DRAFT

BANGLADESH FLOOD ACTION PLAN

FAP 16 Environmental Study

Special Studies Program

IMPACTS OF FLOOD CONTROL AND DRAINAGE ON VECTOR-BORNE DISEASE INCIDENCE IN BANGLADESH

December 1992

9

Prepared for
The Flood Plan Coordination Organization (FPCO)
of the
Ministry of Irrigation, Water Development and Flood Control

by

THE LIVERPOOL SCHOOL OF TROPICAL MEDICINE
THE NATIONAL INSTITUTE FOR PREVENTATIVE AND SOCIAL MEDICINE
THE IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST

ISPAN

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ACRONYMS

DGHS	Directorate General of Health Services
FAP	Flood Action Plan
FCD/I	Flood Control, Drainage, and Irrigation
FPCO	Flood Plan Coordination Organization
HIP	Health Impact Programme
IECDR	Institute of Epidemiology, Disease Control & Research
ISPAN	Irrigation Support Project for Asia and Near East
LSTM	Liverpool School of Tropical Medicine
NIPSOM	National Institute of Preventive & Social Medicine
ODA	Overseas Development Administration
PEEM	Panel of Experts on Environmental Management for vector control
WHO	World Health Organisation

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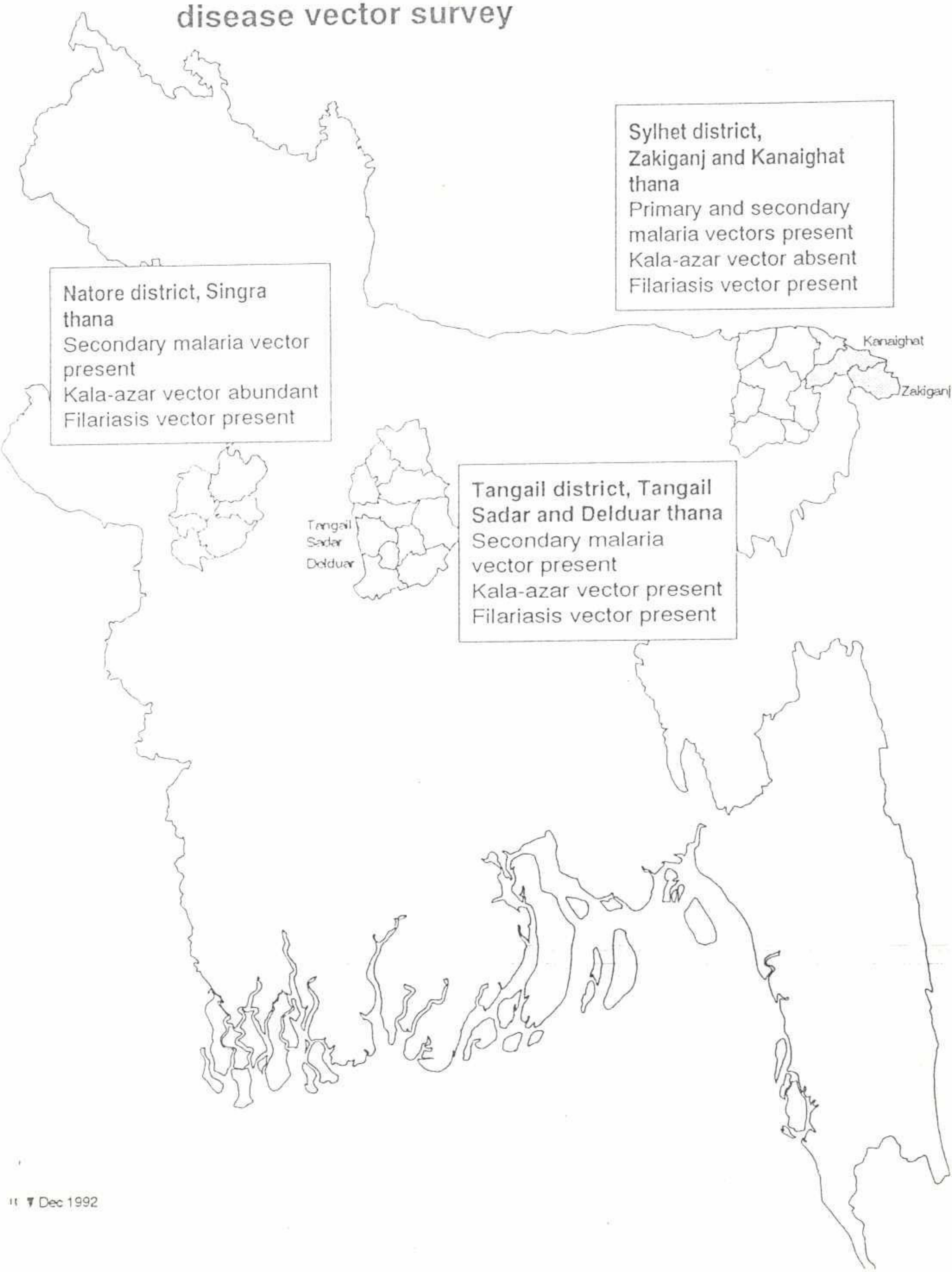
Study sites and main results of Bangladesh disease vector survey



EXECUTIVE SUMMARY

1. Introduction

The construction of works for flood control, drainage, and irrigation (FCD/I) in Bangladesh affects the timing, depth, and duration of flooding and thereby potentially affects the abundance of vectors and the incidence of certain vector-borne[1] diseases. The Bangladesh Flood Action Plan (FAP) is expected to lead to widespread changes in flooding and drainage, with consequent potential changes in disease vector abundance and distribution and in associated vector-borne disease risks to human populations.

A number of interlinked studies were undertaken by the Liverpool School of Tropical Medicine, United Kingdom, and the National Institute of Social and Preventative Medicine (NIPSOM), Bangladesh, in close collaboration with ISPAN, to examine the vector-borne disease implications of the FAP. Four major chapers respectively present an historical perspective of major vector-borne diseases in Bangladesh, results of a sandfly survey, results of a baseline mosquito survey in a number of study areas, and an overview of vector-borne diseases in Bangladesh. This summary presents the key findings of all chapters. An associated study of kala-azar in flooded and protected areas is presented in a separate report.

The assessment procedure distinguished between health hazards and health risks. Health hazards have the potential to cause harm. Health risks provide a measure of the likelihood of the hazard affecting specific community groups. The first task of the health impact assessment was to identify the health hazards. The second task was to interpret the health hazards as health risks. This was accomplished by examining the three major components of health risk:

- community vulnerability (*which communities are exposed to the hazard?*);
- environmental factors (*how are they exposed?*);
- health service capability (*how is the community protected?*).

The assessment recognized that health risks exist in the absence of the project. The objective of the assessment was to identify additional health risks that could be reasonably attributed to the project. Where an increased risk was identified, health risk management measures would be appropriate. This report proposes such measures, but the final decision to implement them is assumed to be the responsibility of the project managers and would be taken within the context of other negotiations for scarce resources.

2. Background

Based on regional information the following vector-borne disease hazards were identified: malaria, kala-azar, filariasis, Japanese encephalitis, dengue, schistosomiasis.

The objective of health impact assessment is to interpret these health hazards as health risks and assess

[1]Vector = biting insects such as mosquitoes and sandflies and intermediate hosts such as aquatic snails.

the change in risk which could be attributed to the project. A seminal component of the health risk is the abundance and distribution of disease vectors. Abundance and distribution is a function of breeding sites. Breeding sites are dependent on environmental conditions associated with land use and seasonal hydrological cycles.

Table 1
Summary Health Impact Assessment:
Vector-Borne Diseases and Flood Control and Drainage in Bangladesh

Health Hazard	Community Vulnerability	Environmental Factors	Health Service Capability	Health Risk Change
Benign malaria *P. vivax*	Prevalence currently low, no drug resistance. Non-fatal, causes morbidity.	Floods and pollution minimize vector breeding. The status of secondary vectors may be increasing.	Chloroquine widely available, diagnosis simple. Existing health service adequate but requires strengthening. Focal vector control.	No change.
Maliguant malaria *P. falciparum*	Highly susceptible, circulating labor provides a reservoir. Prevalence very low. Fatal, drug resistance common.	Floods and pollution minimize vector breeding. No significant local transmission at present.	Not adequately prepared for local epidemics.	No change.
Kala-azar	Highly susceptible, epidemic in progress, reservoir in post kala-azar dermal leishmaniasis sufferers. Fatal and debilitating. Evidence of association with embankments.	Vector widespread. Peridomestic breeding in association with cattle sheds. Insufficient data about association with soil moisture and plant species and hence with embankments.	Inadequate supply of drugs, diagnosis difficult, no vector control program. Surveillance and vector research needs strengthening.	Significant risk of association with embankments in some localities.
Filariasis (bancroftian)	Widespread, but low prevalence with both rural and urban foci. Non-fatal but debilitating.	Vector thrives in foul water which will be increased by poor drainage.	Surveillance poor. Drug therapy cheap and simple; diagnosis simple. No vector control or treatment program.	Slow but widespread increase.
Dengue and Dengue Hemorrhagic Fever	Vulnerability is high. No information about prevalence.	The vector is present, but not associated with embankments.	Supportive treatment in intensive care units would be required and is not widely available.	No change.
Encephalitis (J.E.)	Pig keeping/rice growing communities are vulnerable. Disease believed to be very rare. No data on virus prevalence.	Natural reservoir expected in ardeid birds with pig as amplifier host. Vector is common in ricefields and other water bodies.	Supportive treatment in intensive care units would be required and is not widely available.	No change.
Schistosomiasis	The disease is absent.	No data on presence of vector snail.	No experience of the disease.	No change.

During the last 40 years the ecological environment and the pattern of land use have changed dramatically in Bangladesh. Human density, standards of living, rice cultivation, capture and culture fisheries, agricultural use of pesticides, and silt load have all changed. These factors have contributed to changes in the vector community and partly account for the continued rarity of a malaria vector in an environment dominated by open water. There have been little or no systematic studies of the associated changes in vector abundance and behavior. As a precursor to this report, a one year baseline study of vector diversity and abundance was conducted.

2.1 Malaria

Forty years ago the distribution of malaria in Deltaic Bengal was patchy. A conspicuous feature was that low-lying, waterlogged areas subject to seasonal flooding were less malarious than other areas. Literature reviews list the evidence that embankments constructed for flood control, railways, and roads reduced the spread of silty water, and thereby facilitated vector breeding and increased malaria prevalence. This association of malaria with embankments has clear implications for flood control and drainage programs.

Outside the estuarine zone and the foothills, the vector was a single species of mosquito that had specific and limited breeding site requirements. After the introduction of residual house spraying with DDT the vector became rare in many districts and malaria cases decreased dramatically. Sporadic cases were treated with chloroquine accompanied by focal DDT spraying. The national malaria prevalence rate (indicated by annual parasite index) resurged after 1971 and stabilized in the range 0.4-0.8 per thousand. Although little residual house spraying now occurs, the vector has remained rare in many districts. This may be partly attributed to natural environmental modification. Chloroquine treatment of sporadic cases remains cheap, effective, and accessible. Prevalence rates remain highest in foothills, forests, and border areas.

Secondary vectors have been incriminated during the past year and their importance remains to be assessed.

2.2 Kala-azar

There is a history of kala-azar (visceral leishmaniasis) epidemics in Bihar and Bengal. Residual house spraying for malaria control suppressed the vector. Case incidence is now increasing throughout many areas of Bangladesh and there have been many small epidemics. There is no control program and limited access to an expensive treatment. The association between vector abundance and land use has not been established. There is a single vector species, a sandfly, that breeds peridomestically in moist but not saturated, organically rich soils. Seasonal flooding may limit vector breeding.

2.3 Filariasis

Bancroftian filariasis, transmitted by a mosquito, occurs in both rural and urban foci. The flushing action of seasonal floods contributes to vector control and the limited endemicity. Interrupted flooding without alternative drainage will greatly enhance vector abundance and could contribute to a slow increase in endemicity and clinical symptoms.

2.4 Dengue

Dengue fever is an arbovirus transmitted by mosquitoes. The breeding sites are containers of drinking water and rain water. There is no association with FCD/I projects.

2.5 Japanese Encephalitis

Epidemics of this serious disease in other countries are increasingly associated with rice cultivation in conjunction with pig keeping. No association with flood control and drainage projects in expected.

2.6 Schistosomiasis

The schistosomiasis hazard is negligible as local transmission of the disease has never been reported from Bengal and there are no nearby foci.

3. Benign Malaria

3.1 Community Vulnerability

Benign malaria is rarely fatal but does cause considerable morbidity of 1-2 weeks duration with associated loss of production. It is the only form of malaria that is considered to be endemic on the floodplains. National health records indicate a very low prevalence with small sporadic epidemics. All sections of the community are exposed. Greatest morbidity is expected in children and pregnant women. There is no drug resistance. It is seasonal, and relapse is common.

3.2 Environmental Factors

The primary vector breeds in very restricted habitats of clean water with filamentous algae and other sub-aquatic vegetation. It cannot tolerate either silty flood water or polluted water. It will breed in ricefields but only at very low densities during the partial shaded stage. Breeding habitats have become progressively rarer during the past 50 years due to environmental changes associated with increased cultivation intensity and human population density. In the present study it was only detected in the Sylhet area. Embankments reduce the flushing action and siltiness of inundations and could increase the breeding sites. However, an increase in organic pollution due to drainage obstruction or increased human population density should deter breeding. Abundance is seasonal.

Secondary vectors have recently been incriminated. These are expected to tolerate a wider range of breeding conditions. The conditions are already available and no substantial increase is expected as a result of new embankments. The status of these vectors should be kept under review.

The vectors can be controlled by residual house spraying with insecticides.

3.3 Health Service Capability

The health service has limited resources to monitor and control malaria and provide curative services. However, the curative drug chloroquine is widely available and relatively cheap. Large quantities are dispensed as presumptive treatment. Accurate diagnosis is relatively simple and requires a functional microscope, stains, and motivated technicians. Unfortunately, problems of motivation and quality control are commonplace.

There is a limited ability to respond to focal outbreaks by residual house spraying of insecticides. Until recently, DDT was manufactured and used. DDT is generally regarded as benign when used indoors in a carefully targeted fashion. Unfortunately, DDT is widely misused in agriculture and is now banned in Bangladesh for all purposes. Replacement insecticides are much more expensive and may be unavailable. Therefore, health service capability to respond to local outbreaks is likely to become more limited.

3.4 Health Risk

The low prevalence of benign malaria as well as sporadic epidemics on the floodplains is likely to continue. Flood control and drainage projects are unlikely to increase vector abundance, and no additional transmission is expected.

4. Malignant Malaria

4.1 Community Vulnerability

This is a serious and frequently fatal disease. Drug resistance is common. The distribution in Bangladesh is restricted. The reservoir of infection is forest-dwelling communities.

Circulation of labor leads to occasional cases within the floodplains, but subsequent transmission is considered insignificant. As relapse does not occur and transmission is seasonal, there is no permanent reservoir of infection on the floodplains.

4.2 Environmental Factors

Transmission occurs in forested and forest fringe areas where the primary vector breeds in shaded forest streams. On the floodplains, the vectors are the same mosquitoes that transmit benign malaria.

4.3 Health Service Capability

Widespread resistance to commonly available drugs poses a major problem for disease control in Asia. If a local epidemic of a drug-resistant strain occurred, the health service would be ill-equipped to respond.

4.4 Health Risk

The risk of malignant malaria on the floodplains is very low and no increase is expected as a result of flood control and drainage.

5. Kala-azar

5.1 Community Vulnerability

There is currently a widespread epidemic of this fatal disease in Bangladesh. The most vulnerable communities are poor, rural cattle keepers. Several cases within the same household are common. In districts where it is reported, cases appear to be clustered close to embankments. The epidemiological data are poor. There is no animal reservoir of infection.

Historical evidence indicates that irregular period epidemic waves have occurred in the region since about 1820. Between epidemics, the parasite is maintained in sub-clinical infections and cases of post kala-azar dermal leishmaniasis.

5.2 Environmental Factors

The vector lives and breeds in close association with human dwellings, where households live close to their cowsheds. There is insufficient information about breeding sites to predict the association but there is evidence of larval responsiveness to soil moisture. There is also evidence of adult vector association with species of cultivated plants that are grown on flood-free land. The vector can be controlled by residual house spraying with insecticide.

Historical evidence suggests a link with embankments. When cases where mapped during the baseline study there was evidence of clustering inside embankments. A retrospective case control study clearly identified embankments as a risk factor (odds ratio >8). Deeply flooded areas reported far fewer cases. A longitudinal survey would be required to confirm this observation. It appears that in some localities floods are an important deterrent to vector breeding.

5.3 Health Service Capability

There is no kala-azar control program, and disease surveillance is limited. Vector control is rare. An active and coordinated approach to vector research is required. Accurate diagnosis is relatively difficult. Widely available tests do not distinguish the disease from several other infections. Confirmation depends on painful bone marrow or life-threatening spleen extraction.

Treatment is relatively expensive (equivalent to one month's agricultural wage) and requires daily injections. Availability of the drug in pharmacies is variable and in government dispensaries it is very limited.

5.4 Health Risk

There is significant risk that kala-azar prevalence in some localities will increase as a result of flood control and drainage projects. The health service does not have the capability to manage this risk without additional support. There is poor linkage between the health sector and other sectors so that the risk may not be communicated to the Flood Action Plan.

6. Filariasis

6.1 Community Vulnerability

There was a widespread low prevalence of bancroftian filariasis during the last survey, 20 years ago. Cases occurred in both urban and rural environments. There was one focus with relatively high prevalence. The prevalence rate was higher in males. The large number of hydrocoeles caused considerable morbidity.

6.2 Environmental Factors

The vector mosquito is common and widespread. It breeds in peridomestic ponds, pools, and ditches where water is polluted by organic materials. A disease focus surveyed during the 1970s was close to sugar processing factories.

Increased environmental pollution associated with high population densities and drainage obstruction is expected to favor vector breeding.

There is anecdotal evidence that the vector population density rose in Dhaka following completion of new embankments, which caused drainage obstruction.

6.3 Health Service Capability

There is no recent surveillance data for the whole country, but a slow upward trend in prevalence is expected. There is no national drug treatment or control program. Diagnosis is simple. Drug therapy is cheap and effective during the early stages of the disease.

6.4 Health Risk

The vector population density is expected to rise as a result of an increase in polluted water sources. Drainage obstruction associated with flood control is expected to contribute significantly to this trend. A slow increase in infection rate is expected, and this will be accompanied, after a 10-year lag, with an increase in clinical symptoms and morbidity.

7. Other Vector-Borne Diseases

Dengue and Japanese encephalitis are arboviruses transmitted by mosquitoes. There is insufficient data about both diseases in Bangladesh but they are presumed rare. No association with embankments is expected.

8. Health Risk Management

8.1 Malaria

The status of secondary vectors should be kept under review.

8.2 Filariasis

Risk management will depend on good project design and operation. Polluted water sources require regular flushing by flood action. Drainage obstruction should be avoided. Monitoring populations of the vector should also provide a useful indicator of drainage obstruction.

8.3 Kala-azar

There is a cause for concern that the present epidemic of kala-azar will be exacerbated, in some localities, by flood control and drainage. Further action is recommended. This should be based on a dialogue with the health sector and include a planning workshop attended by national and international experts. The action should include:

- further studies of the vector breeding and feeding habitats in relation to embankments;

- retrospective case control studies in different districts to confirm embankment as a risk factor;
- longitudinal surveillance and mapping of cases in relation to embankments;
- adequate monitoring of development communities using serological techniques supported by confirmatory diagnosis;
- identification of high-risk localities;
- provision of adequate drugs, insecticides, equipment, and trained staff to health centers in those localities.

9. Acknowledgements

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Chapter 1

AN HISTORICAL REVIEW OF MALARIA, KALA-AZAR, AND FILARIASIS IN BANGLADESH IN RELATION TO THE FLOOD ACTION PLAN

1.1 Summary

This paper reviews the evidence for a link between flood control and vector-borne disease in Bengal/Bangladesh.

Malaria is historically associated with reduced flooding and embankment construction in the floodplains of Bengal. The land west and south of the Jamuna River was highly malarious in 1916 but is not so today. The lands east of the Jamuna now have a higher risk, although it is still small. The reduction in health risk can be attributed to the intensification of land use and human population density. Although there are many mosquito species, the abundance of the former malaria vector appears to have declined as environmental change removed its breeding sites.

Visceral leishmaniasis (kala-azar) is a serious disease which is fatal if left untreated. It occurs in irregular, periodic epidemics and is currently increasing in Bangladesh. In the past, malaria and kala-azar were often confused. The prevalence of both may have been increased by embankment programs.

Both diseases are unstable and there is insufficient historical information to predict with certainty the consequences of environmental change. Reduced flooding accompanied by increased pollution will probably control the malaria vector. More information is needed about the response of the kala-azar vector to flooding.

Bancroftian filariasis is non-fatal but causes chronic morbidity. It has had a widespread but usually low prevalence in Bangladesh, and it has both rural and urban foci. There is little recent data on the disease. Increasing organic pollution and drainage obstruction is expected to favor the vector and increase transmission.

1.2 Introduction

In the 19th century and the early part of this century it was believed that epidemic vector-borne disease was associated with flood control in Bengal (Klein, 1972). The disease was probably a mixture of malaria and kala-azar and the two may have "potentiated" each other (Ashford & Bettini, 1987). The advantages and disadvantages of flood control were as hotly debated then as today (Pearce, 1991). This paper reviews those earlier commentaries within the context of the current debate. While the historical evidence is insufficient to predict the outcome of the proposed Flood Action Plan, it provides a necessary background.

1.3 The Need for Flood Control

The disastrous 1987 and 1988 floods stimulated a renewed international interest in flood control in Bangladesh. There are two opposing viewpoints (World Bank, 1990).

- Periodic flooding is technically and economically unavoidable; control would create as many problems as it solved; there is considerable scope to build on the ability of Bangladesh farmers to cope and recover from the annual floods.
- The country cannot be left at the mercy of the floods forever; all major rivers must eventually be contained; this would reduce the risks currently associated with economic activity.

The second viewpoint is part of long-term government policy. As both viewpoints have their merits, the Flood Action Plan seeks to resolve several conflicting requirements. These include the need to improve drainage, enable controlled flooding of agricultural areas, protect major towns and cities, enable groundwater recharge and support fisheries, navigation, communications, and public health. One proposal is to design embankments to avoid drainage congestion by using controlled openings, pumps, and compartments. These would require complex management that critics consider impractical (Custer, 1992).

The World Bank report recognizes that deforestation of the upper catchments may contribute to larger and more frequent flooding. However, the report suggests there is no reliable data and no practical remedy in the short and medium term. The evidence that deforestation in Nepal has contributed substantially to increased flooding in Bangladesh is inconclusive (Ives, 1991). As only 8 percent of the catchment lies within Bangladesh, measures to limit flooding must rely on embankments.

The preliminary studies provided the basis for a five-year Flood Action Plan (FAP) spanning 1990-1995 with structural components and supporting activities. Supporting activity number 16 was an environmental impact assessment. This included a health impact assessment with a vector-borne disease sub-study. The current review was prepared for FAP 16.

1.3.1 The Hydrological Cycle

The three main rivers of Bangladesh are the Ganges, Brahmaputra, and Meghna. The discharges of these rivers are among the highest in the world. The average annual rainfall in Bangladesh is 1,200 mm in the west and rises to 5,000-10,000 mm in the east, and 70 and 85 percent of that rainfall occurs during the monsoon. Overbank and rain-water flooding occurs in the wet season. Flash floods normally occur in the eastern rivers in April and May. The main rivers normally reach their flood peaks in August and September. Whenever the peaks of the Ganges and Brahmaputra coincide, severe floods occur. An average of 22 percent of the land is flooded every year. Catastrophic flood, in excess of 35 percent cover, has a return time of less than 20 years (World Bank, 1990). The difference in maximum flooding height between average flooding and severe flooding is less than 50 cm.

Since the 1850s there has been a major and accelerating increase in the number of roads and railways in the region. These have frequently been constructed in ways that disrupt drainage, and they have been blamed for exacerbating the impact of floods.

1.4 History of Malaria and Kala-azar

It is likely that many diagnoses from the 1800s to the present day have confused malaria and kala-azar (Ashford & Bettini, 1987; Gibson, 1983). Such confusion was particularly marked before 1910 (Sanyal, 1985). Before 1940, the modes of transmission of both diseases were not fully understood. Because of their timing, each major discovery is relevant to review of the effect of embankments on vector-borne disease between 1800 and the 1940s (Bruce-Chwatt, 1985; Desowitz, 1991; Gibson, 1983).

1824	Kala-azar was first described from near Jessore as a fever with splenic enlargement.
1860	Kala-azar spread westward, reaching Burdwan and causing an epidemic. There was severe mortality leading to depopulation. Annual reports during the 1860s indicate disagreement about the type of fever, suggesting that both malaria and kala-azar were involved.
1869	The epidemic had spread to Assam. Some authorities thought that it followed lines of communication and was associated with deficient rainfall.
1880	Laveran identified the malaria parasite.
1886-91	Various workers described the malaria parasite species, and techniques were developed to demonstrate plasmodia in blood films.
1898	Ross and Grassi discovered that malaria was transmitted by mosquitoes.
1903	Leishman, Donovan, Bentley, and others isolated the causal organism of kala-azar from spleens of both live and dead patients.
1904	Rogers cultured kala-azar in vitro, and the search for a vector began.
1910	Parasitological diagnosis of kala-azar became widely available.
1925	Sinton published maps overlaying the distribution of Indian kala-azar with that of the silvery sandfly, *Phlebotomus argentipes* Annandale and Brunetti. Both were restricted to eastern India between Madras and Assam.
1940	It was finally demonstrated that *Phlebotomus argentipes* was the vector of Indian kala-azar.
1943	Second Bengal kala-azar epidemic.

1.4.1 Differential Diagnosis and Treatment

As there has been confusion over malaria and kala-azar in the past, it is desirable to summarize current opinion about the symptoms, diagnosis, and treatment of these diseases (Bell, 1981; Bruce-Chwatt, 1985; Sanyal, 1985; WHO, 1990).

The symptoms of kala-azar, or visceral leishmaniasis, include irregular fever of several weeks duration, early enlargement of the spleen and liver, loss of weight, and anaemia. Untreated kala-azar patients usually die within 1-2 years, although there is some spontaneous recovery followed by immunity. Death is usually by intercurrent infection, including pneumonia and dysentery. In the earlier epidemics mortality is said to have reached 90 percent. A proportion of patients who recover develop post kala-azar dermal leishmaniasis and harbor parasites.

The signs and symptoms can easily be confused with other diseases, including malaria. Definitive diagnosis is not possible without demonstration of the parasites (*Leishmania donovani*). Parasites can only be extracted by painful bone puncture or life-threatening spleen puncture. Both techniques require medical skill and suitable instruments.

There also are several blood tests that can be performed. Although useful, these are not specific and may show cross-reaction with a variety of other infections. The aldehyde test is commonly used in Bangladesh. Serological tests are available and new ones are being used on a very limited scale in Bangladesh. Such tests can detect early stages of infection and self-healing, subclinical forms. Seropositive individuals can then be referred for definitive diagnosis.

Treatment is by daily injection with sodium stibogluconate, a pentavalent antimony compound. One course of treatment requires 20 daily injections. The drug is relatively expensive (Tk. 75 per vial in pharmacies rising to Tk. 500 per vial on the black market) and is in short supply. A complete course of treatment would cost about one month of an agricultural laborer's wage (Ward, *pers. comm.*) Incomplete treatment is common because of high costs and brings temporary relief. In Bihar there is increasing drug resistance attributed to incomplete treatment. This required more than one complete course of treatment for cure (Sanyal, 1985).

Two of the four types of malaria require specific mention in relation to Bengal: *vivax* and *falciparum* malaria. At present, the malaria on the floodplain is almost entirely *vivax* malaria. Cases of *falciparum* are believed to be imported from the forest fringe. The manner in which the ratio has changed since 1850 is unclear.

The symptoms of both types of malaria include fever, prolonged splenic enlargement, and anaemia. *Vivax* today causes little or no mortality but can cause considerable morbidity. Yet early accounts attribute high mortality to malaria on the floodplains of Bengal. An oral course of cheap chloroquine provides relief from the symptoms of *vivax* malaria, but another drug, primaquine, is required to effect a complete cure. Without primaquine, relapse is common and such patients become a reservoir of infection.

Falciparum malaria is often fatal although patients who recover from it develop some immunity. Chloroquine resistance is common as is resistance to more expensive drugs. Treatment may be either oral or by injection. There is no relapse.

Definitive diagnosis of malaria is simple and requires a blood film, some stain, a functioning microscope, and a motivated technician. Unfortunately, problems of motivation and quality control are commonplace. The demonstration of the presence of parasites does not prove that the patient is suffering from malaria because asymptomatic infection is common in endemic areas.

Two indices are in common use to describe the epidemiology of these diseases. The *parasite rate* is the proportion of individuals in a specific group who have demonstrable parasites. The *spleen rate* is the proportion of individuals in a specific group who have enlargement of the spleen. The spleen rate does not distinguish malaria and kala-azar.

Early accounts of malaria relied on the spleen rate. Kala-azar was considered an unusual form of malignant malaria. By the time blood film examination was routinely used, the 19th century kala-azar epidemic was in decline and apparently little *falciparum* was recorded (Klein, 1990).

1.5 History of Kala-azar in Bengal

Irregular epidemic waves have swept through Assam, Bengal, and Bihar since the 1800s with a frequency of 15 to 75 years depending on locality (Ashford & Bettini, 1987; Sanyal, 1985). Peaks occurred in Bengal in 1824, 1873, and 1943. There was an epidemic peak in Sylhet in 1902. Larger epidemics occurred in Assam. Epidemics occurred in Bihar in the 1940s and 1973-79. The poorest rural communities were most at risk.

The All-Bengal Kala-azar Conference mapped "dispensary kala-azar fever" for 1921 and 1924 (Anon., 1925). In 1924 the disease was widespread over much of the country and particularly the districts of Rajshahi, Nadia, Jessore, Mymensingh, and Noakhali. In 1919 Tangail was heavily infected with reports of kala-azar from all villages.

In the Bengal Public Health Report of 1936, the leading causes of death in Bengal were ranked as follows: malaria was the highest with 7 percent, then other fevers, pneumonia and other respiratory diseases, enteric infections, kala-azar, and child birth (Chatterji, 1936). Kala-azar prevalence was highest in Rangpur, Jessore, and Noakhali. Forty seven percent of fever deaths were due to malaria, 47 percent to "other fevers," and 3 percent to kala-azar.

Effective malaria control during the 1950s and 1960s was accompanied by almost complete eradication of kala-azar. A small number of cases were reported in Dhaka between 1968 and 1980, from widely different districts (Elias, Rahman, & Khan, 1989). A small epidemic was reported from Pabna district in 1980, based on the aldehyde test.

Since the late 1980s, cases of kala-azar have being increasingly recognized from most districts of the country (Abdullah El-Masum, *pers. comm.*). A small 1990 survey of 36 blood slides in Tangail district found 21 seropositive (Masum, Badrul, & Rafiquddin, 1990). Parasites were demonstrated in two out of three bone marrow aspirates.

Most of the present global population at risk from kala-azar are in India and Bangladesh and about half the case reports are from that area (Ashford, Desjeux, & de Raadt, 1992).

1.6 History of Malaria in Bengal

Klein has extensively reviewed the causes of mortality in India between 1840 and 1921, summarizing much of the earlier commentaries (Klein, 1972; Klein, 1990). Unfortunately, Klein does not recognize the confusion between malaria and kala-azar. Nevertheless, Klein's summary draws attention to early commentators' conviction that "fever deaths" were associated with developed projects, especially embankments.

Bentley was one of the strongest advocates of the linkage between fever and embankments (Bentley, 1916; Bentley, 1925). One of the anomalies of Bentley's reports is that there is no separation of malaria and kala-azar although he was actively researching kala-azar in 1903 (Gibson, 1983).

In 1916, the areas of intense malaria transmission in Bengal were largely in West and Central Bengal; west of the Jamuna-Padma River and south of the Ganges, the area of moribund rivers known as the Ganges floodplain (Bentley, 1916). Tangail and Sylhet were listed as having very little malaria.

Bentley described the great upsurge in "epidemic fever" during the 19th century and attributed it to embankment construction. For example, an 1836 epidemic in Jessore was attributed to road construction. Embankments for road and rail increased rapidly from the 1850s onward. Bentley quotes a report by Stewart and Proctor (no citation) comparing spleen rates inside and outside an embankment. Bentley supposes that the splenic enlargement was due to chronic malaria, but it may have been due to kala-azar. In either case, Table 2 suggests an association between embankment and disease. Bentley claimed numerous similar examples.

Table 2
Clustering of Splenic Enlargements on the East Bank of the Bhagirathi River, Murshidabad District, 1893 (Bentley, 1925).

Location of embankment	Inside	Outside
Number of villages	29	26
Mean spleen rate	60%	27%

The railways, in particular, required protective embankments, and far too few culverts were constructed. The embankment process cut across natural lines of inundation and drainage. By the 1920s there were 3,000 miles of rail and 1,900 miles of metalled road in Bengal. In Bentley's view the problems of embankments increased geometrically with their length. Bentley campaigned for an end to all embankment construction. He claimed that embankments reduced soil fertility by preventing flooding, caused river silting, and contributed to the development of moribund rivers. He believed that flood water inhibited malaria mosquito breeding through flushing, formation of large pools, suspended silt, and changes in pH. Affected areas suffered population decline. To support his hypothesis he contrasted conditions in West/Central and East Bengal.

Table 3
Summary Comparison of West, Central and East Bengal for 1900-1925 (Bentley, 1925).

West and Central	Production low, fallow common, malaria intense, human population growth low or negative, embankment common, moribund rivers, rainfall high.
East	Production high, fallow uncommon, malaria absent, human population growth high, annual flood, embankment rare, rainfall very high.

Bentley's solution to the problems of malaria in Bengal were threefold. He advocated:

- a detailed survey of the factors that he had outlined;
- drug prophylaxis;
- mosquito control by environmental management ("bonification").

The environment management would consist of permanent source reductions, temporary source reductions, the use of netting and repellents, and the improvement of the human population. In Italy "bonification" had consisted of draining the marshes. In Bengal the opposite would be required. He especially advocated increased intensity of agricultural production coupled with controlled flooding and flushing.

He cites examples of the success of this method in Rajshahi in the 1870s, Kana Nadi in 1874, and Jangipur and Kumarkhali in 1919. At Kumarkhali the spleen rate apparently fell from 77 percent to 10 percent between 1918 and 1922 as a result of a flood-and-flush scheme. Re-excavated portions of the decaying Saraswati River had lower spleen rates than nearby non-excavated portions. The Kana Nadi project consisted of building a canal to enable flood water to flow into a decadent channel and hence into khals, drains, and tanks. A dramatic decrease in malaria was reported. The improvement of human population consisted of increased population density, higher standards of living, and increased cropping intensity. Bentley quoted the Ross malaria model to argue that increased human density associated with fewer bites per person per year would reduce malaria prevalence. Changes in crop were also advocated, including intensive paddy rice cultivation.

Bentley thought that drainage without flushing could have a negative effect. A drainage project at Magrahat in 24-Parganas was started in 1909. Before drainage, the low-lying areas were far less malarious than adjoining higher areas. Following drainage, there was a large increase in the malaria fever index. He concluded that malaria control in Bengal depended on increased irrigation rather than increased drainage.

Iyengar supported Bentley's viewpoint (Iyengar, 1927). The western region was raised by siltation and traversed by moribund or dead distributaries so that the land was generally not flooded. In this zone there was high malaria endemicity. Occasional flooding was associated with health improvement. Low-lying areas were healthy; malarious foci occurred on elevated river banks. The eastern region was low-lying and subject to flooding with a high water table, prosperous, and non-malarious.

In some areas malaria was associated with a shortage of drinking water. Here tanks were on relatively high ground and dried up quickly in the dry season because of low ground water.

Bruce-Chwatt (1985) comments that "In deltaic regions such as Lower Bengal, the annual flooding of the land by the rise of water level in the great rivers provides a striking example of the natural control of malaria. The silty flood waters are inimical to the breeding of the local vectors, the extent of breeding edge is reduced, and the raising of the water level above that of the aquatic vegetation exposes the larvae to the attacks of fish and other predators."

1.6.1 Malaria Zones of Bangladesh

Four main ecological zones of Bangladesh are now recognized in relation to malaria transmission (Elias, Dewan, & Ahmed, 1982; Elias, Rahman, Mobarak, Begum, & Chowdhury, 1987; Rooney & Elias, 1989).

- Stratum 1: Forest, forest fringe, and foothills, where malaria transmission is most intense and the main vector is *An. dirus* Peyton and Harrison (=*balabacensis*) although *An. philippinensis* Ludlow and *An. minimus* Theobald are also present.
- Stratum 2: areas bordering Stratum 1, which have a significant proportion of *falciparum* malaria.
- Stratum 3: the saline coastal zone, where the vector is *An. sundaicus* (Rodenwaldt).
- Stratum 4: the floodplain, where the vector is believed to be *An. philippinensis* and the only indigenous species of malaria is currently *P. vivax*.

The floodplain is the focus for this review. Malaria in the floodplain is unstable and has epidemic potential. Control has been by focal DDT spraying in response to case detection.

1.6.2 Malaria Control

In 1947 the partition of India placed several districts of W. Bengal in India and closed the border to further labor mobility. Part of the district of Sylhet was acquired from Assam.

In 1952 the Indian malaria eradication campaign started, and residual house spraying with DDT proved highly affective against both mosquitoes and sandflies. By 1955, kala-azar had virtually disappeared from India, and it did not return until malaria eradication was abandoned in 1971.

In 1960 the Malaria Eradication Programme started in East Bengal with a survey of the spleen rate in children aged 2-9 years (Kondrashin & Rashid, 1987). By that time the most malarious areas were along the borders and in the hill tracts. The spleen rate in Jessore, previously high, appears to have been low.

In 1971 the war of independence from Pakistan severely disrupted malaria control and created considerable temporary labor mobility. Kala-azar was reported from Bihar, India, and by about 1979, it had spread to Pabna, Bangladesh.

Paul reviewed the change in malaria prevalence rates during the waning period of the Malaria Eradication Programme (1961-71) and the post-independence period (1971-1977) when there was a resurgence (Paul, 1984). Before the eradication program, malaria accounted for 15 percent of the total annual mortality rate. The program was believed to have been successful and the annual parasite index (API) reached a minimum of 0.05 in 1971 (Rooney & Elias, 1989). From 1975 onwards the API has remained in the range of 0.4 to 0.8. The resurgence is partly attributable to the war of liberation and the subsequent disruption. Paul discusses agro-ecological changes. These include the increase in the cultivation of HYV rice from 0.84 million acres during the waning period to a maximum of 3.3 million acres during the resurgence period of 1971-1977.

In 1989 the International Assessment of the Malaria Programme mapped the distribution of malaria and concluded that it was almost exclusively in the eastern part of the country (Rooney & Elias, 1989). This represents a complete reversal of the situation in 1916. The prevalence rate in Jessore, for example, is now considered to be very low. While recognizing the very low reliability of the data, it would appear that some profound changes have taken place. These changes cannot have been maintained only by DDT spraying, as little spraying takes place outside the hill tracts. They must be attributed to environmental change. During the early 1960s, the vectors were probably controlled by DDT. By the end of the 1960s, environmental changes would have occurred as a result of population growth and intensive agricultural production. When DDT spraying ceased or became intermittent, the environmental changes would have remained as a deterrent to vector breeding.

The same report summarized malaria case reports between 1982 and 1989. The annual blood examination rate (ABER) and the slide positivity rate (SPR) are both very low, 1 to 3 percent. Most cases are recorded in the Stratum 1 zone, which is not the floodplain. On the floodplain the *falciparum* rate is low (10 to 30 percent) and believed to be imported by labor circulating between Strata 1 and 3. The annual malaria cases reported are frequently less than 1,000 per district.

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1.6.3 Population Pressure, Malaria, and Environmental Change

There have been many environmental disturbances in Bengal since the 1800s. The most important may have been the devastating effect of British conquest and, later, colonial rule (Ahmed, 1968). High taxes were levied and a well-established cotton industry was destroyed. Later the farmers were forced to grow indigo on all the best agricultural land for an extremely low return, displacing their subsistence crops and reducing their economic status. Later still jute production flourished and is still second only to paddy rice. Jute cultivation requires extensive areas of polluted "retting ponds."

One other obvious source of environmental change is population pressure. Bentley (1925) tabulated population growth from 1872, the first census, to 1921. His data emphasizes the extraordinary lack of growth in the West and Central regions. Klein (1970) describes the numerous causes of high mortality before World War II. They include a series of epidemics of plague, influenza, cholera, and malaria.

More recent data indicate how the enumerated population has changed since 1901 in various districts (Anon., 1990). The population of Jessore and Rajshahi, in the West-Central regions remained almost stable between 1901 and 1961. Since then it has more than doubled. The population of Sylhet, in the Eastern region, continued to increase steadily.

The population density of Jessore was said to have been higher in 1881 than in 1961. The decreasing density was associated with reduced land fertility, which was in turn associated with moribund rivers. "The adverse effects of deteriorating physical conditions are typically reflected in the story of epidemics and diseases in the Jessore district during the last 150 years" (Ahmed, 1968). There were also large migrations of Hindus out of Jessore to India after 1947.

By 1961 the plain area of 49,000 square miles had a population density of 1,030 persons per square mile (Ahmed, 1968). This was already one of the highest rural population densities in the world and contrasts with other high population densities which are usually urban.

After 1961, the population increase must have created environmental changes such as reduction in fallow land and higher levels of organic pollution. As Bentley had suggested earlier, increased density may have been sufficient to suppress malaria. The National Development Plan, started at that time, must also have made an important contribution.

Average population density is currently 1,170 per km^2 (3,030 per mile) on cultivatable land (World Bank, 1990). In response to the growing population, the average farm size has declined from 1.45 ha to 0.90 ha between the 1960s and the 1980s and is expected to continue falling. Seventy-eight percent of the cropped area is planted with rice. Agricultural production has grown considerably since 1947. Before the 1960s most growth came from bringing more land into cultivation and from more intensive use through double cropping. Since the 1960s the increase has been due to minor irrigation, fertilizer, and the introduction of HYVs. Flood control and drainage have been important in protecting the boro (dry season rice) crop and enabling the cultivation of higher yielding varieties.

In addition to intensive agricultural production, high population density increases inorganic pollution, which is frequently inimicable to anopheline mosquitoes, although it favors the culicines.

2+

1.7 Malaria Vectors

For most of this century *An. philippinensis* has been acknowledged as the only malaria vector in the floodplains.

1.7.1 Ecology of *An. philippinensis*

A series of classic studies on the ecology and vectorial status of *An. philippinensis* in the delta were published by Iyengar in the period up to 1944 (Iyengar, 1939; Iyengar, 1942; Iyengar, 1944). The studies confirmed *An. philippinensis* as the only vector in the floodplains and identified its breeding, resting, and biting habits. The breeding requirements were specific with regard to depth of groundwater, shade, and vegetation, and environmental management could be used for vector control. Environmental management included raising groundwater depth by irrigation, covering ponds with water-hyacinth, and the opposite: removing all aquatic vegetation from ponds.

An. philippinensis is now thought to consist of several closely related species (a species complex). Historically, *An. philippinensis* was only a vector in Bengal. In Assam it was zoophilic. It was rarely or never incriminated as a vector in other parts of its range including China, Burma, Assam, and the Philippines (Covell, 1944). Recent studies in India have confirmed that all specimens thought to be *An. philippinensis* from Assam, Meghalaya, Arunachal Pradesh, and Manipur are, in fact, *An. nivipes*. The two species cannot be reliably separated by morphological characteristics, only by examination of polytene chromosomes (IMRC, 1987; Sharma, 1987).

1.7.2 Depth of Groundwater

In the vicinity of the town of Sonarpur in the district of 24-Parganas (now in West Bengal, India) the groundwater varied from 0 to 62 inches over a distance of 4 miles. Vector abundance and malaria prevalence (as indicated by spleen rate) were recorded in eight villages along the transect. The results are listed in Table 4 (Iyengar, 1942).

Table 4
Comparison of Soil Water Depth, Vector Density, and Spleen Rate Along a Transect (Iyengar, 1942)

Village	August subsoil average water depth (inches)	Percent of *An. philippinensis* in larval samples, 1929-1937	Average percent spleen rate, 1929-1937
Sitola	0	0.008	0
Srikanda	17	0.014	0.02
Gaurkhara	21	0.012	2.28
Sonarpur	34	0.073	8.06
Nischintapur	36	0.386	17.97
Malkapur	38	0.595	20.80
Paikpara	51	1.246	28.05
Ukhila	62	1.060	43.07

There were significant correlations between *An. philippinensis*, spleen rate, and water depth. There were no observable variations between the numerous ponds and pond types that could account for this result. Iyengar suggested that waterlogging inhibited the dissolved oxygen content of ponds, which in turn inhibited the growth of green non-filamentous algae on which the larvae fed.

1.7.3 Vegetational Requirements of Breeding Sites

Although *An. philippinensis* has been found breeding in ricefields, it was a far less important habitat than village ponds (Iyengar, 1944; Sen, 1948). It was found only when the rice plants were 12- to 24-inches high, casting partial shade, in the presence of filamentous algae and when the water was perfectly clear (Sen, 1948). Sen proposed that increased rice cultivation would be an environmental change that would reduce vector breeding. Although rare, ricefield breeding is still recorded (Elias, et al., 1987).

Iyengar (*op. cit.*) categorized permanent village ponds as the main breeding site. These ponds were in full sunlight, had a high dissolved oxygen content, and they contained water that was clean of sullage or decaying organic matter. Sub-aquatic, non-shading, vegetation, which was required for breeding, often formed mats or bushes beneath the surface. This vegetation included *Hydrilla verticulata* and filamentous algae (*Spirogyra* spp.). Floating aquatic vegetation was inimical to larvae and included *Azolla, Salvinia*, and *Eichhornia*, as well as duckweed. Shade was believed to inhibit the growth of green non-filamentous algae, which was the larval food. Certain species of blue-green algae, including *Microcystis ruginosa*, were also inhibiting.

Even in hyperendemic villages only 10 percent of the 50 to 90 ponds per village were positive.

Other breeding sites included blocked rivers and canals and vegetated marshes (beels). Shallow borrow pits and drains were not important.

1.7.4 Adult Resting and Biting Sites

Before the DDT era, *An. philippinensis* rested mainly in human dwellings and within 0.5 m of the floor (Iyengar, 1944). In 1952, *An. philippinensis* were the only anopheline more abundant indoors than outdoors and entered houses after midnight (Gramiccia, 1952). After 1961, malaria control was based on residual house spraying with DDT. As a result of DDT spraying, both the biting and resting behavior changed to outdoors, although susceptibility to DDT remained (Elias, Rahman, & Mizanur, 1985).

1.7.5 *Anopheles aconitus*

In October 1991, *An. aconitus* Donitz was incriminated as a vector for the first time in Bangladesh. The parasites were detected in patients' salivary glands in the upazila of Araihazar, Dhaka district, following a small malaria outbreak (*pers. comm.* N.P. Mahaswary, Directorate of General Health Services). *An. aconitus* is recognized as an important malaria vector in the ricefields of Indonesia. It also breeds in sunlit swamps, irrigation ditches, pools, and streams (Bruce-Chwatt, 1985).

1.7.6 Other Malaria Vectors

An. culicifacies Giles, the principal malaria vector in neighboring India, has been recorded in the past from various parts of Bengal, but it is rare in Bangladesh (Subbarao, 1988). In India, four sibling species are recognized. Species A is considered the principal vector and predominates in W. India and Pakistan. Species B is associated with riverain villages and is a poor vector. It predominates in Bihar and Nepal. *An. stephensi* Liston, also an important vector in India and Pakistan, is very rare in Bangladesh (Elias, et al., 1982). The most likely explanation for the absence of these vectors is the higher rainfall and humidity of Bangladesh.

1.7.7 Anopheline Diversity

Iyengar recorded *An. philippinensis* as about 1 percent of total anopheline larval collections in the 1929-37 period and about 10 percent of indoor biting collections. *An. philippinensis* represented 1.4 percent and *An. aconitus* 1.7 percent of the total anophelines collected in 1984-89. The most common species in that period (50 percent) was *An. vagus*. The results of a special human bait study in Stratum 1 during 1988-89 were 37 percent *An. philippinensis* and 2.5 percent *aconitus*, of which 88 percent were outdoor biting (Rooney & Elias, 1989). There is no comparable data for the floodplains.

1.7.8 Seasonality

Iyengar observed *An. philippinensis* throughout the year, but the main season for them was from July and October with a single peak. At other times numbers were very low. Elias observed a single peak in October, and the main season was from August to December (Elias, et al., 1987). Gramiccia *et al.* observed a double peak in May-July and October-November in Mymensingh district (Gramiccia, 1952). Heavy rains in August-September greatly disturbed breeding.

1.8 Kala-azar

1.8.1 Epidemiology

A distinct epidemic area is recognized. This area includes the alluvial valleys of the Bramaputra and Ganges between Lucknow and Sylhet and south along the Indian east coast. The bioclimatic limitations include: hottest month with mean maximum below 38°C; coldest month with the mean minimum of 7°C; diurnal temperature variation of 12°C for at least three months; humidity above 70 percent; rainfall above 50 in. (1250 mm); alluvial soil; abundant vegetation with subsoil water (Ashford & Bettini, 1987). Other reported factors include overcrowding, poor ventilation, and collection of organic materials in houses. Interepidemic periods are maintained by asymptomatic cases and chronic post kala-azar dermal leishmaniasis (PKDL).

Sandfly densities peak from August to October. Since there is an incubation period of two to six months, human disease incidence peaks are later.

Family clustering of cases is characteristic of Indian kala-azar. Exposure occurs in the domestic environment, and all family members may be equally exposed. During the 1978 epidemic in northern Bihar, higher disease incidence was noted in villages with crowded houses and cowsheds and in the poorest communities (Sanyal, 1985; Thakur, 1984). The majority of cases were in children and young adults.

There is normally a sex bias for kala-azar, more cases occurring in males. The ratio varies from 1.3:1

to more than 5.5:1 (Thakur, 1984). There are no changes in age distribution during an epidemic. The incubation period varies from two days to nine months (Thakur, 1984). Masum noted a sex ratio of 2:1 in Kalihati during 1990 (Masum, et al., 1990). Studies in the 1930s showed that both age and sex distributions were affected by distance from the dispensary. It is suspected that more cases are detected in males than females because women's mobility is restricted by purdah (Brabin & Brabin, 1992).

1.8.2 Vector Ecology and Control

The vector sandfly, *Ph. argentipes*, is more widespread than the disease but mainly a cattle feeder—especially at the limits of its range (Ashford & Bettini, 1987). It is synanthropic and has been successfully controlled by residual house spraying with 4 percent DDT on the lower 2 m of walls. This is usually effective for 6 to 12 months.

Ph. argentipes collected in Sirajganj in 1981 were DDT susceptible (Ahmed & Ahmed, 1983). They were found resting in human dwellings during the day and in cattle sheds at night. DDT resistance was observed for the first time in northern Bihar during 1989 (Mukhopadhyay, L, & Narusimham, 1992).

Sandflies are known to require plant sugars for both survival and transmission of *leishmania* parasites. A recent study in Bihar recovered *Ph. argentipes* from *Amaranthus spinosa* and *Musa sapientum* (Dinesh & Dhiman, 1991). An unpublished ecological study of Northwest Bangladesh surveyed the distribution of these plant species (D. Cross *pers comm.*). Both were commonly cultivated on flood-free land and in the vicinity of homesteads. These observations suggest the hypothesis that specific cultivation practices associated with flood control may affect the vectorial capacity of *Ph. argentipes*.

1.8.3 Hydrological Features and Sandfly Breeding in Bangladesh

The sandfly breeds in decaying organic material around cattle sheds and troughs. The breeding sites are usually within 5 cm of the surface in soil of high organic content with a broken surface and high humidity. Larvae have been found in 19 percent of samples from the corners of cow sheds in Burdwan and in soil samples from human dwellings and cow sheds in Bihar (Dhiman, Shetty, & Dhanda, 1983; Hati, Manjulika Auddy, Das, & Gosh, 1982). The breeding sites have to be reasonably sheltered from both flooding and desiccation (Shortt, Smith, & Swaminath, 1930). An early study found larvae only within 6 m of dwellings and the type of site varied with season (Smith, Mukerjee, & Chiranji Lal, 1936). In the dry season, larvae were in shaded soil near tanks. In the wet season, they were closer to houses, protected by eaves and often indoors. In cattle sheds they were found beneath cracked earthenware cattle troughs. Peak breeding was during and just after the monsoon.

Kala-azar has always been associated with the alluvial soils of the river valleys. The effect of floods on larval distribution has been studied in a flood-prone area of Bihar (Mukhopadhyay, Rahaman, & Chakravarty, 1990). During the flood all ground level breeding sites were submerged by up to 60 cms. Larvae were found in earth scrapings as high as 90 cm up house walls. After the floods the larvae returned to ground level. The study demonstrated that larval breeding is not completely prevented by deep flooding.

It appears that the larvae are responsive to soil moisture and will move in search of the optimum. Inundation, flood control, irrigation, drainage, and soil type all affect soil moisture. In Bangladesh the soil catena is characterized by sandy or silty ridges adjacent to heavier, clay texture basins (Pitman, 1987). Houses are built on the ridges to escape the worst of the floods. Soil moisture is a combination of vertical infiltration and capillary flow from shallow water tables. Vegetation cover is also important. The relationship between these factors has been comprehensively studied by soil scientists (Pitman, 1987). However, the association with phlebotomine breeding sites has not been systematically studied.

1.9 Filariasis

Hydrocele, probably due to filariasis, was prevalent in lower Bengal in the 19th century, suggesting the existence of a long-term, widespread reservoir (Wolfe & Aslamkhan, 1971). Limited parasitological investigations during the 1920s detected *Wuchereria bancrofti* in the towns of Dinajpur and Pabna and the districts of Rangpur and Noakhali. During the late 1960s microfilaria were detected in night blood film surveys from all 17 districts of what was then East Pakistan (Wolfe & Aslamkhan, 1971). On average, 3 percent of people examined were infected. The highest rate, 14 percent, was in the district of Dinajpur, on the north-west border with Bihar. The rate was very low in the city of Dhaka, despite the potential abundance of the mosquito vector, *Culex quinquefasciatus*. The infection rate was twice as high in males as females.

Detailed surveys in Thakurgaon, Dinajpur district, detected both microfilaria and clinical manifestations (Barry, Ahmed, & Khan, 1971). Genital symptoms were more common than swelling of the limbs. The focus was categorized as moderately endemic with a 10 percent clinical manifestation rate. It was estimated that 10 years of exposure was necessary before clinical symptoms developed. Seventy percent of those with clinical symptoms were not microfilaria carriers.

Further investigations in Thakurgaon described the foci as largely rural, in contrast to the largely urban foci found elsewhere in Asia (Wolfe & Aslamkhan, 1972). The large number of hydroceles caused considerable morbidity. The vector was found infective for six months of the year during the hot and rainy period (Aslamkhan & Wolfe, 1972). Larvae were not found in ponds or other permanent water collections, but only from small polluted peridomestic pools, sullage pits, and open dirt drains. The authors discuss why filariasis should be more prevalent in this single locality compared with other parts of East Pakistan. The extensive production and processing of sugarcane in the area was felt to be an important contributory factor, possibly favoring the vector.

The *Culex vishnui* complex were incriminated as minor vectors.

The other filarial parasite, *Brugia malayi*, has been recorded from the eastern border districts. It had remained rare up to the 1960s despite the abundance of vector *Mansonia* mosquitoes.

A survey of refugee populations in Dhaka demonstrated an 8 percent infection rate with Bancroftian filariasis in 1983 (Ahmed, Maheswary, & Khan, 1986). This contrasted with the very low rate found during the 1960s. During the independence war of 1971 there had been great social disruption and Dhaka had tripled in size. Many refugees came from the north-west. The vector, *Culex quinquefasciatus*, had become "extremely common" and represented 85 percent of the total mosquitoes caught. Active transmission was demonstrated. The discussion noted that the overburdening of the sewage system and stagnation of water in Dhaka would lead to an increase in the vector population and an increase in urban filariasis.

Since the late 1960s there has also been a large increase in the rural population together with environmental changes. These changes include an increase in polluted water favorable to the breeding of the filariasis vector. Increased drainage obstruction of both rural and urban localities is likely to provide additional breeding sites and lead to a higher prevalence of Bancroftian filariasis.

1.10 Dynamics of Vector-Borne Disease

The Ross-Macdonald model predicts that malaria prevalence rate will vary with the vectorial capacity of the mosquito population in a non-linear fashion. Vectorial capacity is a linear function of the mosquito density and the human blood index and a non-linear function of mosquito survival rate. Residual house spraying reduces survival rate and can have a dramatic effect on malaria prevalence rate.

The unstable, low prevalence of *vivax* malaria on the Bangladesh floodplains locates the system where small changes in vectorial capacity greatly influence prevalence. These changes could be the result of changes in vector density, human blood feeding, or survival. Changes in density would be associated with changes in abundance of suitable breeding habitats. Small environmental changes could tip the balance between low and high malaria prevalence.

Mathematical models have been used to study kala-azar epidemics in Assam (Dye & Wolpert, 1988). It was concluded that the epidemic waves were irregular and more the result of intrinsic population processes than extrinsic driving variables, such as earthquakes or influenza. Epidemic potential appeared to be particularly sensitive to small reservoirs of human infection.

1.11 Discussion

Malaria and kala-azar are both dynamic, unstable diseases. Small changes in the number of vectors, vector survival rate, human blood feeding, and the prevalence of infective hosts can have a dramatic effect on the incidence of disease. Such changes can be triggered by environmental modification and they remain hard to predict.

There is a large body of information about malaria and kala-azar in Bengal up to about the 1940s. After that date the information about East Bengal (Bangladesh) becomes progressively more sparse. The historical record suggests that large-scale modifications first increased and later decreased the health risk of vector-borne disease. Now that large-scale modification is again planned there is a need for continuing vigilance. The amount of good quality information currently available is insufficient to draw any reliable conclusions about the potential impact of embankments. However, it seems possible that widespread flooding, rice cultivation, and organic pollution militate against malaria vector breeding. As reduced flooding is likely to be accompanied by an increase in organic pollution and rice cultivation, vector breeding will probably not increase.

Vivax malaria is not a life-threatening disease and does still respond to chloroquine therapy. Chloroquine is plentiful and malaria prevalence appears to be low. *Falciparum* malaria is a life-threatening disease and parasite resistance creates problems of effective therapy. There does not appear to be significant transmission of *falciparum* malaria on the floodplain. Kala-azar is a life threatening disease that requires complex diagnosis and therapy. The therapy is relatively costly and not widely available. There is a kala-azar epidemic in progress and insufficient data are available about its prevalence. Bancroftian filariasis has had a widespread but low prevalence in both rural and urban Bangladesh. There is no recent information. Drainage obstruction, human population density, and intensive land use are all likely to favor the mosquito vector. This may lead to a slow rise in the prevalence of infection and, eventually, to a rise in clinical symptoms.

The current capabilities of the health service to undertake surveillance, treatment, and control of vector-borne diseases are crucial to the management of risks associated with flood control. Desowitz (1991, p. 73) provides a critical account of the capabilities of certain Bangladeshi institutions in the recent past. The International Assessment of the Malaria Programme noted that government entomologists had poor facilities for field surveys, morale was low, training inadequate, and microscopy poor (Rooney & Elias, 1989). A recent review of kala-azar control in Bangladesh recognized a lack of diagnostic facilities, trained staff, adequate reporting system, and a low level of awareness among medical personnel (Elias, et al., 1989). It also noted a shortage of suitable drugs and their intermittent supply.

The Fourth Five Year Plan of the Government of Bangladesh noted the severely restricted capabilities of the national health service and the low per capita expenditure on health (Government of Bangladesh, 1990). It noted the inadequate multisector support for the health service and attributed this to poor linkages between health and other sectors. There was an absence of appropriate guidelines and orientation for the heath sector to cope with developments such as the Flood Action Plan.

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Chapter 2

SANDFLY BASELINE SURVEY

2.1 Introduction

The fatal disease called kala-azar is transmitted in Bangladesh by a single species of sandfly called *Phlebotomus argentipes*. There are a number of other non-vector species including *Ph. papatasi* and *Sergentomyia sp.* The objective of this survey was to determine the distribution of *argentipes* between districts and between villages within districts. In each of three districts, three villages were selected on the basis of their relative elevation. We hypothesized that elevation affected soil moisture and soil moisture affected larval habitats. We also hypothesized that embankment projects may affect soil moisture.

2.2 Sampling Method

Resting male and female sandflies were aspirated from human and animal dwellings during the morning. They were not separated by sex. In each of the nine villages, one collection was made per month for one year. House location was not fixed, but houses were drawn from a pool of 25 in the vicinity. There was unrecorded variation in the amount of sampling effort per month. Sampling was undertaken by two technicians supervised by a district or divisional entomologist or Mr. Hassan.

Specimens were identified into two groups: *Phlebotomus argentipes*, the vector species, and others.

2.3 Results

A total of 2,707 sandflies were captured of which 22 percent were *Ph. argentipes*. Seventy-nine percent of the *Ph. argentipes* were captured in human dwellings. The proportion of *Ph. argentipes* was similar in both animal and human dwellings.

{Steve to describe environment from his data} Eighty-one percent of all sandflies and 89 percent of all *argentipes* were captured in Natore district. *Argentipes* was absent from Sylhet. Table 5 indicates the distribution of *argentipes* between villages in Natore and Tangail. In Tangail, the highest densities of both *argentipes* and other sandflies were found in villages that were located beside rivers or beels. This probably reflects a need for optimal soil moisture in larval habitats. In Natore, the highest density was in a village beside a blocked river.

Table 5
Distribution of Sandflies between Villages

District	Village	Elevation	Non-vectors	*Ph. argentipes*	*% argentipes* from district
Natore	Katapukuria	High	566	64	12
	Koigram	High	359	123	24
	Puthimari	Beside blocked river	750	334	64
Tangail	Agbetoir	Beel (low)	101	28	42
	Gopalpur	High	27	6	9
	Porabari	Riverside	31	33	49

Figure 1 indicates the time series from each district and separates *argentipes* from other species. Peak densities for all species together occurred from April through July.

Figure 2 indicates the time series from each village in Natore and separates *argentipes* from other species. The trends in Koigram and Puthimari are similar, with two seasonal peaks. The seasonal peak in Katakupuria is earlier, of longer duration, and largely of non-vector species.

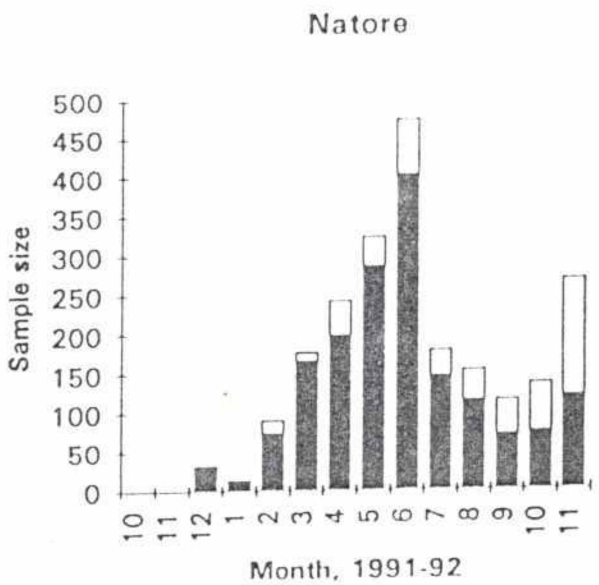
Figure 3 indicates the time series of *argentipes* in Natore and separates samples from human and animal dwellings. The *argentipes* time series does not have a seasonal peak in contrast to the total sandfly series of Figure 1. The reason is unknown.

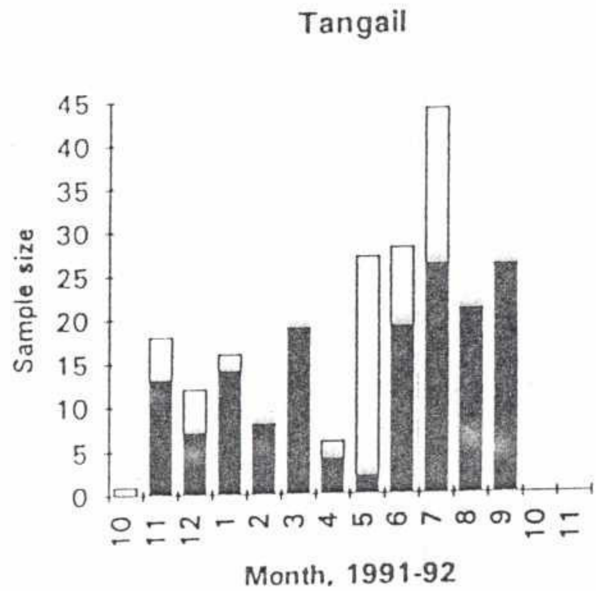
A short survey in May 1991 confirmed that the majority of daytime and nighttime resting samples were female. By contrast, the majority of flies caught on a tethered cow were male.

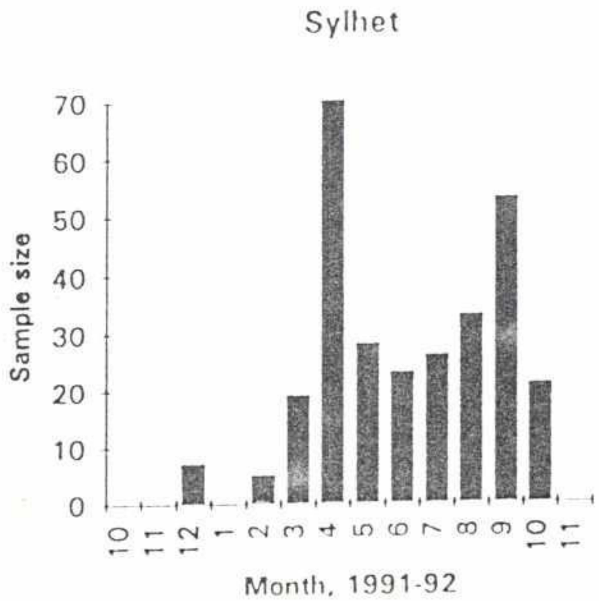
2.4 Discussion

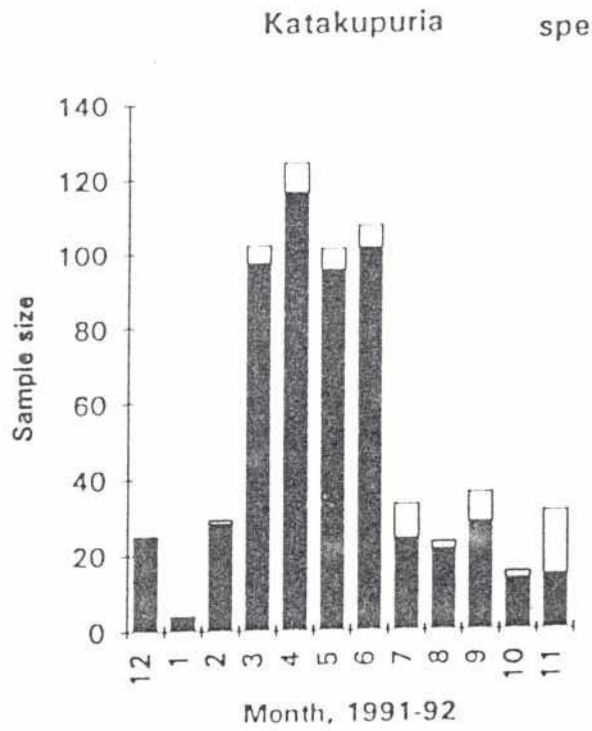
Considerable variation in vector abundance was noted. The vector was absent from the sample sites in Sylhet. Within each district there was variation between villages. This was most apparent in Natore, where the sample size was large. There was considerable seasonal variation but more information would be required to relate this to environmental conditions.

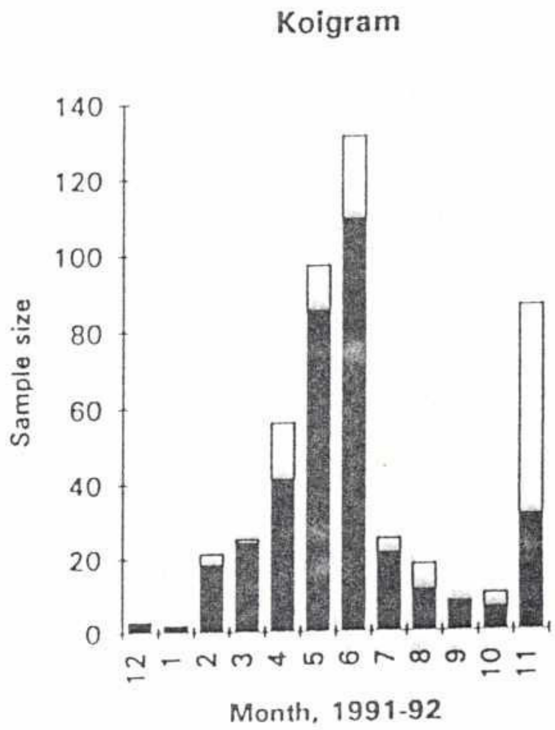
Figure 1. Time series of sandfly densities in the districts of Natore, Tangail and Sylhet, 1991-92. *Ph. argentipes* are clear columns, other species are shaded.











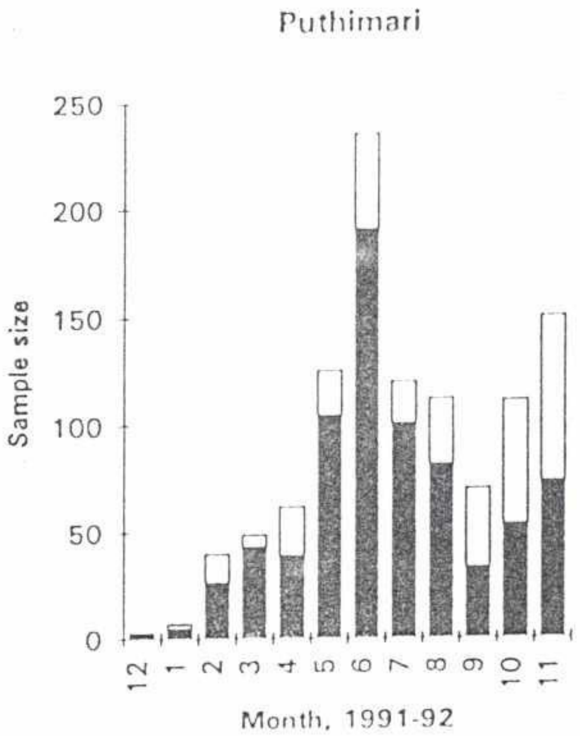
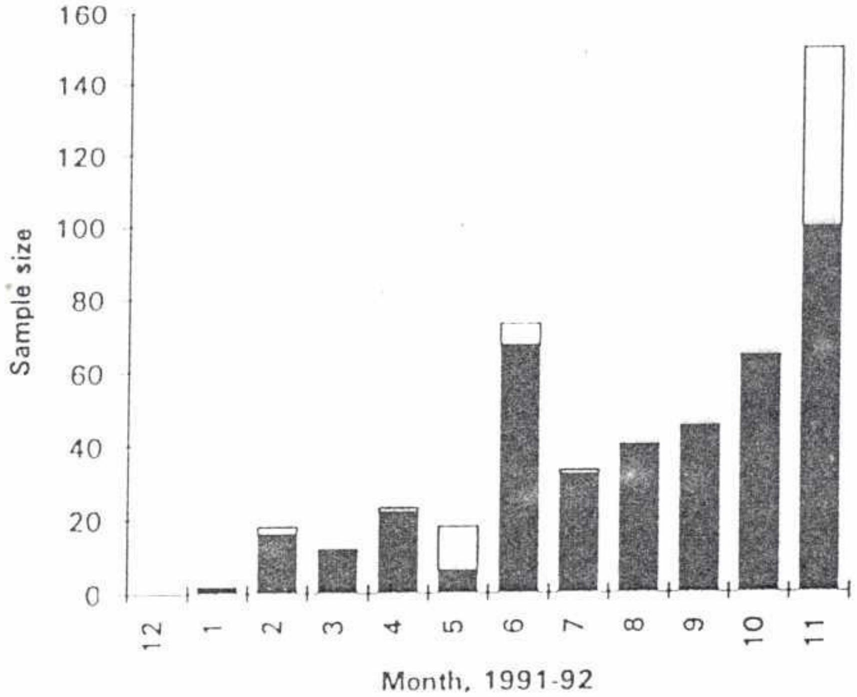


Figure 2. Time series of sandfly densities in three villages of Natore district, 1991-92. *Ph. argentipes* are clear columns, other species are shaded.

Figure 3. *Ph. argentipes* in Natore district, 1991 92. The clear columns indicate resting densities in animal dwellings, shaded columns are human dwellings.



Chapter 3

MOSQUITO BASE LINE FIELD STUDY

3.1 Objectives

(1) To determine the seasonal abundance and diversity of vector community in selected sampling sites;

(2) To determine the seasonal association of the vector community with land use type;

(3) To determine the impact of FCD/I projects on the ratio of the existing land use types and the nature of any new land use types which may be created;

(4) To assess the impact of FCD/I's induced changes on vector abundance and relate to disease risk;

(5) To carry out a preliminary assessment of the utility of GIS/RS technology in FAP vector studies.

3.2 Methods

3.2.1 Sampling Sites

Three districts, Tangail, Sylhet, and Natore, representing central, eastern, and western regions of Bangladesh were selected for the survey. In each district, three villages were selected. Thus, a total of nine villages were sampled throughout the year at monthly intervals. The villages were selected by field site visits by Prof. Elias, Mr. Maheswary, Mr. Minkin and Dr. Birley.

3.2.1.1 Tangail District

The district of Tangail is in a floodplain, and all three selected villages, Agbetoir, Gopalpur, and Porabari (Sadar Thana) are within embankments. The villages are, however, non-malarious. Kala-azar has not been reported from any of the villages. Lymphatic filariasis is known to occur rarely, if at all. No previous information existed regarding the disease vector abundance and/or diversity. The main criteria for selection of these villages were: (a) they are within FAP embankments, (b) their elevation status was known, and (c) they are accessible throughout the year, facilitating monthly night-time biting mosquito catches and day-time resting sandfly and mosquito larvae collections.

3.2.1.2 Sylhet District

All three selected villages, Bayampur, Bishnopur (Kanaighat Thana), and Bilerbond (Zokiganj Thana) of Sylhet District are in a floodplain and within the Kushiara embankment project. The following were the criteria for selection of these villages: (a) they are within or near embankments, (b) they are adjacent to high malarious areas (Stratum 1), (c) they are accessible throughout the year, facilitating monthly night-time biting mosquito catches and day-time resting sandfly and mosquito larvae collections.

3.2.1.3 Natore District

The three Natore District (Rajshahi Division) villages, Pomgaon-Puthimari, Katapukuria, and Koigram (Singra Thana), are also in a floodplain, and within the FAP Chalan Beel embankment project. The villages are non-malarious, but are in a zone affected by kala-azar. The criteria for selection of these villages were: (a) they are within or near embankments, (b) two villages, Pomgaon-Puthimari and Katapukuria, are known to be endemic for kala-azar from the past 3 to 4 years, (c) they are all accessible throughout the year, facilitating monthly night-time biting mosquito catches, and day-time resting sandfly and mosquito larvae collections.

3.2.2 Sampling Period and Time, and Sampling Methods

Sampling in Tangail District was conducted for 12 consecutive months starting in October 1991 and ending in September 1992. In Sylhet District work started in November 1991 and continued for a 12 month period ending October 1992. In Natore District, the work began in December 1991 and continued 12 months, until November 1992. Sampling was done monthly in each of the nine selected villages.

3.2.2.1 Biting Mosquito Catches

Biting mosquito catches were simultaneously made indoors and outdoors. To do so, pairs of people were stationed in two houses that were within 100 m of each other. One person in each pair was indoors and the other was outdoors. Each human bait exposed his bare feet to lure biting mosquitoes, which were then captured by the subject using an aspirator. In each of the nine selected villages, one such night-time human bait capture was made in each month.

Night-time biting collections were restricted to three hours from sunset. The collections did not necessarily coincide with the peak biting times of any medically important species. During periods of heavy rain, outdoor sampling was curtailed, but indoor sampling continued.

Unbiased sampling would have required that collections be made all night long. Limited study resources made this impractical, however.

3.2.2.2 Mosquito Larvae Collection

Mosquito larvae were collected from all the available breeding sources, as far as practicable, from 0800 to 1300 hours. These collections were done one day each month in each of the nine selected villages.

The water sources where larvae were collected were not fixed, and collections were made randomly. The number of dips of larvae collecting pans were not also fixed. The dips were usually continued till a number of larvae were detected or discontinued when the collector felt that there were no larvae (negative) in that particular spot. Only the positive breeding sources were recorded. The number of positive dips and the total number of dips made were recorded for each of those sources. The type of aquatic vegetation, i.e., water hyacinth or algae, and type of habitat, i.e., ponds, ricefield, or river were also recorded. The percentage of vegetation in each breeding site was rarely noted. The conditions of the breeding site, i.e. polluted, partially polluted, or clear, and the shade conditions of the site, i.e., fully shaded, partially shaded, or sunny, were also recorded.

3.2.2.3 Resting Sandfly Collection

Resting sandflies were collected from human as well as animal dwellings usually between 0800 and 1300 hours. The collections were made one day per month in each of the nine selected villages.

The houses where resting sandflies were collected were not fixed, and the collections were made randomly. The collections each month were made in the same area, and were concentrated among 20 to 25 houses.

3.2.3 Composition of Sampling Teams

The sampling team for biting collections consisted of four entomology technicians. They were supervised by a district or divisional entomologist or by Mr. Hassan. Members of the team took occasional rests of up to half an hour during which time the supervisor acted as a technician. The entomology technicians were mainly government employees. The program also paid one casual worker to be an entomology technician. The individual membership of sampling teams varied from month to month.

The larval collections were undertaken by two entomology technicians supervised by the district or divisional entomologist and/or Mr. Hassan. Between February 1992 and April 1992, additional larval collections were made by Dr. M. Renshaw, Mr. J. Silver, and Prof. Elias or Mr. Maheswary.

Resting sandflies were sampled by two entomology technicians supervised as above. In May 1992 Dr. R.D. Ward made a special sandfly collection in Singra Thana, Natore.

In June 1992 Dr Abdullah El-Masum collected a short series of blood samples in the three Natore villages for serological analysis of kala-azar. He was assisted by three or four laboratory technicians.

3.2.4 Specimen Identification

All the mosquitoes, sandflies, and larvae were brought from the field to the National Institute of Preventive & Social Medicine (NIPSOM) entomology laboratory in Dhaka for identification. The identification of adult mosquitoes and sandflies was done using stereoscopic microscopes and the mosquito larvae were identified using compound microscopes. The culicine mosquitoes and sandflies were also examined by Mr. Rafiquddin Ahmed. The mosquito larvae were identified by Dr. Renshaw during her visit to Bangladesh from February 1992 to April 1992, and by Mr. Hassan. Mr. Hassan also worked with Dr. Renshaw and Dr. Ward in the field and in the laboratory, and got hands-on training in larval and sandfly sampling and identification. The NIPSOM entomology technicians worked with Mr. Hassan during the identification process.

3.2.5 Supervision and Monitoring

The field teams were usually visited for a short while when they were at work by Prof. Elias or Mr. Maheswary. They were accompanied on occasion by senior district and/or divisional health administrators.

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3.3 Mosquito Species of Public Health Importance

Among the 34 anopheline and 79 culicine mosquito species recorded in Bangladesh, six kinds of anophelines and eight kinds of culicines are known to be medically important. Of the known malaria vectors, which are *Anopheles aconitus, An annularis* (very recently incriminated), *An dirus, An minimus, An philippinensis, An sundaicus*, only three species, *An aconitus, An annularis*, and *An philippinensis* are known to be responsible for transmitting malaria in the floodplains of Bangladesh. *Culex quinquefasciatus (fatigans)* is the principal vector of Bancroftian filariasis in Bangladesh. *Cx vishnui* is also known to be the vector of filariasis and is abundant in Bangladesh. *Culex tritaeniorhynchus, Cx gelidus, Cx vishnui, Cx fuscocephala*, and *Cx sinensis*, known vectors of Japanese encephalitis in South-East Asian countries, are also abundant in Bangladesh. The well-known dengue vectors *Aedes aegypti* and *Ae albopictus* are also found in Dhaka. All other mosquito species, although as yet not recognized transmitters of diseases, are a known public nuisance owing to their irritating bites.

3.4 Biting Mosquitoes

3.4.1 Species Diversity

A total of 14,462 biting mosquitoes were caught during the study period in the nine study villages. Thirty-six species of six genera, *Anopheles, Culex, Aedes, Aedeomyia, Armigeres*, and *Mansonia*, were identified. A few species of *Aedes*, however, were identified only to genus level. Of the 36 species, 15 were anophelines and 21 were culicines (Table 6).

Among the anophelines, *Anopheles vagus* was the most abundant species, followed by *An annularis, An nigerrimus, An philippinensis, An barbirostris, An aconitus*, and others (Figure 1a). The relative abundance may be a function of the restricted sampling method used.

Table 6
Biting Mosquito Species Composition

Genus/Species	Number	Percent
Anophelines		
a vag	650	72
ann	70	8
nig	56	6
phi	39	4
bar	26	3
aco	23	3
sub	12	1
var	11	1
mac	3	0
tes	3	0
koc	2	0
ped	2	0
cul	1	0
jam	1	0
pal	1	0
Total	900	
Culicines		
c vis	4901	36
c fus	1914	14
c sin	1505	11
c qui	1134	8
m uni	904	7
c hut	823	6
c tri	625	5
m ann	468	3
c bit	366	3
c gel	290	2
ar sub	219	2
m ind	175	1
c fsc	81	1
ad cat	47	0
c hal	39	0
ae spp	30	0
c epi	19	0
c sit	15	0
ae sca	3	0
c whi	2	0
ae aeg	1	0
ar fla	1	0
Total	13562	
Grand Total	14462	

Table 7

Biting Species Distribution by District

Genus/Species	District		
	Tangail	Sylhet	Natore
Anophelines			
a aco	+	+	+
ann	+	+	+
bar	+	+	+
cul	+		
jam		+	
koc		+	
mac		+	
nig	+	+	+
pal		+	
ped	+	+	
phi		+	
sub	+	+	+
tes		+	+
vag	+	+	+
var	+	+	+
Total	9	14	8
Culicines			
ad cat			+
ae aeg	+		
sca			+
spp*	+	+	+
ar fla	+		
sub	+	+	+
c bit	+	+	+
epi	+		+
fsc	+		+
fus	+	+	+
gel	+	+	+
hal	+	+	+
hut	+	+	+
qui	+	+	+
sin	+	+	+
sit	+	+	
tri	+	+	+
vis	+	+	+
whi	+		
m ann	+	+	+
ind	+	+	
uni	+	+	+
Total	19	14	16

*Identified up to genus level only.

Among the culicines, *Culex vishnui* was the predominant species, followed by *Cx fuscocephala*, *Cx sinensis*, *Cx quinquefasciatus*, and others (Figure 1b).

3.4.2 Species List by District

The occurrence of each species of biting mosquitoes in each district is shown in Table 7. Of the 36 detected species, 28 (9 anophelines and 19 culicines) were found in Tangail, 28 (14 anophelines 14 culicines) in Sylhet, and 24 (8 anophelines and 16 culicines) in Natore (Figure 2a, 2b).

3.4.3 Species Variation between District

Figures 3 and 4 show the abundance of individual anopheline and culicine mosquito species according to district. Among the anophelines, *An philippinensis*, the principal malaria vector of the floodplains, was encountered only in Sylhet. Secondary malaria vectors *An aconitus* and *An annularis* were found in all three districts and had similar trends of abundance. Among the culicines, *Cx quinquefasciatus*, the principal vector of bancroftian filariasis, was also encountered all three districts and with similar abundance trends. *Cx vishnui*, the vector of both bancroftian filariasis and Japanese encephalitis was the most common and most abundant species in all the sampled districts. The other Japanese encephalitis vectors, *Cx gelidus*, *Cx tritaeniorhynchus*, and *Cx fuscocephala*, showed similar trends in all three districts. Only a lone *Ae aegypti*, the vector of dengue, was found in Agbetoir village of Tangail District.

3.4.4 Species Variation within the District

Tables 8 through 10 and Figures 5 through 7 show the distribution of biting mosquito species by village for each of the sampled three districts. Among the important disease vectors, *An philippinensis* was found only in the three Sylhet district villages; none were found in any of the Tangail and Natore villages. Biting *An aconitus* was caught in almost all the villages except Gopalpur (Tangail) and Pomgaon-Puthimari (Sylhet). *An annularis* was found biting in all nine study villages. *Cx quinquefasciatus* was found distributed in all three districts, but no larvae were found in any of the Sylhet villages.

Figures 8 through 13 show the abundance of biting anopheline and culicine mosquito species according to village. The anopheline *An vagus* and culicine *Cx vishnui* were the most common and most abundant species in each village.

3.4.5 Seasonal Variations

Figures 14 through 16 show the seasonal patterns of biting anophelines and culicines, taken individually and together. Generally, there are two seasonal peaks for both genera, one in February-March and the other in August-September. In Tangail, however, the second peak for anophelines was in June, which was due to the influence of a lone *An vagus*. (The seasonality of each disease vector species is discussed in Section 2.7.)

3.5 Mosquito Larval Habitat

Figure 17 shows the relative abundance of disease vector species according to larval habitats. A total of 19 water body types were detected larval habitats for mosquito breeding. They were: tanks, ponds, pools (*dobas*), puddles, ditches, ricefields, marshes, lakes (*zhils*), beels, rivers, blocked rivers, canals, large drains and irrigation drains (*nalas*), troughs, hoof prints, boats, containers, outlets, and tree holes. Ponds, pools, and ricefields were the most abundant habitats in the study villages, and they produced the most larvae. (The larval diversity of medically important mosquitoes is discussed in Section 2.7.)

3.5.1 Ricefield Larvae

The larval mosquito species collected from ricefield habitats are shown in Figure 18. The survey found seven larval anopheline species. Among them, *An vagus* was the most

Table 8
Biting Species Distribution by Village (Tangail)

	Village		
Genus/Species	Agbetoir	Gopalpur	Porabari
Anophelines			
a aco	+		+
ann	+	+	+
bar	+	+	+
cul		+	
jam			
koc			
mac			
nig	+	+	+
pal			
ped	+		
phi			
sub		+	
tes			
vag	+	+	+
var	+		
Total	7	6	5
Culicines			
ad cat			
ae aeg	+		
sca			
spp*			+
ar fla	+		
sub	+	+	+
c bit	+	+	+
epi	+	+	
fsc	+		+
fus	+	+	+
gel	+	+	+
hal	+	+	
hut	+	+	+
qui	+	+	+
sin	+	+	+
sit		+	
tri	+	+	+
vis	+	+	+
whi		+	+
m ann	+	+	+
ind	+	+	
uni	+	+	+
Total	17	16	13

*Identified up to genus level only.

Table 9
Biting Species Distribution by Village (Sylhet)

Genus/Species	Village: Bilerbond	Bishnopur	Bayampur
Anophelines			
a aco	+	+	+
ann	+	+	+
bar	+	+	+
cul			
jam			+
koc		+	
mac	+	+	
nig		+	+
pal			+
ped			+
phi	+	+	+
sub		+	+
tes		+	
vag	+	+	+
var		+	
Total	6	11	10
Culicines			
ad cat			
ae aeg			
sca			
spp*	+	+	+
ar fla			
sub	+	+	+
c bit	+	+	+
epi			
fsc			
fus	+	+	+
gel	+		
hal			+
hut	+	+	+
qui	+	+	+
sin	+	+	+
sit			+
tri	+	+	+
vis	+	+	+
whi			
m ann	+	+	+
ind	+	+	+
uni	+	+	+
Total	12	11	13

*Identified up to genus level only.

Table 10
Biting Species Distribution by Village (Natore)

Genus/Species	Village: Katapukuria	Koigram	Pomgaon
Anophelines			
a aco	+	+	
ann	+	+	+
bar	+	+	+
cul			
jam			
koc			
mac			
nig	+	+	+
pal			
ped			
phi			
sub		+	+
tes			+
vag	+	+	+
var	+	+	+
Total	6	7	7
Culicines			
ad cat			+
ae aeg			
sca		+	+
spp*		+	+
ar fla			
sub	+		+
c bit	+	+	+
epi		+	+
fsc		+	+
fus	+	+	+
gel	+	+	+
hal		+	+
hut	+	+	+
qui	+	+	+
sin	+	+	+
sit			
tri	+	+	+
vis	+	+	+
whi			
m ann	+	+	+
ind			
uni	+	+	+
Total	11	14	16

*Identified up to genus level only.

common, followed by *An hyrcanus*, *An annularis*, *An barbirostris*, *An jamesii*, *An subpictus*, and *An pallidus*. Of the nine culicine larvae caught in ricefields, *Cx tritaeniorhynchus* was the most common, followed by *Cx vishnui*, *Cx halifaxii*, *Cx fuscanus*, *Cx bitaeniorhynchus*, *Fc minima*, *Cx pseudovishnui*, *Cx quinquefasciatus*, and *Cx sinensis*.

3.6 Important Disease Vectors Related to Floodplains

3.6.1 *Anopheles philippinensis*

Anopheles philippinensis is the principal vector of malaria in the floodplains of deltaic Bengal, including Bangladesh. In the present survey, however, the species was obtained only from Sylhet, where malaria is still endemic.

A total of 39 biting *An philippinensis* were caught in the three Sylhet villages. Among all the biting anophelines caught, *philippinensis* was the third most abundant (7 percent in Bayampur, 17 percent in Bishnopur, and 11 percent in Bilerbond, see Figure 10).

Figure 19 shows the seasonal biting pattern of *philippinensis*. The species started biting in July, during late monsoon, and continued escalating gradually through the post-monsoon period to November, when it reached its peak. The peak drops precipitously in December, when the cold winter season begins in Sylhet.

An philippinensis larvae were only found on two occasions, once in Bilerbond in December 1991, and once in Bayampur in October 1992. On both occasions they were discovered in partially shaded ponds of clear water with water hyacinth and grass.

3.6.2 *Anopheles aconitus*

Anopheles aconitus is the principal vector of malaria in Java (Indonesia), and recently has been incriminated as a malaria carrier in the floodplains of Bangladesh.

A total of 23 biting *An aconitus*, which comprised 3 percent of the captured anophelines, were found during the study. Four of these were caught indoors and 19 were caught outdoors. The species had similar distribution trends in all three districts (Table 7). None were detected in Gopalpur village in Tangail District or Pomgoan-Puthimari in Natore District (Tables 8 through 10).

A total of 108 *An aconitus* larvae were caught from among all nine study villages. In Gopalpur (Tangail), however, only one *aconitus* larva was caught.

An aconitus larvae were detected in seven of the 19 mosquito-breeding habitats (Figure 17). As Figure 20 shows, *An aconitus* larvae were most abundant in rivers and ponds, where they were found in clean and turbid water, but rarely in polluted water. Most *aconitus* habitats contained water hyacinth. The figure also indicates that the larvae were most abundant in the drier months from December to April.

3.6.3 *Anopheles annularis*

Anopheles annularis is the principle malaria vector in India, and it has recently been incriminated as a malaria vector in the floodplains of Bangladesh.

The study found a total of 70 biting *annularis*, which comprised 8 percent of the anophelines caught (Table 6). They were distributed among all nine villages (Tables 8 through 10), and showed similar trends in all the three districts (Figure 3).

A total of 58 *An annularis* larvae were caught in Sylhet and Natore districts. The larvae were not detected in any of the Tangail villages or in Pomgaon-Puthimari (Natore). The reason for this is not clear.

An annularis larvae were detected in five of the 19 breeding habitats: ricefields, canals, rivers, blocked rivers, and ponds (Figure 21). They were found mostly in turbid water (57 percent) and clear water (43 percent), and none were found in polluted water. Most of them were associated with grass and water hyacinth. Figure 21 also indicates that the larvae are most abundant from February through April.

3.6.4 *Culex quinquefasciatus*

Cx quinquefasciatus is the principal vector of bancroftian filariasis in Bangladesh.[2]

A total of 1,134 biting *quinquefasciatus* adults, comprising 8 percent of the captured culicines, were found during the study (Table 6). Of these, 435 were caught indoors and 699 were taken outdoors. They were distributed throughout the nine study villages. There were no marked variations in abundance between districts or villages.

A total of 445 *quinquefasciatus* larvae were caught in Tangail and Natore districts. Although none were found in Sylhet, adults of the species were found. The reason for the absence of larvae is unclear.

Quinquefasciatus larvae were found in 9 of the 19 breeding habitats. Figure 22 shows that its seasonal abundance is highest in drier months, from December through April, and in September. Relatively more *quinquefasciatus* larvae were found in pools, ponds, and ditches. The larvae of *quinquefasciatus* were most common in turbid and polluted water (66 percent) and in clear water (34 percent). The definition of clear water was probably too general.

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[2] In 1969, Aslamkhan and Wolfe surveyed the vector in Dinajpur District, where filariasis was relatively common. At that time, the species represented 15 percent of the total biting sample. The area was free from flooding.

ABBREVIATIONS

District and village
tan = Tangail; agb = Agbetoir; gop = Gopalpur; por = Porabari
syl = Sylhet; bay or bya = Bayampur; bil = Bilerbond; bis = Bishnopur
nat = Natore; pom or put = Pomgaon-Puthimari; kai or koi = Koigram; kan = Katapukuria

Desc = Larval habitat/Water bodies
B = beel; C = canal; D = ditch; E = puddle; P = pond; T = tank; O = pool; M = marsh; R = ricefield; V = river; BV = blocked river; H = hoof-print; U = out let; CT = container; N = nala (irrigation drain); TH = tree hole; Z = zhil (lake)

Water type
C = clear; T = turbid; P = polluted

Shade
S = sun light; P = partially shaded; F = fully shaded

Vegetation type
A = algae; FGA = filamentous green algae; G = grass; RP = rice plant; L = lemna; H = herb; TP = topa pana (small water hyacinth); LV = leaf; WH = water hyacinth

Genus and species
a or AN = Anopheles: aco = aconitus; ann = annularis; bar = barbirostris; ben = bengalensis; cul = culicifacies; flu = fluviatilis; gig = gigas; hyr = hyrcanus; jam = jamesii; koc = kochi; mac = maculatus; nig = nigerrimus; ped = peditaeniatus; phi = philippinensis; pal = pallidus; sub = subpictus; tes = tessellatus; vag = vagus; var = varuna
ae = Aedes: aeg = aegypti; sca = scatophagoides
ad = Aedeomyia: cat = catasticta
ar = Armigeres: fla = flavus; sub = subalbatus
c or CX = Culex: bit = bitaeniorhynchus; epi = epidesmus; gel = gelidus; fsc = fuscanus; fus = fuscocephala; hal = halifaxii; hut = hutchinsoni; psi = pseudosinensis; pvi = pseudovishnui; qui = quinquefasciatus; sin = sinensis; sit = sitiens; tri = tritaeniorhynchus; vis = vishnui; whi = whitmorei
Fc = Ficalbia: min = minima
m = Mansonia: ann = annulifera; ind = indiana; uni = uniformis
He = Heizmannia: cov = covelli

Fig 1a: Biting Anopheline species composition

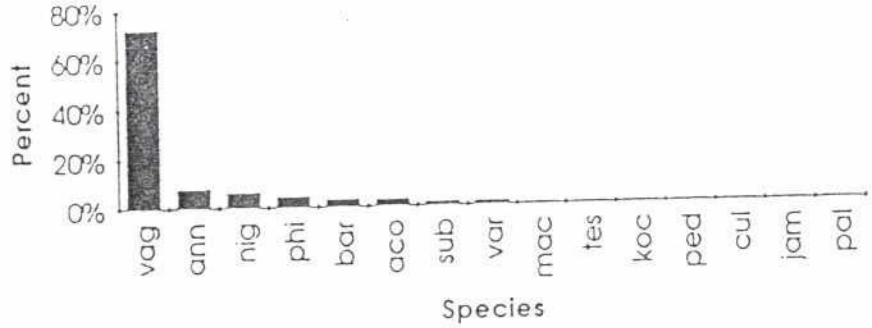


Fig 1b: Biting Culicine species composition.

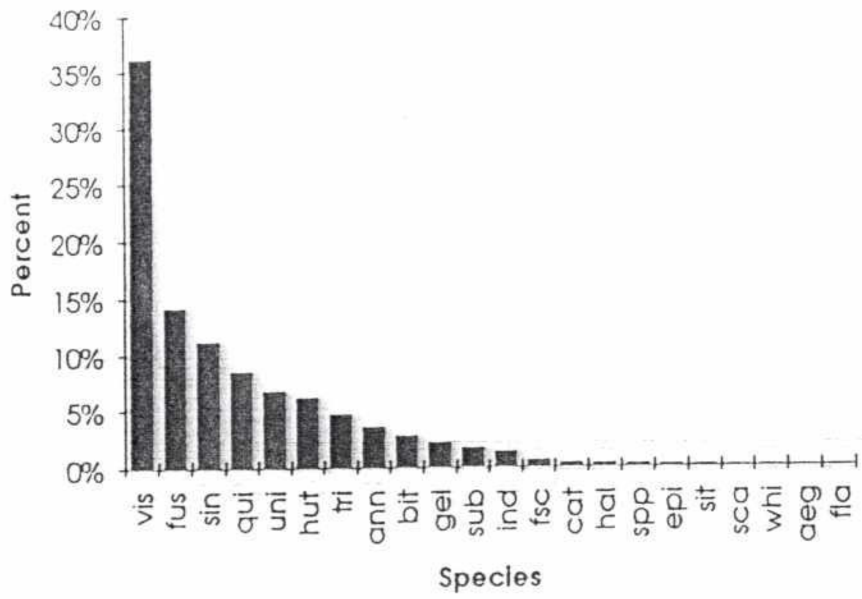


Fig 2a: Biting Anopheline distribution

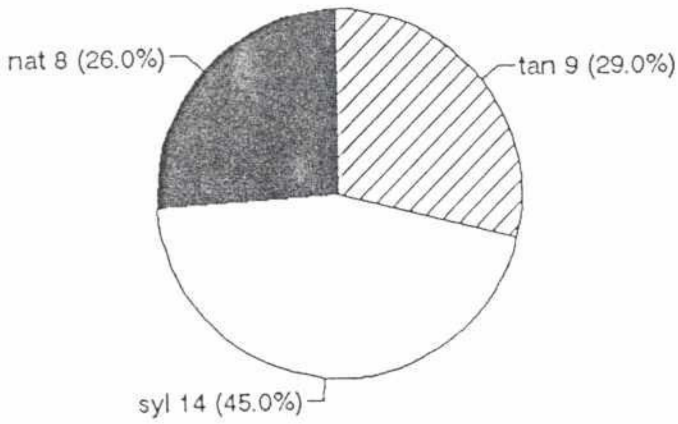


Fig 2b: Biting Culicine distribution

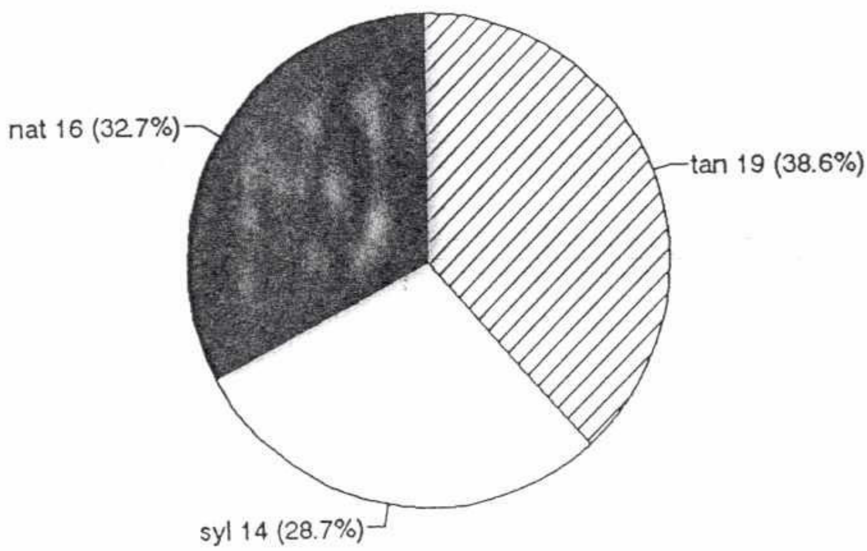


Fig 3 a: Biting Anopheline species variation in Tangail.

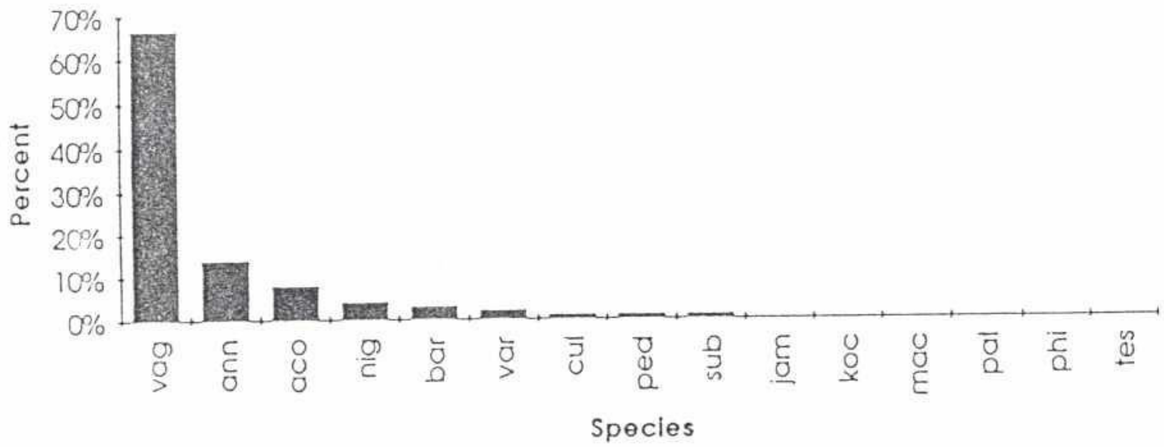


Fig 3 b: Biting Anopheline species variation in Sylhet.

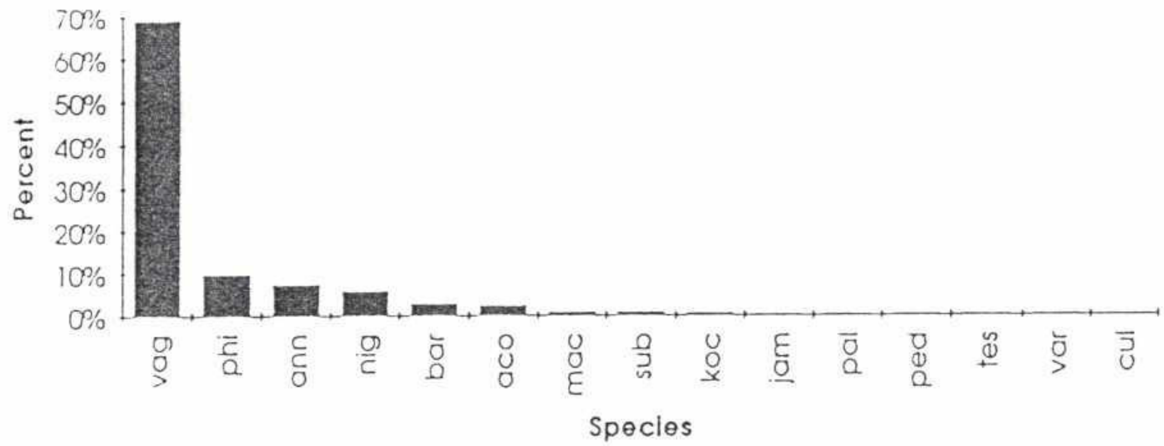


Fig 3 c: Biting Anopheline species variation in Natore.

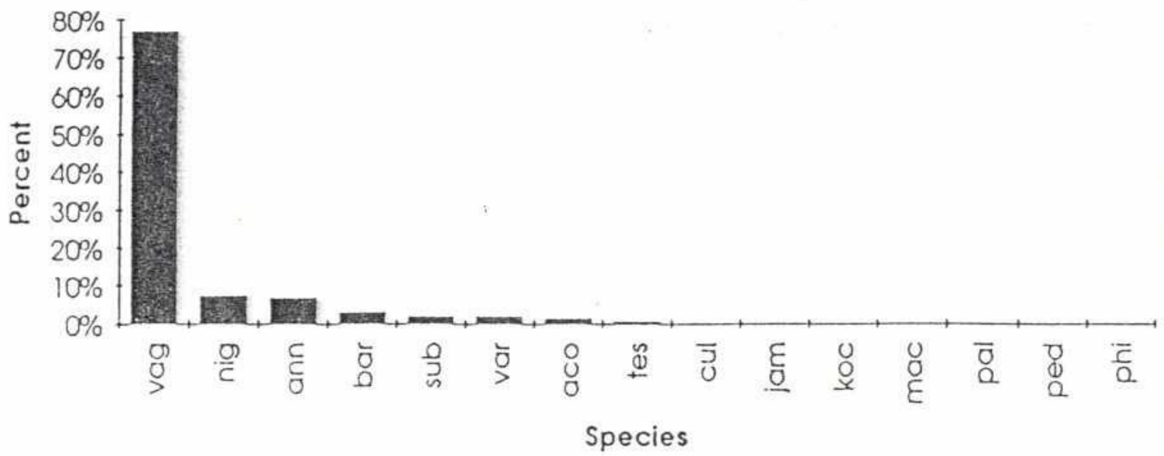


Fig 4a: Biting Culicine species variation in Tangail.

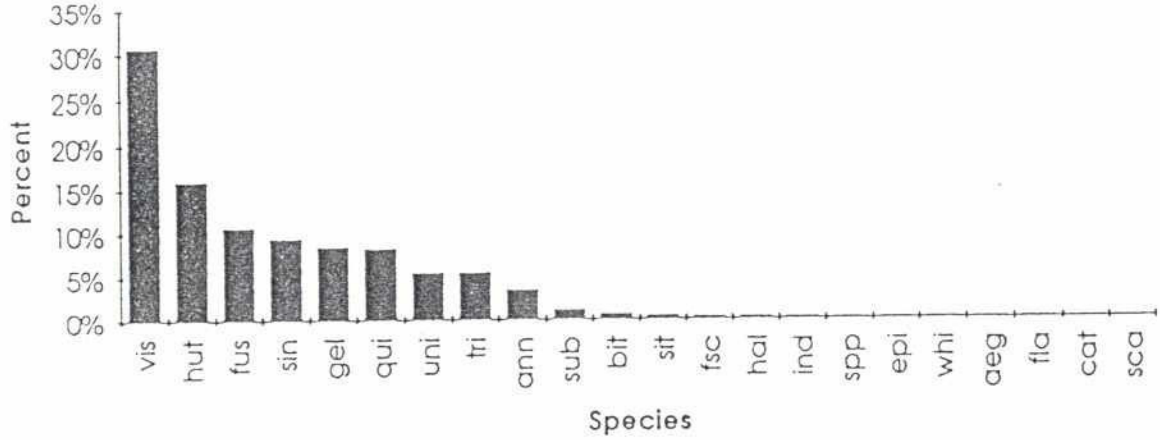


Fig 4b: Biting Culicine species variation in Sylhet.

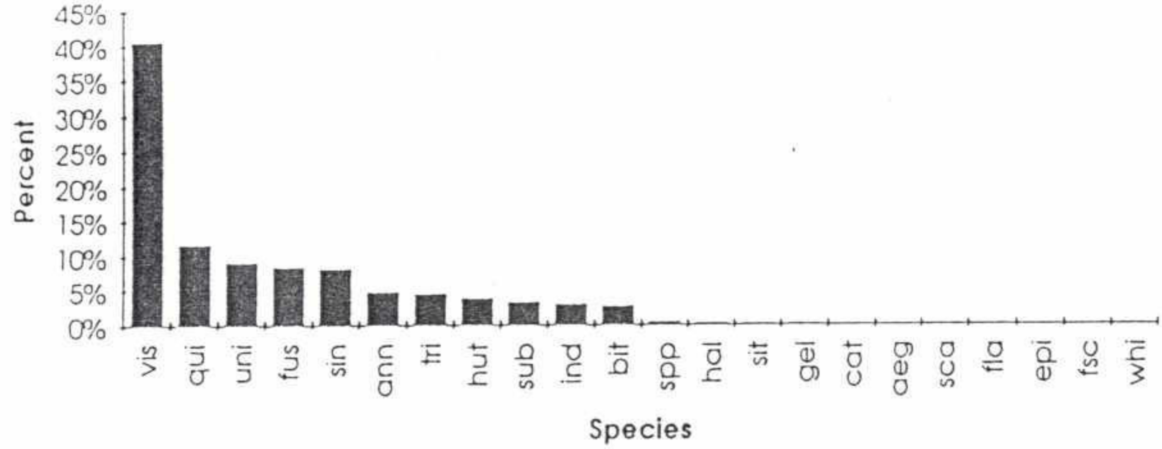


Fig 4c Biting Culicine species variation in Natore

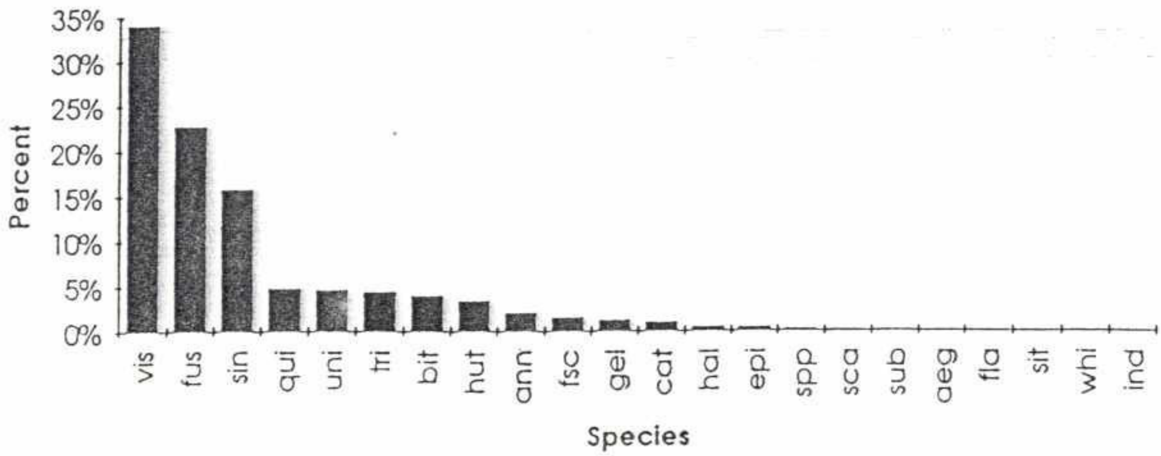


Fig 5a: Biting Anopheline species distribution by villages of Tangail.

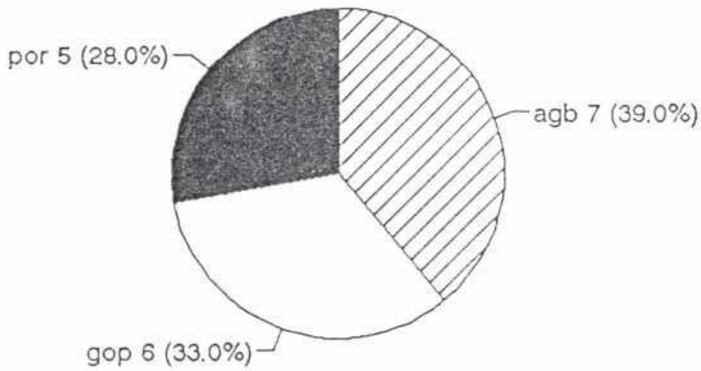


Fig 5b: Biting Culicine species distribution by villages of Tangail.

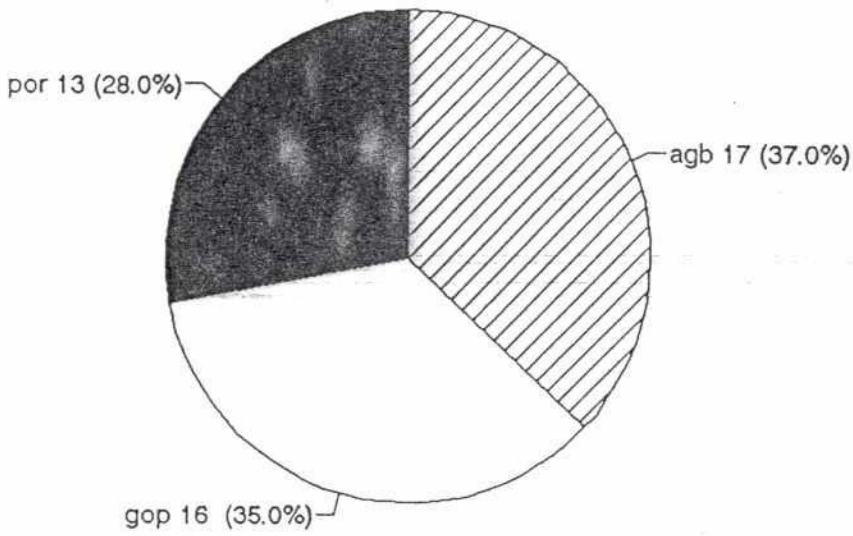


Fig 6a: Biting Anopheline species distribution by villages of Sylhet.

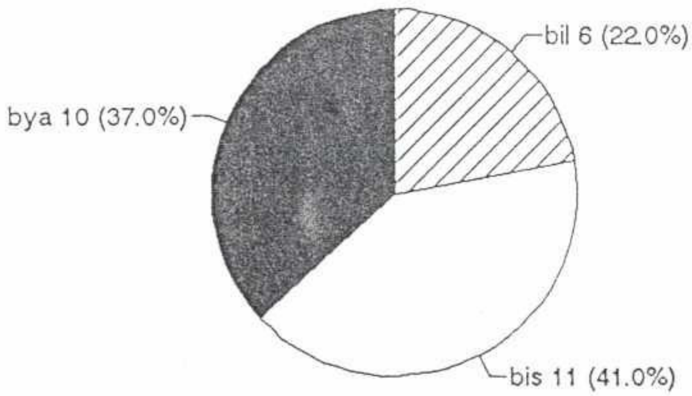


Fig 6b: Biting Culicine species distribution by villages of Sylhet.

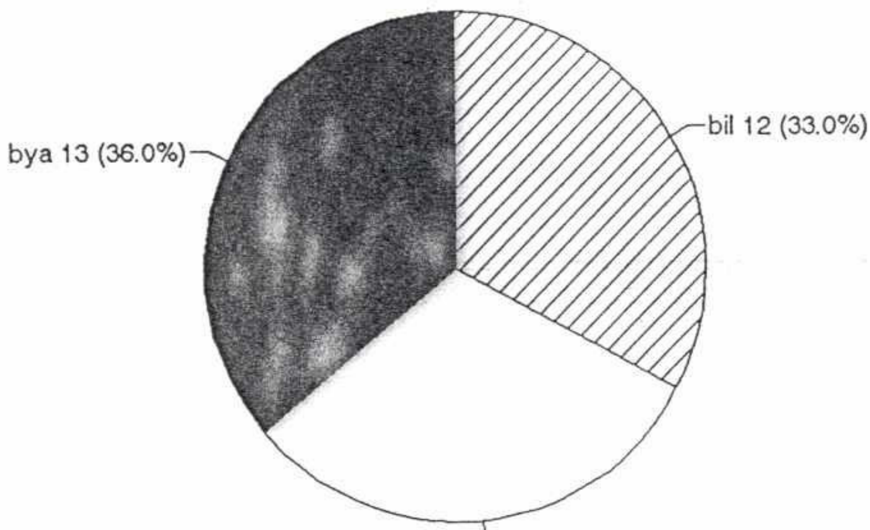


Fig 7a: Biting Anopheline species distribution by villages of Natore.

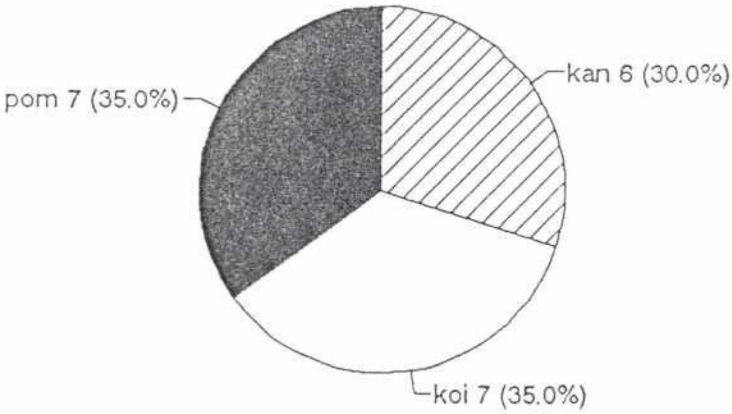


Fig 7b: Biting Culicine species distribution by villages of Natore.

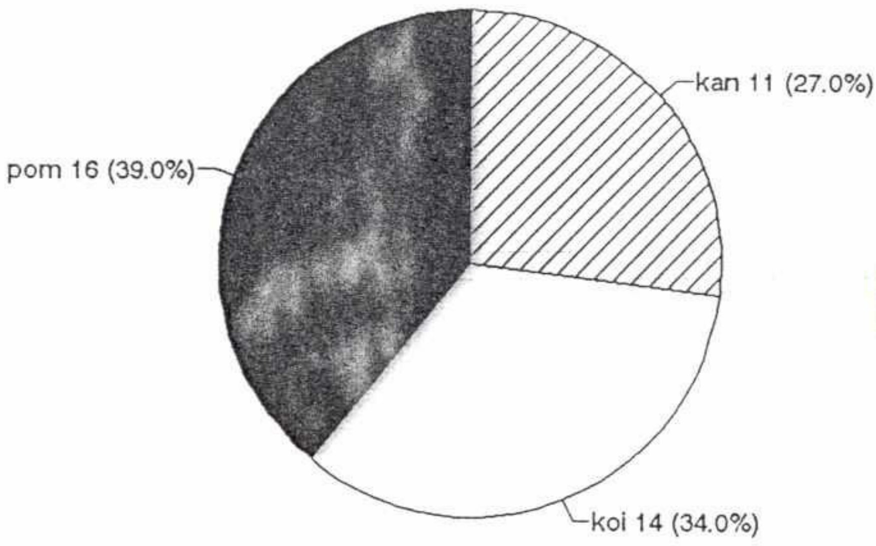


Fig 8a: Biting Anopheline species abundance in village Agbetoir, Tangail.

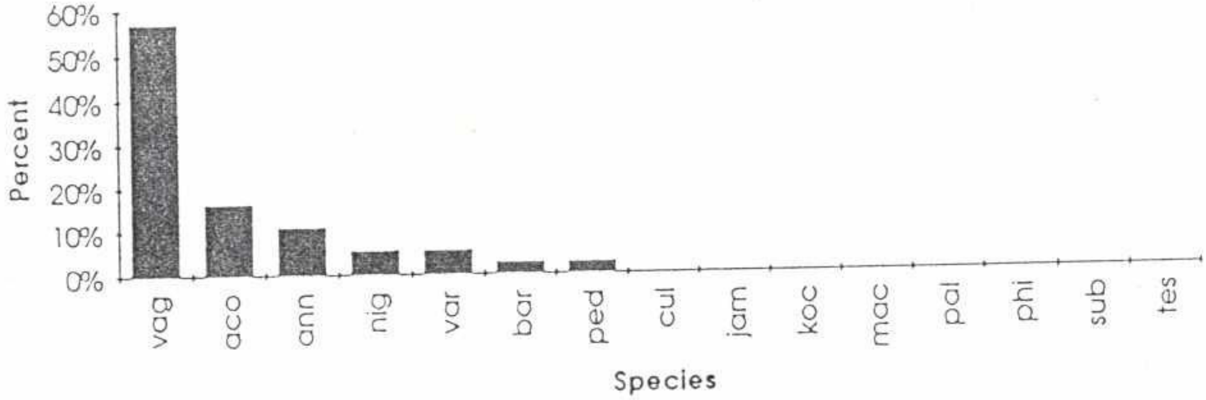


Fig 8b: Biting Anopheline species abundance in villgae Gopalpur, Tangail.

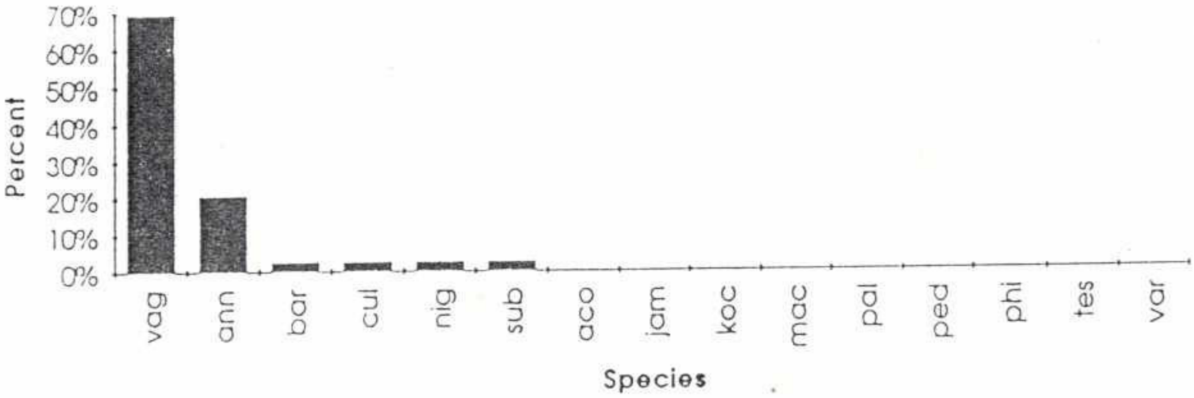


Fig 8c: Biting Anopheline species abundance in village Porabari, Tangail.

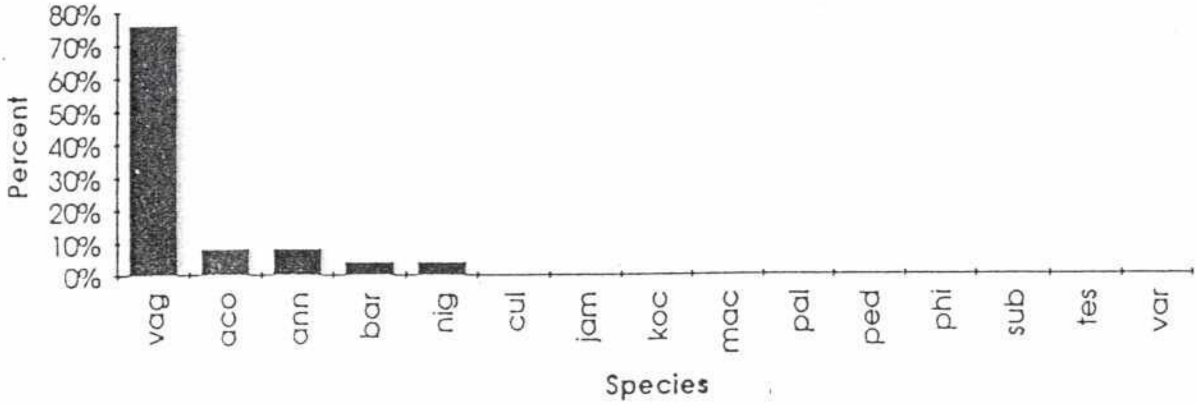


Fig 9a: Biting Culicine species abundance in village Agbetoir, Tangail.

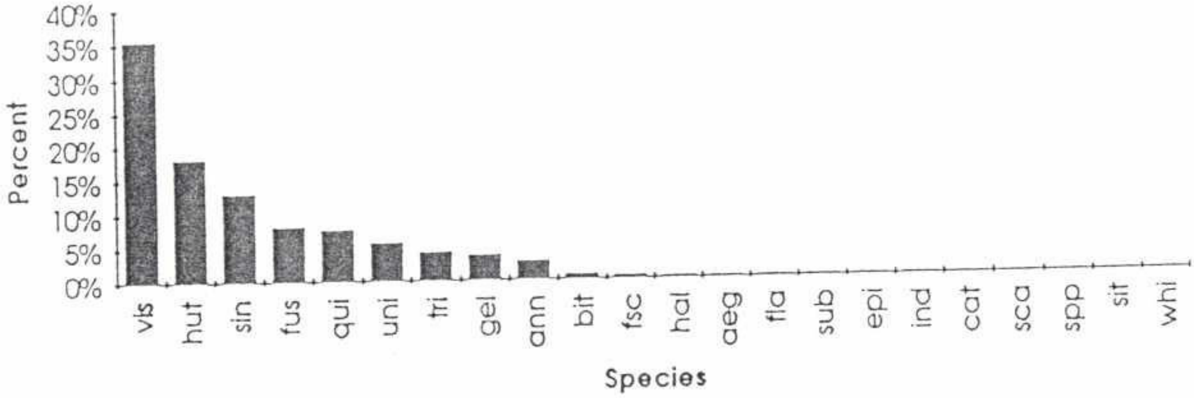


Fig 9b: Biting Culicine abundance in village Gopalpur, Tangail.

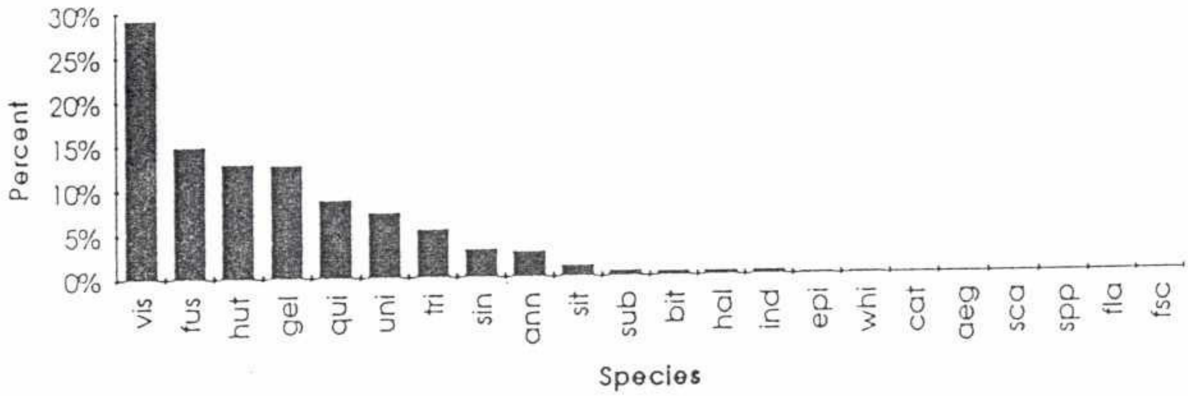


Fig 9c: Biting Culicine species abundance in village Porabari, Tangail.

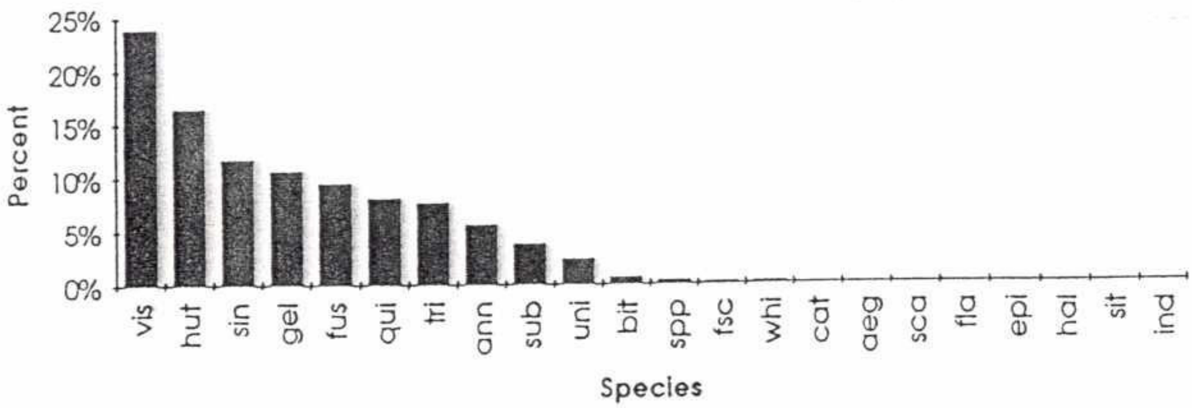


Fig 10a: Biting Anopheline species abundance in village Bilerbond, Sylhet.

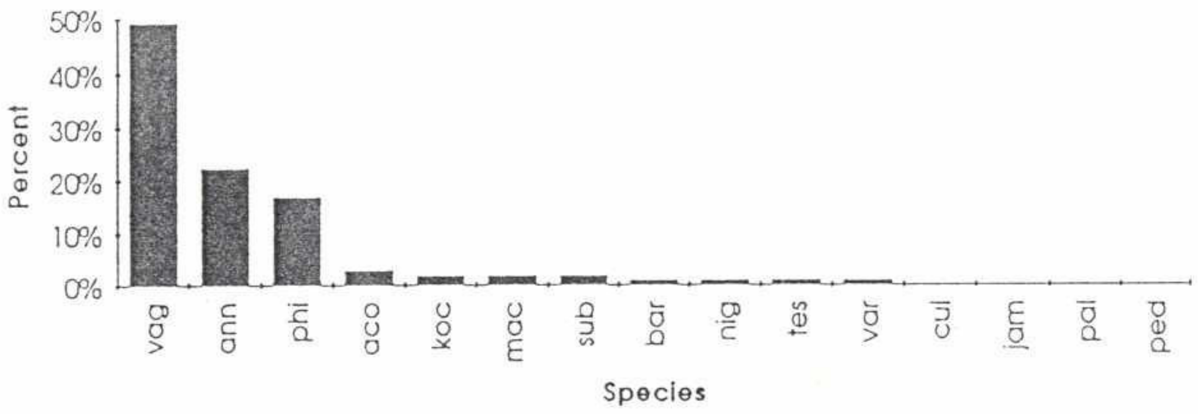


Fig 10b: Biting Anopheline species abundance in village Bishnopur, Sylhet.

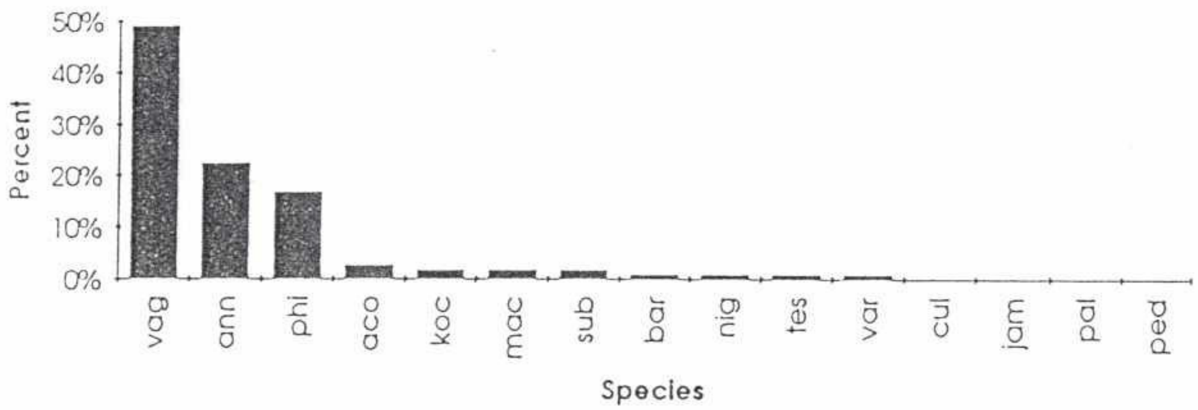


Fig 10c: Biting Anopheline species abundance in village Bayampur, Sylhet.

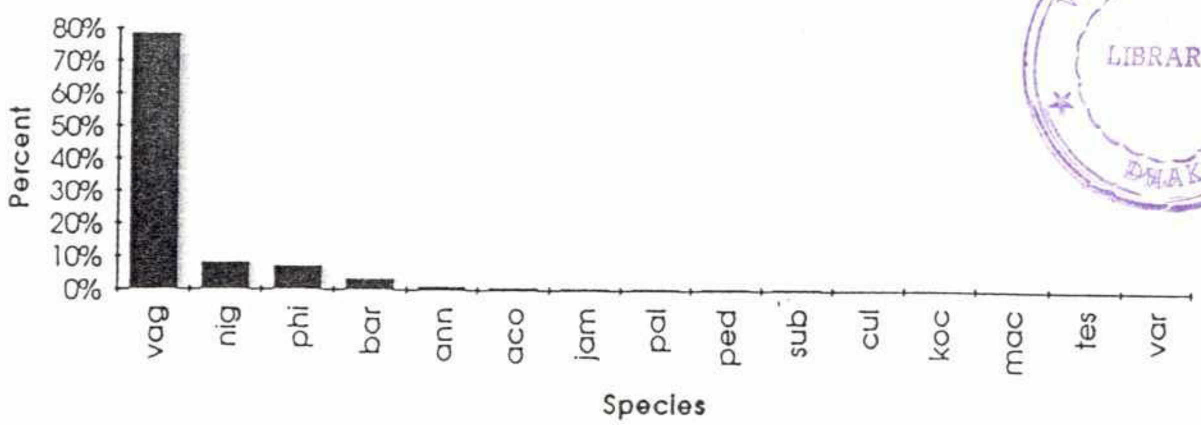


Fig 10a: Biting Anopheline species abundance in village Bilerbond, Sylhet.

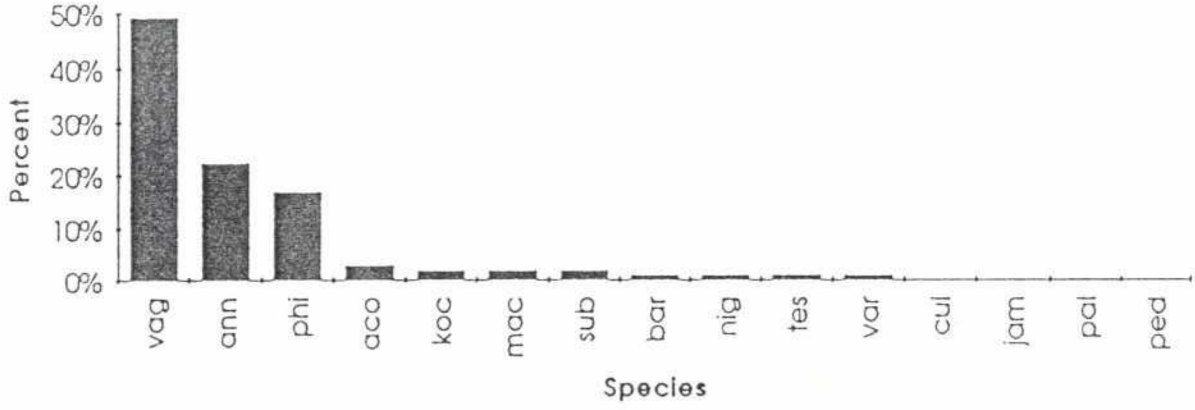


Fig 10b: Biting Anopheline species abundance in village Bishnopur, Sylhet.

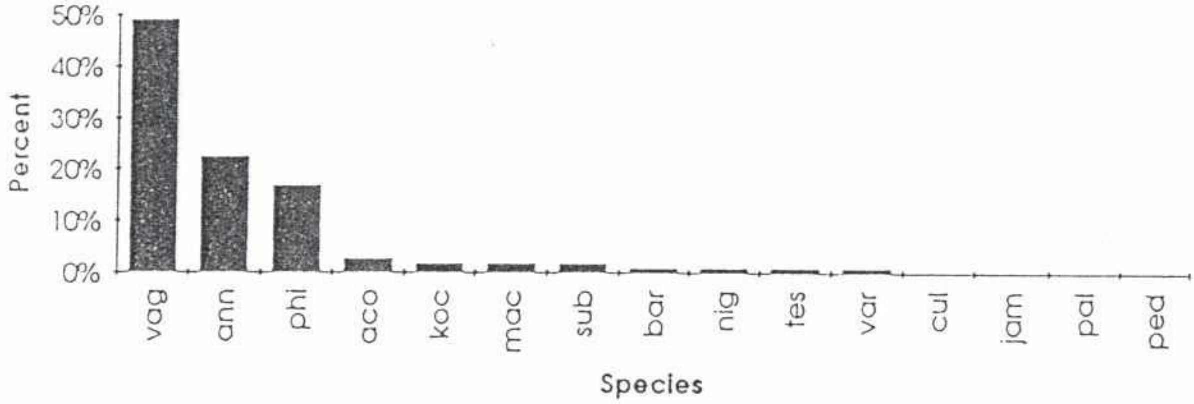


Fig 10c: Biting Anopheline species abundance in village Bayampur, Sylhet.

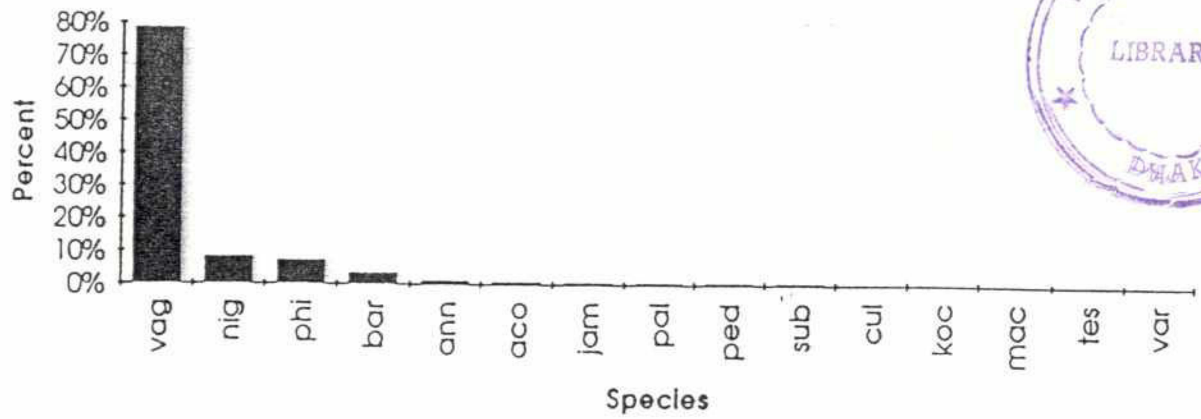


Fig 11a: Biting Culicine species abundance in village Bilerbond, Sylhet.

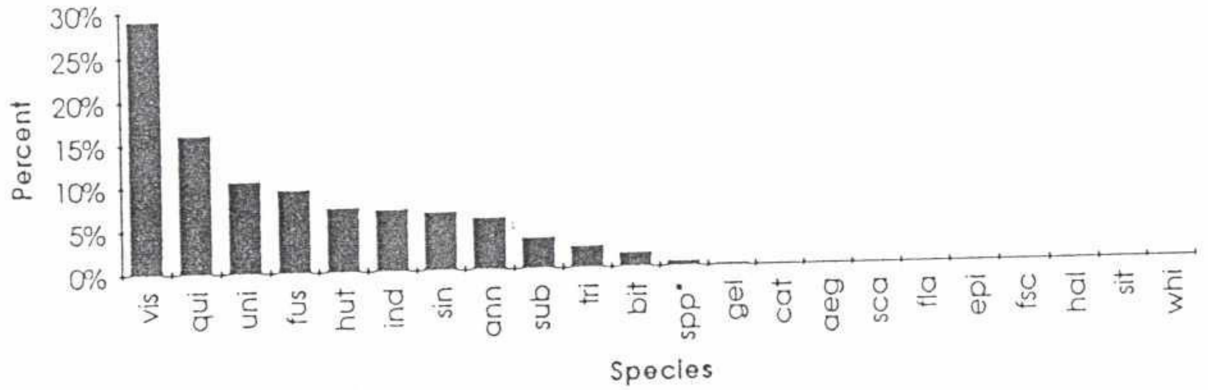


Fig 11b Biting Culicine species abundance in village Bishnopur, Sylhet.

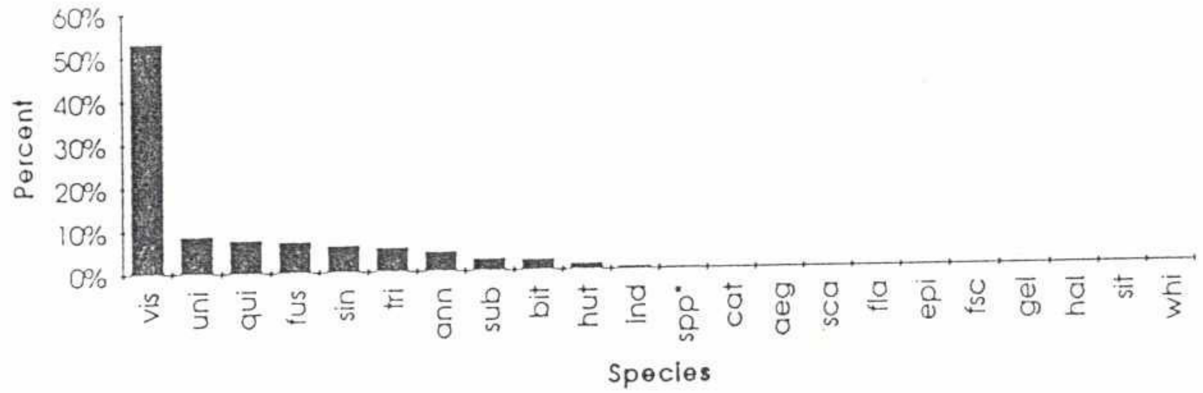


Fig 11c Biting Culicine species abundance in village Bayampur, Sylhet

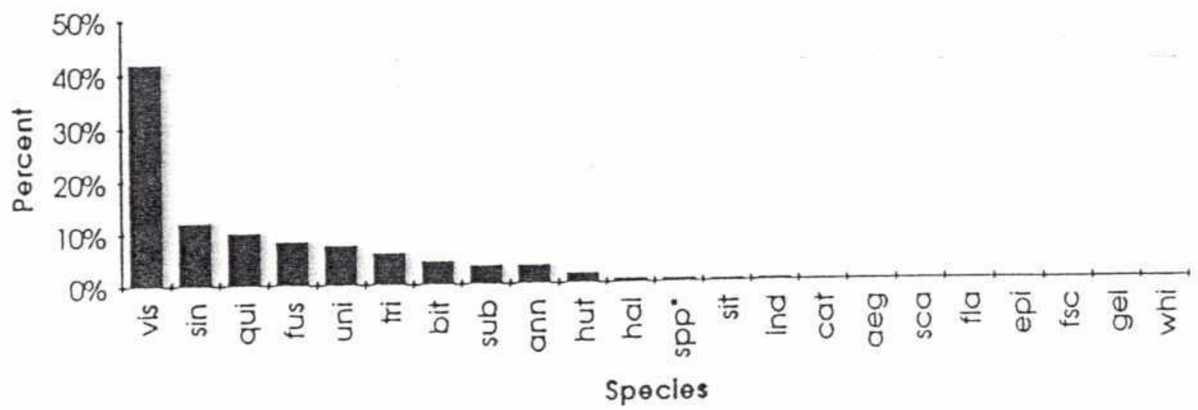


Fig 12a: Biting Anopheline species abundance in village Katapukuria, Natore

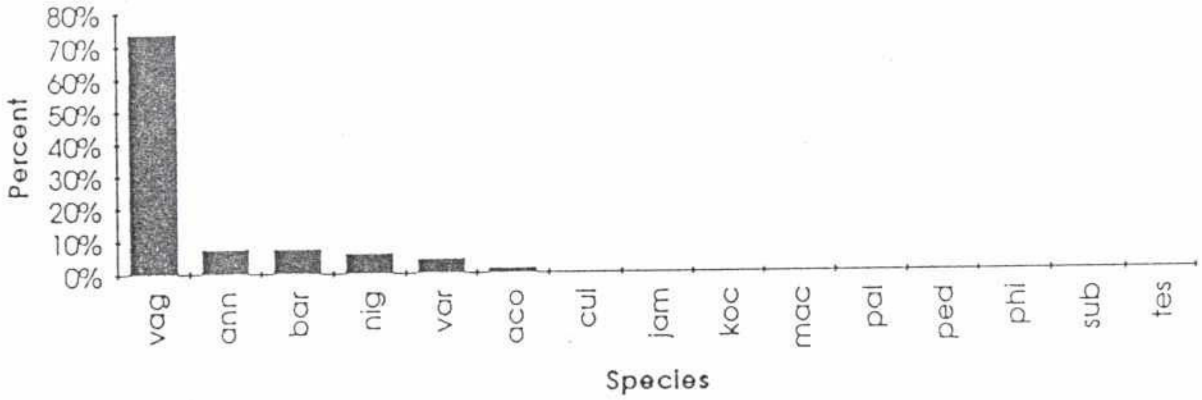


Fig 12b: Biting Anopheline species abundance in village Koigram, Natore.

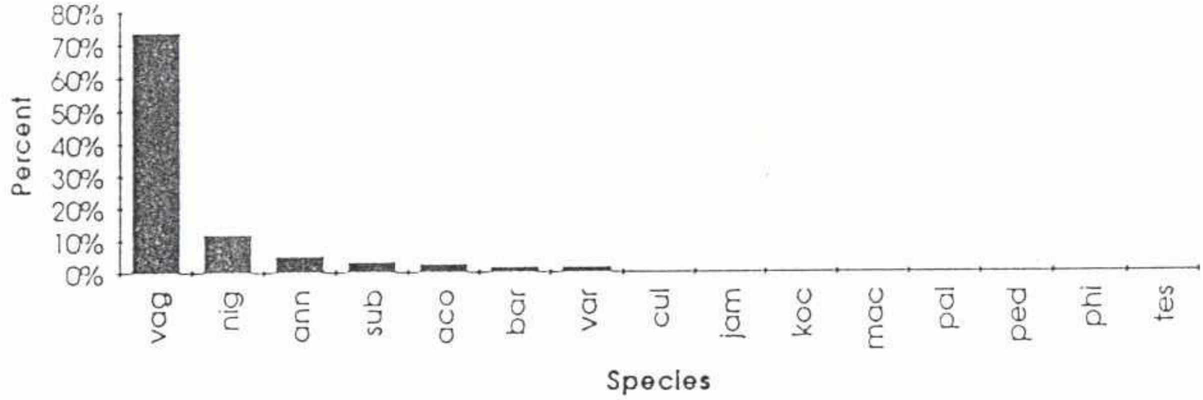


Fig 12c: Biting Anopheline species abundance in village Pomgaon-putimari, Natore.

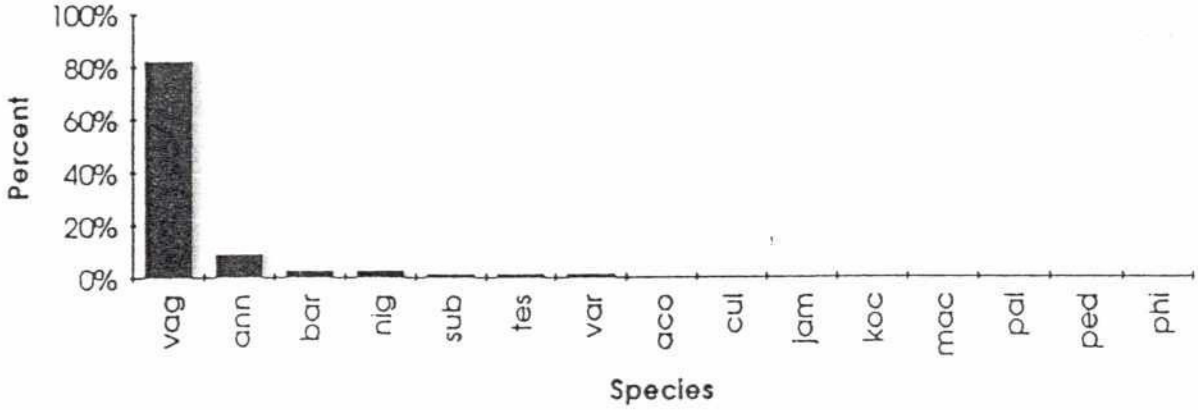


Fig 13a : Biting Culicine species abundance in village Katapukuria, Natore.

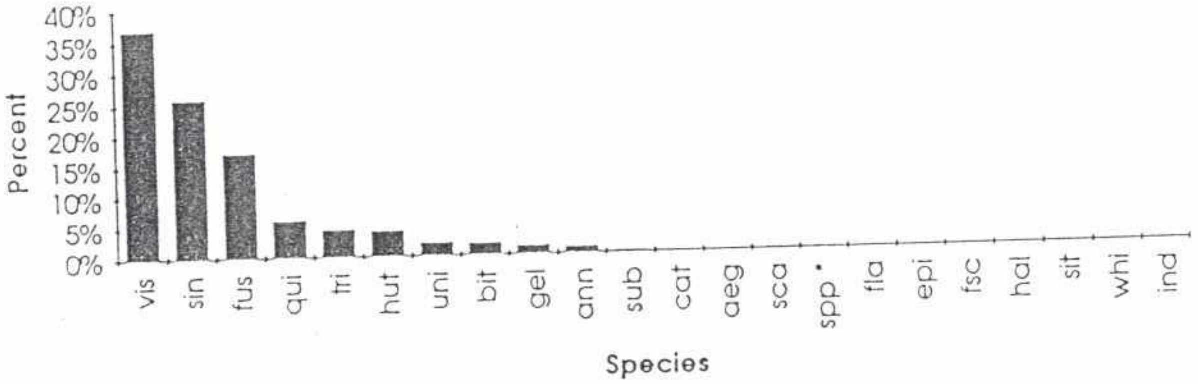


Fig 13b : Biting Culicine species abundance in village Koigram, Natore

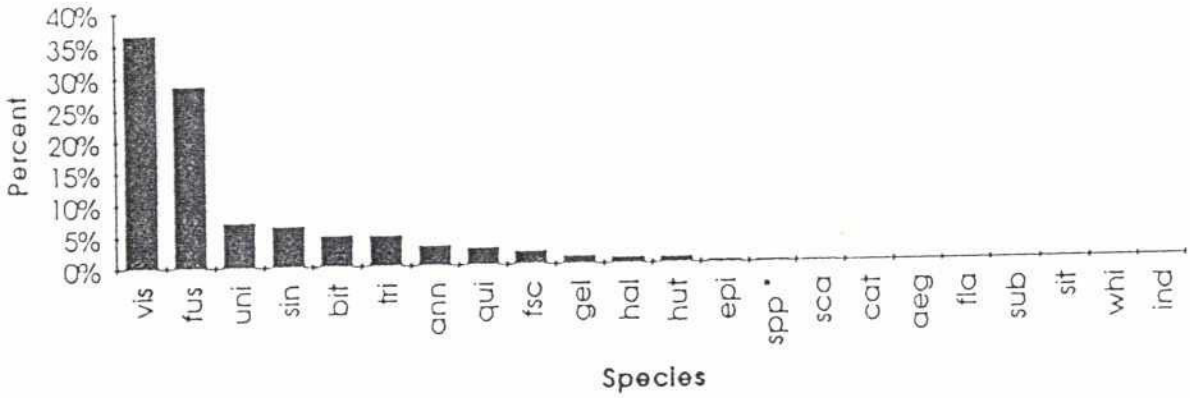


Fig 13c: Biting Culicine species abundance in village Pomgaon-putimari, Natore.

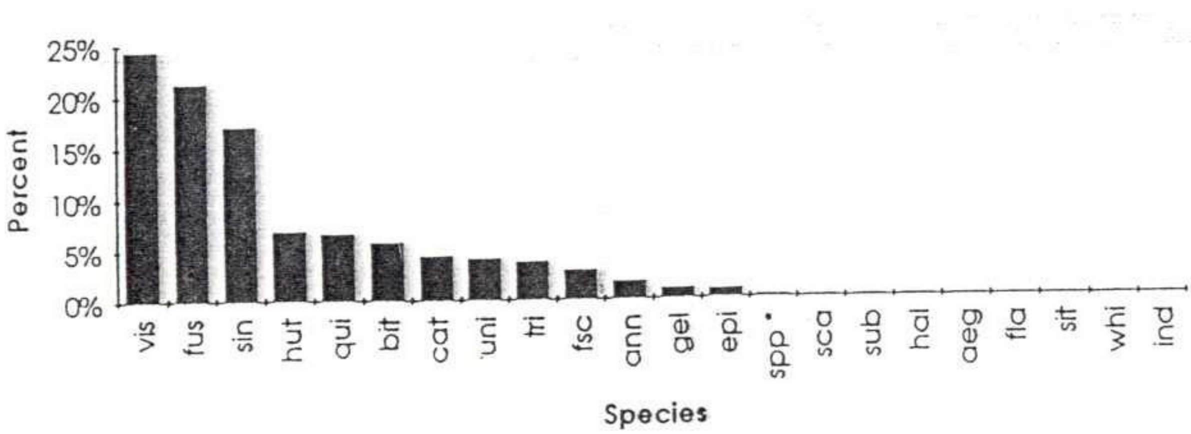
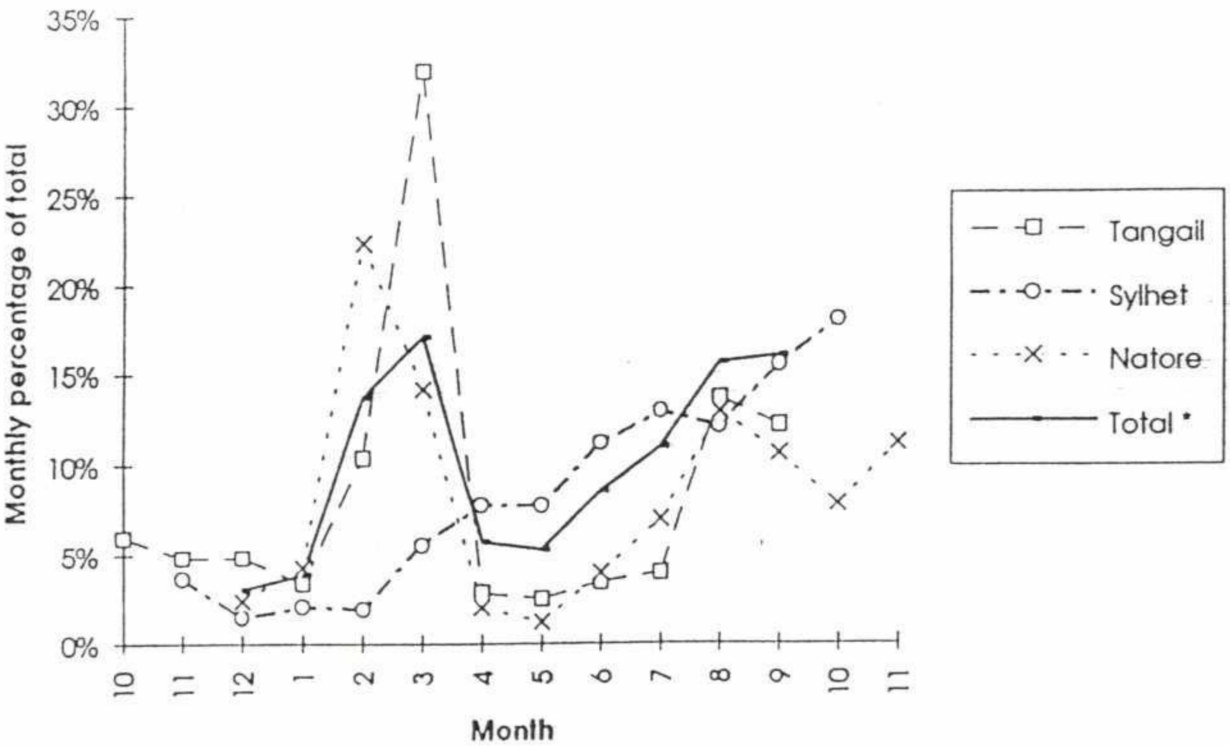


Table 6: Sum of the number of biting mosquitoes (anophelines and culicines together) by season (all districts).

Sum of Number		District							
								Total *	%
Year	Month	tan	%	syl	%	nat	%		
1991	10	168	6%						
	11	136	5%	228	4%				
	12	137	5%	91	1%	128	2%	356	3%
1992	1	95	3%	129	2%	228	4%	452	4%
	2	294	10%	121	2%	1199	22%	1614	14%
	3	903	32%	347	6%	760	14%	2010	17%
	4	81	3%	484	8%	108	2%	673	6%
	5	72	3%	486	8%	67	1%	625	5%
	6	98	3%	701	11%	212	4%	1011	9%
	7	113	4%	810	13%	377	7%	1300	11%
	8	388	14%	761	12%	697	13%	1846	16%
	9	346	12%	972	16%	572	11%	1890	16%
	10			1131	18%	419	8%		
	11					603	11%		
Grand total		2831	100%	6261	100%	5370	100%	11777	100%

* Total only calculated for the months during which all districts were sampled.

Fig 14: Total biting mosquitoes (anophelines and culicines together) by season.



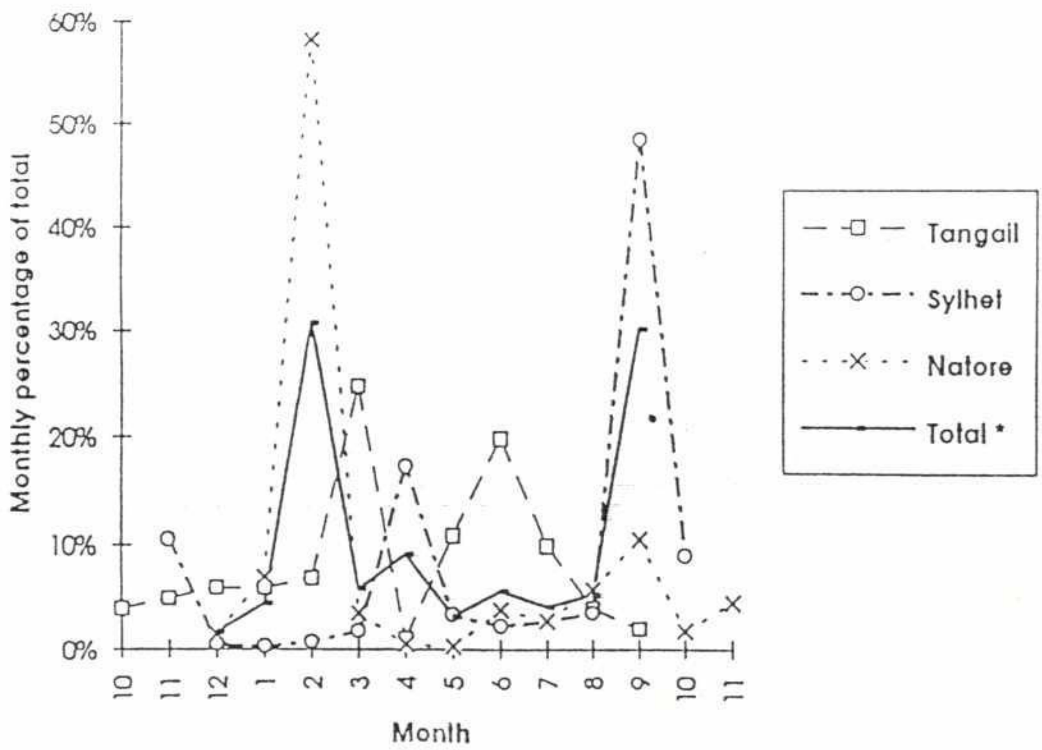
* Total only calculated for the months during which all districts were sampled.

Table 7: Sum of the number of biting Anophelines by season (all districts).

Sum of Number		District							
								Total *	%
Year	Month	tan	%	syl	%	nat	%		
1991	10	4	4%						
	11	5	5%	42	11%				
	12	6	6%	2	1%	6	2%	14	2%
1992	1	6	6%	1	0%	28	7%	35	4%
	2	7	7%	3	1%	232	58%	242	31%
	3	25	25%	7	2%	14	4%	46	6%
	4	1	1%	69	17%	2	1%	72	9%
	5	11	11%	13	3%	1	0%	25	3%
	6	20	20%	9	2%	15	4%	44	6%
	7	10	10%	11	3%	11	3%	32	4%
	8	4	4%	14	4%	23	6%	41	5%
	9	2	2%	193	48%	42	11%	237	30%
	10			36	9%	7	2%		
	11					18	5%		
Grand total		101	100%	400	100%	399	100%	788	100%

* Total only calculated for the months during which all districts were sampled.

Fig 15: Total biting anophelines by season.



* Total only calculated for the months during which all districts were sampled.

Table 8: Sum of the number of biting Culicines by season (all districts).

Sum of Number		District							
								Total *	%
Year	Month	tan	%	syl	%	nat	%		
1991	10	164	6%						
	11	131	5%	186	3%				
	12	131	5%	89	2%	122	2%	342	3%
1992	1	89	3%	128	2%	200	4%	417	4%
	2	287	11%	118	2%	967	20%	1372	12%
	3	878	32%	340	6%	746	15%	1964	18%
	4	80	3%	415	7%	106	2%	601	5%
	5	61	2%	473	8%	66	1%	600	5%
	6	78	3%	692	12%	197	4%	967	9%
	7	103	4%	799	14%	366	7%	1268	12%
	8	384	14%	747	13%	674	14%	1805	16%
	9	344	13%	779	13%	530	11%	1653	15%
	10			1095	19%	412	8%		
	11					538	11%		
Grand total		2730	100%	5861	100%	4924	100%	10989	100%

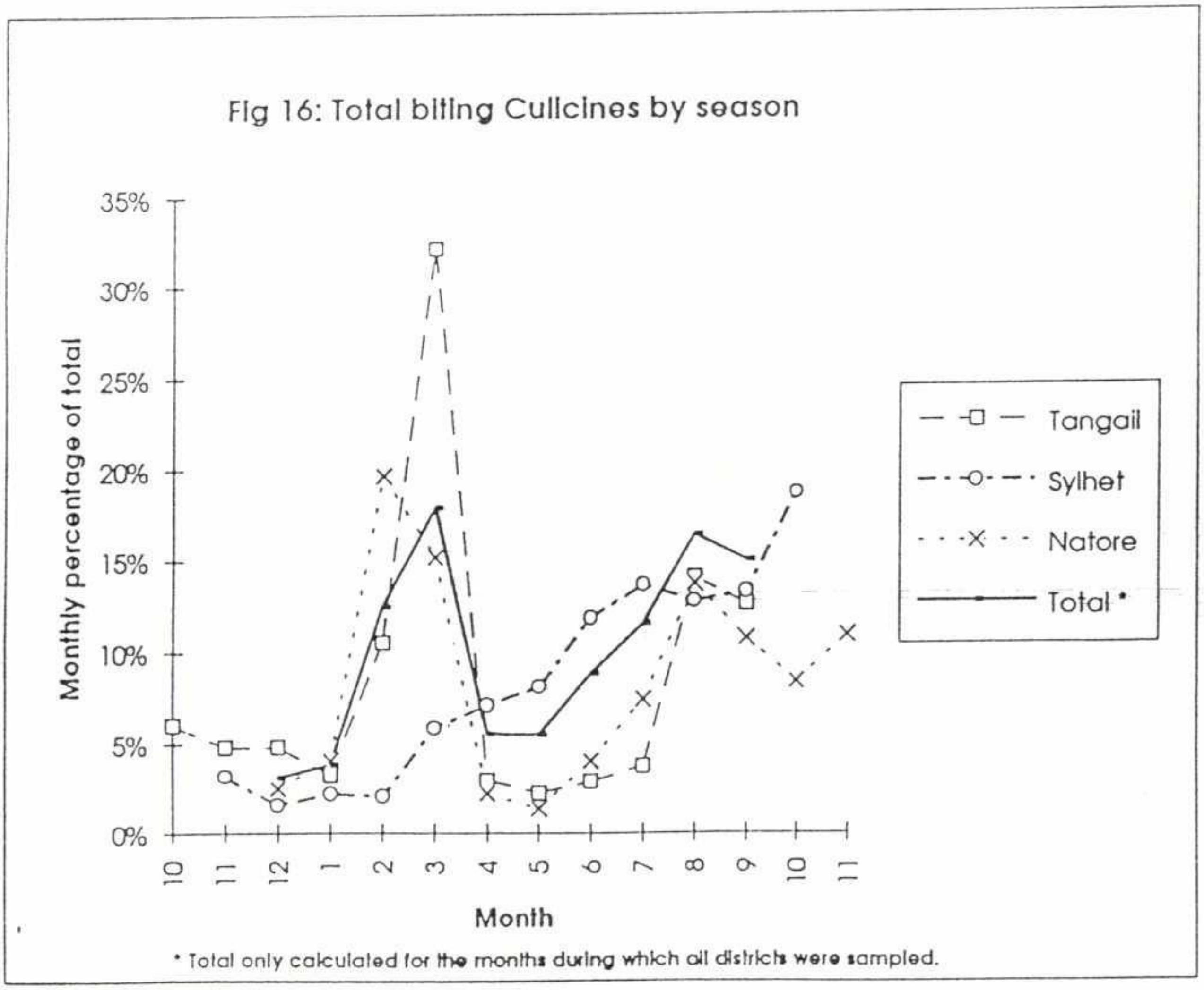


Fig 16: Total biting Culicines by season

* Total only calculated for the months during which all districts were sampled.

Fig 17: Relative abundance of selected mosquito larvae by habitat (all districts).

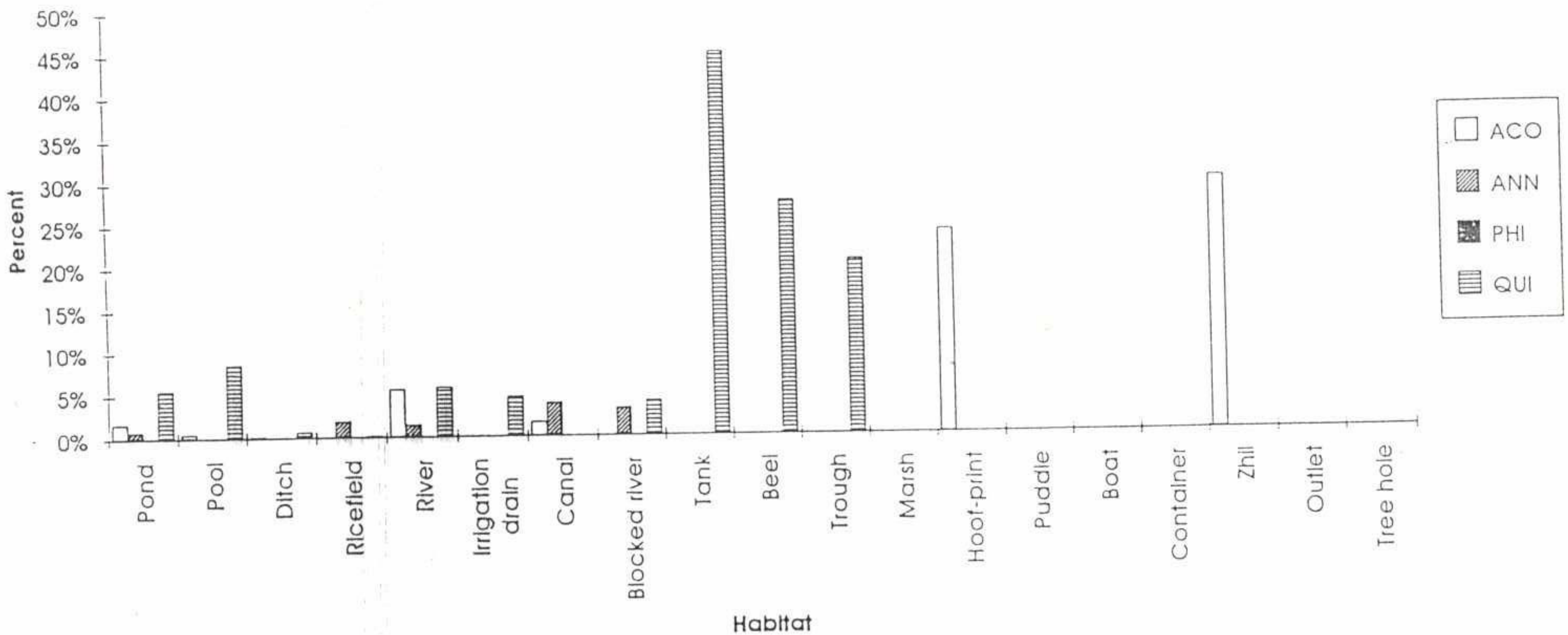


Fig 18a: Ricefield habitat, Anopheline larval species (all districts).

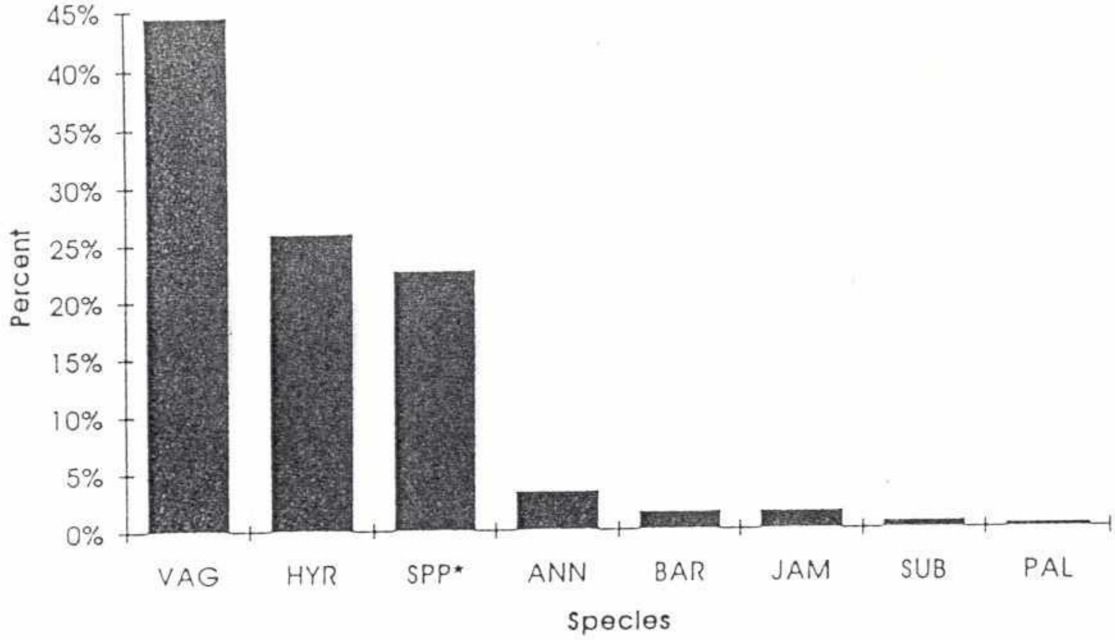


Fig 18 b: Ricefield habitat, Culicine larval species (all districts).

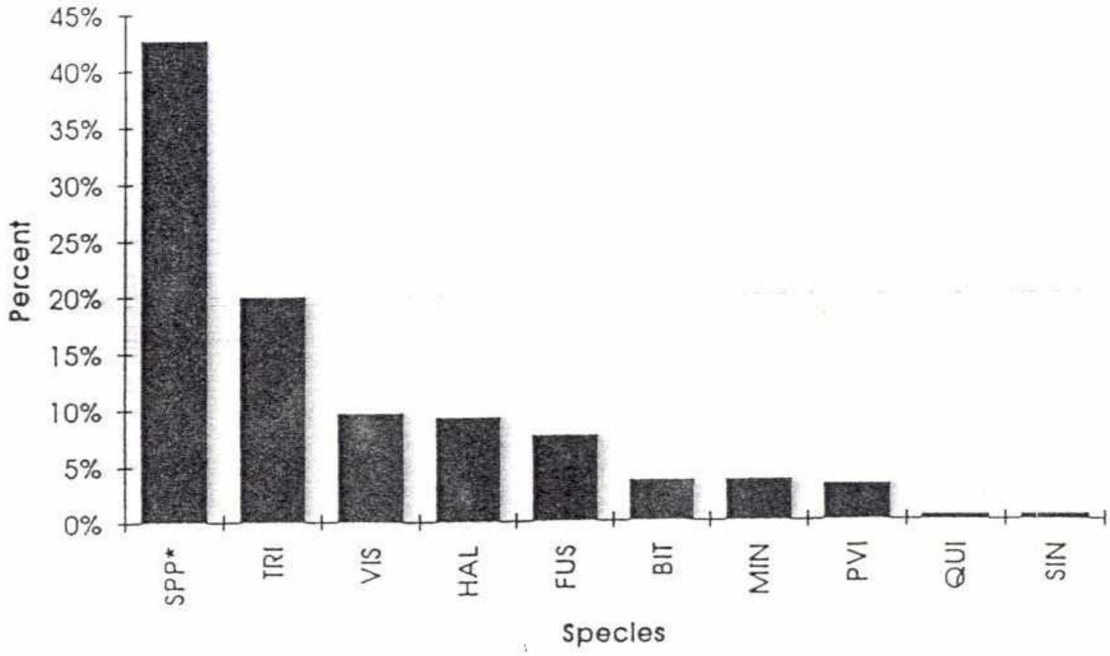


Fig 19: Seasonal biting abundance of An. philippinensis in Sylhet district.

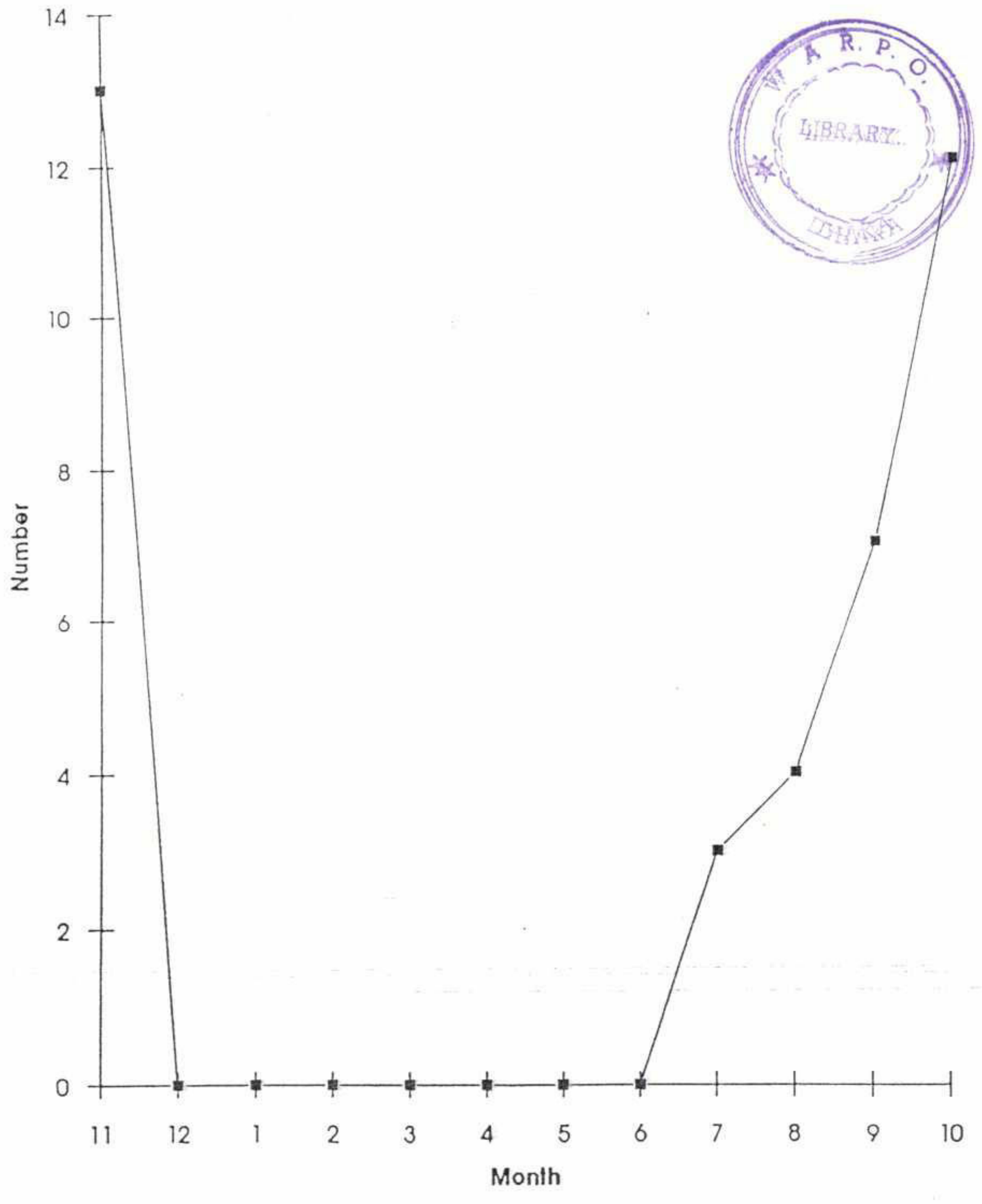


Table 9a: Sum of the number of An. aconitus larvae and total larvae caught in individual positive habitats of An. aconitus by month (all districts).

Sum of Number YEAR	MONTH	DESC Ponds aco	Ponds total	Rivers aco	Rivers total	Pools aco	Pools total	Hoof-prints aco	Hoof-prints total	Canals aco	Canals total	Zhil aco	Zhil total	Ditches aco	Ditches total	Grand total aco	Grand total total
91	12	7	154	0	0	2	50	0	0	0	3	3	8	0	0	12	323
92	1	15	218	0	17	0	49	0	0	1	25	0	0	1	115	17	542
	2	4	544	7	107	2	204	6	25	0	4	0	0	0	205	19	1158
	3	12	682	7	23	0	126	0	0	0	67	0	0	0	43	19	1242
	4	15	325	0	18	2	101	0	0	2	25	0	2	0	34	19	647
	5	1	204	0	0	0	169	0	0	0	0	0	0	0	86	1	494
	6	0	252	0	0	0	355	0	0	0	13	0	0	0	28	0	677
	7	1	279	6	73	1	125	0	0	0	8	0	0	0	5	8	557
	8	0	209	4	93	0	158	0	0	0	26	0	0	0	28	4	632
	9	0	214	0	40	0	245	0	0	0	5	0	0	0	13	0	610
Total		55	3081	24	371	7	1582	6	25	3	176	3	10	1	557	99	6882

Table 9b: Relative abundance of An. aconitus larvae in individual positive habitats of An. aconitus by month (all districts).

YEAR	MONTH	DESC Ponds	Rivers	Pools	Hoof-prints	Canals	Zhil	Ditches	Grand total
91	12	5%	*	4%	*	0%	38%	*	4%
92	1	7%	0%	7%	*	4%	*	1%	3%
	2	1%	7%	1%	24%	0%	*	0%	2%
	3	2%	30%	7%	*	0%	*	0%	2%
	4	5%	0%	2%	*	8%	0%	0%	3%
	5	0%	*	0%	*	*	*	0%	0%
	6	0%	*	0%	*	0%	*	0%	0%
	7	0%	8%	1%	*	0%	*	0%	1%
	8	0%	4%	7%	*	0%	*	0%	1%
	9	0%	0%	7%	*	0%	*	0%	0%
Total		2%	6%	7%	24%	2%	30%	0%	1%

* No positive sites of this habitat type were recorded during this month.

· This figure corresponds to the sum of the number of all larvae caught in the month indicated.

Fig 20: Relative abundance of An. aconitus in selected habitats by month (all districts).

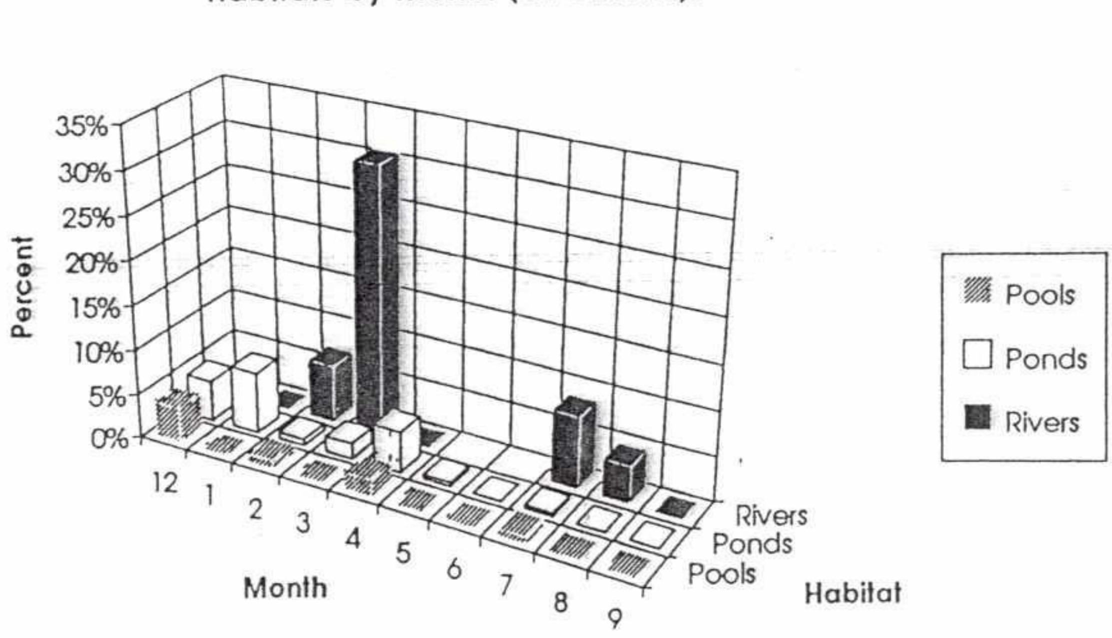


Table 10a: Sum of the number of An. annularis larvae and total larvae caught in individual positive habitats of An. annularis by month (all districts).

Sum of NUMBER YEAR	MONTH	DESC Ponds ann	total	Ricefields ann	total	Canals ann	total	Rivers ann	total	Blocked rivers ann	total	Grand total ann	total·
91	12	2	154	0	0	0	3	0	0	0	0	2	323
92	1	0	218	0	84	0	25	0	17	0	0	0	542
	2	2	544	0	23	0	4	7	107	0	0	9	1158
	3	16	682	10	238	7	67	0	23	4	38	37	1242
	4	5	325	0	28	0	25	0	18	0	85	5	647
	5	0	204	0	23	0	0	0	0	0	0	0	494
	6	0	252	0	13	0	13	0	0	0	0	0	677
	7	0	279	0	37	0	8	0	73	0	0	0	557
	8	0	209	0	26	0	26	0	93	0	0	0	632
	9	0	214	0	22	0	5	0	40	0	0	0	610
Total		25	3081	10	494	7	176	7	371	4	123	53	6882

Table 10b: Relative abundance of An. annularis larvae in individual positive habitats of An. annularis by month (all districts).

YEAR	MONTH	Ponds	Ricefields	Canals	Rivers	Blocked rivers	Grand total
91	12	1%	*	0%	*	*	1%
92	1	0%	0%	0%	0%	*	0%
	2	0%	0%	0%	7%	*	1%
	3	2%	4%	10%	0%	11%	3%
	4	2%	0%	0%	0%	0%	1%
	5	0%	0%	*	*	*	0%
	6	0%	0%	0%	*	*	0%
	7	0%	0%	0%	0%	*	0%
	8	0%	0%	0%	0%	*	0%
	9	0%	0%	0%	0%	*	0%
Total		1%	2%	4%	2%	3%	1%

* No positive sites of this habitat type were recorded during this month.
· This figure corresponds to the sum of the number of all larvae caught in the month indicated.

Fig 21: Relative abundance of An. annularis in selected habitats by month (all districts).

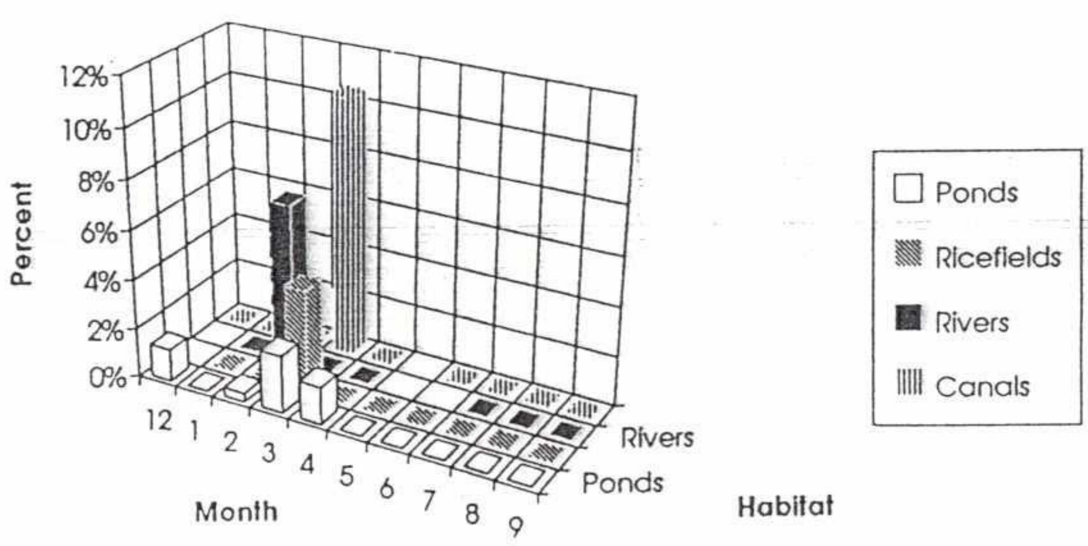


Table 11a: Sum of the number of Cx. quinquefasciatus larvae and total larvae caught in individual positive habitats of Cx. quinquefasciatus by month (all districts).

Sum of Number

Year	Month	DESC Ponds		Pools		Tanks		Beel		Irrigation Drains		Troughs		Blocked rivers		Ditches		Ricefields		Grand total	
		qui	total	qui	total	qui	total	qui	total	qui	total	qui	total	qui	total	qui	total	qui	total	qui	total•
91	12	0	154	0	50	0	0	0	0	12	108	0	0	0	0	0	0	0	0	12	323
92	1	5	218	0	49	0	0	0	0	0	0	7	34	0	0	0	115	0	84	12	542
	2	100	544	9	204	38	38	0	0	0	0	0	0	0	0	1	205	0	23	148	1158
	3	2	682	34	126	0	9	0	0	0	0	0	0	0	38	0	43	0	238	36	1242
	4	6	325	0	101	0	0	0	0	0	0	0	0	5	85	3	34	0	28	14	647
	5	0	204	0	169	0	0	0	12	0	0	0	0	0	0	0	86	0	23	0	494
	6	1	252	0	355	0	0	0	0	0	13	0	0	0	0	0	28	0	13	1	677
	7	0	279	1	125	0	0	0	0	0	20	0	0	0	0	0	5	0	37	1	557
	8	9	209	0	158	0	0	0	9	0	78	0	0	0	0	0	28	1	26	10	632
	9	64	214	92	245	0	12	13	18	0	41	0	0	0	0	0	13	0	22	169	610
Total		187	3081	136	1582	38	59	13	39	12	260	7	34	5	123	4	557	1	494	403	6882

Table 11b: Relative abundance of Cx. quinquefasciatus larvae in individual positive habitats of Cx. quinquefasciatus by month (all districts).

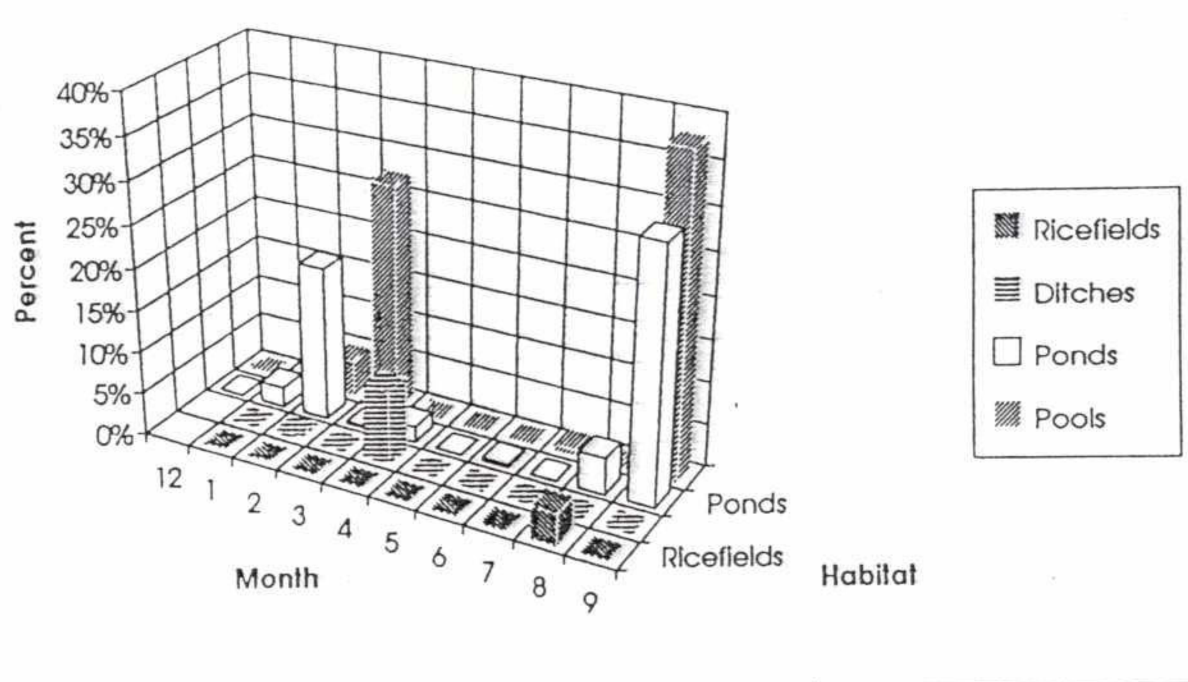
Sum of Number

Year	Month	DESC Ponds	Pools	Tanks	Beel	Irrigation Drains	Troughs	Blocked rivers	Ditches	Ricefields	Grand total
91	12	0%	0%	*	*	11%	*	*	*	*	4%
92	1	2%	0%	*	*	*	21%	*	0%	0%	2%
	2	18%	4%	100%	*	*	*	*	0%	0%	13%
	3	0%	27%	0%	*	*	*	0%	0%	0%	3%
	4	2%	0%	*	*	*	*	6%	9%	0%	2%
	5	0%	0%	*	0%	*	*	*	0%	0%	0%
	6	0%	0%	*	*	0%	*	*	0%	0%	0%
	7	0%	1%	*	*	0%	*	*	0%	0%	0%
	8	4%	0%	*	0%	0%	*	*	0%	4%	2%
	9	30%	38%	0%	72%	0%	*	*	0%	0%	28%
Total		6%	9%	64%	33%	5%	21%	4%	1%	0%	6%

* No positive sites of this habitat type were recorded during this month.

• This figure corresponds to the sum of the number of all larvae caught in the month indicated.

Fig 22: Relative abundance of Cx. quinquefasciatus in selected habitats by month (all districts).



Chapter 4

OVERVIEW OF VECTOR-BORNE DISEASE IN BANGLADESH

The following six tables provide a comparative overview of vector-borne disease issues in Bangladesh.

Table 11
Summary of Vector-Borne Disease Status in Bangladesh

Health Hazard	Case Severity	Pre-project Transmission Status on Floodplains
Benign malaria	Rarely fatal, treatment available	Occurs on floodplains, prevalence low
Malignant malaria	Frequently fatal, drug resistance	Occurs in forests, occasionally imported to floodplains
Kala-azar	Frequently fatal, drug expensive	Epidemic in progress, no resources for control
Filariasis	Chronic rather than fatal, debilitating, drug available	Several small foci, much less common than in India or Burma
Dengue	Varies from mild fever to life threatening, no treatment	No data
Japanese encephalitis	Frequently fatal or causes brain damage, no treatment	Very rare
Schistosomiasis	Chronic, debilitating, cheap drug available	Does not occur in Bangladesh nearest foci are China and Iraq

9y

Table 12
Possible Effect of Flood Action Plan on Vector Breeding Sites

Disease Hazard	Vector Breeding Site	Pathway to Increased Vector Breeding Due to FAP
Malaria	Mainly ponds and ricefields with algae and clear, silt-free water	Reduced flushing action and silty water of floods balanced by increased water pollution, which is inimical to breeding
Kala-azar	Peridomestic, organically rich soil, cowsheds	Reduced flushing action of floods
Filariasis	Peridomestic, foul or organically rich water, blocked drains	Reduced flushing and increased drainage obstruction
Dengue	Containers of clean water	No effect
Japanese encephalitis	Ricefields and other water bodies	No effect

Table 13
Disease Vectors

Disease Hazard	Vector	Common Name
Malaria	*An. philippinensis* *An. aconitus* *An. annularis*	Anopheline mosquito
Kala-azar	*Ph. argentipes*	Sandfly
Filariasis	*Cx. quinquefasciatus*	Culicine mosquito
Japanese encephalitis	*Cx. tritaeniorhynchus*, *gelidus* and others	Culicine mosquito
Dengue	*Ae. aegypti*	Aedine mosquito

Table 14
Animal Reservoirs of Disease

Disease	Animal Reservoir	Notes
Malaria	Human	Cattle can be important diversionary host for the vectors
Kala-azar	Human	Vectors feed on cattle
Filariasis	Human	Vectors are peridomestic
Dengue	Human	
Japanese encephalitis	Pig, bird	Non-muslim minorities keep pigs

Table 15
Vulnerable Communities

On the basis of general information about these diseases we predict the following groups would be most vulnerable.

Disease Hazard	Urban/Rural	Habits	Male/Female
Malaria	Rural	All	Females most vulnerable
Filariasis	Both	All	Male
Kala-azar	Rural	Cattle keepers	Male*
Dengue	Urban	All	All
Japanese encephalitis	Rural	Pig keepers	All

*May be due to bias in case reporting.

9b

Table 16
Mortality, Treatment, and Diagnosis

Disease Hazard	Morbidity, Mortality	Treatment	Confirmatory Diagnosis
Benign malaria	Fever, low mortality	Cheap presumptive	Simple, but often poorly managed
Malignant malaria	Fever, high mortality	More expensive drugs required	Simple, but often poorly managed
Kala-azar	Fever, high mortality	Expensive	Difficult
Filariasis	Swelling and pain, not fatal	Cheap	Simple
Dengue	Fever, variable mortality	Supportive only	Difficult
Japanese encephalitis	Permanent disability, high mortality	Supportive only	Difficult