various pollutants. The index has a gradient from 1 to 10 (ranging from a
pollution tolerant to a pollution sensitive community) (Chessman, 1995). The higher values represent lower levels of tolerance. A low grade number means that the macro invertebrate is tolerant of a range of environmental conditions, including common forms of water pollution. This SIGNAL score is also in use for wetland studies (Chessman, 2003). As the study is on the order Hemiptera, for computation of SIGNAL scores only hemipteran families were taken into consideration. On that basis among the different sites higher scores were recorded in oxbow lakes i.e. presence of relatively low tolerant Hemiptera families. This indicated relatively better quality of water in oxbow lakes than that of other sites.

The dendrogram of Bray-Curtis Cluster Analysis showed that on the basis of the species composition and population, the percentage of similarity of the sites showed temporal variation. In the premonsoon of the first year, site 2 and site 7 are different from other sites. But site 8 and 3 are closely similar at 87.68% may be due to more or less same types of vegetation and dissolved oxygen content. The similarities between site 5 and 6 at 66.52%, proves that both are the same habitat (temple ponds) and permanent in nature. Site 4 and 10 are also similar at 75.79% although two are completely different systems. In the monsoon, closely related sites are S4 and S10 at 78.10% could be due to food and habitat availability although they are completely different systems. Similarities at 57.82% was observed between site 1 and 3. Site 7 and 8 was at 64.63% similarity could be due to same type of permanent habitats and also affected by seasonal rainfall. In the post monsoon, site 2 was not related to other sites as this system was totally covered by water hyacinth and very high EC as 1097.31 µS/cm. Site 6 and 10 was at 64.21% similarity and site 3 and 9 at 83.76%
similarity were probably due to closely related environmental factors. In the winter, similarity between site 1 and 4 was at 82.31% as both are oxbow lakes and not disturbed by surface runoff. Again similarities between site 5 and 6 at 78.87% also might be due to same type of habitat.

In the premonsoon of the second year, the maximum faunal similarity at 84.49% in site 2 and 4 and 89.42% similarity in site 1 and 8 were found. In the post monsoon, site 1 and 4 are similar at 73.18% as both are similar systems and not disturbed by rainfall. But in the winter, site 2 and 7 were similar as the systems partially dried in the winter.

**Fifth chapter - Density and Relative Abundance of Aquatic Hemiptera**

Hemipterans are used as bio-indicators of specific environment and habitat conditions. In India although there are several works on density and relative abundance of aquatic and semi aquatic Hemiptera, in north eastern part in India it is rather poorly documented. In the aforementioned context, the present study was carried out to investigate the density and relative abundance of aquatic and semi aquatic Hemiptera in the selected fresh water systems of Barak Valley.

Hemipterans were collected in three replicates by standard method, sorted and identified by standard keys. The dominance status was recorded by Engelmann’s scale. It has been estimated that the total Hemipteran density during 2008-09 were highest in S1 (254) followed by S3 (205) and lowest in S7 (57) but during 2009-10 highest density was recorded as S6 as 322 and lowest was recorded from S7 (84). Highest density in the oxbow lakes could be due to the fact that as oxbow lakes are directly connected with the rivers and during the monsoon and
post monsoon river water carried debris and floating macrophytes into the system. The migrated macrophytes provided habitat and nutrients to the aquatic insects. But in the second year the density was highest in the temple pond might be due to rich vegetation of the pond. From the present investigation it has been noted that the insects of both the families Nepidae and Belostomatidae were only found in the sites where the systems were totally covered by aquatic plants. These hydrophytes not only provided physical structure, but also contributed changes in abundance and quality of food. Similar observation was recorded by Burdett and Watts (2009).

In 2008-09, the relative abundance of species *Anisops lundbladiana* was found highest (35%) in S4 as they seem to prefer cleaner and fresh water supported by the findings of Tonapi (1959), followed by highest *Micronecta scutellaris* (34%) in S9 and lowest was *Paraplea* sp. (8%) in S6. while in 2009-10, highest relative abundance was recorded from S7 *Micronecta haliploides* (42%) followed by *Rhagovelia* sp. (38%) in S6 and lowest was *Ranatra varipes* (10%) in S2. According to Engelmann’s scale (Engelmann,1973) the eudominant species recorded in the whole study period in different sites are *Micronecta scutellaris, Micronecta haliploides, Rhopalosiphum nymphaeae, Anisops lundbladiana,* and *Rhagovelia* sp. In S3 in the first year no Eudominant species was recorded.

In both the years, the Hemipteran population has been influenced by rain fall and highest density was recorded either in monsoon or in post monsoon in almost all the study sites. In both the years S7 had less number of individuals. The reducing number of aquatic insects in certain sites is attributed to
environmental pollution, unfavorable weather condition or unavailability of food resources.

**Sixth Chapter- Colonization Pattern**

Freshwater habitats were very slowly colonized over hundreds of millions of years during the late Paleozoic. Colonization can be viewed as the sequence of events that leads to the establishment of individuals, populations, species or higher taxa in places from which they were, however temporarily, absent. Habitat that dry and fill repeatedly may be preoccupied by colonists or by reactivation of resistant stages. Traditionally, entomologic studies of insect colonization have focused on repopulation of the habitat after some disturbance—drought, flash floods, pesticide applications, or chemical spills. The fresh water systems of Cachar district are colonized by different types of insects after the systems receive rainwater. This study aimed to evaluate the pattern of colonization, breeding habits of a particular species and environmental factors that may structure the insect communities and taxon composition in four different kinds of habitats.

For this study four different types of aquatic habitats were selected from the different areas of Cachar district. Water and insect samples were collected in three replicates from each of the sites in twelve different sampling dates. Selected physico-chemical parameters were analyzed by standard methods (APHA, 2005). Cluster analysis was done by Biodiversity pro Vs 2.0, and one way analysis of variance (ANOVA) was worked out by SPSS Vs. 12.0.
Analysis of the environmental variables of the four sites revealed that lowest air temperature was recorded in the month of March as 28.00 °C and highest was in the month of June as 37.00 °C. Water temperature ranged from 25.20 °C to 39.23 °C. Total rainfall ranged from 7mm to 510.5mm. All the sites had acidic pH ranging from 2.36 in site A to 8.9 in site B. Electrical conductivity ranged from 120.20 µS/cm to 1010.20 µS/cm. Acidic pH may be due to the type of the soil of Barak Valley, which is mostly acidic. Texture is generally clayey loam to clay.

One of the underlying dogmas in disturbance and community ecology is that there is a group of specialist taxa that are good colonisers but weak competitors, which arrive in a habitat soon after a disturbance, and another group of taxa that take longer time to arrive but eventually displace those colonisers through their competitive superiority (Begon et al. 1990; Roxburgh et al. 2004; Shea et al. 2004). In the present study highest density of insects was seen in the month of March’09 (96) and lowest in July (13).

The study recorded 7 species of aquatic insects throughout the study period in four sites, they were M.haliploides, M. scutellaris, Gerris lepcha, Anisops lundbladiana, Rhagovelia sp.,Culex sp. and Copelatus. In Site A to Site D during the study period order Hemiptera was found to be the most prominent order followed by Diptera and Coleopetra.

In Site A, absence of insects on the 1st date could be correlated with very low pH (2.36) indicating stressful environment. Rhagovelia sp. colonized in 2nd to 4th sampling dates. Gerris lepcha also colonized in Site A, in spite of low pH which depicted that water striders are successful colonizers. On 6th and 7th
sampling date *Micronecta scutellaris* colonized in this site but on 8th and 9th sampling dates of study period there was no insect and on 10th sampling date *Micronecta haliploides* and *Gerris lepcha* colonized in this site and on 11th sampling date only *Gerris lepcha* was present.

In Site B, Dipterans (*Culex* sp.) colonized up to 4th sampling dates. This could be due to the conducive environmental condition for them. Diptera (*Culex* sp.) are among the most able flying insects, especially when compared with water beetles and bugs; so they are well suited to colonize new sites. On the first date about 96 Dipterans colonized, but in the 2nd sampling date the number reduced to 83 and then to 47 and then replaced by *Micronecta scutellaris*. Many small Diptera have long flight periods and short life-cycles, in contrast to most water beetles and bugs which are mainly univoltine (Williams and Feltmate 1992).

In site C, both *Micronecta haliploides* and *Micronecta scutellaris* colonized during the 1st sampling date when the pH was 2.58, On the 2nd sampling date there were no insects. There was only one species of *Copelatus* (Dytiscidae) present on the 6th and 8th sampling dates.

In site D, in the first sampling date both prey and predator, *Culex* sp. and *Anisops lundbladiana* colonized the system. This might be due to the fact that both of them survived better with shrubs and other aquatic vegetation of the site. Their presence in low pH (5.96) conformed to the findings of Bendell 1986, who observed that Notonectids prefer to settle in water with very low pH where fish cannot survive. The presence of *Anisops lundbladiana* in the first six sampling dates out of twelve sampling dates could be due to suitable niche and food availability as *Culex* sp. larvae is a known prey of *Anisops* (Gittelman, 1974).
This is confirmed by the reduced number of *Culex* sp. in the subsequent sampling dates. Again on 8\textsuperscript{th} sampling date, *Anisops lundbladiana* was replaced by carnivorous *Micronecta* and was dominant in this site.

Temporary pools are more threatened than permanent waters. In recolonization strategy there are often several more complex adaptations, such as short life-cycle, high fertility, high migration ability and habitat selectivity etc. (Williams, 1987). During monsoon due to heavy rainfall the population density was low as disturbance removes habitat, individuals and their food resources (Holomuzki and Biggs, 2000; Scarsbrook, 2002).

**Seventh Chapter- General Discussion and Conclusion**

This is the first scientific study on the diversity and ecology of Hemiptera in lentic systems of Cachar district, Assam. The investigation spanning two years (2008-09 & 2009-2010), recorded a total of 18 numbers of species of Hemiptera which reflected the fact that the study area is a part of Indo-Burma Biodiversity hotspot. 7 species were semi-aquatic and 11 species were truely aquatic. Biodiversity within inland water ecosystems in the Eastern Himalaya region is highly diverse. One of the main reasons cited for inadequate representation of biodiversity is lack of readily available information on the status and distribution of inland water taxa (Allen *et al*., 2010). This study revealed occurrence of eighteen numbers of species and their distribution in different ecosystems which reduced the data deficiency of hemipterans of this region.
In all the oxbow lakes, the most abundant family was Notonectidae, whose SIGNAL sensitivity grade is just 1 followed by Corixidae having sensitive grade 2. The family Notonectidae was recorded from all the sites in two years of study period. As the study is on the order Hemiptera, for computation of SIGNAL scores only hemipteran families were taken into consideration. On that basis among the different sites higher scores were recorded in oxbow lakes i.e. presence of relatively low tolerant Hemiptera families. This indicated relatively better quality of water in oxbow lakes than that of other sites. The BMWP/ASPT data in the first year showed that the water quality was very good in all the oxbow lakes and water of S6 and S7 were above average and average respectively. But in the second year, the water quality was estimated very well in the entire sites except S9.

Virtually all aquatic habitats experience periodic disturbances at some scale of space and time (Resh et al., 1988; Sparks et al., 1990), and disturbances of human origin are increasingly influential. The lakes and reservoirs, all over the country without exception, are in varying degrees of environmental degradation. There has been a quantum jump in population during the last century without corresponding expansion of civic facilities resulting in lakes and reservoirs, becoming sinks for incoming contaminants and leading to their impairment. In the present study it has been seen that oxbow lakes are very important as these provide suitable habitats for aquatic insect orders particularly Hemiptera. They are very much important as fish-food and these systems also support fishes. In this valley a large number of people belonged to the fisher-folk community and people mostly lived in rural areas mainly depended on these ecosystems to fulfill
their basic needs. Greater research effort should be devoted to studying the controlling influences of the biological environment as these are wealth of the nature. The majority of oxbow lakes outside protected banks are used for intensive, pond-like fish production. About 90 percent of this area produces market fish from fingerlings by polyculture methods. About 10 percent of the area produces fingerlings through stocking. A major challenge for fisheries managers is to gain a functional understanding of population and community response to environmental variation and disturbance at varying spatiotemporal scales. Another detrimental activity in Barak Valley deserve mentioning is rampant use of pesticides during dry season for trapping fishes which pollute the system highly leading to biomagnifications effecting human wellbeing.

References


Resh, V.H., Brown, A.V., Covich, A.P., Gurtz, M.E., Li, H.W., Minshall, G.W., Reice, S.R.


