Bulletin of the World Health Organization, **58** (5): 791-798 (1980)

Importance of the aquatic weed *Ceratophyllum* to transmission of *Schistosoma haematobium* in the Volta Lake, Ghana*

R. K. KLUMPP[1] & K. Y. CHU[2]

Results of 5 years of sampling for Bulinus rohlfsi *in human-water contact sites of villages along the Volta Lake, Ghana, have confirmed that the aquatic macrophyte,* Ceratophyllum, *is the most important ecological factor for sustaining high levels of cercarial transmission of* Schistosoma haematobium. *Data available so far indicate that growth of this weed largely determines the size of the snail populations. Increasing density of* Ceratophyllum *correlates with increasing levels of cercarial transmission potential in the water contact sites and of* S. haematobium *infection in the village populations.*

Soon after the filling of the man-made Volta Lake in 1966, *Schistosoma haematobium* spread rapidly throughout most branches of the lake and soon became a public health problem. Early research into the epidemiology and transmission of the disease by Paperna (*1*) and also by C. R. Jones and M. A. Odei (unpublished data), revealed that infection rates in humans and the vector snail, *Bulinus rohlfsi*, were highest in areas where the submerged weed *Ceratophyllum demersum* was present in considerable density. Later malacological work by Paperna (*2*) showed that the weed was the most important plant for promoting large populations of vector snails. Odei (*3*) mapped the *Ceratophyllum* distribution throughout the Volta Lake and concluded that the weed was almost an indicator plant for the presence of *B. rohlfsi*. Odei (*4*) also established that this snail was the only intermediate host for the infection in the lake.

Working in a UNDP/WHO Schistosomiasis Research and Control Project in the Pawmpawm and Afram branches of the Volta Lake, Klumpp & Chu (*5*) found that, when sampling was conducted by palm-leaf traps (palm mats) and dip-nets, over 68% and 83%, respectively, of all *B. rohlfsi* collected came from *Ceratophyllum*. Other aquatic plants were of malacological importance each year only during the period from November to March when the lake was receding from its annual peak.

Analysis of data collected in the Project suggests a high degree of positive correlation between the degree of *Ceratophyllum* growth in lakeside village water contact sites, positivity of these sites, and levels of infection in humans living in the same villages.

MATERIALS AND METHODS

Collection of snails and calculation of Ceratophyllum *density*

Monthly pre- and post-intervention snail sampling and ecological surveys were conducted and maintained in the main human-water contact sites (WCSs) of 16 study unit villages in the project area (Fig. 1). These surveys began in March 1973 in 8 villages. Snails were collected in WCSs using standardized palm-leaf mats (*6*). The number of WCSs sampled in each village ranged from 3 to 6. In January 1974, another 8 villages were added to give wider coverage to the northwestern sector of the project area where prevalence and intensity of *S. haematobium* infection in humans were highest. In each of the latter villages, snails were collected by 4 men using dip-nets in the two most heavily used WCSs. In both groups of villages, these pre-intervention surveys continued until May 1975 when the control of cercarial transmission by focal molluscicidng began in WCSs of all 26 study unit villages. Control by chemotherapy began in October 1975, and water supplies were made available to 7 of the villages at about the same time, by drilling bore-wells.

For each WCS surveyed, sketch maps were made showing the surface area, shape, location, vegetation distribution, and other ecological information. When snails were collected, a record was made of the sampling area within the WCS in which they were

---

* From the WHO Schistosomiasis Control Project, P.O. Box M.190, Accra, Ghana.

[1] Scientist.

[2] Senior Biologist.

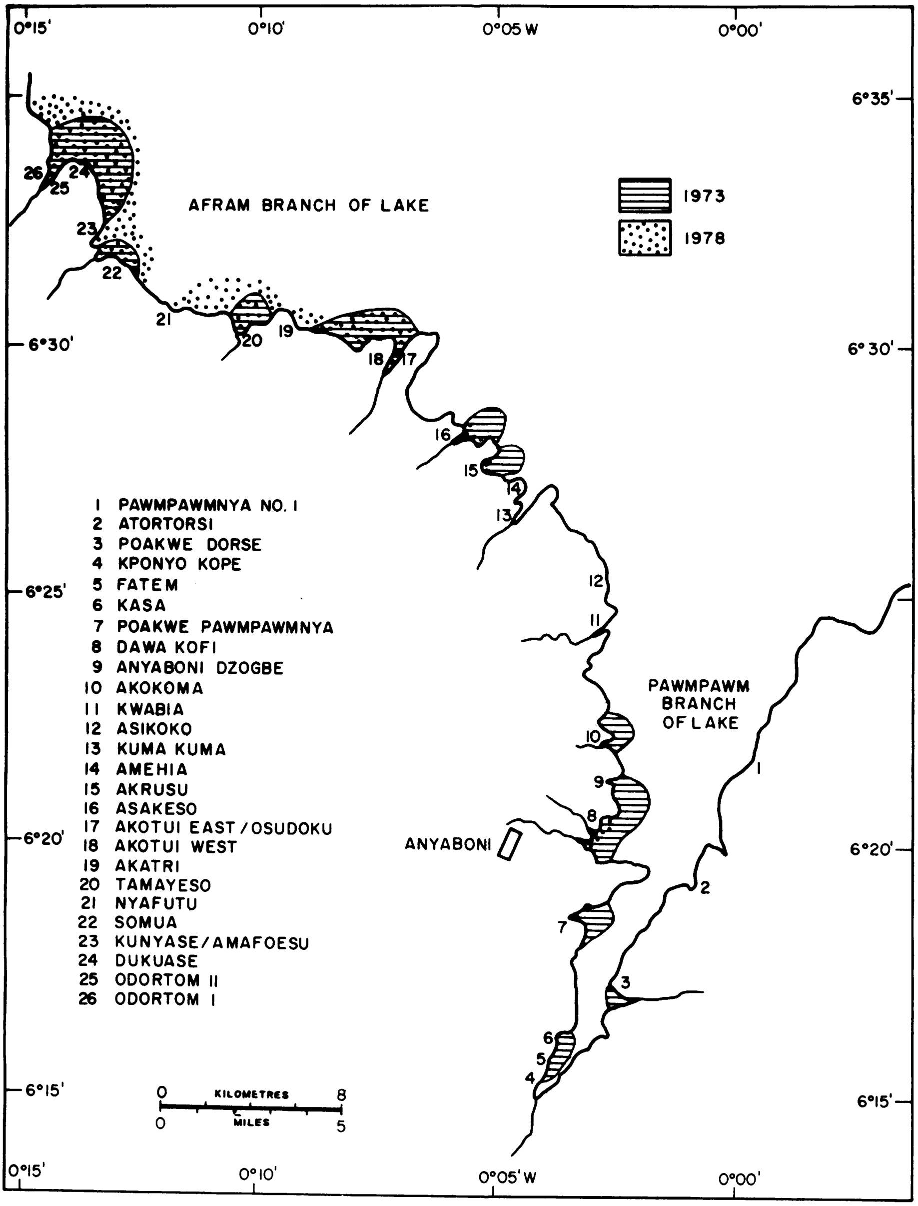

Fig. 1. Project area showing changes in *Ceratophyllum* distribution in the littoral zone between 1973 and 1978.

found and also of the vegetation from which they were collected. The snails were then taken to the field laboratory, crushed between glass slides, and examined for evidence of both mature and immature *S. haematobium* cercariae. Details of this work have been presented elsewhere (*5*).

It was not practical to make measurements of the *Ceratophyllum* biomass when the snail sampling surveys took place; however, the maps of the WCSs were accurate enough to allow for a simple quantitative assessment of the weed density in each. We have ranked this density as follows: no *Ceratophyllum* = 0; little = 1; medium = 2; heavy = 3. Each year from April to August (the open beach season), *Ceratophyllum* was usually the only weed present in the littoral zone of the lake. Thus, it was easy to determine its density rank by simple inspection of our maps. During the high-water period from September to November each year, *Ceratophyllum* density was more difficult to assess. This was because the main growth of the weed was offshore and within the WCSs the weed, when present, usually existed as numerous floating fragments or stationary clumps. But the density rank could be accurately ascertained by inspection of the maps, forms showing snail catches according to the type of vegetation, and information indicating whether the weed was growing offshore. The overall mean density of the weed in each village was calculated by adding up the monthly ranks of the weed for each WCS sampled and then dividing this sum by the total number of WCSs.

Use of epidemiological data

Epidemiological data on human prevalence rates and geometric means of *S. haematobium* eggs per 5 ml of filtered urine were taken from project records. For comparing *Ceratophyllum* density and the snail findings with the above data, we used the human data from Survey 4—the last of two full pre-intervention surveys, which ended in late 1974. The epidemiological index is defined here as the product of prevalence (%) and the geometric mean of egg density in positive cases for all age groups of people examined per village.

RESULTS

Changes in Ceratophyllum *growth*

Fig. 1 shows the geographical distribution of *Ceratophyllum* in the project area in 1973 and 1978. For the purpose of illustration, the growth limits from shore to deep water are shown about 10 times the actual limits. The limits between the villages are drawn to scale.

Initially, the weed was widely distributed. But after 1973, *Ceratophyllum* began dying off in and around most lakeside villages in the Pawmpawm branch (comprising study units (s.u.) 1–14). It first disappeared from Fatem (s.u. 5) and Kasa (s.u. 6) in 1975 and from Kuma Kuma (s.u. 13) in 1976. It grew in dense masses at Poakwe Pawmpawmnya (s.u. 7) in 1973 but could be found there only as scattered fragments in 1977. During the latter period, the weed also began dying off at Dawa Kofi (s.u. 8) and Akokoma (s.u. 10). In the Afram branch villages (comprising s.u. 15–26), *Ceratophyllum* started to disappear from Akrusu (s.u. 15) and Asakeso (s.u. 16) in late 1976, but remained in medium to heavy densities in all other villages except Akatri (s.u. 19). It increased in distribution and density at Tamayeso (s.u. 20) and Nyafutu (s.u. 21), becoming very thick in both places after 1975. By early 1978, *Ceratophyllum* was first noted growing in Akatri, where it appeared in light density.

The relationship between Ceratophyllum *density and snail density*

Yearly changes in *Ceratophyllum* density and numbers of *B. rohlfsi* collected in the 16 villages are presented in Table 1. This period covers 2 years of pre-intervention sampling, beginning in June 1973, and 3 years of post-intervention sampling. Since sampling in the second 8 villages did not begin until January 1974, data for the 1973–74 and 1974–75 periods were included only for the comparable months of January –May, respectively. This 5-month period represents most of the high-transmission season, when most snails and most infected snails were collected each year. In the post-intervention period of mollusciciding, all months were included.

The villages have been grouped according to similar patterns of *Ceratophyllum* growth and changes in density. Longitudinally, the results show a clear association between the total numbers of snails during the pre-intervention period and the degree of *Ceratophyllum* growth in the sampled WCSs. In the villages where the weed did not grow, total snail catches were extremely low despite abundant growth of rooted *Polygonum* and of numerous grasses in sampled sites each year from September to February or March. In the 4 villages where *Ceratophyllum* died off rapidly, the calculated density of the weed decreased by 43% after the first pre-intervention year, the numbers of *B. rohlfsi* collected dropped by almost 50%, and the number infected with mature *S. haematobium* cercariae fell by 75%. *Ceratophyllum* density remained light to moderate in Dawa Kofi, Akokoma, and Asakeso between the first and second year. In the same period, the total numbers and the numbers of infected *B. rohlfsi* also remained about the same.

Table 1. Yearly changes in the number of mature *Schistosoma haematobium* infections in *B. rohlfsi* per number of all *B. rohlfsi* collected and mean density rank of *Ceratophyllum* (in parentheses) according to the pattern of *Ceratophyllum* growth in 16 villages

Study units (villages) with different patterns of *Ceratophyllum* growth	Pre-intervention period		Post-intervention period		
	1973 –74	1974 –75	1975 –76	1976 –77	1977 –78
Pawmpawm branch of lake					
None 01, 02[a], 11, 12[a]	3/42 (0)	1/22 (0)	0/15[b] (0)	0/9[b] (0)	0/5[b] (0)
Rapid die-off 05, 06, 07, 13	60/1094 (0.75)	15/530 (0.43)	5/128[c] (0.14)	1/53 (0.04)	0/63[b] (0)
Gradual die-off 08[a], 10[a], 16	37/431 (1.45)	32/383 (1.54)	3/107 (0.43)	0/57 (0.39)	1/1 (0.05)
Afram branch of lake					
Light to heavy 20[a], 21[a]	6/61 (0.69)	5/122 (0.88)	3/160 (1.56)	0/307 (1.94)	1/409 (2.21)
Remaining heavy 18, 24[a], 25[a]	197/1378 (2.08)	139/1593 (2.12)	3/211[d] (1.67)	2/270[d] (2.03)	1/134[d] (2.56)

[a] Includes data only for the period January to May during 1973–74 and 1974–75.

[b] Molluscicidng not carried out.

[c] All 5 positive snails from one lesser-used WCS; molluscicidng not conducted in that site on a regular basis.

[d] Molluscicidng operations 3 times every 2 months.

There was a decrease in infected snails at Asakeso due mainly to the excessive flooding there during October and November 1974. This made cercarial transmission diffuse and light until 1975. At Tamayeso and Nyafutu, the weed began to increase in distribution and density between the first and second year, which led to increasing numbers of *B. rohlfsi*. At Akotui West, Dukuase, and Odortom II, the density of *Ceratophyllum* remained moderate to heavy; the total number of *B. rohlfsi* increased from 1378 to 1593 but the number infected dropped from 197 to 139. This reduction, like that at Asakeso, was attributed to the rapid lake flooding of the foreshore in 1974. The people using one main WCS sampled at Akotui West were forced to move from their compounds after the structures were inundated in October. Thereafter, they had no further contact with the WCS although sampling there was maintained until June 1975.

In the post-intervention period of monthly or more frequent focal molluscicidng, the numbers of infected snails were greatly reduced in all villages. The ever changing lake level kept shifting the WCSs horizontally along the drawdown area so that the sites were never quite the same in successive months. Even after successful molluscicidng in a WCS with heavy growth of *Ceratophyllum*, new snails would quickly enter the site in washed-in fragments of the weed from offshore. The more rapid the lake regression, the more rapid the snail invasion. Thus, snail control *per se* was impossible in such a habitat—transmission control was our goal (*8*).

Correlation between Ceratophyllum *density and cercarial transmission*

From earlier studies (*5*), it was learned that the best long-term indicator of cercarial transmission potential in a lakeside village was the percentage of WCSs found "positive" per total number of WCSs sampled. Since WCSs were well defined and generally less than 600 m^2 in area, our criterion for a WCS to be positive was if at least one *B. rohlfsi* infected with mature *S. haematobium* cercariae was collected from that site during each period of monthly snail sampling.

This percentage of WCS positivity was considered a more valid measure of comparing cercarial transmission potential between villages than either the total number of infected snails or the percentage of infected snails collected. There were two main reasons for this. Firstly, in some villages, especially Poakwe Pawmpawmnya, most of the infected snails collected came from just one or two WCSs used exclusively by a small fraction of the village population over a short period and therefore would not have been as accurate a measure of transmission potential for the entire village as finding fewer infected snails from more WCSs over a longer period. Secondly, the percentage of snails found infected in WCSs was generally independent of overall snail density; a village showing a high percentage of infected snails based on a low number of total snails did not necessarily have a higher transmission potential than a village where a low percentage of infected snails came from a much larger number of total snails.

Fig. 2 shows the result of plotting the total mean *Ceratophyllum* density rank of the sampled sites for each village in the pre-intervention period against the percentage of WCSs found to be positive. Until the *Ceratophyllum* density rank reached about 1.5 (medium density) the percentage of positive WCSs increased almost linearly, but beyond that the increase was very rapid. It was found that a third degree polynomial regression gave a good fit of the data for the full range of values.

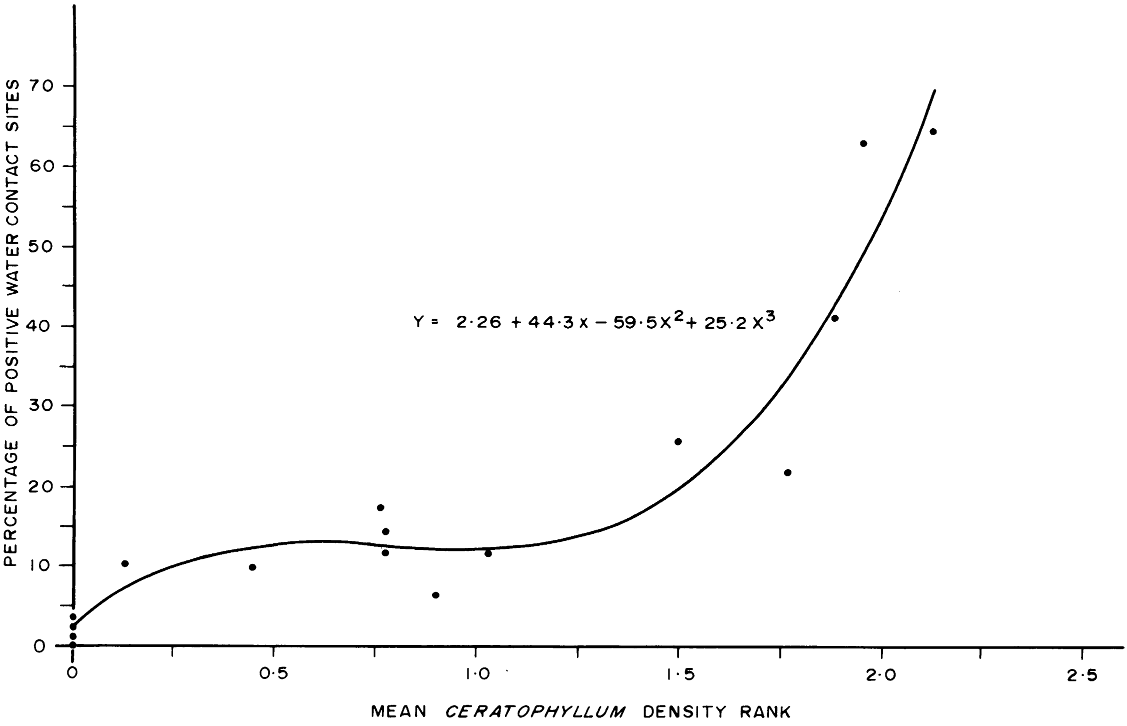

Fig. 2. Relationship between *Ceratophyllum* density and cercarial-infested water contact sites.

Fig. 2 can be described as follows. In the villages where *Ceratophyllum* was absent, very few WCSs were found to be positive since very few snails were ever found, regardless of season or other types of vegetation. In the villages where the weed grew in light density, the percentage of positive WCSs was higher but not entirely correlated with *Ceratophyllum* density. Almost all the infected snails were found each year between December and March in foci of pocket-shaped WCSs, usually bounded on the sides by solid *Polygonum* extending to water depths of 1 metre or more. In the centres of these protected WCSs, *Ceratophyllum* grew in patches or scattered fragments. Few positive WCSs were detected in these latter villages each year between April and July in the low-water period after the water receded beyond the limits of the emergent plant growth and WCSs became open beaches along sandy or muddy shores. *Ceratophyllum* patches or fragments were soon washed ashore by increased wave action, and hence, populations of *B. rohlfsi* greatly contracted in the exposed habitat. But in the villages with moderate to heavy *Ceratophyllum*, the weed survived well in and around WCSs during the entire open beach season. Heavy growth of the weed restricted human water contact to well defined points near shore, lessened wave action, and sustained relatively large populations of the snail. In this type of habitat, the probability of finding at least one infected *B. rohlfsi* was high every month.

However, when *Ceratophyllum* density became so heavy that the weed grew in a solid mass along the shore from shallow water to depths exceeding 5 metres, cercarial transmission would become interrupted. This was observed in the Project Comparison Area further north-west in the Afram branch (Klumpp & Chu, unpublished data). There, extremely heavy growth of the weed caused the water to become stagnant and often foul, and the weed itself died off temporarily during the hot months of February–May. In these conditions, which were unusual for the lake as a whole, snail populations quickly contracted, and people using the lake kept changing their sites of water contact along the shoreline to the least polluted points.

Table 2. Correlations between *Ceratophyllum* density, cercarial-infested water contact sites, and infected people in 16 villages during the pre-intervention period

Villages (study units) with different patterns of *Ceratophyllum* growth	Mean weed density rank per sampled WCS	Percentage of sampled WCSs found positive	Survey 4 (1974) Prevalence (%)	Geometric mean egg output (per 5 ml of urine)	Epidemiological index[a]
Pawmpawm branch of lake			(1)	(2)	(3)
None					
(01) Pawm. No. 1	0	1.2	33.3	17.4	5.8
(12) Asikoko	0	0	36.6	15.5	5.7
(11) Kwabia	0	2.5	71.9	33.3	23.9
(02) Atortorsi	0	3.3	77.6	41.9	32.5
Rapid die-off					
(13) Kuma Kuma	0.13	10.4	72.2	32.3	23.3
(05) Fatem	0.45	9.9	70.6	45.2	31.9
(06) Kasa	0.76	17.3	74.3	37.2	27.6
(07) P. Pawmpawmnya	0.90	6.5	68.3	36.6	25.0
Gradual die-off					
(10) Akokoma	0.78	11.8	68.1	31.6	21.5
(08) Dawa Kofi	1.50	25.8	84.6	44.9	38.0
(16) Asakeso	1.77	21.7	71.4	31.6	22.6
Afram branch of lake					
Light to heavy					
(21) Nyafutu	0.78	14.7	88.1	53.5	47.1
(20) Tamayeso	1.03	11.8	87.5	77.6	67.9
Remaining heavy					
(24) Dukuase	1.88	41.2	89.6	61.1	54.7
(18) Akotui West	1.95	63.0	77.7	63.9	49.6
(25) Odortom II	2.12	64.7	95.2	75.9	72.2
Correlation coefficients (r)					
Ceratophyllum density		0.874[b]	0.622[d]	0.668[c]	0.679[c]
Percentage of positive WCSs			0.570[d]	0.694[c]	0.697[c]

[a] Epidemiological index (3) = (1) x (2)/100.

[b] $P < 0.001$

[c] $P < 0.01$

[d] $P < 0.05$

Correlation between Ceratophyllum *density, cercarial transmission, and human infection*

These positive correlations are presented in Table 2. Similar degrees of correlation resulted when both the pre-intervention *Ceratophyllum* densities and the percentages of positive WCSs were compared with human prevalence rates, geometric means of egg density, and their products, the epidemiological indices, in the 16 villages. Despite expected discrepancies between the results of snail sampling in an unstable environment compared with more stable endemic levels of *S. haematobium* infection, the figures indicate that the baseline snail sampling results correlate closely with differing levels of endemicities in all but 4 villages: Atortorsi, Asakeso, Tamayeso, and Nyafutu. In each of the first 2 villages, less than 50 people were examined in Survey 4,[a] the lowest number among all project area villages. In the last 2 villages, low percentages of positive WCSs contrasted with high prevalence rates. Since snail searches were always fairly exhaustive (1 man-hour per WCS per visit), it seems clear that in Tamayeso and Nyafutu the epidemiological indices were already very high before snail sampling started, and the period of snail sampling coincided with reduced *Ceratophyllum* growth in the WCSs when snail populations were low.

Theoretically, it would have been preferable to compare the snail data and *Ceratophyllum* densities with human incidence rates in the villages. However, this was not possible. Initial pre-control prevalence rates were so high in most villages, especially in the Afram branch, that very few children were negative

---

[a] The last of the two full pre-intervention surveys, which ended in late 1974.

for *S. haematobium* infection. In the largest villages and lower transmission villages, crude incidence data are available from consecutive prevalence surveys, but these data are difficult to analyse because of the possibility of false positives and false negatives as well as the high degree of migration by the people, both within and outside the project area.

DISCUSSION

It is now confirmed that the presence of *Ceratophyllum* is the main ecological factor determining the duration of cercarial transmission each year in the Volta Lake. The weed is now confined mainly to the southern sectors of the lake and is most dense in the large Afram branch. *Ceratophyllum* grows best in deep stream inlets of the lake receiving seasonal discharge from nearby escarpments or hills. This discharge probably supplies the nutrients required by the weed; the narrow inlets offer protection against wind and wave action. The weed cannot maintain growth in exposed areas of the lake where the slope of the foreshore is minimal. Perhaps that is why *Ceratophyllum* has never become established in the flat savanna branches of the lake, or exposed sections in the project area.

Many distinct and synergistic factors most likely affect *Ceratophyllum* distribution and density in the lake. We lacked sensitive water-quality testing equipment and were unable to measure nutrient levels or other important water-quality parameters with our field kits. Thus, the reasons for the rapid disappearance of *Ceratophyllum* in the Pawmpawm branch of the project area are still unknown. This die-off was preceded by a die-back of *Pistia*, also a floating plant, in the southern tip after 1971. Before that, it extended in a solid mat almost up to Kponyo Kope (s.u. 4). Hall & Okali (7) studied the *Pistia* decline and attributed it mainly to declining levels of dissolved phosphate and nitrate around the mouth of the Pawmpawm River. The continuing drought of 1976 and 1977 further curtailed stream and river discharge into the Pawmpawm branch, and this has probably caused a concomitant decrease in nutrient levels in the entire southern section of the branch. However, we noticed that *Ceratophyllum* reductions at Fatem, Kasa, and Poakwe Pawmpawmnya began when the lake was still high and the Pawmpawm River flowing. The die-off may be only temporary, and a few continuous years of above-average stream and river discharge into the branch might lead to a resurgence of the weed.

The reasons for the increase of *Ceratophyllum* around Tamayeso, Nyafutu, and more recently Akatri, are also unclear. Wide belts of the weed were already present in the deep water in the Tamayeso stream inlet during 1974 and 1975 when the lake level was at its highest ever peak. The subsequent fall in the level of the lake during 1976 and 1977 just shifted the shoreline into this wide stationary mass. But no such off-shore weed mass was observed at Nyafutu or Akatri during 1974 or 1975. The weed first became a problem at Nyafutu in 1976 and was first seen in medium density at Akatri in January 1978.

Since *Ceratophyllum* is such a dangerous weed for promoting schistosomiasis in the Volta Lake, its removal from populated areas should be a very effective way of reducing or even controlling transmission. From our experience, this is possible and practical only in areas where it grows in light density. In areas where it grows in medium to heavy density, its removal is extremely difficult, even with the full participation of the villagers. The wide distribution and heavy weight of water-logged *Ceratophyllum* makes removal by hand or with rakes a very difficult, time-consuming, and expensive operation. Incomplete removal of the weed could actually increase transmission by creating larger areas in which children could swim and play, with *B. rohlfsi* surviving in the remaining patches and bottom growths. Moreover, because *Ceratophyllum* often extends as a solid mass from shore to deep water, its removal would have to be maintained fortnightly in WCSs during lake drawdown because of the receding water. As a result of this constant fluctuation, control by herbicides has also proved ineffective (Klumpp, Rafatjah, & Chu, unpublished report). Mechanical removal would be impractical, owing to the numerous submerged and projecting tree stumps all over the lake shallows.

For the meantime, the only effective way to control *S. haematobium* transmission in lakeside villages with fairly heavy *Ceratophyllum* growth is by focal molluscicidin g with the 2-aminoethanol salt of niclosamide (Bayluscide) carried out 3 times every 2 months during most of the year, combined with a selective programme of population chemotherapy using metrifonate.

ACKNOWLEDGEMENTS

We are grateful to Dr E. G. Beausoleil, Director of Medical Services, Ghana Ministry of Health, for his active support of our work and for permission to publish this paper. We also thank Professor G. Webbe, consultant to the Project, for his encouragement of our research, Dr D. Scott, Project Manager, and Dr A. Davis, WHO, Geneva, for their administrative support, Dr K. Senker, Project Epidemiologist, for permission to use the epidemiological data, Mr H. Dixon, WHO, Geneva, for fitting the polynomial regression, Mr D. Y. Kofi, Mr M. M. Agbodo, and Mr P. K. Aparku for their competent technical assistance, and Mr Israel Fiamanya for drawing the figures.

RÉSUMÉ

RÔLE DE LA PLANTE AQUATIQUE *CERATOPHYLLUM* DANS LA TRANSMISSION DE *SCHISTOSOMA HAEMATOBIUM* SUR LES RIVES DU LAC VOLTA (GHANA)

Une série d'enquêtes par sondage ont été faites de 1973 à 1978 en vue de déterminer la densité des populations de *Bulinus rohlfsi* aux points de contact avec l'eau (WCS) les plus fréquentés dans 16 villages situés sur les rives du Lac Volta au Ghana. Les deux premières années d'enquête ont été consacrées à la collecte de données de base. En mai 1975 a débuté une série d'interventions visant à réduire la transmission de *Schistosoma haematobium* dans les 26 villages de la zone du projet, notamment par l'application focale de molluscicides. Des campagnes chimiothérapiques destinées à des groupes particuliers de population ont en outre été menées dans tous les villages dès octobre 1975 et elles ont été complétées par un approvisionnement en eau, des puits ayant été creusés dans sept villages. Les opérations d'échantillonnage des populations de mollusques ont été régulièrement effectuées chaque mois jusqu'à et après la campagne de lutte, et elles se poursuivent actuellement.

L'un des premiers résultats des enquêtes menées sur les mollusques a été la découverte du facteur écologique qui, à lui seul, est principalement responsable de l'extension des populations de *B. rohlfsi*. Il s'agit d'une plante aquatique, *Ceratophyllum*, et il a été établi que le nombre des mollusques et celui des personnes infectées étaient au plus haut niveau dans les villages situés sur des rives où cette plante était abondante; la transmission des cercaires et le taux d'infection dans la population humaine augmentaient avec la densité de *Ceratophyllum*.

Les auteurs ont groupé les villages selon la distribution et la densité de *Ceratophyllum*, cette dernière étant évaluée selon une échelle variant de 0 à 3 (0: absence de *Ceratophyllum*; 1: faible densité; 2: densité moyenne; 3: forte densité). La densité était relativement facile à déterminer, notamment par l'examen des cartes qui avaient été dressées des points de contact avec l'eau (WCS) et sur la base de divers éléments d'information recueillis lors des enquêtes. Pour chaque village, la densité moyenne annuelle a été calculée en additionnant les degrés mensuels de densité pour tous les WCS et en divisant le total par le nombre des WCS.

Le potentiel de transmission cercarienne pour chacun des 16 villages a également été défini comme équivalant au pourcentage des WCS où un mollusque au moins avait été trouvé porteur de cercaires adultes de *S. haematobium* par rapport au nombre de WCS surveillés. Un degré élevé de corrélation s'est établi entre la densité moyenne de *Ceratophyllum* et le pourcentage des WCS positifs. De plus, chacun de ces éléments s'est révélé en corrélation avec le taux de prévalence de l'infection à *S. haematobium* dans le village et la moyenne géométrique de l'excrétion d'œufs, ainsi que l'indice épidémiologique calculé en fonction des paramètres précédents (tableau 2).

L'élimination de *Ceratophyllum* des points de contact avec l'eau n'a guère été possible que là où sa densité était faible. Il est difficile, lorsque cette algue prolifère, de la faire disparaître manuellement car cela mobiliserait de nombreux bras pendant un temps appréciable. La végétation de *Ceratophyllum* constitue souvent une masse compacte qui va du fond du lac à la surface, et ceci depuis le rivage jusqu'à des profondeurs dépassant 5 m, d'où son volume et son poids considérables. La destruction de la plante par des herbicides ne peut non plus être envisagée en raison des fluctuations incessantes dues aux variations du niveau des eaux du lac selon la saison. Ces fluctuations imposeraient d'ailleurs, en cas d'élimination manuelle, la répétition des opérations tous les 15 jours à l'époque où l'eau se retire progressivement.

Le seul moyen efficace de lutte contre la transmission des cercaires aux points de contact avec l'eau où *Ceratophyllum* est abondant est, dans le contexte actuel, l'application de molluscicides 3 fois au cours de chaque période de 2 mois pendant presque toute l'année, parallèlement à un programme sélectif de chimiothérapie.

REFERENCES

1. PAPERNA, I. Study of an outbreak of schistosomiasis in the newly formed Volta Lake in Ghana. *Zeitschrift für Tropenmedizin und Parasitologie,* **21**: 411-424 (1969).
2. PAPERNA, I. Aquatic weeds, snails and transmission of bilharzia in the new man-made Volta Lake in Ghana. *Bulletin de l'Institut français d'Afrique noire,* **31**, Ser. A (2): 487-499 (1969).
3. ODEI, M. A. Observations of some weeds of malacological importance in the Volta Lake. *Bulletin de l'Institut français d'Afrique noire,* **35**, Ser. A (1): 57-66 (1973).
4. ODEI, M. A. Some preliminary observations on the distribution of bilharzia host snails in the Volta Lake. *Bulletin de l'Institut français d'Afrique noire,* **34**, Ser. A (3): 534-543 (1972).
5. KLUMPP, R. K. & CHU, K. Y. Ecological studies of *Bulinus rohlfsi,* the intermediate host of *Schistosoma haematobium* in the Volta Lake. *Bulletin of the World Health Organization,* **55**: 715-730 (1977).
6. CHU, K. Y. & VANDERBURG, J. A. Techniques for estimating densities of *Bulinus truncatus rohlfsi* and its horizontal distribution in the Volta Lake, Ghana. *Bulletin of the World Health Organization,* **54**: 411-416 (1976).
7. HALL, J. B. & OKALI, D. U. U. Phenology and productivity of *Pistia stratiotes* on the Volta Lake, Ghana. *Journal of applied ecology,* **11**: 709-726 (1974).
8. CHU, K. Y. Trials of ecological and chemical measures for transmission control of *Schistosoma haematobium* in a Volta Lake village. *Bulletin of the World Health Organization,* **56**: 313-322 (1978).