Studies on the bionomics of *Anopheles dirus* (Culicidae: Diptera) in Mudon, Mon State, Myanmar

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ABSTRACT: This study examined some environmental factors influencing the larval habitats of *Anopheles dirus* (breeding in wells) in Mudon, Myanmar, from May 1998 to March 2000. The larval/pupal density was found to be directly proportional to rainfall and indirectly proportional to the well water level. Shade, vegetation and debris on the surface of well water were important factors influencing the abundance of the aquatic stages of *An. dirus*. Salinity had an inverse correlation with the larval and pupal density. Other mosquito species associated with *An. dirus* were identified. Important predators of the mosquito larvae were larvivorous fish, damselfly and dragonfly nymphs. All wells examined were lined with lateritic rocks. Chemical analysis of water samples from wells was conducted. ***Journal of Vector Ecology* 27(1): 44-54. 2002.**

Keyword Index: *Anopheles dirus*, ecology, breeding behavior, wells.

INTRODUCTION

The species group of *Anopheles* (Cellia) is of major public health significance in the Southeast Asian and Indian subregions of the Orient (Reid 1968). At least 3 species are recognised as primary vectors of human malaria parasites. They are *An. balabacensis balabacensis* Baisas, 1936, from East Malaysia and several islands of the Philippines (Balbac, Palawan) and Indonesia (Java, Kalimantan), *An. dirus* (Peyton and Harrison, 1979), in all mainland of Southeast Asian countries and from Nepal to West Malaysia, Thailand, Myanmar, and Vietnam, and *An. leucosphyrus* Dönitz, 1901, from Indonesia (Sumatra, Kalimantan). *Anopheles dirus* is an important vector of malaria in Myanmar (Vector-Borne Disease Control, VBDC report. 1990, Paing et al. 1989). It normally occurs in the forest and forest fringes where it transmits malaria efficiently (Kyi 1970, 1975, Kyi and Winn, 1976). Changes in the ecology of an area induced by new development projects, like deforestation, construction of dams, and irrigation projects have profound or indirect effects on vector occurrence because of the creation of suitable ecotype for the completion of their life cycle. Thus, the dangerous vector *An. dirus* could invade human settlements. This typical forest breeder could successfully adapt and spread all over the Quarters of Mudon.

MATERIALS AND METHODS

Description of study area

Mudon, a coastal township in Mon State, covers an area of 23.96 square kilometres, which has stratified into four Quarters, bordering the Gulf of Martaban, which is part of the Andaman Sea (Figure 1). It is situated between longitudes 97° and 97° 53´ east, and the latitudes 16° and 16° 25´ north, bounded by Azin Dam and Azin Creek in the north. A central agricultural area (26.9 hectares) and rubber plantation (236.3 hectares) are located north of the Azin Creek. Kyonpike Creek marks the border in the south and Mawlamyine-Ye' railway track in the west. Pastures and paddy fields dominate the area between the railway track and the Andaman Sea. The Tanintharyi Yoma mountain range borders the eastern side of Mudon (Figure 2).

Condition of wells

The wells were of varying size, depth and shape, approximately 4.5-12 meters deep, either circular or square in shape. Most of the wells were dug under the shade of coconut palms, mango, banana, tamarind, horseradish (drum-stick), rubber and jackfruit trees. These wells were usually located within the compound and near houses. The soil was friable with porous soft lateritic rocks, dried fairly rapidly by percolation (high soil infiltration rate) and evaporation (Moe 1985). This

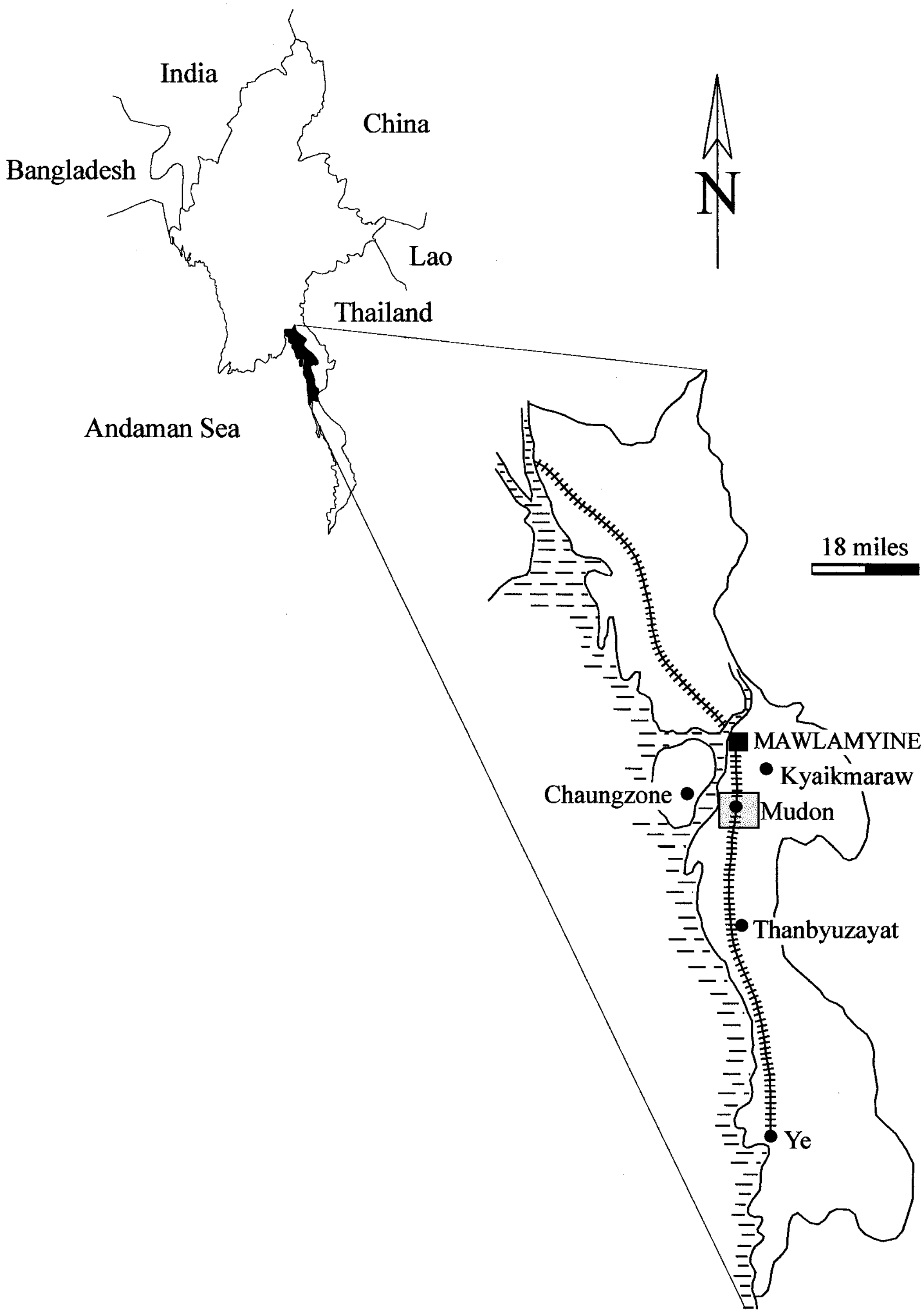


Figure 1. Location map of the study area (Mudon area), Myanmar.

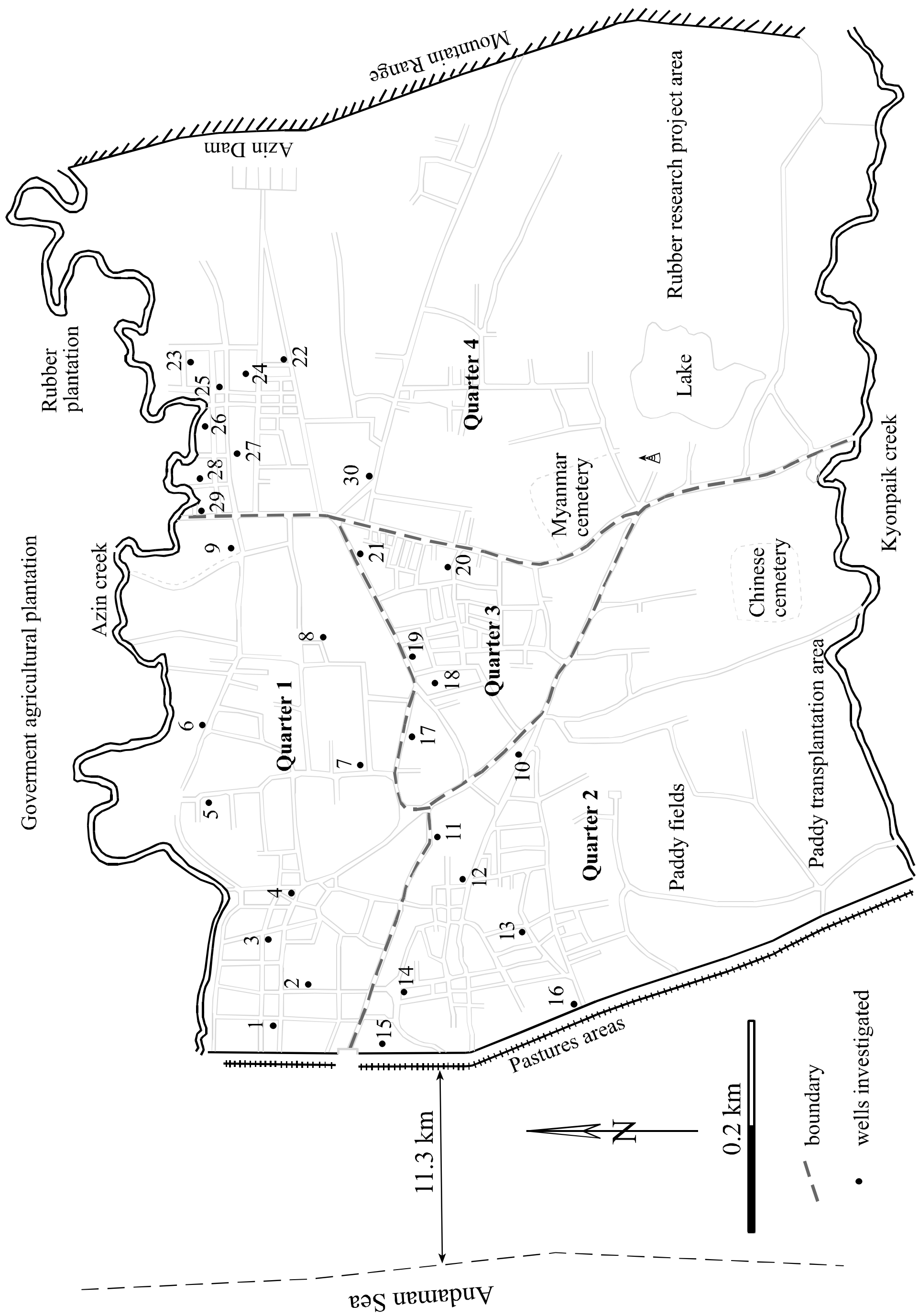


Fig. 2. Map of Mudon Town, Myanmar, showing study sites.

accounted for most of the wells drying up during summer.

The lateritic rock lining these wells was a residual clay enriched with ferrichydroxide as a result of chemical weathering in the tropics (Mineral Development Corporation, Mudon 1984). The mosquito breeding sites were considered as shaded when the well water surface had no direct contact with sunlight even during the afternoons. The coconut and tamarind trees provided most of the shade. The wells were considered to be overgrown with vegetation (grass and shrubs) when approximately 10% of the upper well wall was lined by vegetation. The surface of the well was considered "debris-loaden" if it covered 20% of the water surface.

Meteorological conditions

Data on precipitation and temperature were obtained from the Department of Meteorology and Hydrology, Mudon. In the study area, maximum rainfall was recorded during the southwest monsoon, peaking in August. The coastal areas received higher levels of rain than the interior upland. The maximum daily temperatures ranged between 27° and 30°C during the Southwest monsoon, and 31° and 32°C during the Northeast monsoon seasons.

Selection of 30 wells

Wells were selected randomly from all four Quarters. The criteria were as follows: (i) From each Quarter a lamp-post was chosen (each Quarter has between 14 to 18 lamp-posts and each lamp-post has between 65 to 300 households). (ii) From each chosen lamp-post, three shady sites were selected randomly. (iii) from each shady site, within a radius of 135 meters, 2-3 wells were chosen that were not in direct contact with sunlight during the afternoon. A total of 30 wells were selected, nine of which were in Quarter 1, seven in Quarter 2, five in Quarter 3 and nine in Quarter 4.

Larval surveys

Larvae were sampled at mosquito breeding sites on a weekly basis and appropriate data were recorded. Larval sampling was carried out using a well net. The net consisted of a conical shaped, white cloth dipper with a diameter of 35 cm and length of 46 cm. It was held at an angle by four strings and controlled by a long string

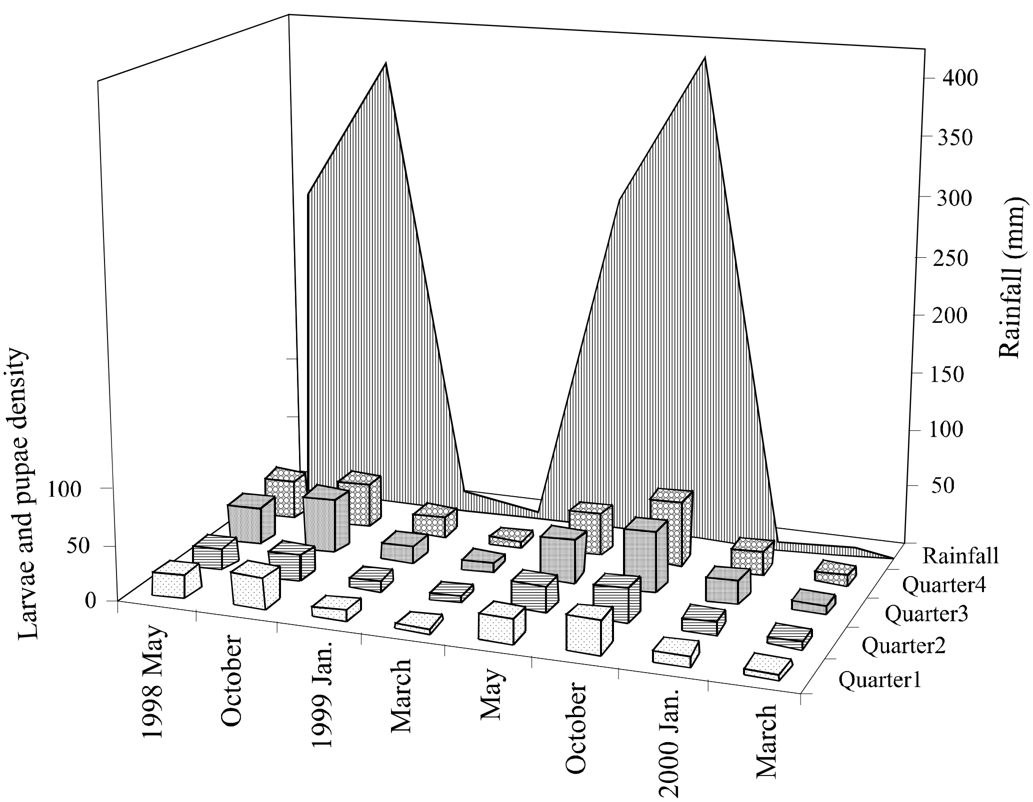


Figure 3. Correlation with rainfall and average number of *An dirus* larvae and pupae/dip/well in Quarters 1, 2, 3, and 4 during the study period.

Table 1. Percentage distribution of wells positive for *An. dirus* breeding in Mudon.

Period	Percentage of wells positive for *An. dirus* breeding in Quarters				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
1998					
May	55.5 (5/9)*	28.5 (2/7)	60.0 (3/5)	77.7 (7/9)	56.6 (17/30)
October	66.6 (6/9)	28.5 (2/7)	80.0 (4/5)	88.8 (8/9)	66.6 (20/30)
1999					
January	33.3 (3/9)	14.2 (1/7)	80.0 (4/5)	77.7 (7/9)	50.0 (15/30)
March	22.2 (2/9)	14.2 (1/7)	60.0 (3/5)	66.6 (6/9)	40.0 (12/30)
May	44.4 (4/9)	28.5 (2/7)	80.0 (4/5)	88.8 (8/9)	60.0 (18/30)
October	55.5 (5/9)	28.5 (2/7)	80.0 (4/5)	88.8 (8/9)	63.3 (19/30)
2000					
January	44.4 (4/9)	28.5 (2/7)	80.0 (4/5)	66.6 (6/9)	53.3 (16/30)
March	44.4 (4/9)	14.2 (1/7)	40.0 (2/5)	66.6 (6/9)	43.3 (13/30)

N.B. *(x/y) = x, positive wells and y, investigated wells

Table 2. Correlation with rainfall and average number of *An. dirus* larvae-pupae/dip/well in Quarters 1,2,3 and 4.

Period	Average number of larvae-pupae/dip/well				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Rainfall (mm)
1998					
May	20.7	20.1	34.1	35.2	288.46
October	28.9	22.5	50.0	39.2	415.12
1999					
January	9.3	8.9	15.5	18.2	12.82
March	2.5	4.5	8.0	3.5	0.00
May	21.7	23.4	38.2	38.0	303.84
October	29.9	29.8	55.7	58.4	436.41
2000					
January	10.0	11.2	21.3	22.1	0.51
March	3.5	3.1	7.5	8.9	2.56

Table 3. Mosquito species associated with *An. dirus* in investigated wells, during the rainy season, July 1999.

Site	Total number of larvae collected	*An. dirus*	Co-breeder Species	Co-breeder Number
Quarter 4	302	272	*Culex malayi*	25
			An. vagus	1
			An. maculates	3
			An. barbirostris	1
Quarter 3	255	237	*Culex malayi*	18
Quarter 2	5	5	0	0
Quarter 1	15	15	0	0

Table 4. Chemical analysis of well-water samples in January 1999 (cold-dry season).

Well no.	M.D of L/dip	Iron	Sulphate	Nacl (ppm)	Chlorine (ppm)	Nitrates (ppm)	Dissolved O_2	Ammonia	pH	Hardness
C1-1	17.7	0.07	2	150	0.05	0.5	0.72	0.054	7.0	17.16
C1-2	21.5	0.08	1	100	0.05	0.5	0.66	0.065	7.0	17.16
C1-3	17.0	0.08	1	150	0.05	0.9	0.85	0.070	7.0	17.16
C1-4	18.5	0.08	1	100	0.06	0.5	0.76	0.050	7.0	17.16
C1-5	19.5	0.08	1	100	0.05	0.5	0.90	0.070	7.0	17.16
C2-1	0.9	0.07	2	200	0.06	1.0	0.80	0.050	7.0	17.16
C2-2	0.0	0.07	2	250	0.06	0.7	0.65	0.070	7.0	17.16
C2-3	0.0	0.08	2	250	0.05	0.7	0.70	0.050	7.0	17.16
C2-4	1.3	0.08	1	150	0.05	0.6	0.64	0.070	7.0	17.16
C2-5	2.0	0.08	2	150	0.05	0.5	0.70	0.055	7.0	17.16

M.D. of L/dip = Mean Density of Larvae-pupae/dip
C1-1 to C1-5 = wells which had a mean density of more than 10 larvae-pupae/dip
C2-1 to C2-5 = wells which had a mean density of less than 10 larvae-pupae/dip

Table 5. Chemical analysis of well-water samples in March 1999 (dry season).

Well no.	M.D of L/dip	Iron	Sulphate	Nacl (ppm)	Chlorine (ppm)	Nitrates (ppm)	Dissolved O_2	Ammonia	pH	Hardness
C1-11	0.5	0.07	2	150	0.05	0.5	0.65	0.050	7.0	17.16
C1-2	13.5	0.08	1	100	0.05	0.5	0.65	0.065	7.0	17.16
C1-3	10.1	0.08	1	150	0.05	0.6	0.80	0.070	7.0	17.16
C1-4	10.5	0.08	1	100	0.06	0.5	0.75	0.065	7.0	17.16
C1-5	12.2	0.08	1	100	0.05	0.5	0.85	0.070	7.0	17.16
C2-1	0.0	0.07	2	250	0.06	0.6	0.80	0.050	7.0	17.16
C2-2	0.0	0.07	2	250	0.06	0.5	0.75	0.070	7.0	17.16
C2-3	0.0	0.08	2	250	0.05	0.6	0.75	0.050	7.0	17.16
C2-4	1.0	0.08	1	150	0.05	0.6	0.65	0.070	7.0	17.16
C2-5	2.1	0.08	1	150	0.05	0.5	0.70	0.055	7.0	17.16

M.D. of L/dip = Mean Density of Larvae-pupae/dip.
C1-1 to C1-5 = wells which had a mean density of more than 10 larvae-pupae/dip.
C2-1 to C2-5 = wells which had a mean density of less than 10 larvae-pupae/dip.

Table 6. Chemical analysis of well-water samples in October 1999 (rainy season).

Well no.	M.D of L/dip	Iron	Sulphate	Nacl (ppm)	Chlorine (ppm)	Nitrates (ppm)	Dissolved O2	Ammonia	pH	Hardness
C1-1	37.0	0.07	2	100	0.05	0.5	0.70	0.055	7.0	17.16
C1-2	50.8	0.08	1	100	0.05	0.5	0.70	0.065	7.0	17.16
C1-3	34.0	0.08	1	100	0.05	0.7	0.80	0.070	7.0	17.16
C1-4	35.2	0.08	1	100	0.05	0.5	0.70	0.065	7.0	17.16
C1-5	40.8	0.08	1	100	0.05	0.5	0.80	0.070	7.0	17.16
C2-1	9.0	0.07	2	150	0.06	0.6	0.80	0.050	7.0	17.16
C2-2	0.0	0.07	2	250	0.06	0.7	0.65	0.070	7.0	17.16
C2-3	4.1	0.08	2	200	0.05	0.7	0.65	0.050	7.0	17.16
C2-4	7.0	0.08	2	150	0.05	0.5	0.70	0.055	7.0	17.16
C2-5	1.8	0.07	2	150	0.05	0.5	0.70	0.055	7.0	17.16

M.D. of L/dip = Mean Density of Larvae-pupae/dip.
C1-1 to C1-5 = wells which had a mean density of more than 10 larvae-pupae/dip.
C2-1 to C2-5 = wells which had a mean density of less than 10 larvae-pupae/dip.

or rope. The net was introduced into the well with the lower side of the net just under the surface of the water and its opening at an angle of about 45°. The net was moved slowly around the side of the well twice, then quickly withdrawn and inverted into a bowl of water. The larvae and pupae were collected in vials for species identification. Ten dips per well, per week were taken and the mean number of larvae and pupae per dip were determined.

Assessment of environmental and biological factors

We recorded the following data: (a) the water level of the well was taken as the distance between the well-water surface and the surface ground level. (b) degree of shade. (c) Grass, herbs and shrubs on the inner walls of the wells and debris on the well water surface. (d) Predators: Larvivorous fish and other predators such as dragonfly naiads. (e) Presence of cattle and other animals as blood meals for adult mosquitoes. (f) Water chemistry: pH, nitrate, iron, dissolved oxygen, sodium chloride (NaCl), sulphate, chlorine, ammonia content and water hardness were determined from water of 10 randomly selected wells out of a total of 30 investigated wells (5 wells which had a mean density of more than 10 and 5 wells which had a mean density of less than 10 larvae-pupae/dip).

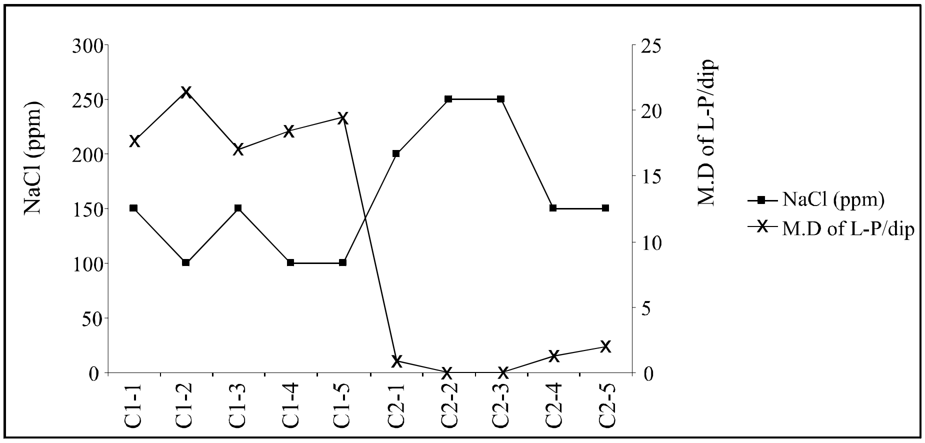
RESULTS

Table 1 shows the percentage distribution of wells that were positive for *An. dirus* breeding, during the pre-monsoon (May), post-monsoon (October), cool-dry month (January) and hot-dry month (March) for two years. The highest numbers of *An. dirus* larvae and pupae were found during pre-monsoon and post-monsoon, whereas the lowest numbers were recorded during cool-dry and hot-dry months. Because the average number of *An. dirus* larvae and pupae per dip per well showed a definite increase in pre-monsoon and post-monsoon time periods, a strong correlation with rainfall could be demonstrated (Table 2 and Figure 3).

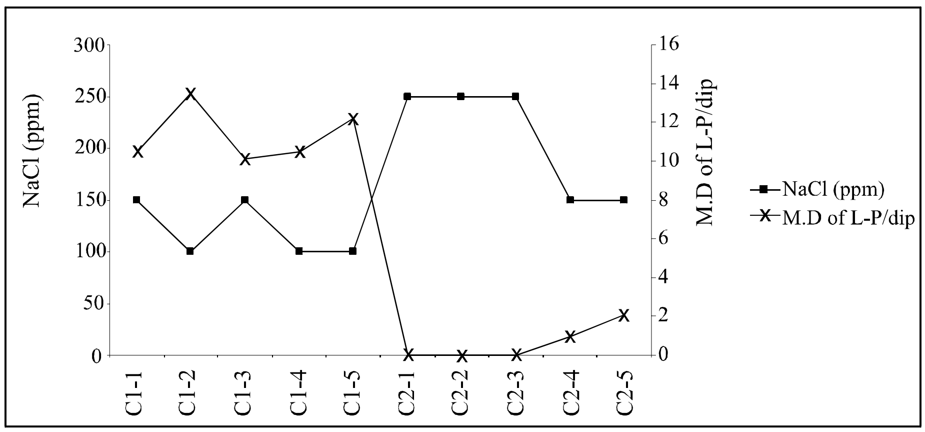
In addition to *An. dirus*, other mosquitoes included *An. vagus*, *An. maculatus* and *An. barbirostris* and *Culex malayi*. *Cx. malayi* accounted for about 80%of the co-breeders, and the other species were found in smaller numbers (Table 3).

Almost all wells harbored at least one or more predators. The most common predators were Notonectidae (backswimmer), Agrionidae (damselfly larvae), Nepidae (water scorpion) and *Orthetrum sabina* (dragonfly). Carnivorous fish, *Ophicephalus sp.*, catfish, and *Panchax* (a local species), were also found in some wells.

A. January 1999 (cold-dry season)



B. March 1999 (dry season)



C. October 1999 (rainy season)

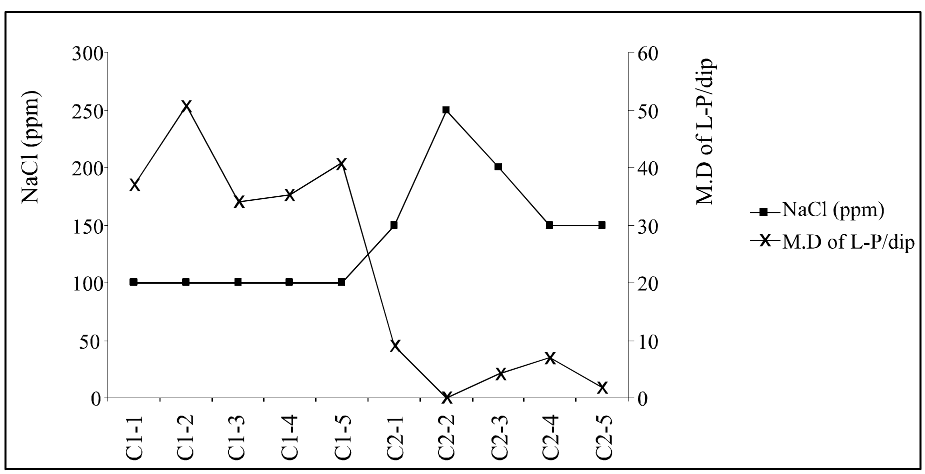


Fig. 4. Correlation with mean density of *An. dirus* larvae and pupae per dip (M.D of L-P/dip) and NaCl concentration. C1-1 to C1-5=wells which had a mean density of more than 10 lavae and pupae/dip, C2-1 to C2-5=wells which had a mean density of less than 10 lavae and pupae/dip.

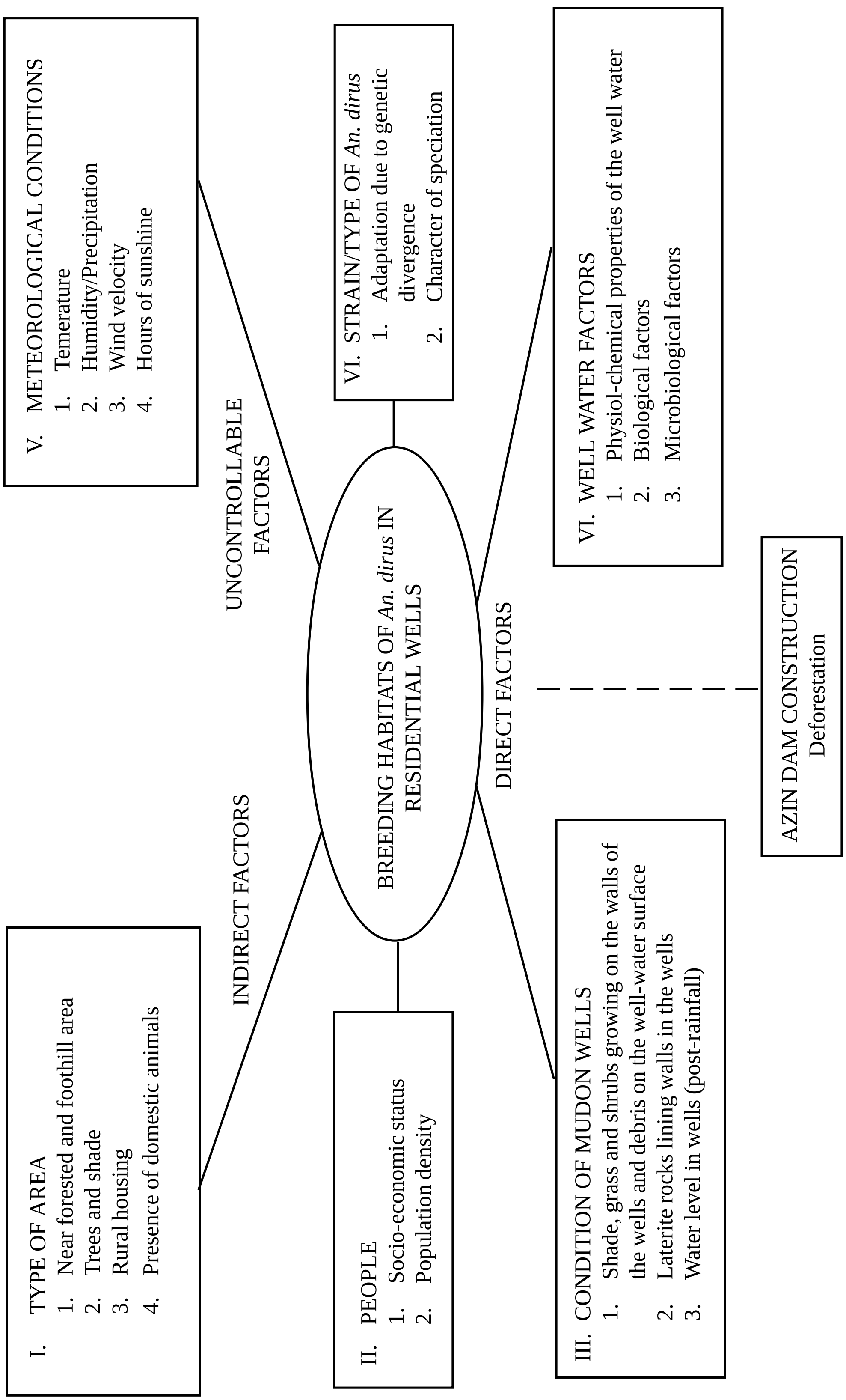


Figure 5. Factors influencing or associated with *An. dirus* breeding in Mudon wells, Myanmar.

All the wells inhabited by the immature stages of *An. dirus* were partially or totally shaded and contained debris and vegetation. None were exposed to direct sunlight. The majority of wells (66%) were situated in compounds, which had either cattle/fowl, dogs or cats. The results of the chemical analysis of the 10 randomly selected wells indicated that there was an inverse correlation between sodium chloride and the mean density of *An. dirus* larvae. It appeared that the other recorded parameters did not influence the breeding of this species (Tables 4,5,6 and Figure 4).

DISCUSSION

In Mudon, *An. dirus* larvae were found in large numbers within domestic wells. These wells provided water for drinking, washing, bathing and cooking. During the rainy season, the larval and pupal density of *An.dirus* was usually high, whereas during the cool-dry season, their numbers were reduced. In the wells of Quarters 3 and 4, the number of larvae and pupae was significantly higher than in those of Quarters 1 and 2. The reason may be the distance of the Quarters from the natural habitat of *An. dirus*. Quarters 3 and 4 are only 2 to 3 km away from the foothills (natural habitat) of the mountain range, whereas Quarters 1 and 2 are further away. The spilling-over of *An. dirus* from the forest fringes and adaptation to the well-breeding condition in Quarters 3 and 4 are a possibility. During the rainy season, the spreading of *An. dirus* adults from Quarters 3 and 4 to Quarters 1 and 2 is likely when the flight range, 1.5 km (Rosenberg 1982) is taken into consideration. During the cool-dry season, this species remains mainly in Quarters 3 and 4 due to favourable conditions for breeding, low numbers of predators and low salinity. The absence or very low density of *An. dirus* larvae/pupae in the wells of quarters 1 and 2 may be due to the lower water level, higher salinity and presence of more predators compared to the wells in Quarters 3 and 4.

The water level is influenced by rainfall and shade. The heavier the rainfall, the higher the water level. The wells under tree canopy usually contain more water and provide better conditions for larval breeding. However, if the water level is very high near the ground level, the exposure to direct sunlight reduces the density of the immature stages of *An. dirus.* This may also be one of the factors influencing the low density or absence of *An. dirus* breeding in Quarter 2, where the water level is usually very high. The wells start overflowing when the rainfall is greater than 1794 mm.

The salinity of well water may also play a role in influencing the breeding of *An. dirus* in these wells. The results obtained from the chemical analysis of 10 randomly selected wells from quarters 1, 2, 3 and 4 indicated that there was an inverse correlation between sodium chloride concentration (ppm) and the mean density of *An. dirus* larvae and pupae. This may also be one of the factors limiting the number of *An. dirus* larvae and pupae in quarter 2, which is nearer to the sea.

It appears that the availability of food (debris) has a marked influence on larval survival and development. In this study, the wells with moderate to high amounts of debris (organic food) harbored the highest number of larvae. The rock-lined walls of the wells may offer a sustained cooling effect which, together with shade, debris (organic food) on the water surface and other factors, creates an ideal micro-environment for the breeding of *An.dirus.*

Finally, Figure 5 shows all possible factors influencing or associated with the well-breeding of *An. dirus* in Mudon. This is a good example of the adaptation of a mosquito species to favourable breeding sources in human settlements. *An. dirus* is well known for breeding in shaded habitats in forested areas. Due to deforestation resulting in shortage of *An. dirus,* residential wells appear to have provided new breeding resources. The wells are usually shaded, densely vegetated and relatively cool due to the underground water supply and are therefore, similar to the natural breeding places. This close contact of one of the major malaria vector with humans could be one of the reasons for the increasing number of malaria cases in this region.

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