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A Case Study on Physical and Biological Factors in Relation to Mosquito Emergence in Abandoned Gem Pits in Elahera, Sri Lanka

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ABSTRACT. Field experiments were conducted in Elahera gem mining area from January to May 2000 in four stations along Kalu ganga to evaluate the physico-chemical aspects, biological aspects such as associated mosquito larvae and larvivorous predator communities in abandoned gem pits. The correlation between rainfall and disease incidences in the area with three month lag period (r_s = -0.335; p = 0.04) and four month lag period (r_s = -0.439; p = 0.009) were significant. All the water quality parameters estimated in the gem pits were within the range where the fish can survive. Puntius filamentosus, P. bimaculatus, Rasbora cavarie and Esomus thermoicos were the dominant fish species observed in the pits. There was a significant relationship between the presence or absence of fish and the presence or absence of mosquito larvae in experimented pits at 5% level. When fish were present, only 13.3% of the pits had mosquito larvae. When the fish were absent, 73.7% of the pits had mosquito larvae. The presence of mosquito larvae in gem pits reduced significantly (94.5%) in the presence of fish in pits. Littoral and submerged vegetation in the pits were having a positive effect on mosquito larval survival in the pits (r_s = 0.50; p = 0.005). Plankton studies in the pits indicated the occurrence of predators of mosquito larvae such as copepods and aquatic insects.

INTRODUCTION

Mosquito born diseases poses significant health and economic problems to many countries of the world today. Malaria is historically one of the most devastating diseases and is endemic to 101 countries and it is estimated that about 40% of the world's population (2,400 million) are at risk. It is affecting 300-500 million people and killing 1-2 million world wide every year. Apart from human sufferings, the economic cost to affected countries for preventive measures and for providing treatments is also significantly high. In Sri Lanka the economic cost of malaria amounts approximately 60% of its public health budget (Amarasinghe, 2000).

Among the many factors leading to the outbreak of mosquito born diseases, human causative factors can significantly lead to the increase of disease incidences in some locations. In Sri Lanka, it has been reported that mosquito born diseases and gem mining have close relationship and mining lead to increased incidence or outbreaks of malaria in some localities (Wickremasinghe, 1991). The possibility of discovering a new gem bearing location is largely a matter of chance and this has led to much haphazard digging in search of gem bearing gravels and consequent damage to the environment. *Anopheles culicifacies* the major vector of malaria parasite, is a sun-loving species in the early larval stages. It

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favours breeding in clear waters with little aquatic vegetation in a variety of breeding places. Abandoned gem pits in mining areas serve as ideal habitats for this mosquito to breed.

Field investigations made in a gemming area at Elahera in the Matale District during 1975 revealed that illicit gem mining has been carried out over an area of 6000-8000 ha. On an average the number of man made potential mosquito breeding places was estimated as 250-370 ha (Wickremasinghe, 1991). Even though gem mining is not intensive as in 1970's in this area, still the problem of abandoned gem pits distributed throughout the area has become a severe problem (field observations).

Today mosquito control programmes are geared as integrated approaches. The beneficial effects of biological control methods over the chemical control methods on environment have been identified in many situations. This has made biological controlling methods an important part of mosquito control programmes today. There are wide range of animal phyla among the natural enemies of mosquitoes, which can be used to control mosquito populations. Among them are viruses, pathogenic bacteria, protozoa, nematodes, invertebrates and other vertebrate predators (WHO, 1975). However, those that can be used operationally with any degree of success are a few.

Present study aims at evaluating the physico-chemical aspects, biological aspects such as associated mosquito larvae and larvivorous predator communities in abandoned gem pits in Elahera gem field. Such information could be a basis to establish ecologically sound and comprehensive strategies for the control of mosquitoes and consequent control of mosquito born diseases in these areas.

MATERIALS AND METHODS

This study was conducted during January to May 2001 in Elahera gem mining area at four locations along Kalu ganga. The Elahera gem field covers approximately 7000 ha in the Matale and Polonnaruwa districts of central Sri Lanka (Fig. 1) which extends from approximately 80° 45' to 80° 55' east and from 7° 35' to 7° 50' north (Gunawardene and Rupasinghe, 1986). The principal gem mining area is centred at 80° 50' longitude from north to south. Two tributaries of Mahaweli Ganga, known as Amban Ganga and Kalu Ganga run through the main gem area.

The relationship between rainfall and malaria out break in Elahera MOH area

Monthly records of rainfall and malaria disease incidence in the Elahera MOH area from 1998-2000 were taken and the relationship between rainfall and disease outbreak were made using Spearman's rank correlation test. Daily rainfall data for the years from 1998-2000 were obtained from the Irrigation Department Office at Elahera and mean monthly rainfall for the years were calculated. Monthly malaria disease incident data in the area was obtained from the Antimalaria Campaign Office in Colombo.

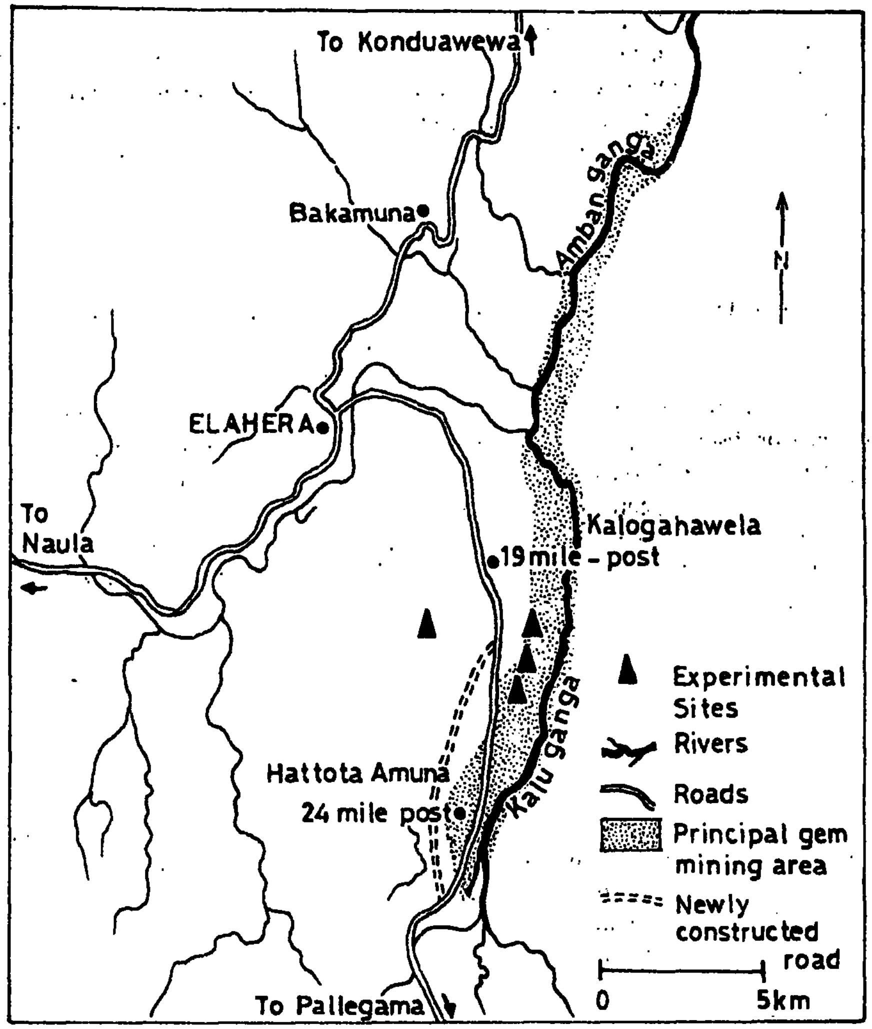

Fig. 1. The Elahera gem field in central Sri Lanka and experimental locations.

Physical, chemical and biological parameters of gem pits

Twenty eight gem pits were randomly selected from the four locations and, physical, chemical and biological parameters of gem pits were studied to estimate its suitability for any fish introduction. Water depth, surface area of the pit, conditions of the margins, plants and animals within the pits were observed during the study period. Water quality parameters such as Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), nitrates (NO_3^-), phosphates (PO_4^{3-}), ammonia (NH_3), pH and temperature were also recorded in randomly selected pits throughout the study period. Planktons were collected using a 15 µm mesh plankton net and preserved in 10% formalin until identification in the laboratory according to Fernando (1990). Presence of mosquito larvae was visually confirmed and they were sampled using a dipper, with 1-20 dippings depending on the pool size. The dip contents from a single pool were combined and sieved through a 30 µm mesh and preserved using 10% formalin for later identification. Fish samples from the pits were collected using a fish net (45×30 cm) and brought to the laboratory for later identification. Identification was made according to Pethiyagoda (1991) and Deraniyagala (1938). Some live specimens were reared under laboratory conditions and provided them with mosquito larvae to estimate its predatory efficiency for mosquito larvae. Other organisms present in pits were also examined to estimate the possible predators of mosquito larvae and of fish. Sampling was done at every three-week interval from January 2001 to May 2001.

Estimation of the effect of fish and littoral vegetation on emergence of mosquito larvae

Sixty-four observations of pits, were categorised into eight groups according to the amount of marginal and submerged vegetation present, presence or absence of fish and presence or absence of mosquito larvae. The relationship between the presence of fish and vegetation on mosquito larval emergence were determined using the Person's chi-square test in SAS package. Spearman's rank correlation test was also performed to find out any relationship between the density of littoral vegetation and the number of mosquito larvae present. For this, pits were categorized according to the degree of littoral zone present as low, medium and high and were given values 1, 2 and 3 respectively.

RESULTS AND DISCUSSION

The relationship between rainfall and malaria out break in Elahera MOH area

The correlation between monthly rainfall and monthly malaria incidence was found to be significant when no lag period was considered (Spearman's rank correlation (r_s) = 0.506; p = 0.002). The correlation between rainfall and disease incidence with one month lag period and two month lag period were not significant indicating no relationship between, rainfall and disease incidence one month (r_s = 0.308; p = 0.07) or two months later (r_s = -0.065; p = 0.715). However, when three month and four month lag periods were considered, there was a significant negative relationship between rainfall and disease incidence (three month lag; r_s = -0.335; p = 0.04, four month lag; r_s = -0.439; p = 0.009) (Fig. 2). This indicates that lower rainfall in the area results in higher disease incidences after three to four months period. Even though the relationship between rainfall and malaria incidences at zero lag period was significant, it is not biologically acceptable as time is needed for breeding sites for vectors to become established, for breeding to take place, and for the life cycle of the malarial parasite to be completed in both the vector and the human host (Hoek *et al.*, 1997). Therefore, three to four month lag period can be considered acceptable from the biological point of view. According to Gill (1936), excessive rainfall in the dry zone was likely to be followed by high incidences of malaria. Unusually low rainfall in the wet zone favoured a later epidemic. Even though the studied area fall within the dry zone of Sri Lanka, it shows a relationship between rainfall and disease incidences characteristic to wet zone. It is possible that the many changes in the environment brought about by man have affected malaria transmission and local climate conditions enough to complicate the relationship between rainfall and malaria. The increase of mosquito breeding sites such as stagnant water pools created by human activities may have contributed to the increased disease incidences in the following months after a dry period. When the rainfall increases most of these habitats may be flushed away. In addition to that, due to the change of physical parameters of the water such as increased turbidity prevents the breeding of vector mosquitoes causing reduced disease incidence following the rainy seasons. Malaria mosquitoes breed only in clean waters (Wickremasinghe, 1981).

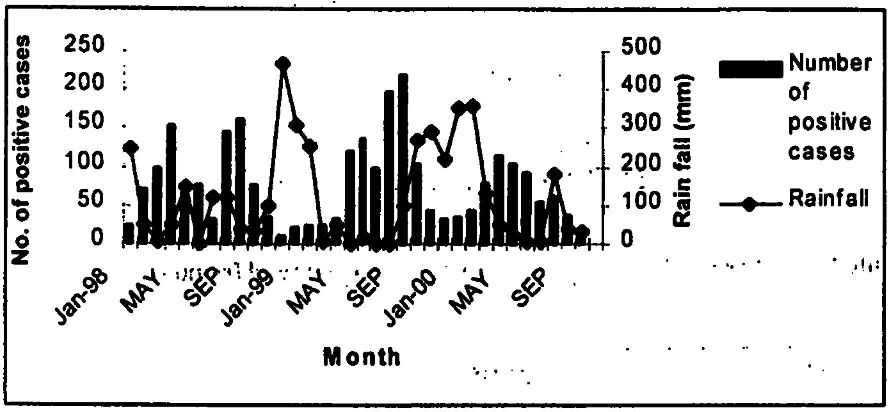

Fig. 2. Relationship between rainfall and malaria incidences with four months lag period.

Physical, chemical and biological parameters of gem pits

The surface area of gem pits varied in size from 0.4 - 4 m^2 and the depth varied from 0.6 - 4.0 m. Gem mining in that area was mostly shallow mining and most of the pits were covered with vegetation. In most of the pits around and in the bottom, aquatic plants such as *Chara, Hydrilla* could be seen. Water levels of the pits were fluctuating and gradually reducing and dried up during April, May onwards coinciding with the onset of dry period in the area.

All the water quality parameters observed (Table 1) were within the range where fish can survive (Swingle, 1969). In many of the pits fish species such as *Puntius filamentosus, P. bimaculatus, Rasbora cavarie, Esomus thermoicos* and tadpoles could be observed with *Rasbora cavaria* being the most abundant species in all the habitats (Table 2). The only possible way of fish entering to the pits was during the rainy season, when the pits were merged and inundated with river water. Laboratory studies confirmed that *Rasbora cavarie* and *Esomus thermoicos* are effective predators of mosquito larvae. Pethiyagoda (1991) also reported similar feeding behavior in these fish. Even though the herbivorous nature of tadpoles could be expected to have less effect on mosquito larval control, frogs can be expected to have an effect on mosquito control in the pits.

Plankton studies indicated that most of the pits were having rich plankton diversity (Table 2). Zooplanktons such as Copepods (*Eucyclops sp., Acanthocyclops sp.,* Nauplius, which is the larval stage of Cyclops) were commonly observed in pits. In field investigations made in south-western Lousiana rice fields Marten *et al.* (2000), Copepods were observed to kill first instars of *Anophelese spp.*. According to this survey *Mesocyclops, Macrocyclops* and *Acanthocyclops* were effective in controlling mosquito

Table 1. Water quality parameters observed in randomly selected gem pits.

Parameter	Range
pH	6.9-8.8
DO (mg/l)	3.5-11
BOD (mg/l/5 days)	2.48-4.88
NH_3 (mg/l)	0.07-2.45
PO_4^{3-} (mg/l)	0.05-0.21
NO_3^- (mg/l)	0.07-2.59

Table 2. Taxa which have been observed in gem pits and frequency of occurrence.

Taxon	Species	Frequency (%)[1]
Insects		10.0
Anisoptera[2]	*Anisops sp.*	
Corixidae	*Micronecta punctata*	
Gerridae[3]	*Limnogonus sp.*	
Culicidae		31.3
Culicines		
Anophelines		
Zooplankton		64.2
Copepods[2] (Including nauplius stages)	*Eucyclops sp.*, *Acanthocyclops sp.*	
Rotifers	*Asplanchna sp.*, *Lecane sp.*, *Keratella sp.*, *Dipleuchlania sp.*, *Brachionus sp.*	98.0
Cladocerons	*Daphnia sp.*	50.0
Filamenmtous algae	*Spirogyra sp.*, *Zygnema sp.*	40.0
Phytoplankton	*Chroococcus*	100.0
Blue green algae	*Gleotrichia sp.*, Pediastrum *sp.*,	
Green algae	*Scenedesmus sp.*, *Closterium sp.*, *Cosmarium sp.*	
Teleostomi		70.3
	Rasbora cavaria[2]	(100%)
	Esomus thermoicos[2]	(30%)
	Puntius filamentosus	(30%)
	P. bimaculatus	(40%)
Anura (tadpoles)		37.5

[1] Percentage no. positive pools/no. all pools; [2] Aquatic predators; [3] Surface predators

larvae. Other predators observed in the pits were aquatic insects belonging to orders such as Anisoptera and Gerridae (Table 2). However, the abundance of insects, in observed samples were very low (10%). This may be an underestimated value because they are strong and agile swimmers and not easily caught during sampling. These results indicate that zooplankton present in the pits may have a positive effect in controlling mosquito larvae. However, the predation of fish may have negative effect on the population growth of zooplankton.

Estimation of the effect of fish on emergence of mosquito larvae

According to the results of Person's chi-square test, a significant relationship at 5% level was found between the presence or absence of fish and the presence or absence of mosquito larvae in the gem pits studied. When fish were present, only 13.3% of the pits had mosquito larvae. When the fish were absent, 73.68% of the pits had mosquito larvae (Table 3). The presence of mosquito larvae in gem pits reduced significantly (94.5%) in the presence of fish in pits. These results further confirm the effectiveness of fish in the given area in controlling mosquito larvae. Similar results have been observed by many authors when fish were used to control mosquito larvae. According to Wu *et al.* (1991) edible fish stocked in rice fields at a density of 600-800 fry per 1/15 ha for 150-170 days has acted as effective mosquito biocontrol agents. Rajnikant *et al.* (1993) effectively controlled the mosquito larval breeding through the introduction of *Poecilia reticulata* into disused wells.

Table 3. The effect of fish and littoral vegetation on occurrence of mosquito larvae in gem pits.

Description	% of pits having mosquito larvae	% of pits not having mosquito larvae
Fish present	13.3	86.7
Fish absent	73.7	27.3
Littoral vegetation present	43.5	56.5
Littoral vegetation absent	24.4	75.6

According to the Spearman's rank correlation test there was a significant positive relationship between the degree of littoral zone present and mosquito larval emergence in the pits ($r_s = 0.50$; $p = 0.0046$). This indicates that the emergent or submergent macrophytes can enhance the survival of Anopheles larvae by providing favourable microhabitats, which offers refuge from predation. Orr and Resh (1989), reported a similar result on the survivability of Anopheles larvae in habitats having aquatic macrophytes. Similarly, it can be expected that predatory zooplankton species of mosquito larvae may seek refuge from predation by the fish when the submerged vegetation is present and thus counteract the effect. Asimeng and Mutinga (1992), indicated that the presence of vegetation and turbidity significantly reduced larval predation by *Tilapia zillii* and the negative effects of vegetation could be averted by combining *T. zilli* with herbivorous fish such as grass carp.

The results of this experiment indicate that our indigenous fish types also can be successfully used to control mosquito larvae. According to the observations made in the study, those pits close to a river or tributaries are having enough fish trapped to control mosquito larvae and they serve as natural controlling agents. During the onset of dry period, most of the pits started to dry up and fish in the pits also died. With the onset of next rainy periods, most of the pits start to fill up with rainwater but without predatory fish of mosquito larvae until heavy rains bring them from river or from a tributary. In such a situation, identification of possible local fish species which are having mechanisms to withstand drought conditions and maintain the stock continuously is necessary. Further investigations have to be made to identify local fish species, which have potential to withstand such situations. In addition to pits, which do not have access to natural stocking, stocking of larvivorous fish can be recommended. Use of insecticides for control of mosquitoes in gem pits may have adverse effects, since it destroys predator populations and thus may induce resurgence of mosquitoes after the loss of insecticide efficacy.

In organizing a fish introduction programme, mass rearing of selected fish and operational aspects can be handled by an existing organization such as Anti-malaria Programme, together with community participation. Rearing of fish in local villages is usually more cost effective than centralized mass breeding and distribution. The local community can play an important role in rearing, transportation and dissemination of fish. In addition to that, community can be encouraged to grow edible fish which also can be used to control mosquitoes. According to Wickramasinghe and Costa (1986) in some countries where communities are actively involved in mosquito control using fish, fishery development programmes have been started by growing fish both for consumption and for utilization as predators of mosquito larvae in various water bodies. *Oreochromis mossambicus* and *O. niloticus* have proved suitable for this programme in Indonesia, Malaysia, Sudan and Somalia. The edible value and the high larvivorous potential of common carp (*Cyprinus carpio*), the grass carp (*Ctenopharyngodon idella*) and Catla (*Catla catla*) have been combined in the composite fish culture which has been introduced with community involvement and government support for mosquito control in ponds in rural areas of India (Wickremasinghe and Costa, 1986). The initiation of such programmes in Sri Lanka is essential to prevent the mosquito born diseases accelerated due to human activities and to reduce the malnutrition of the rural people.

CONCLUSIONS

A negative relationship between monthly rainfall and malaria positive cases were observed in the area when three and four month lag periods were considered indicating an increase of malaria incidences in the area three to four months after a low rainfall period. All the water quality parameters in the pits were within the range where fish can survive. The fish species existed naturally in the pits were *Puntius filamentosus*, *P. bimaculatus*, *Rasbora cavarie*, *Esomus thermoicos* that have entered the pits during the rainy season when the pits were merged and inundated. There was a significant effect of fish on the removal of mosquito larvae in abandoned gem pits. This indicates the possibility of using our indigenous fish species in mosquito control programmes. Littoral and submergent vegetation in the pits is having a positive effect on mosquito larval survival. Plankton studies in the pits indicate the occurrence of predators of mosquito larvae such as copepods and some predatory aquatic insects. Use of insecticides for control of mosquitoes in gem pits may have adverse effects, since it causes the removal of predator populations of mosquitoes and thus may induce resurgence of mosquitoes after the loss of insecticide efficacy.

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