Chapter 9

GENERAL DISCUSSION AND CONCLUSIONS

The chapters in this thesis all contain a section with conclusions, so it is rather unproductive to summarize these conclusions in this chapter. For that information, please refer to the summary at the end of this book. Instead, in this chapter an attempt will be made to analyse what the achievements of the research project were with respect to the expansion of scientific knowledge in general and the control of schistosomiasis in particular.

Part I: General Background

The publication in paragraph 2.1 serves a nonspecialist audience to understand the interrelation between wetland management, irrigation development and transmission of schistosomiasis. The approach of the Lagdo Fishculture Project was presented as a possible way to deal with adverse health effects of a water resources management project. This paper was written as a case study in a book on the sustainable use of tropical wetlands, aimed at persons working at the regional administrative level in wetland areas. It shows the intricate interrelationships in a wetland system and the multitude of problems that have arisen after the large-scale changes that have taken place. It is informative with respect to the general achievements of the Fishculture Project and the problems that we encountered during implementation. The description of the results of a participatory approach as applied in Gounougou gives good insight in problems that at first sight have nothing to do with the objective we deal with in this thesis, i.e. the control of schistosomiasis. Land-tenure rights, access of women to resources, relations with neighbouring villages, and last but not least the presence of a hippopotamus family, can all be seen as important obstacles to the implementation of successful measures to control snail intermediate hosts of schistosomiasis.

Part II: Descriptive research

In spite of three years of research efforts, an accurate description of the transmission dynamics of schistosomiasis in the Benue valley was still lacking in July 1991. This can be attributed to several complicating factors. The formerly sparsely populated Benue valley was flooded with immigrants in the last decade. Most of these migrants came from areas endemic to schistosomiasis. Hence, many people must have carried infections upon arrival. It is impossible to distinguish between local and imported infections, so data obtained from a schistosomiasis survey do not give reliable information on transmission in the area. Secondly, due to the recent and continuing large scale modifications in the hydrology of the valley, newly created habitats have to be colonised by populations of snail intermediate hosts. Data indicate that this colonisation and the subsequent succession of species has not reached its end yet. From the available evidence it can be deduced that in former days seasonal transmission in temporary habitats was the most important source of infection in the valley, which is reflected by high prevalence rates among school children in those villages that only possess seasonal transmission pools. Gradually, permanent transmission increases in importance because of the creation of permanent habitats in and around the irrigation scheme, as seen in Gounougou where prevalence rates are slowly increasing. Since no infected snails have been found in 36 months of sampling, it is obvious that transmission is not wide-spread. In spite of the incompleteness in the description of the transmission cycle, several new and relevant aspects are presented in the papers in part II.

Any longitudinal study on populations of snail intermediate hosts of schistosomiasis undoubtably has scientific value, as this kind of field observations is rare. The climatological and logistical conditions in West Africa do not contribute to the popularity of field research. The work is tedious and standard procedures have to be maintained under all weather conditions. This is the reason why snail sampling along the shores of lake Lagdo was not considered feasible. The sampling sites that were studied for 36 months were situated within moped- range of the laboratory facilities.

The succession of species as described for the Gounougou irrigation scheme is one of only a few longitudinal studies that confirm the succession of species in West Africa as postulated in several earlier publications. From the available evidence from other irrigation schemes, it seems probable that the succession has not reached its climax yet. This is confirmed by recent observations by Vroeg (pers. com.), who in March 1993 for the first time observed large numbers of *Biomphalaria pfeifferi* in the irrigation scheme.

As in many other studies it was difficult to find parameters that might explain the distribution of snail species. Only water temperature correlated significantly with snail densities. During prolonged periods throughout the year the water temperature exceeds the optima! temperature for three snail species. In spite of the high water temperatures, varying numbers of these snails can be found throughout the year .The distinction between different types of habitat appeared to be more effective in explaining differences in snail densities. Without exactly knowing in what parameters these habitats differ, it is possible to make a sensible distinction between three main habitat types, *i.e.* (1) large reservoirs, (2) medium- sized, semi-natural water bodies and (3) man-made, man-managed water bodies. The observation that man-made reservoirs harbour the largest numbers of intermediate hosts once again proves that schistosomiasis is, to a large extend, a man-made disease.

The construction of a species growth curve of snails collected in the field was a tricky affair. With fast growing *B. forskalii*, even intensive weekly samplings of snails could not give satisfactory results. Only a mark and recapture technique may give reliable data. The method of following size-cohorts as applied in §3.1 is a goad second choice method, if samplings are carried out more often and larger numbers of snails can be collected. It must be stressed that these field observations remain necessary in order to corroborate laboratory observations. After all, experiments in the laboratory have little resemblance with natural habitats.

B. senegalensis can easily be confused with *B. forskalii*, a species not capable of transmitting vesical schistosomiasis. The difficulty in distinguishing *B. forskalii* and *B. senegalensis* has been solved by a fruitful cooperation with Dr Mimpfoundi of the Faculty of Sciences in Yaoundé. By means of iso-enzyme detection in the Yaoundé laboratory, it was possible to prove that *B. senegalensis* is also endemic in the Soudanian zone of Cameroon. This finding can have implications for the understanding of seasonal transmission in the entire Soudanian zone. *B. forskalii* is widespread in West Africa, but since *B. senegalensis* was not known to occur South of the Sahelian zone, it might be possible that the latter species has often been overlooked in the past.

Water contact studies have often been used to explain the prevalence and intensity of infection among different groups of inhabitants. In many cases this appears to be a fruitless exercise since transmission dynamics can hardly be captured in a simple linear model of parameters derived from observations on water contacts. However, this kind of study can be helpful in differentiating various groups of people that make use of open water. By recognizing and classifying high risk activities and sites, the study in Gounougou was helpful in identifying different target groups. It became clear that these groups perform different activities and that entirely different approaches are needed to reduce the exposure to potentially infested water. The study provides tools to study the problem and develops guidelines for possible measures aimed at the reduction of health risks.

The demographic characteristics of two villages in the Benue valley that are presented in paragraph 5.1 demonstrate the complexity of an immigrant society . One village is turned into a multi-ethnic society with over 20 different ethnic groups, speaking different languages, having different religions, etc. In the neighbouring village the autochthonous Islamic Foulbé are outnumbered by a large immigrant majority belonging to a single Christian ethnic group. The daily problems arising from this mixture of peoples are plenty, ranging from pigs that belong to a Christian group entering a musulman's rice field, to the refusal by autochthones to share land with immigrants. It is remarkable that so little of the disputes between people in Gounougou and Riao get out of control, given the enormous changes which have taken place in a few years time.

The most important conclusion that can be drawn from the epidemiological data is that in the year the surveys were carried out, schistosomiasis was not a major health problem in these villages. Recent information, however, indicates that transmission of schistosomiasis in Gounougou is increasing; *S. haematobium* prevalence has increased from 21% in 1986 to 43% in January 1993 (Brussel & Contant, pers. com.).

Part III: Experimental control

The general failure of *Astatoreochromis alluaudi* in snail control will not really astonish schistosomiasis experts with field experience. Seasonal streams, seepage pools in irrigation schemes, and shallow water borders with dense stands of vegetation are notorious sites for schistosomiasis

transmission. The physical characteristics of these transmission habitats are such that fish cannot control snail populations because they are hardly be able to reach these snails. In fact, fish may not even be able to survive in these surroundings. The only realistic option for biological snail control with fish that remained was fish culture, also because molluscicides are toxic to fish. The evidence given in §6.3 and §6.4 dashes ail hopes on effective control in fishculture ponds. The availability of food, a prerequisite for fish culture, seems to stimulate growth and reproduction of snails but simultaneously reduces the fish's "appetite" for snails. The resulting reduction in the pharyngeal jaw apparatus of the fish does not make the fish incapable of eating snails, but reduces the benefit obtained from eating snails.

The need for biological control efforts has often been stressed by many authors, but for a long period necessary field evidence was lacking. It is hoped that the evidence accumulated by this research and the review on the role of fish in biological snail control, win help to fin this gap. The hope to find the perfect snail predator among fish is very dim. Therefore, the review ends with a recommendation that future experiments in snail control should concentrate on the field of integrated vector control. In integrated water and habitat management efforts, fish can possibly have an additional role as a snail predator in a surrounding where snails are already under high pressure.

An important conclusion that can be drawn from this study is that fishculture inevitably increases the risk of schistosomiasis transmission. It is highly probable that snail hosts will establish themselves in fish ponds. Therefore it should be strongly discouraged to propagate communal fish ponds near village compounds in schistosomiasis endemic areas, unless these ponds can be fenced in some way or another.

As stated before, good irrigation practise is the backbone of the control of disease transmitting organisms. The design of the irrigation scheme of Gounougou illustrates the ignorance often encountered among irrigation designers. The increased health risks that were created near the village by the absence of a functional drainage system, could be prevented if the scheme had been proper I y constructed. Our alternative approach to the drainage problem showed that successful vector control can be combined with economic activities. More important, it also showed that the inhabitants of Gounougou were very interested in utilising this opportunity by establishing vegetable gardens near the reconstructed drainage canal. Unfortunately, the hippopotamus family was also very interested in these gardens which they appreciated as grazing grounds. It was impossible to divert the animals to the alternative grazing area that was created nearby. According to recent information from Cameroon, many gardens have been abandoned. The only solution to this problem is an investment in the planting of thorn trees around garden plots, which will only be possible after the village has solved its land ownership problems between autochthones and immigrants.

The relatively restricted number of people that actually develop illness due to infection puts a constraint on large scale schistosomiasis control campaigns with active case detection in areas with moderate to low prevalence rates. The cost per treated individual will be very high. .Treatment of ill people at a health care facility is the only feasible alternative to such campaigns. The Lagdo area reflects the present day situation in many rural areas of Africa, where the passive case detection at health centres is the only available instrument in disease control.

The method of evaluating the efficacy of the health care facilities that is presented in chapter 8 urgently needs to be refined. Many methodological obstacles remain which are subject of study at present. Furthermore it seems useful to invite epidemiologists into this research, to analyse health care records and to evaluate the reliability of conclusions derived from this analysis. It should be possible to develop a standardized protocol for the evaluation of health statistics with guidelines on how to deal with a schistosomiasis problem at regional level. With this approach the need for active case detection is reduced and the available resources can be focused on problem areas that have been identified by the analysis of the health statistics.

The data presented in chapter 8 indicate that a considerable number of heavily infected persons indeed visit the Lagdo health centre with complaints related to schistosomiasis. These persons receive treatment on the spot. By treating 70 persons, the total reduction in egg-output achieved by the health centre probably is larger than that achieved by the lake-wide survey in 1986 among approximately 1,000 inhabitants, and this was achieved at much lower costs. The reduction of egg-

output is one of the means that can contribute to a reduction in transmission. It is an important observation that, compared to a vertically organized campaign with active case detection, the Lagdo health centre is achieving better results at lower costs, as well in treating people with high intensities of infection, as in the total reduction of egg-output.

The last question to be answered is whether all these activities have contributed to a reduction in the number of people becoming ill. Clearly, this question cannot be answered. The hydrological changes in the area are still continuing. Not all of the numerous potential snail breeding sites have been colonized by intermediate hosts yet. The activities of the fishculture project were aimed at reduction in the risk of infection in the Gounougou drainage system. The effects of such actions can only be evaluated after a prolonged period, because morbidity due to infection only develops slowly. Consequently, the effect of reduced infection will only become visible after several years. Given the large number of other potential transmission sites it is doubtful whether the effect of the reconstruction of the Gounougou drainage system will ever be visible.

Several achievements of this research project can be applied to schistosomiasis control elsewhere:

- The achievement of the experiments on biological control is, that for the first time a comprehensive study has been dedicated to lacustrine snail-eating cichlid fishes (chapter 6). The results convincingly show the failure of the use of fish in snail control, and a scientifically valid explanation for this failure is given.
- In the approach to drainage management (chapter 7) it is shown that an economic incentive can enhance the active participation of a local community in resolving a drainage problem and reducing the health risks.
- The assessment of the role of health care facilities in the control of morbidity due to schistosomiasis infection (chapter 8) points towards a new direction of research that may eventually lead to the formulation of an effective strategy for schistosomiasis control in areas with moderate to low prevalences.

It is my hope that this thesis has shown that promising directions in schistosomiasis research, applicable under field conditions in the less-developed parts of the world, are still existing. Even in areas with low standards of living and little money available, there is still some room for progress in the control of morbidity due to schistosomiasis.

SUMMARY

In the planning and construction process of hydraulic projects, such as dams and irrigation systems, health aspects are often neglected. This oversight can be dangerous because newly created freshwater habitats often serve as breeding sites for organisms that transmit parasitical diseases such as schistosomiasis and malaria. In 1982 a dam was constructed in the Benue river near Lagdo, North Cameroon. The dam was designed for the production of hydro-electricity and large scale irrigated agricu1ture in the former floodplains downstream from the dam. Because of the dam, yearly flooding was greatly reduced thus diminishing the traditional uses of the floodplains. Especially fish production suffered dramatic losses.

Moreover, the construction of an irrigation scheme in 1987 has increased the risk of transmission of various forms of schistosomiasis, a parasitic disease that was already present in the area. In order to compensate for the losses in fisheries production and to tackle the predictable health problems, the Cameroonian government asked The Netherlands to finance the Projet Pisciculture Lagdo (Lagdo Fishculture Project). The purpose of this project was (1) the restoration of floodplain fishery by means of water management and the introduction of fingerlings, and (2) the control of schistosomiasis in just downstream from the Lagdo dam.

This thesis describes the research and control experiments on schistosomiasis which have been performed within the framework of this project. The research has been subdivided in a descriptive section and a section that deals with the various forms of control activities. Both sections are structured according to the schistosomiasis transmission cycle. The parasite's transmission cycle has been divided in three distinct phases: (I) the snail intermediate hosts, (2) the man-water interface, and (3) the adult worm in the human body.

Descriptive research

The snail intermediate hosts of schistosomiasis: succession and population dynamics of snails. For 36 months a monthly sampling program was carried out at various sites around the village of Gounougou, in order to obtain data on the population dynamics throughout the year .In addition the succession of species in the Gounougou irrigation scheme was studied. Sampling started at the end of the first year of operation of the irrigation scheme. At several sampling sites bi-hourly temperature and oxygen measurements were taken, in order to assess the fluctuations throughout the day. In the Gounougou fishculture station weekly temperature measurements were taken at a fixed hour in order to record seasonal fluctuations. Based on these measurements, three main habitat types could be distinguished: (I) large reservoirs with constant water temperature and oxygen concentration, (2) stagnant water in semi-natural reservoirs with low oxygen contents and rapidly increasing water temperature in morning hours, and (3) man- made, man-managed reservoirs with large fluctuations in water temperature and oxygen contents during the day. In the first habitat type only occasionally populations of *Biomphalaria pfeifferi* and *Bulinus truncatus* were found. In the other two habitat types temporary as well as permanent populations of *Bulinus forskalii*, *B. truncatus*, *B. globosus*, and *Lymnaea natalensis* were found. The largest numbers of snails were found in man-managed reservoirs, i.e. in fish ponds and in the irrigation scheme.

In the irrigation scheme a succession of species was observed that is typical for this climatic zone. *B. forskalii*, a pioneering species that invaded the newly created scheme immediately after it was put into operation, was followed after two years by *B. truncatus* and *L. natalensis*. *Biom. pfeifferi* and *B. globosus* were also present in the study area but these species did not establish themselves in the irrigation scheme (yet?). In temporary pools and streams that only fill up in the rainy season, *Bulinus senegalensis* was found; this is the southernmost site where this typical Sahelian species has ever been recorded. Probably this phenomenon can be explained by the existence of the Mayo Kebi, a waterway connecting the Benue valley and the more northern Logone valley. In table 13, a summary is given of the parasites that are transmitted by the different snai1 species.

Two yearly peaks in snail reproduction can be recognized, coinciding with periods of lower temperatures. The cool dry season between December and February is the most important reproduction period for all species except *B. senegalensis*. In the middle of the rainy period, July/August, a second reproduction peak has been observed. This is the only period in which *B. senegalensis* is found. The numbers of *Biom. pfeifferi* were too low to be able to define reproduction seasons.

It is remarkable that during the entire sampling programme, no infected snails have been found, indicating that transmission was erratic and focal. From these data and from the epidemiological studies it can be concluded that seasonal transmission by *B. senegalensis* and *B. globosus* in streams and pools still is the main source of schistosomiasis infection. The recent establishment of populations of *B. truncatus* in the irrigation scheme gives reason to expect that transmission in the scheme will become more important in the near future. Based on experience in similar schemes elsewhere it is expected that *Biom. pfeifferi* will establish itself in the scheme. It is expected, therefore, that the prevalence of intestinal schistosomiasis will rise in due course.

Table 13: Parasites that can be transmitted by freshwater snails of the Benue valley.

Intermediate host	*Parasite*
Biomphalaria pfeifferi	*Schistosoma mansoni*; intestinal schistosomiasis
Bulinus truncatus	*S. haematobium*; vesical schistosomiasis
Bulinus globosus	idem
Bulinus senegalensis	idem
Bulinus forskalii	in this region no parasites
Lymnaea natalensis	*Fasciola* spp. ; blood flukes in cattle

The man-water interface: water contact study. The behaviour of humans in relation to water has been observed and quantified during 49 days of observation over an eight month period. With the help of scaling techniques an index has been calculated that categorizes the exposure to water for different activities and sites. Three main types of water contact can be recognized: domestic, occupational and recreational. Within these categories, several activities of high infection risk could be recognized: (I) bathing and washing of dishes and clothes, (2) working on rice fields and fishing without boat, (3) playing and swimming. The observations have led to the conclusion that the introduction of irrigated agriculture has added new infection risks to the already existing risks. It is also concluded that in the design of measures to reduce tbe infection risk, a distinction bas to be made between the different categories of activities.

Water contacts through domestic activities can be reduced by providing reliable water. The availability of relatively safe irrigation water offers a possibility to create safer washing sites. The analysis of the present water supply shows that certain village quarters have a chronic shortage of water, which forces the inhabitants to use potentially infected water bodies nearby.

Unlike domestic water contact, fishery and work on irrigated fields inevitably bring along infection risks, because people are forced to actually enter the water. Prevention of infection can only be achieved by snail control; health care facilities are essential in detecting and curing infected persons.

Recreational water contact, mainly a children’s' activity, is hard to prohibit. By regularly searching for snails, it is possible to determine which sites are safe to swim and which are not. At school, children may be instructed where to swim.

All measures described above cannot eliminate but can only reduce the risk of infection. After people become infected, the primary health care facilities play a major role in the control of morbidity due to schistosomiasis.

Man and the adult parasite: epidemiology of schistosomiasis. Riao and Gounougou, two villages situated in the study area, are characterized by large numbers of immigrants from the overpopulated Extreme Northern Province of Cameroon. The national government stimulates migration towards areas where arable land still is available. Between 1974 and 1988 the number of families in Gounougou has increased from 15 to 425, distributed over some 20 ethnic groups. In Riao the number of families has increased from 35 to 147, distributed over only two ethnic groups. The prevalence rate of vesical schistosomiasis in 1989 was 29% for Gounougou and 11% for Riao; rates for intestinal schistosomiasis were 12 % and 4% respectively. Since both forms of schistosomiasis are also endemic to the region of origin of most migrants, it is difficult to indicate what proportion of the population is infected in the Benue valley itself. It is certain, however, that transmission is taking place in the valley, because small children who never have left the village are found to be infected. The fact that Gounougou has a higher prevalence than Riao cannot entirely be attributed to the presence of an irrigation scheme near Gounougou. Among pupils of the Gounougou primary school it was observed that children with highest prevalence came from distant villages. This indicates that transmission dynamics of schistosomiasis are quite complex in the study area. In spite of this complexity it is justified, however, to conclude that schistosomiasis transmission has not explosively increased in the villages, but that there is a real danger of an increase in transmission in and around the newly created irrigation schemes.

Control

The intermediate host: biological control by means of snail eating fish. Some examples of snail control by snail eating fish have been described in the scientific literature. Usually these descriptions deal with experiments that have been performed in the margin of projects related to aquaculture or water supply. Few of these publications describe experiments that were designed explicitly to test the ability of snail-eating fish to control snails. Nevertheless, several experiments appeared to be successful, although there is no definite proof yet. The experiments in Africa always involved members of the cichlid family (Cichlidae), and particularly a snail eating cichlid from Lake Victoria, *Astatoreochromis alluaudi.*

To put an end to all speculation about the potential use of this species in snail control, an elaborate research program with laboratory and field experiments was launched. In the laboratory , observations were made on prey selection on several species of snail eating fish. The experiments revealed that the prey choice of these species could to a large extend be explained by a simple foraging model, in which the choice is determined by the yield in prey mass per unit of time invested. Different prey types can be arranged according to their yield per second handling time (the time required for searching, processing and ingestion of a prey). When offered an excess of prey the fish chose the prey-type with highest yield per second.

Among the snail eating cichlids, the best known and well described species *Astatoreochromis alluaudi* was selected for field trials in Cameroon. Before introducing the fish into the Benue valley of Cameroon, the possible risks of introducing this exotic species were assessed. No reasons against the introduction could be found. A number of fish were transported from the Leiden laboratory to the fishculture station of Gounougou in Northern Cameroon. There, fish could be reproduced and introduced into tria1s together with fish that were cultured for human consumption. On some occasions fish have a1so been used in controlled field experiments outside the fishculture station.

In order to be effective in snail control, the fish had to meet two criteria:

1. It should be possible to produce sufficient numbers of juveniles for large scale introduction of fish in natural and artificial habitats.

2. To be really effective against schistosomiasis transmission, snail populations needed to be virtually eradicated. In general it is assumed that only a few snails are already capable of maintaining a certain level of transmission.

Pond trials during several seasons have shown that the reproduction of *A. alluaudi* is low, and the numbers of juveniles are totally insufficient. Probably the adult fish on1y produce one or two brood per year and cannibalism may explain the disappearance of large numbers of juveniles. Even more serious is the observation that the fish did not achieve any significant reduction in the number of snails in fish ponds. Experiments in fish ponds led to the conclusion that the permanent availability of food in these production ponds enhances the growth of snail populations and reduces the fishes' interest in eating snails. Based on the earlier mentioned foraging model and with additional evidence from laboratory observations it became clear that snails were not the prey type with highest yield per second. Consequent1y the fish will not search for snails if more profitable food items are available. The few field experiments that were carried out in addition to the pond experiments, further corroborate the conclusion that the fish were not capable of controlling snail populations.

A third reason for the failure of *A. alluaudi* in snail control can be found in the phenotypic plasticity of the pharyngeal jaw apparatus and muscles that are used to crush snail shells. Fish raised in the fishculture station showed a reduction in the size of the jaw and the muscles that operate on the pharyngeal jaw, as compared to fish that were caught in Lake Victoria. Due to the absence of competition such as can be found in Lake Victoria, the pond-raised fish were not forced to eat snails and consequently did not develop their jaw apparatus. The result is that snails are becoming less profitable and fish will be even less inclined to eat snails.

The conclusion of these trials is that it has no use to invest much more energy in experiments with lacustrine cichlids from Lake Victoria in snail control. The reasons for the failure of *A. alluaudi* as described above will most certainly also apply to other related cichlids. In snail control more attention should be paid to an integrated approach in which habitat management can alter the living conditions for snails so that natural predators or competitors can put more pressure on snail populations. Snail eating fish species that may be useful in such an approach are *Serranochromis mellandi*, *Lepomis microlophus*, *Mylopharyngodon piceus* and *Trematocranus placodon*, possibly assisted by the herbivorous *Ctenopharyngodon idella*. Unfortunately, in most schistosomiasis endemic areas this approach will be difficult to implement because the knowledge for such an integrated approach is entirely lacking.

The man-water interface: water and habitat management. The observations of snail populations and number of contacts of humans with water revealed that the depression alongside the village of Gounougou has become a potential transmission site of schistosomiasis since the depression has been put into use as a drainage area for the irrigation scheme. The depression has turned into a permanent marsh where snails, but also mosquitoes, find a good place to breed. The area is useless for agricultural purposes because the water level is unpredictable and fully depends on the timetable used for the irrigation scheme. However, the villagers do use the water for domestic purposes. The number of water contacts further increases because people have to wade through the depression to reach their fields on the other side. In order to reduce the risk of infection and to increase the possibilities to produce fish and vegetables, the depression was reconstructed in consultation with the villagers. The entire depression bas now been canalised and a cofferdam with removable valves enables the villagers to regulate the water level in the canal. This project had several beneficial consequences:

- the marshes were reclaimed and a considerable surface of arable land became available;
- the water level can be regulated, enabling the villagers to grow vegetables in the dry season;
- by opening the valves in the cofferdam at the end of the dry season, the depression can be drained and fish can be caught;
- all these activities have resulted in a strong decline in numbers of snails;
- the frequency of water contact decreased because a bridge for pedestrians and the dam itself now allow people to cross the depression without having to wade.

The benefits derived from vegetable and fish production highly motivates the villagers to manage the depression properly, which in turn has the beneficial side- effect of reducing the risk of infection because snail populations are kept at a minimal level. It is obvious that the proper management of the depression depends on the willingness of the villagers to cooperate. For the time being, problems persist between immigrants and autochthones with respect to the allocation of land. The national government has promised that all immigrants would have the right to possess land, but the autochthones appear to be very reluctant to give up their traditional rights.

Man and parasite: morbidity control by the health centres. The ultimate goal in the control of schistosomiasis is the prevention of transmission of the parasite. It has gradually become clear that in less wealthy parts of the world this goal cannot be achieved. Therefore the goal had to be adjusted to the prevention of illness due to schistosomiasis. The drug currently available, praziquantel, not only kills the parasite but also partly heals physical damage to the intestines. Formerly it was thought that this damage was irreversible. Morbidity control can be achieved by active detection and treatment of infected persons, thus preventing the development of serious disease resulting from prolonged infection. The costs of such an approach are high. It is also possible to treat people that actually feel ill at the health centres. This approach is based on passive case detection, which entirely depends on the motivation and available financial means of the affected persons. In most areas where schistosomiasis is endemic, this primary health care approach appears to be the only feasible way to control schistosomiasis. Hardly any quantitative data exist on the effectiveness of this approach.

In this thesis a first at tempt is made to quantify the role of the existing health care facilities in controlling morbidity due to schistosomiasis. The records of health centres provided data on the number of recorded cases of schistosomiasis, and the sex, age, and village of origin of the victims. These data were compared with the results of an independent schistosomiasis survey that was carried out in the same region. Finally, the intensity of infection was determined in people that visited the health centre. This comparison revealed that the passive case detection as applied in the health centres' policy, is highly selective in discovering cases of heavy infection. This implies that people who actually feel ill are willing to let themselves be treated against the disease. Both men, women and children have access to the health facilities, although women and especially girls between 5 and 10 years of age report in smaller numbers than would be expected from the survey data. From the health centre's records it was possible to identify villages with high numbers of heavily infected people. If morbidity control is the objective in schistosomiasis control, than these preliminary results indicate that the existing health facilities play a major role in this approach. There is a high probability that using the health care facilities to combat morbidity may be an effective method in areas with low to moderate prevalence rates.

Although this new direction of research on morbidity control is promising, there are still plenty of methodological problems that need to be overcome. The presented research approach still has to be verified with data from a larger number of health centres. This is an important task for the new project team that is working in Cameroon at the moment of writing.

Acknowledgement

Wim Slootweg is kindly acknowledged for his corrections on the English translation.

RÉSUMÉ

Les aspects de santé sont souvent négligés dans la planification et la réalisation d'aménagements hydro-agricoles tels que les barrages et les périmetres d'irrigation. Des gites d ' eau douce nouveIlement créés servent souvent de sites de reproduction aux organismes qui transmettent des maladies parasitaires comme Ie paludisme et la schistosomiase. En 1982, un barrage fut construit sur Ie fleuve Bénoué, pres de Lagdo {province du Nord, Cameroun). Ce barrage est destin é a produire de l'électricité et a approvisionner en eau de nouveaux périmetres d'irrigation aménagés dans les anciens plaines d'inondation, en aval du barrage. La disparition des inondations annuelles a entrainé une baisse de 1 'utilisation traditionnelle des ces plaines. La pêche, en particulier, a enregistré d'importantes pertes. La mise en place, en 1987, d'un systeme d'irrigation a accru Ie risque de transmission de plusieurs especes de schistosomiases déja présentes dans la région. Afin de restaurer la production piscicole et pour prévenir les probIemes de santé potentiels qui avaient été identifiés au préalable, Ie gouvernement Camerounais a demandé au gouvernement Néerlandais de financer Ie Projet Pisciculture Lagdo. Ce projet vise, au moyen d'une meilleure gestion de l'eau et de l'introduction d'alevins, a (1) restaurer Ia production piscicole dans les plaines d'inondation et (2) luter contre la schistosomiase dans la zone du projet, en aval du barrage de Lagdo.

Les expériences de Iutte contre Ia schistosomiase, effectuées dans Ie cadre du projet sont présentées dans cette these. Cet ouvrage comporte deux sections, Ia premiere décrivant Ie cycle de transmission tandis que Ia deuxieme présente les différentes expériences de Iutte. Ces deux sections sont structurées selon Ie cycle de transmission du parasite, qui comporte trois phases distinctes: (1) Ie mollusque en tant qu'hóte intermédiaire, (2) Ia phase homme-eau, et (3) Ie ver adulte dans Ie corps humain.

Partie descriptive

Le mollusque hôte intermédiaire de la schistosomiase: succession et dynamisme des populations de mollusques. Un échantillonnage mensuel a été effectué autour du village de Gounougou pendant 36 mois, afin d'étudier Ie dynamisme des populations de mollusques au cours de l'année. De plus, la succession des especes a été suivie dans Ie systeme d'irrigation. L 'échantillonnage débuta a la fin de la premiere année d'opération du périmetre irrigué. La température et la teneur en oxygene de l'eau ont été mesurées toutes les deux heures sur quelques sites d'échantillonnage. Les variations saisonnieres ont été observées dans les étangs du Centre de Pisciculture de Gounougou ou des mesures hebdomadaires ont été effectuées à heure fixe. Sur la base des données ainsi obtenu, trois grands types de gites peuvent être distingués: (1) les grands réservoirs d'eau ou la température et la teneur en oxygene sont constantes, (2) les eaux stagnantes des réservoirs semi-naturels ou la teneur en oxygene est faible et la température s'éleve rapidement pendant la matinée, et (3) les réservoirs construits et gérés par l'homme qui se caractérisent par de grandes fluctuations de température et de teneur en oxygene pendant la journée. Des population incidenteIles de *Biomphalaria pfeifferi* et de *Bulinus truncatus* ont été trouvés dans le premier type de gites. Des populations temporaires et permanentes de *Bulinus forskalii*, *B. truncatus, B. globosus* et *Lymnaea natalensis* ont été observées dans les deux autres types de gites. Le nombre de mollusques Ie plus élevé a été enregistré dans les gites géré par l'homme, c'est-á-dire dans les étangs de pisciculture et Ie systeme d'irrigation.

Dans Ie systeme d'irrigation, la succession des especes est typique de cette zone climatique. L' espece pionniere, *B. forskalii*, envahit les nouveaux périmetres irrigués jusqu'apres leur mise en service. Ell fut suivie, deux ans plus tard, par *B. truncatus* et *L. natalensis*. *Biom. pfeifferi* et *B. globosus* sont présents dans la zone d'étude maïs ne se sont pas (encore?) établis dans le systeme d'irrigation. *Bulinus senegalensis* a été observé dans les cours d'eau et les flaques d'eau temporaïres qui se remplissent seulement pendant la saïson des pluies; la zone du projet constitue la région la plus méridionale dans laquelle cette espece Sahélienne a été rencontrée. Ce phénomene s'explique probablement par l'existence au Nord d'une communication entre la vallée de la Bénoué et la vallée du Logone: le fleuve Mayo Kebi. Le tableau 12 indique les parasites transmis par les mollusques de la vallée de la Bénoué.

Aucun mollusque infecté par des schistosomes n'a pu être trouvé pendant toute la période d'échantillonnage, ce qui constitue un fait remarquable. A partir de ces donnés et des études épidémiologiques, on peut conclure que la transmission saisonniere par *B. senegalensis* et *B. globosus* demeure la source d'infection la plus importante. Néanmoins, l'établissement de *B. truncatus* dans Ie systeme d'irrigation est inquiétant et il faut s'attendre, dans un proche avenir, a une transmission plus importante dans les systemes d'irrigation. Sur la base d'expériences effectuées dans des systemes comparables, il est aussi à prévoir que *Biom. pfeifferi* s'établira dans le systeme de Gounougou; en conséquence, la prévalence de la schistosomiase intestinale augmentera.

Tableau 1: Parasites transmis par les mollusques d'eau douce dans la vallée de la Bénoué.

Hote intermédiaire	***Parasite***
Biomphalaria pfeifferi	*Schistosoma mansoni* (schistosomiase intestinale)
Bulinus truncatus	*S. haematobium* (schistosomiase vésicale)
Bulinus globosus	Idem
Bulinus senegalensis	Idem
Bulinus forskalii	dans cette région pas de parasites
Lymnaea natalensis	*Fasciola* spp. (grande douve du bétail)

La phase homme-eau: I'étude des contacts homme-eau. Le comportement humain par rapport a l'eau a été observé et quantifié pendant 49 jours repartis sur une période de 8 mois. Un index d'exposition a l'eau a été calculé pour les différentes activités et les différents sites selon des méthodes de calcul adaptées. Trois grandes catégories de contacts homme-eau ont été identifiées: (1) les contacts liées aux activités domestiques, (2) les contacts liées aux activités professionnelles, et (3) les contacts liées aux loisirs. A I'intérieur de ces catégories des activités a haute risque ont été identifiées: (1) Ia baignade/toilette, le lavage de la vaisselle et la lessive, (2) Ie travaïl dans les rizieres et la pêche sans pirogue, et (3) la nage et les jeux. Les observations montrent que l'introduction de l'agriculture irriguée s'est traduite par une augmentation du risque d'infection maïs qu'il existe aussi d'autres sources d'infection. Il était aussi évident qu'une distinction doit être faite entre les différents catégories d'activités lors d'élaboration de mesures prophylactiques.

Il est possible de réduire le nombre de contacts liées aux activités domestiques par l'adduction d'eau non-contaminée. La présence d'une source d'eau assez fiable, c'-est-à-dire l'eau d'irrigation, donne la possibilité de créer des lavoirs offrant peu de dangers. Une analyse de la disponibilité d'eau dans Ie village de Gounougou montre que certains quartiers souffrent d'un manque d'eau permanent, ce qui force les gens a utiliser les réservoirs potentiellement infectés a coté du village.

Contrairement au contacts liées aux activités domestiques, la pêche et le travail dans les rizieres comporte inévitablement un risque d'infection puisque les gens sont obligés d'entrer dans I'eau. La prévention de l'infection peut se faire seulement par l'éradication des mollusques; le service de santé est essentiel en matiere de détection et de traitement des individus infectés.

Les cantacts liées aux loisirs, il s'agit ici natamment d'enfants, sont tres difficiles à interdire. L'échantillannage régulier dans les lieux de baignade permet d'identifier les sites dépourvus de danger, c'est-à-dire de mollusques. Les endroits ou la baignade est autorisée peuvent être indiqués aux jeunes par le biais de l'école.

Les mesures décrites ci-dessus visent seulement à réduire le risque d'infection. Le service de santé primaire joue le róle principale dans le contróle de la morbidité causée par la schistosomiase dès lors que les gens sont infectés.

L'homme et le parasite adulte: épidémiologie de la schistosomiase. Riao et Gounougou, deux villages dans la zone du projet, se caractérisent par un grand nombre d'immigrés provenant de la province de l'Extrême Nord. Le gouvernement national encourage cette migration vers les zones ou des terres cultivables sont encore dispooibles. Entre 1974 et 1988 la population de Gounougou est passée de 15 a 425 familles, réparties en plus de 20 ethoies. A Riao le nombre de familles est passé de 35 a 147, reparties en seulement deux ethnies. En 1989, la prévalence de la schistosomiase vésicale était de 29% a Gounougou et 11 % a Riao; la prévalence de la schistosomiase intestinale était de 12% et 4% respectivement. Ces deux formes de schistosomiase étant aussi endémiques dans la zone de provenance des immigrés, il est difficile d'indiquer quelle partie de la population a été infectée dans la vallée de la Bénoué même. Il est néanmoins certain que la transmission a lieu dans la vallée puisque l'infection a été observée chez des petits enfants qui n'ont jamais quitté leur village. Le fait que Gounougou ait une prévalence plus élevée que Riao ne peut pas être attribué entierement a la présence d'un périmetre irrigué a Gounougou. Parmi les éleves de l'école primaire de Gounougou, l'intensité d'infection la plus élevée, est observé chez des enfants provenant des villages éloignés. Le dynamisme de transmission de la schistosomiase dans la zone d'étude est donc tres complexe. Malgré cette complexité, il est justifié de conclure que la schistosomiase n'a pas augmenté de maniere explosive dans les villages, mais qu'il y a un véritable risque d'intensitication de transmission autour des périmetres irrigués.

Lutte expérimental

L'hote intermédiaire: lutte biologique contre les mollusques au moyen de poissons malacophages. Les publications scientifiques donnent quelques exemples de lutte hiologique grâce à l'utilisation de poissons malacophages. En général, ces descriptions concernent des expériences réa!isées en marge de projets d ' aquaculture ou d'approvisionnement en eau. Seules quelques unes de ces expériences ont été effectuées dans le but explicite de tester les poissons en matiere de lutte contre les mollusques. Néanmoins, quelques expériences semblaient être des réussites, bien que la preuve définitive n'ait pas été fourni. Toutes les especes de poissons utilisées dans les expériences effectuées en Afrique, appartenaient a la famillE des Cichlidae, en particulier une espece malacophage du Lac Victoria: *Astatoreochromis alluaudi*.

Afin de mettre fin à toutes les spéculations sur l'utilisation potentielle de cette espece dans la lutte contre les mollusques, un vaste programme de recherches a été mis en place avec des expériences en laboratoire et sur le terrain. En laboratoire, des observations ont été faites sur le choix des proies par différentes especes de poissons. Ces observations ont relevé que ce choix pouvait être expliqué en grande partie par une modele simple. Ce modele prédit le choix sur Ie base du quantité de nourriture ingurgitée par unité de temps. Les différents types de proies peuvent être classifiés en fonction de leur rendement par seconde de traitement (c'est-à-dire le temps nécessaire pour chercher, manipuler et consommer la proie). Dans une situation d 'abondance, les poissons choisissent la proie qui fournit le rendement le plus élevé.

Parmi les cichlides malacophages, l'espece la plus connue, *Astatoreochromis alluaudi*, a été choisie pour des essais sur le terrain au Cameroun. Avant d'introduire les poissons dans la vallée de la Bénoué, les risques potentiels liées à l'introduction d'une espece exotique ont été évalués. Cette évaluation n'a pas donné d'avis négatif sur l'introduction. Une quantité de poissons a été transportée du laboratoire de Leyde au centre de pisciculture a Gounougou. Les poissons purent se reproduire au centre de pisciculture et être introduits dans les étangs expérimentaux avec des poissons destinés à la consommation. Dans quelques cas, les poissons ont été introduits dans des sites expérimentaux sur le terrain, hors du centre de pisciculture.

Afin d'être un moyen efficace de lutte contre les mollusques, le poisson sélectionné devait satisfaire a deux criteres:

(1) La production des alevins doit être suffisante afin de permettre une introduction a grande échelle dans les gites naturels ou artificiels.

(2) Pour réduire la transmission de la schistosomiase, les populations de mollusques doivent être pratiquement éliminées. On suppose généralement que quelques individus sont en mesure de maintenir la transmission.

Les essais réalisés dans les étangs ont montré que la reproduction d' *Astatoreochromis alluaudi* est faible et que le nombre d'alevins est insuffisant. Cette espece ne compte qu'un seul frai par an et le cannibalisme peut probablement expliquer la disparition d'un grand nombre d'alevins. Il a de plus été constaté que les poissons ne sont pas du tout en mesure de réduire les populations de mollusques, ce qui est plus grave. Les résultats des essais en étang nous amènent a conclure que la présence permanente de nourriture stimule la croissance des populations de mollusques et réduit en même temps la disposition des poissons a se nourrir de mollusques. Sur la base du modele de choix de proies (voir ci-avant), et les preuves supplémentaires apportées par des observations faites au laboratoire, il est clair que les mollusques ne constituent pas la proie fouroissant de plus haut rendement. Pour cette raison, les mollusques ne constituent pas la proie préférée; par conséquent, les poissons se détoument des mollusques lorsque d'autres types de nourriture pl:us rentables sont dispooibles. Les quelques essais réalisés sur Ie terrain ont démontrés, eux aussi, que les poissons ne sont pas en mesure de réduire la taille des populations de mollusques.

Une troisième cause de l'échec des poissons est liée à la plasticité phénotypique de leurs mâchoires pharyngales et les muscles qui y sont rattachés, c- est-à dire l'ensemble constituant l'appareil qui permet au poisson de casser les coquilles des mollusques. L 'analyse des poissons produits par le centre de pisciculture montre que ces animaux ont des mâchoires et des muscles plus petits que ceux des poissons du Lac Victoria. La compétition entre les différents especes de poisson étant moins forte que dans le Lac Victoria, les poissons du centre de pisciculture à Gounougou ne sont pas obligés de se nourrir de mollusques; en conséquence, leurs mâchoires ne se développent pas. Ce phénomene rend les mollosques encore moins "rentable" et les poissons sont encore moins inclinés a inclure les mollusques dans leur menu.

En résumant, on peut conclure qu'il est inutile de poursuivre les travaux de recherche sur la lutte biologique contre les mollusques avec les cichlides lacustres du Lac Victoria. Les raisons données ci-avant pour expliquer l'échec d' *Astatoreochromis alluaudi*, sont surement aussi valable pour les cichlides apparent és a cette espece. La démarche la plus digne d'attention en matiere de lutte contre les mollusques est la démarche intégrée. Selon cette démarche, la modification des gites rendent les conditions de vie des mollusques plus difficiles et leurs ennemis naturels sont mieux en mesure d'exercer une pression soutenu sur les populations de mollusques. Dans le cadre d'une telle démarche, les poissons malacophages suivants méritent une plus grande attention: *Serranachramis mellandi*, *Lepomis microlophus, Mylopharyngodon piceus*, et *Trematocranus placodon*. Ces poissons pourraient éventuellement être complétés par une espece herbivore telle que *Ctenopharyngodon idella*. Malheureusement, il est souvent difficile de suivre une telle démarche parce que dans la majorité des régions ou la schistosomiase est endémique, les connaissances pertinentes a une telle démarche sont inexistantes.

La phase homme-eau: gestion de l'eau et modification des gîtes. Les études décrivant les populations de mollusques et les observations relatives a l'utilisation de l'eau ont montré que, depuis qu'elle est utilisée comme drain principal du périmètre irrigué, la dépression longeant le village de Gounougou est devenue un site potentiel de transmission de la schistosomiase. Cette dépression a été transformée en zone marécageuse ou les mollusques et les moustiques peuvent se reproduire. La zone est devenue inutile pour l'agriculture parce-que le niveau d'eau dans la dépression étant dépendant de la gestion du périmètre irrigué, ses fluctuations sont imprévisibles et cette zone est inutilisable a des fins agricoles. Cependant, la population utilise l'eau, en grandes quantités, pour des activités domestiques. En outre, les agriculteurs sont obligés de traverser le marais pour atteindre leurs champs

situés de l'autre coté de la dépression. Afin de diminuer les risques de transmission et d'accroitre la production maraichere et la production piscicole, la dépression a été modifiée en consuItation avec la population locale et avec sa coopération. La dépression a été canalisée et munie d'une vanne. Cette intervention a eu les effets favorables suivants:

- le marais a été drainé et une superficie considérable de terre cultivable est maintenant disponible;
- les cultivateurs peuvent régulariser le niveau de l'eau dans le canal, ce qui permet la culture maraichère pendant la saison sèche;
- l'ouverture de la vanne à la fin de la saison seche donne la possibilité de pêcher tous les poissons présents dans cette zone;
- l'ensemble des interventions a abouti à une forte réduction du nombre de mollusques;
- la possibilité de traverser la dépression grace a un pont piétonnier et a la vanne a fortement diminué les contacts homme-eau.

Les bénéfices provenant de la culture maraichere et de la production piscicole stimulent la population a mieux gérer la dépression. Ceci a pour effet favorable de maintenir les risques de transmission a un niveau bas en raison de Ia lutte contre les populations de mollusques. II est devenu clair, cependant, qu'une gestion efficace de la dépression requiert une coopération étroite entre les villageois. Actuellement les probiemes entre autochtones et immigrants concernant la répartition des parcelles autour du canal dans la dépression constituent une entrave a une telle coopération. Le gouvernement Camerounais a promis des parcelles aux immigrants, mais les autochtones sont réticents en ce qui concerne l'abandon de leurs droits traditionnels.

L'homme et le parasite adulte: lutte contre la morbidité par service de santé. L' objectif final de la lutte contre la schistosomiase est la prévention de la transmission. Au cours des années, il est devenu clair que dans les régions les moins riches du monde, il est impossible d'atteindre cet objectif; l'option la plus réaliste est donc la prévention de la morbidité causée par le parasite. Le médicament disponible, Praziquantel, est efficace dans la lutte contre le parasite. De plus, ce médicament annule les dommages physiques autrefois considérés comme irréversibles. On peut lutter contre la morbidité grace a un dépistage actif de toutes les personnes infectées qui sont traitées sur place. La morbidité causé par une infection de longue durée peut être prévenue en grande partie de cette manière, mais le cout d'une telle prévention est élevé. On peut aussi traiter les malades dans les centres de santé locaux. Ce dépistage passif dépend entierement de la motivation et des moyens financiers des patients. Dans la pratique, cette méthode de lutte contre la schistosomiase est la seule méthode faisable dans la plupart des régions endémiques, bienqu'il n'existe presque pas d'informations sur son efficacité.

Cette these constitue un premier effort en matière de quantification du role joué par le service de santé existant dans la lutte contre la morbidité causé par la schistosomiase. Les registres des centres de santé fournissent des informations sur l'age, le sexe et le village de provenance des personnes atteintes de schistosomiase. Ces données furent comparées avec celles fournies par une enquête dans la région. De plus, l'intensité de l'infection fut déterminée pour tous les cas de schistosomiase enregistrés au centre de santé. Ces données montrent que le dépistage passif, qui résulte de la politique des centres de santé, est tres sélectif pour les infections graves. Ceci indique que les gens qui se sentent malade du fait de l'infection, cherchent effectivement a se faire traiter. Les hommes, les femmes et les enfants ont acces au service de santé, bien que les femmes, et en particulier les filles entre 5 et 10 ans, se rendent moins au dispensaires qu'il n'avait été prévu en tenant compte de la prévalence mesurée dans le cadre de l'enquête. Les registres des dispensaires permirent aussi d'identifier les villages ou la prévalence des cas graves est grande. Si l'on considere la lutte contre la morbidité comme l'objectif principal, les données provisoires présentées dans cette these montrent que le service de santé existant joue un role important dans les efforts visant a atteindre cet objectif. Cette approche peut s'avérer suffisante en matiere de lutte contre la morbidité dans les zones de ou la prévalence est faible ou moyenne.

Pour l'instant, des probiemes méthodoiogiques jouent un roie principal dans cette recherche. L 'approche proposée ci-avant devra être mise a l'épreuve en faisant usage de données provenant d'autres

centres de santé. Ceci constitue une tâche importante pour l'équipe travaillant actuellement au Cameroun.

Remerciement

Henri Roggeri et Eelco Bruinsma sont remerciés aimablement pour leur corrections dans la traduction française.